SEMESTER WISE COURSE STRUCTURE

&

EVALUATION SCHEME

B. TECH. DEGREE PROGRAMME
IN CHEMICAL ENGINEERING

(Effective from the session 2022-23 for new entrants)

DEPARTMENT OF CHEMICAL ENGINEERING
HARCOURT BUTLER TECHNICAL UNIVERSITY
KANPUR

Chemical Engineering Department

OUR VISION

To emerge as a global leader in the areas of education and research in Chemical Engineering to handle the technological challenges in Chemical Engineering & Allied Fields and catering the requirements of stakeholders and society.

OUR MISSION

The missions of the Department of Chemical Engineering are:

M1: To provide state-of-art technical education to the undergraduate and post graduate students.

M2: To create a conducive and supportive environment for the overall growth of our students.

M3: To cultivate awareness of social responsibilities in students to serve the society.

M4: To groom students with leadership skills helpful in Startups, professional ethics and accountability along with technical knowledge to face the changing needs of industry and environment.

M5: To provide consultancy services to the Chemical and Allied industries of the region, state and the country.

For UG

Program Educational Outcomes (PEOs)

The educational objectives of B.Tech. Chemical Engineering are:

- **PEO1:** Graduates from our department will be proficient in varied areas of Chemical Engineering that are industrially and academically significant such as Petroleum Refining, Petro Chemicals, Instrumentation & Process Control, Modeling & Simulation, Nanotechnology, Electrochemical technology, Process Engineering & Design along with recent advances.
- **PEO2:** Graduates will exhibit entrepreneurship, leadership and high professional skills while maintaining ethical and moral values.
- **PEO3:** Graduates will continuously strive and align their activities for betterment of the society.
- **PEO4:** Graduates will discharge their duties with professional attitudes and ethics.

Program Outcomes (POs)

The expected outcomes of the Program are:

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
PO4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations
PO6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics, responsibilities, and norms of the engineering practice.
PO9	**Individual and Teamwork**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

The Program specific outcomes (PSOs) of B.Tech. Chemical Engineering are:

PSO1	Design and development of eco-friendly, energy efficient and sustainable chemical engineering processes.
PSO2	Apply the knowledge and analytical ability to solve problems related to chemical process industry.
PSO3	Analyze and formulate economically viable solutions for environmental and waste management systems.

HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR
School of Chemical Technology
B. Tech Chemical Engineering
Semester wise Course Structure
(Applicable from Session 2022-2023 for new entrants)

Year I, Semester-I

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	BSC	Engg. Physics	NPH101	4	3	0	2	15	20	15	50	50	100
2	BSC	Engg. Mathematics-I	NMA101	4	3	1	0	30	20	-	50	50	100
3	ESC	Int. to Electrical Engg.	NEE101	4	3	0	2	15	20	15	50	50	100
4	ESC	Int. to Mech. Engg.	NME101	4	3	1	0	30	20	-	50	50	100
5	HSMC	Professional Communication	NHS103	4	2	1	2	15	20	15	50	50	100
6	ESC	Engg. Graphics	NCE103	2	0	0	4	30	20	-	50	50	100
Total Credits: 22													**600**

Year I, Semester-II

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	BSC	Engg. Chemistry	NCY102	4	3	0	2	15	20	15	50	50	100
2	BSC	Int. to CSE	NCS102	4	3	1	0	30	20	-	50	50	100
3	ESC	Int. to Electronics Engg.	NET102	4	3	1	0	30	20	-	50	50	100
4	ESC	Int. to Civil Engg.	NCE102	4	3	1	0	30	20	-	50	50	100
5	ESC	Int. to CHE/CT	NCT102	4	3	1	0				50	50	100
6	ESC	Workshop Practice	NWS102	2	0	0	4	30	20	-	50	50	100
Total Credits: 22													**600**

HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR
School of Chemical Technology
B. Tech Chemical Engineering
Semester wise Course Structure
(Applicable from Session 2023-2024 for new entrants)

Year II, Semester-III

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	BSC	Engg. Math-II	NMA 201	4	3	1	0	30	20	-	50	50	100
2	ESC	Chemical Engineering Fluid Mechanics	NCH 201	5	3	1	2	15	20	15	50	50	100
3	PCC	Particle and Fluid Particle processing	NCH 203	4	2	1	2	15	20	15	50	50	100
4	PCC	Chemical Engineering Thermodynamics -1	NCH 205	4	3	1	0	30	20	-	50	50	100
5	PCC	Chemical Process Calculation	NCH 207	4	3	1	0	30	20	-	50	50	100
6	HSMC	Industrial Economics & Management	NHS 201	3	3	0	0	30	20	-	50	50	100
Total Credits: 24													**600**

Year II, Semester-IV

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	BSC	Modern Analytical Techniques	NCY	4	3	1	0	30	20	-	50	50	100
2	ESC	Computer Oriented Numerical Methods	NMA	4	3	0	2	15	20	15	50	50	100
3	PCC	Process Heat Transfer	NCH 202	5	3	1	2	15	20	15	50	50	100
4	PCC	Mass Transfer Operations -I	NCH 204	4	2	1	2	15	20	15	50	50	100
5	PCC	Chemical Engineering Thermodynamics -II	NCH 206	3	2	1	0	30	20	-	50	50	100
6	PCC	Chemical Reaction Engineering -I	NCH 208	4	2	1	2	15	20	15	50	50	100
Total Credits: 24													**600**

HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR
School of Chemical Technology
B. Tech Chemical Engineering
Semester wise Course Structure
(Applicable from Session 2024-2025 for new entrants)

Year III, Semester-V

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	PCC	Computer Aided Equipment Design	NCH 301	4	2	1	2	15	20	15	50	50	100
2	PCC	Chemical Reaction Engineering -II	NCH 303	4	3	1	0	30	20	-	50	50	100
3	PCC	Mass Transfer operations -II	NCH 305	4	2	1	2	15	20	15	50	50	100
4	PCC	Transport Phenomena	NCH 307	4	3	1	0	30	20	-	50	50	100
5	PCC	Chemical Technology	NCH 309	3	3	0	0	30	20	-	50	50	100
6	HSMC	Entrepreneurship Development	HSS	3	2	0	0	30	20	-	50	50	100
Total Credits: 22													**600**

Year III, Semester-VI

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	PCC	Process Control & Instrumentation	NCH 302	4	2	1	2	15	20	15	50	50	100
2	PCC	Plant Design & Economics	NCH 304	3	3	0	0	30	20	-	50	50	100
3	PCC	Process Modelling & Simulation	NCH 306	4	2	1	2	15	20	15	50	50	100
4	PCC	Plant safety and environmental aspects	NCH 308	3	3	0	0	30	20	-	50	50	100
5	PCC	Material Science and Engineering	NCH 310	3	3	0	0	30	20	-	50	50	100
6	PEC-I	Program Elective - I	NCH 312-318	3	3	0	0	30	20	-	50	50	100
7	OEC-I	Open Elective - I		2	2	0	0				50	50	100
Total Credits: 22													**700**

HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR
School of Chemical Technology
B. Tech Chemical Engineering
Semester wise Course Structure
(Applicable from Session 2025-2026 for new entrants)

Year IV, Semester-VII

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	PEC-II	Program Elective - II	NCH 401-407	4	3	1	0	30	20	-	50	50	100
2	PEC-III	Program Elective - III	NCH 409-417	3	3	0	0	30	20	-	50	50	100
3	PEC-IV	Program Elective - IV	NCH 419-425	3	3	0	0	30	20	-	50	50	100
4	Industrial Training	Industrial Training	NCH 427	2	0	0	4	-	50	-	50	50	100
5	OEC-II	Open Elective		2	2	0	0	30	20	-	50	50	100
6	Project	Project - 1	NCH 429	6	0	0	12	-	50	-	50	50	100
7	Seminar	Seminar	NCH 431	2	0	0	4	-	50	-	50	50	100
Total Credits: 22													**700**

Year IV, Semester-VIII

S. No.	Course Type	Subject Title	Course Code	Credits	Period			Sessional Marks				ESE	Total Marks
					L	T	P	MSE	TA	Lab	Total		
1	PEC-V	Program Elective - V	NCH 402-408	4	3	1	0	30	20	-	50	50	100
2	OCE-III	Open Elective - III		2	2	0	0	30	20	-	50	50	100
3	Project	Project-2	NCH 410	16	0	0	32	-	200	-	200	200	400
Total Credits: 22													**600**

LIST OF ELECTIVES

Open Elective-I [2-0-0]

NCH	Industrial Pollution Control and Waste Management

Open Elective-II [2-0-0]

NCH	Energy Resources and Utilization

Open Elective-III [2-0-0]

NCH	Process Utilities

Elective-I [3-0-0]

NCH 312	Mathematical Methods in Chemical Engineering
NCH 314	Design of Experiments
NCH 316	Process Optimization
NCH 318	Advanced Control System

Elective-II [3-1-0]

NCH 401	Advanced Separation Processes
NCH 403	Conceptual Design of Chemical Processes
NCH 405	Energy Resource & Energy Conservation
NCH 407	Pipeline transportation of Oil & Gas

Elective-III [3-0-0]

NCH 409	Petroleum Refining & Petrochemical Technology
NCH 411	Nano Technology
NCH 413	Bio Process Engineering
NCH 415	Electrochemical Technology
NCH 417	Principle of Polymer Engineering

Elective-IV [3-0-0]

NCH 419	Green Chemistry
NCH 421	Micro-Chemical System
NCH 423	Colloids & Interface Science and Engineering
NCH 425	Corrosion Science and Engineering

Elective-V [3-1-0]

NCH 402	Management of R&D
NCH 404	Environmental Impact Assessment
NCH 406	Air Pollution Monitoring & Control
NCH 408	Energy Management

II B.Tech. Chemical Engineering Semester-III

NCH-201 CHEMICAL ENGINEERING FLUID MECHANICS

L	T	P	C
3	1	2	5

Assessment:

Sessional: 50 marks
End Semester: 50 marks

Course Objectives:

The objective of this course is to introduce the mechanics of fluids (fluid statics, kinematics and fluid dynamics), relevant to chemical engineering operations. The course will introduce students to forces on fluids, Eulerian and Lagrangian descriptions of flow, flow visualization, integral analysis involving mass and momentum balances, Bernoulli equation, flow through pipes and ducts, flow measurement and instruments, flow transportation - pumps, blowers and compressors, conservation of mass, linear and angular momentum in differential form, Navier-Stokes equation, viscous flows, skin and form friction, potential flows and boundary layer theory. Turbulence and turbulent flows will be introduced.

Course outcomes:

Students completing the course will be able to

CO1	Understand basic concepts pertaining to fluids, fluid flow and fluid statics	Remember, Understand
CO2	Analyze and describe the fluid flow and apply conservation equations of mass momentum and energy	Analyze, create
CO3	Calculate Boundary layer thicknesses, pressure drop and power requirements in pipe flow for fully developed laminar and turbulent regimes.	Analyze, Evaluate
CO4	Compare and select suitable device for flow measurement in open and closed channels.	Analyze, Evaluate
CO5	Design a pump type and pump size to meet the specific pumping requirements	Design, Evaluate
CO6	Conduct various experiments to apply the concepts of fluid mechanics	Understand, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3												3	
CO2	3	3	3	3											
CO3	3	3	3	3	3							2	3	3	
CO4	3	3	3	3	3							2	3	3	
CO5	3	3	3	3	2							2	3	3	
CO6	3			3	2			2	3	2	2	3	2	3	1
Avg.	3	3	3	3	2.5			2	3	2	2	2.25	2.75	3	1

Module 1 Properties of Fluid and Fluid Statics (8 hours)

Properties of Fluid: Density, Compressibility, Vapor pressure, Surface tension, Capillarity, Viscosity, Types of fluids, Newton's Law of Viscosity, Power law, Types of fluid flow

Fluid statics: Pascal's law, Hydrostatic law, Hydraulic Pressure, Absolute, gauge pressure & vacuum, Pressure Measurement: Barometers, Piezo meters, Manometers (different types).

Module 2 Fluid Kinematics and Fluid Dynamics (8 hours)

Flow description using Lagrangian and Eulerian approaches, Relationship between material and local derivatives of fluid properties. Conservation equation of mass, momentum, and energy balances in both differential and integral forms, Specific cases of equation of continuity, motion and energy: Naiver Stokes Equation; Hagen Poiseuille Law; Engineering Bernoulli's Equation; Calculations and balances using spreadsheets/ MS Excel

Module 3 Boundary layer concepts and pipe flow (8 hours)

Introduction Development of boundary layer for flow over a flat plate, Development of boundary layer for flow through circular pipe, entry length, fully developed flow, Boundary layer separation

Flow of incompressible fluid in pipes: Laminar flow, Hagen Poiseuille equation, Friction factor, Pressure drops in turbulent flow (major loss), Flow through non-circular pipes, Minor Losses (Expansion losses, Contraction losses, Losses for flow through fittings). Equivalent length of pipe fittings, Design of piping network.

Module 4 Flow measurement (6 hours)

Closed channel flow measurement: Venturi meter, Orifice meter, Pitot tube, Rotameter, Flow measurement based on Doppler effect, Hot wire and hot film anemometer, Magnetic flow meter, Coriolis Flow Meters, Open channel flow measurement: Elementary theory of weirs and notches.

Module 5 Pumps (10 hours)

Positive displacement pumps: Piston pumps, single and double acting Plunger pumps, Diaphragm pump, Rotary pumps, Gear pumps, Lobe pumps Screw pumps, Airlift pump, Jet pump.

Characteristics and constructional details of centrifugal pumps, Pump priming and cavitation, Affinity laws for pumps, System and Pump Characteristics Curves, NPSH calculations, Calculations using spreadsheets/MS Excel.

List of Experiments

1. To Verify Bernoulli's Theorem
2. To calculate frictional loss in various pipe fittings.
3. To calibrate Venturi meter and calculate its discharge coefficient.
4. To calibrate orifice meter and calculate its discharge coefficient.
5. Study of Rotameter

6. To calculate Drag coefficient
7. To study Reynolds experiment

Suggested Text Books

1. McCabe W., Smith, J. and Harriot P., "Unit Operations of Chemical Engineering", 7th Edn. McGraw Hill, 2005.
2. Gupta, Vijay and Gupta, S.K. "Fluid Mechanics and its Applications", Wiley Eastern, New Delhi 1984.

Suggested Reference Books

1. Fox, R.W., Pritchard, P.J. and McDonald, A.T., "Introduction to Fluid Mechanics", 7th Edition, Wiley-India 2010.
2. Coulson & Richardson, Chemical Engineering Vol. I: McGraw Hill. 1979
3. Bansal, R.K., "Fluid Mechanics and Hydraulic Machines", Laxmi Publications (P) Ltd., New Delhi 2005

NCH-203 PARTICLE AND FLUID PARTICLE PROCESSING

L	T	P	C
2	1	2	4

Assessment:
Sessional: 50 marks
End Semester: 50 marks

Course Objective:
Objective of this course is to introduce students to the numerous industrial operations dealing with the particulate solids, their handling in various unit operations, and those in which particle fluid interactions are important. The course addresses fundamentals of fluid-particle mechanics, such as the notion of drag, and builds on those fundamentals to develop design concepts for various industrial processes like packed bed operation, fluidized operations, sedimentation, filtration, separation of solids and fluids, etc.

Course outcomes:
Students completing the course will be able to

CO1	Analyze particle size of mixtures with varying sizes and shapes.	Remember, Understand, Apply
CO2	Select and calculate power for size reduction equipment.	Remember, Describe, Calculate
CO3	Choose a separation device and calculate pressure drop and separation time	Recognize, Compare, Recommend
CO4	Select suitable filtration equipment; design a thickener.	Define, Differentiate, Design
CO5	Understand solid material storage, handling, and conveying/transportation; Design agitator/mixing equipment.	Understand, Analyze, Evaluate, Create
CO6	Conduct various experiments to apply the concepts of particle and fluid processing	Identifiy, Explain, Execute

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2								2		3	1
CO2	3	2	2	2								2		3	1
CO3	3	2	3	3	3							2	2	3	1
CO4	3	2	3	3	3							2	3	3	3
CO5	3	2	3	3	3							2	3	3	3
CO6	3			3	2			2	3	2	2	3	2	3	1
Avg.	3	2	2.6	2.7	2.8			2	3	2	2	2.17	2.5	3	1.67

Module 1 (6 hours)

Particle Technology: Particle shape, shape factor, sphericity, particle size, different ways of expression of particle size, mixed particles size analysis, specific surface of a mixture of particles, number of particles in a mixture, Screens – ideal and actual screens, standard screens, effectiveness of screen, industrial screening equipments, motion of screen, grizzlies, gyratory screens, vibrating screens and trommels, Sub sieve analysis – Air permeability method, sedimentation and elutriation methods.

Module 2 (6 hours)

Size Reduction: Introduction – types of forces used for communition, criteria for communition, characteristics of communited products, laws of size reduction, work index, energy utilization, Methods of operating crushers – free crushing, choke feeding, open circuit grinding, closed circuit grinding, wet and dry grinding, Equipments for size reduction – Blake jaw crusher, gyratory crusher, smooth roll crusher, toothed roll crusher, impactor, attrition mill, ball mill, critical speed of ball mill, ultrafine grinders and cutters.

Module 3 (6 hours)

Flow of Fluid Past Immersed Bodies: Drag, drag coefficient, Pressure drop in a bed of solids– Kozeny – Carman equation, Burke- Plummer equation, Ergun equation, Fluidization - conditions for fluidization, minimum fluidization velocity, types of fluidization, applications of fluidization, slurry transport, pneumatic conveying.

Motion of Particles Through Fluids: Mechanics of particle motion, equation for one dimensional motion of particles through a fluid in gravitational and centrifugal field, terminal velocity, drag coefficient, motion of spherical particles in various regimes, criterion for settling regime, hindered settling, modification of equation for hindered settling, centrifugal separators, cyclones and hydro-cyclones.

Module 4 (6 hours)

Sedimentation: Batch settling test and its applications, Coe and Clevenger theory, Kynch theory, thickener design. Filtration: Classification of filtration, cake filtration, clarification, batch and continuous filtration, pressure and vacuum filtration, constant rate filtration and cake filtration, principles of cake filtration, characteristics of filter media, filter aids and its applications, industrial filters, sand filter, filter press, leaf filter, rotary drum filter, horizontal belt filter, bag filter, centrifugal filtration- suspended batch centrifuge.

Module 5 (6 hours)

Agitation and Mixing: Agitation equipment, Types of impellers–Propellers, Paddles and Turbines, Flow patterns in agitated vessels, Prevention of swirling, Standard turbine design, Power correlation and Power calculation, Mixing of solids, Various types of mixers and blenders Storage and Conveying of Solids: Storage of solids, Open and closed storage, Bulk and bin storage, Conveyors – Belt conveyors, Chain conveyor, Apron conveyor, Bucket conveyor, Screw conveyor.

List of Experiments

1. To perform differential and cumulative screen analysis
2. To calculate reduction ratio in Jaw crusher
3. To calculate efficiency of Jaw crusher
4. To calculate reduction ratio in crushing roll
5. To calculate efficiency of crushing roll
6. To calculate critical speed of Ball mill
7. Settling of Calcium carbonate slurry.
8. Filtration experiment – plate & frame filter press/ rotary vacuum filter

Suggested Text books

1. McCabe, W., Smith, J. and Harriott, P., "Unit Operations of Chemical Engineering", 7th edition, McGraw-Hill,2017
2. Badger, W.L. and Banchero, J.T. "Introduction to Chemical Engineering", McGraw-Hill, 1979
3. Coulson & Richardson's Chemical Engineering, Vol. 2, Butterworth-Heinemann, Fifth edition 2002.

Suggested Reference Books

1. Rhodes, M.J., "Introduction to Particle Technology", 2nd edition, John Wiley, Chichester; New York, 2008.
2. Allen, T., "Powder Sampling and Particle Size Determination", Elsevier, 2003.
3. Masuda, H., Higashitani, K., Yoshida, H., "Powder Technology Handbook", CRC/ Taylor and Francis, 2006.

NCH-205 CHEMICAL ENGINEERING THERMODYNAMICS -1

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Principles and application of first and second law of thermodynamics and Equation of State

Course Outcome

Students completing the course will be able to

CO1	Understand the first law of thermodynamics and calculate changes in system properties and heat and work exchanged with the surrounding for open/close system.	Understand, Analyze
CO2	Evaluate the volumetric properties of ideal and real gases.	Apply, Analyze, Evaluate
CO3	Understand of second law and entropy and calculate of ideal and lost work.	Apply, Analyze, Evaluate
CO4	have a comprehensive understanding of the thermodynamic analysis of steam power plants as well as internal combustion engines.	Analyze, Evaluate
CO5	Solve problems involving liquefaction, refrigeration and different power cycles.	Understand, Apply, Evaluate

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	2	3								2			
CO2	3	3	2	3	3							2	3	3	
CO3	3	3	3	3	3	2	2					2	3	3	3
CO4	3	2	3	3								2	3	3	3
CO5	3	2	3	3								2	3	3	2
Avg.	3	2.6	2.6	3	3	2	2					2	3	3	2.67

Module 1 (8 hours)

Introduction- Scope of thermodynamics, Temperature, Pressure, Work, Heat, Energy, Equilibrium, Processes- Reversible & Irreversible, System & Surroundings, Joule's Experiment, Internal energy, The First Law of Thermodynamics, Enthalpy, Heat capacities, Mass and Energy Balances for Open Systems.

Module 2 (8 hours)

The Phase Rule, PVT behavior of Pure Substances, Ideal gas law, Van der Waals equation, Virial and cubic equations of state, Generalized Correlations for Gases, Calculations using tools like spreadsheets/MS Excel; Defining Thermodynamic packages in simulators

Module 3 (10 hours)

Second Law of Thermodynamics, Heat Engines and Heat Pumps, Carnot Engine with ideal-gas-state working fluid, Clausius Inequality and Introduction to Entropy, Entropy change for ideal gas state, Entropy balance for open system, Calculation of ideal work, Lost work, Exergy (Availability) and Exergy Analysis, The Third Law of Thermodynamics, Entropy from the microscopic viewpoint.

Module 4 (6 hours)

Applications of thermodynamics to flow processes, Turbines (Expanders), Compression processes, Thermodynamic analysis of steam power plants; Rankine cycle; Internal combustion engine, Otto engine; Diesel engine; Jet engine.

Module 5 (6 hours)

The Carnot refrigerator; Vapour-compression cycle; Absorption refrigeration; Heat pump, Liquefaction processes

Suggested Text Books

1. Smith, J.M. and Van Ness, H.C. "Introduction to Chemical Engineering Thermodynamics" 9th Edition, McGraw Hill International Ltd, 2020
2. Nag, P.K**.** **"**Engineering Thermodynamics", McGraw Hill, 6th Edition, 2017

Suggested Reference Books

1. Moran, M.J., Shapiro, H.N., Boettner, D.D. and Bailey, M.B. "Principles of Engineering Thermodynamics, 8th Edition, Willey, 2020
2. Cengel, Y. and Boles, M. "Thermodynamics - An Engineering Approach", 8th Edition, Publisher & year?
3. Rao, Y.V.C. "Chemical Engineering Thermodynamics" University Press (India) Ltd. Hyderabad, 2013
4. Kyle, B.G. "Chemical and Process Thermodynamics", 3rd Edn., Prentice Hall. 1999.

NCH 207 CHEMICAL PROCESS CALCULATIONS

L	**T**	**P**	**C**
3	**1**	**0**	**4**

Assessment:
Sessional: 50 marks
End Semester: 50 marks

Course Objective

To understand material and energy balance concepts and their applications in different unit operations and unit processes

Course Outcome

Students completing the course will be able to

CO1	Understand fundamentals of gas law, vapor pressure, Psychrometric chart for application in material and energy balance	Recognize, Explain, Evaluate
CO2	Appropriate basis and block diagram approach for solving material and energy balance problems	Identify, Describe, Solve

CO3	Perform process calculations for material and energy balance in different unit operations	List, Interpret, Calculate
CO4	Perform process calculations for material and energy balance in different unit processes involving recycle and bypass	Recognize, Compare, Evaluate
CO5	Energy balance calculations and reaction temperature	Define, Analyze, Calcualte

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	3	2							2	3	3	
CO2	3	3	2	3	3							2	3	3	
CO3	3	3	3	3	3	2						2	3	3	
CO4	3	2	3	3	3							2	3	3	2
CO5	3	2	3	3	2							2	3	3	
Avg.	3	2.6	2.6	3	2.6	2						2	3	3	2

Module 1 (6 hours)

Units and dimensions, Conversion of units, Fundamental concepts of stoichiometry, Ideal gas law and its application.

Module 2 (6 hours)

Vapor pressure, Effect of temperature on vapor pressure, Vapor pressure plot, Raoult's Law, Solutions and phase behavior. Humidity and saturation, Use of humidity charts for calculations.

Module 3 (5 hours)

Material balances without chemical reaction, application of material balance in different unit operations, Introduction to unsteady state material balance.

Module 4 (5 hours)

Material balance with chemical reaction, bypass, recycle and purge operations

Module 5 (8 hours)

Components of energy balance equations, Heat capacities, Energy balance in Non flow and flow process, Effect of temperature on standard heat of reaction, Temperature of reaction.

Suggested Text books

1. Hougen, O.A., Watson, K.M and Ragatz, R.A., "Chemical Process Principles Part-I ", John Wiley and Asia Publishing, 1970.

2. Felder, R.M. & Rousseau, R.W. "Elementary Principles of Chemical Processes", 3rd edition. JohnWiley, 1999.
3. Naraynan, K.V. and Lakshmikutty, B. “Stoichiometry and Process Calculations” 2nd edition PHI, 2019.

Suggested Reference Books

1. Himmelblau, D.M., “Basic Principles and Calculations in Chemical Engineering", sixth Edition, Prentice Hall Inc., 1996.

II B. Tech. Chemical Engineering Semester-IV

NCH 202 PROCESS HEAT TRANSFER

L	T	P	C
3	1	2	5

Assessment:

Sessional: 50 marks
End Semester: 50 marks

Course Objective:

To understand the fundamentals of heat transfer mechanisms in solids, fluids and vacuum and their applications in various heat transfer equipment in process industries like evaporators, condensers and double pipe heat exchangers.

Course outcomes:

Students completing the course will be able to

CO1	Apply analytical methods to calculate heat transfer in one-dimensional, steady and unsteady state conduction in solids and determine heat rate through composite assemblies.	Identify, Explain, Determine
CO2	Analyze the momentum boundary layer, thermal boundary layer, and apply dimensional analysis in the context of process heat transfer.	List, Describe, Analyze
CO3	Apply the relevant laws and principles related to radiation and radiation exchange between black bodies and gray bodies.	Recognize, Explain, Apply
CO4	Utilize the concept of phase-change phenomena to design single effect evaporators.	Define, Understand, Design
CO5	Design heat exchangers using log-mean temperature difference and overall heat transfer coefficient concepts.	List, Interpret, Design
CO6	Conduct various experiments to apply the concepts of Heat Transfer	Identify, Explain, Conduct

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	1							2	2	3	
CO2	3	3	3	2	1							2	2	3	
CO3	3	3	3	2	1							2	2	3	
CO4	3	3	3	2	1							2	2	3	
CO5	3	3	3	2	1							2	2	3	
CO6	3			3	2			2	3	2	2	3	2	3	1
Avg.	3	3	3	2.2	1.2			2	3	2	2	2.17	2	3	1

Module 1 (8 hours)

Basic Concepts: Modes of heat transfer, conduction, convection and radiation, analogy between heat flow and electrical flow. Conduction: One dimensional steady state heat conduction, the Fourier heat conduction equation, conduction through plane wall, conduction through cylindrical wall, spherical wall, variable thermal conductivity, conduction through composite slab, cylinder and sphere, critical radius of insulation, Extended surfaces: heat transfer from a fin, fin effectiveness and efficiency, Introduction to unsteady state heat conduction.

Module 2 (6 hours)

Convection: The convective heat transfer coefficient, momentum and thermal boundary layers for the cases of flow of fluid over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance, dimensional analysis, Buckingham's pi theorem, application of dimensional analysis to forced convection. Correlation equations for heat transfer in laminar and turbulent flows in circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer, heat transfer to liquid metals. Natural Convection, Grashof and Rayleigh numbers.

Module 3 (6 hours)

Heat transfer by radiation: Basic Concepts of radiation from surface : black body radiation, Plancks law, Wien's displacement law, Stefan Boltzmann's law, Kirchhoff's law, grey body, Radiation intensity of black body, View factor, emissivity, radiation between black surfaces and grey surfaces.

Module 4 (5 hours)

Boiling and Condensation: Pool boiling, pool boiling curve for water, drop wise and film wise condensation, Nusselt analysis for laminar film wise condensation on a vertical plate. Evaporation: Types of evaporators, boiling point elevation and Duhring's rule, material and energy balances for single effect evaporator, forward, mixed and backward feeds arrangements of multi-effcct evaporators, capacity and economy of evaporators

Module 5 (5 hours)

Double pipe heat exchangers, log-mean temperature difference, overall heat transfer coefficient, fouling factors, Design of double pipe heat exchangers for counter current and co-current flow arrangements.

List of experiments

1) Heat transfer through composite wall assembly
2) Heat flow rate through a lagged pipe
3) Heat transfer from a vertical cylinder under natural convection
4) Heat transfer by forced convection inside a horizontal pipe
5) Heat transfer from pin fin
6) Study of heat pipe

7) Determination of Stefan Boltzmann constant for radiation heat transfer
8) Study of a double pipe heat exchanger

Suggested Text Books

1. “Heat transfer principles and applications” Dutta, B.K., PHI
2. “Heat Transfer” Holman J.P., 9th Ed., McGraw Hill.
3. “Fundamentals of Heat and Mass Transfer, Roy, G. K., 5th Ed., Khanna Publishers, Delhi, 2011.

Suggested reference Books

1. Heat and Mass Transfer Fundamentals and Applications, Cengel, Y. A., Ghajar, A. J., 5th Ed., McGraw Hill, Chennai, 2016.
2. Process Heat Transfer, Kern, D. Q., Tata McGraw Hill, New Delhi, 2000.
3. Incropera F.P. and Dewitt D.P, “Fundamentals of Heat and Mass Transfer”, 5th Ed., John Wiley. 2001

NCH 204 MASS TRANSFER OPERATIONS-I

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
2	1	2	4

Course Objectives:

The purpose of this course is to introduce the undergraduate students with the laws of diffusion; convective mass transfer, interphase mass transfer and mass transfer coefficients, mass transfer correlations; mass transfer theories/models. This course will also provide proper understanding of unit operations such as absorption, drying, crystallization and humidification and dehumidification.

Course outcomes:

Students completing the course will be able to

CO1	Apply principles of molecular diffusion to estimate transfer rates using diffusion coefficients for liquids and gases.	Identify, Explain, Estimate
CO2	Analyze gas absorption systems and calculate the number of stages or column height.	Recognize, Analyze, Calculate
CO3	Perform calculations related to humidification and dehumidification processes using psychometric charts.	List, Describe, Perform
CO4	Evaluate batch drying data and design dryers.	Recognize, Evaluate, Design
CO5	Design crystallization and membrane processes for various industrial applications.	Define, Analyze, Design
CO6	Conduct experiments to apply mass transfer concepts.	Identify, Explain, Conduct

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3		1						3	3	3	2
CO2	3	3	3	3	2	1						3	3	3	2
CO3	3	3	3	3	2	1						3	3	3	2
CO4	3	3	3	3	2	1						3	3	3	2
CO5	3	3	3	3	2	1						3	3	3	2
CO6	3			3	2			2	3	2	2	1	2	3	1
Avg.	3	3	3	3	2	1		2	3	2	2	2.67	2.83	3	1.83

Module 1 (10 hours)

Mass Transfer and Diffusion: Steady-state ordinary molecular diffusion: Fick's law of diffusion; Velocities in mass transfer, Equimolar counter diffusion; unimolecular diffusion, Diffusion coefficients: Diffusivity in gas mixtures, diffusivity in liquid mixtures, Diffusivity in solids, One-dimensional, steady-state, molecular diffusion through stationary media, Mass transfer in turbulent flow: Reynolds analogy; Chilton-Colburn analogy; Other analogies, Models for mass transfer at a fluid-fluid interface: Film theory; Penetration theory; surface-renewal theory; film-penetration theory, Two-film theory and overall mass transfer coefficients

Module 2 (8 hours)

Absorption and Stripping: Equipments, Gas-liquid equilibrium, Henry's law, Selection of solvent, Absorption in tray column, Graphical and analytical methods, Absorption in packed columns, HTU, NTU & HETP concepts, Design equations for packed column.

Module 3 (8 hours)

Humidification and Dehumidification: Vapour-liquid equilibrium and enthalpy for a pure substance, vapour pressure temperature curve, Vapour gas mixtures, Definition and derivations of relationships related with humidity, Fundamental concept of humidification, Dehumidification and Water cooling, Wet bulb temperature, Adiabatic and non-adiabatic operations, Evaporative cooling, Classification and design of cooling towers.

Module 4 (7 hours)

Drying: Solid-gas equilibrium, Different modes of drying operations, Definitions of moisture contents, Types of batch and continuous dryers, Rate of batch drying, Time of drying, Mechanism of batch drying, Continuous drying.

Module 5 (7 hours)

Crystallization: Thermodynamic considerations Solubility and material balances, Enthalpy balance; Kinetic and transport considerations Supersaturation, Nucleation, Crystal growth;

Crystallization Equipment. Concept of Membrane, Membrane processes, Pressure driven processes, Ultra-filtration, Nano filtration and reverse osmosis, Electro driven processes, Concentration driven processes

List of Experiments

1. To determine of diffusion coefficient of organic liquid vapor in air.
2. To determine of diffusion coefficient of naphthalene in fixed/fluidized bed.
3. To determine of diffusion coefficient of salt in liquid.
4. To evaluate the performance of gas liquid absorption in an absorption column.
5. To evaluate the performance of air stripping column.
6. To evaluate the performance of cooling tower.
7. To evaluate the performance of dehumidification column.
8. To plot the drying curves using moisture analyzer.
9. To evaluate the performance of a tray dryer.
10. To determine the yield of crystals in a crystallizer.

Suggested Text Books

1. Treybal, R.E. "Mass Transfer Operations", 3rd ed. New York: McGraw-Hill, 1980.
2. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd Edn., Wiley India Pvt. Ltd., New Delhi 2013.

Suggested Reference Books

1. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. "Mass Transfer" McGraw Hill 1975.
2. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi 2012.

NCH 206 CHEMICAL ENGINEERING THERMODYNAMICS-II

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
2	1	0	3

Course Objective:
To introduce the concepts of fugacity, activity coefficient, vapour-liquid equilibrium and reaction equilibrium.

Course outcomes:
Students completing the course will be able to

CO1	Calculate thermodynamic properties using residual properties and exergy analysis for simple systems.	Define, Calculate
CO2	Estimate the thermodynamic properties of ideal and real mixture/solutions.	Estimate, Analyze, Evaluate

CO3	Evaluate dew point and bubble point for two-components and multi-components in Vapor-Liquid equilibrium.	Understand, Analyze, Evaluate
CO4	Assess industrially important phase equilibrium processes and their implications.	Assess, Evaluate, Create
CO5	Evaluate Gibbs free energy and analyze the effect of change in temperature, pressure and composition on equilibrium conversions of chemical reactions.	Evaluate, Analyze, Create

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	1						3	3	3	1
CO2	3	3	3	3	3	1						3	3	3	1
CO3	3	3	3	3	3	1						3	3	3	1
CO4	3	3	3	3	3	1						3	3	3	1
CO5	3	3	3	3	3	1	2					3	3	3	1
Avg.	3	3	3	3	3	1	2					3	3	3	1

Module 1 (10 hours)

Review of laws of thermodynamics, Exergy (Availability) and Exergy Analysis Thermodynamic properties of fluids: property relations for homogenous phases, Maxwell relations, various equations of enthalpy, entropy and internal energy, Residual properties, two phase systems: Clapeyron equation.

Module 2 (8 hours)

Solution thermodynamics Theory: Fundamental property relation, Chemical potential and phase equilibrium, Partial properties, Ideal gas mixture model, fugacity and fugacity coefficient for pure species and in solution, Ideal solution model and excess properties

Module 3 (6 hours)

Phase Equilibria: Nature of equilibrium, phase rule, VLE qualitative behavior, Simple Models for VLE, VLE by Modified Raoult’s law and VLE from K-value charts, UNIFAC and UNIQUAC models.

Module 4 (8 hours)

Solution thermodynamics Application: Liquid phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing. Equilibrium and stability, Osmotic Equilibrium and osmotic pressure, liquid- liquid equilibrium and solid liquid equilibrium.

Module 5 (8 hours)

The reaction coordinates, Application of the criteria for equilibrium to chemical reactions, the standard Gibbs free energy change and the equilibrium constant, effect temperature on equilibrium constant, evaluation of the equilibrium constants, Relation of equilibrium constants to composition, equilibrium conversions for reactions, phase rule for reacting systems

Suggested Text Books

1. Smith, J.M. and Van Ness, H.C. "Introduction to Chemical Engineering Thermodynamics" McGraw Hill International Ltd, 2005.

Suggested Reference Books

1. Sandler, S. "Chemical, Biochemical & Engineering Thermodynamics" 4th Ed., John Wiley & sons, 2006.
2. Narayanan, K.V., "Chemical Engineering Thermodynamics", Prentice Hall. 2007
3. Rao, Y.V.C., "Chemical Engineering Thermodynamics" University Press (India) Ltd. Hyderabad. 1997
4. Kyle, B.G., "Chemical and Process Thermodynamics" 3rd Edn., Prentice Hall. 1999

NCH 208 CHEMICAL REACTION ENGINEERING -I

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
2	1	2	4

Course Objective:

To apply knowledge from calculus, differential equations, thermodynamics, general chemistry, and material and energy balances to solve reactor design problems, To examine reaction rate data to determine rate laws, and to use them to design chemical reactors, To simulate several types of reactors to choose the most appropriate reactor for a given need, To design chemical reactors with associated cooling/heating equipment, To analyze Non-ideal flow behaviour in reactors.

Course Outcomes:

Students completing the course will be able to

CO1	Demonstrate and classify reactions based on reaction mechanisms, reaction rates and reactors based on flow patterns	Remember, Understand
CO2	Develop the kinetics of single and multiple homogeneous reactions	Apply, Evaluate
CO3	Design an appropriate reactor type and operating conditions to achieve a desired output such as reactant conversion, selectivity and yield.	Apply, Evaluate
CO4	To formulate a set of consistent material and energy balance equations to describe the operation of the batch, semi-continuous and continuous reactor systems with single or multiple reactions	Apply, Evaluate, Analyze
CO5	Understand the effect of temperature and pressure on equilibrium conversion and choice of reactors.	Understand, Analyze, Create
CO6	Conduct various experiments to apply the concepts of Chemical Reaction Engineering	Apply, analyze, Evaluate

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	1			1			1		1	2	3	
CO2	2	2	3	2	1		1				1	1	3	3	
CO3	3	2	3	2	1	1	1				1	1	3	2	
CO4	2	3	3	2	1	1					1	1	3	3	
CO5	2	2	3	2	2		1		1		1	1	3	2	
CO6	3			3	2			2	3	2	2	1	2	3	1
Avg.	2.5	2.2	2.8	2	1.4	1	1	2	2	1.5	1.2	1	2.66	2.66	1

Module 1 (8 hours)

Rate of Reaction, Elementary and non-elementary homogeneous reactions, Molecularity and order of reaction, Mechanism of reaction, Temperature dependency from thermodynamics, collision and activated complex theories. Integral and differential methods for analyzing kinetic data, Interpretation of constant volume reactor for zero, first, second and third order reactions, Half-life period, Irreversible reaction in parallel and series, Catalytic reactions, Auto catalytic reactions, Reversible reactions.

Module 2 (7 hours)

Interpretation of variable volume batch reactions for zero, first and second order reactions, Space-time and state-velocity, design equation for ideal batch, steady-state continuous stirred tank, steady-state plug flow reactors for isothermal reactions.

Module 3 (7 hours)

Design for single reactions, Size comparison of single reactors, Multiple reactor systems, plug flow/mixed flow reactors in series and parallel, reactors of different types in series, optimum reactor size, recycle reactor, and autocatalytic reactions.

Module 4 (10 hours)

Introduction to multiple reactions, qualitative discussion about product distribution, quantitative treatment of product distribution and of reactor size, selectivity, the side entry reactor, irreversible first-order reactions in series, Quantitative treatment: plug flow or batch reactor, Quantitative treatment: mixed flow reactor, Successive irreversible reactions of different orders, reversible reactions, irreversible series-parallel reactions, the Denbigh reactions and their special cases, Heat of reaction from thermodynamics, equilibrium constants from thermodynamics, General graphical design procedure for non-isothermal reactors, Optimum temperature progression, Heat effects: Adiabatic operations and non- adiabatic operations, Exothermic reactions in mixed flow reactors.

Module 5 (8 hours)

Residence time distribution of fluids in vessels, State of aggregation of the flowing systems, earliness of mixing, Role of RTD, State of Aggregation and earliness of mixing in determining reactor behavior, E, F and C curves, Conversion in Non-ideal flow reactors.

List of Experiments

1. To study the fundamental concepts of a batch reactor by operating it.
2. To study the fundamental concepts of a CSTR by operating it.
3. To study the fundamental concepts of a PFR by operating it.
4. To determine the rate law of saponification reaction by using a batch reactor.
5. To determine the activation energy of saponification reaction by using a batch reactor
6. To determine the rate law of saponification reaction by using a CSTR.
7. To determine the activation energy of saponification reaction by using a CSTR.
8. To determine the rate law of saponification reaction by using a PFR
9. To determine the activation energy of saponification reaction by using a PFR.

Suggested Text Books

1. Levenspiel, O. (1998). "Chemical Reaction Engineering", John Wiley & Sons, 1988.
2. Fogler, H.S. "Elements of Chemical Reaction Engineering", 4th Edition, Prentice Hall of India Pvt. Ltd. 2008

Suggested Reference Books

1. Smith, J, M, "Chemical Engineering Kinetics", 3rd edition, McGraw-Hill 1990.
2. Schmidt, L.D. "Engineering of Chemical Reactions", Oxford Press. 1998
3. Carberry, J.J., "Chemical and Catalytic Reaction Engineering", McGraw-Hill, New York 1976.

III B.Tech. Chemical Engineering Semester-V

NCH 301 COMPUTER AIDED EQUIPMENT DESIGN

Assessment

L	T	P	C
2	1	2	4

Sessional: 50 marks

End Semester: 50 marks

Course Objectives: To impart knowledge about mechanical design of chemical process equipments. The objective of this course is to acquire basic understanding of design parameters, complete knowledge of design procedures for commonly used process equipment and their attachments (e.g. internal and external pressure vessels, tall vessels, high pressure vessels, supports etc.), and different types of equipment testing methods.

CO1	Understand the basics of process equipment design and important parameters of equipment design.	Understand, Apply
CO2	Design internal pressure vessels and external pressure vessels.	Apply, Evaluate

CO3	Select standard piping, flanges, gaskets and bolts associated with the vessels.	Apply, Analyze, Evaluate
CO4	Design special vessels such as tall vessels and different supports for vessels	Understand, Apply, Evaluate
CO5	Design of liquid and gas storage tanks with and without floating roof.	Apply
CO6	Conduct experiments to apply computer aided equipment design	Apply, Evaluate, analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	3	2	2	1				2	2	3	1
CO2	3	3	3	3	3	2		1				2	2	3	1
CO3	3	3	3	3	3	2		1				3	2	3	1
CO4	3	3	3	3	3	2		1				3	2	3	1
CO5	3	2	3	3	3	2		1				3	2	3	1
CO6	3			3	2			2	3	2	2	1	2	3	1
Avg	3	2.8	2.8	2.8	2.83	2	2	1.16	3	2	2	2.33	2	3	1

Module 1 (7 hours)

Introduction: Classification of engineering materials, properties of Ferrous metals, Non ferrous metals, alloys & Ceramic materials. Structure-Property relationship in materials. Deformation of Materials Fracture: Elastic deformation, Plastic deformation, Creep, Viscoelastic deformation, Different types of fracture, Corrosion and Prevention: Direct Corrosion, electro-chemical corrosion, Galvanic cells, High temperature corrosion, Passivity, factors influencing corrosion rate, Control of corrosion-modification of corrosive environment, Inhibitors, Cathodic protection, protective coatings. Corrosion charts, Metal forming techniques e.g. bending, Rolling, Forming & Metal joining techniques, welding – such as Butt, Lap, fillet, corner. Inspection and testing of process vessels.

Module 2 (10 hours)

Pressure Vessels: Type of pressure vessels, Thin cylinder theory for internal pressure. Code & standard for pressure vessels (IS:2825: 1969), Design considerations, classification of pressure vessels as per codes, design of cylindrical and spherical shells under internal and external pressure, selection and design of closures and heads such as Flat, hemispherical, torispherical, elliptical & conical; Introduction to compensation for opening such as nozzles & manholes etc.

Module 3 (10 hours)

Flanges: Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Inspection and testing of vessels, heads and flanges as per code specifications. Piping: Pipe thickness calculation under internal and external pressure, introduction to flexibility analysis of piping system.

Module 4 (8 hours)

Design of vessel subject to external pressure and combined loading (Tall Tower Design), Supports: Design of lug support and saddle support including bearing plates and anchor bolts.

Module 5 (5 hours)

Storage Tanks: Introduction to Indian standards, filling and breathing losses; Classification of storage tanks; Design of liquid and gas storage tanks with and without floating roof. High-pressure vessels, Fundamental equations, Mechanical design of centrifuges, Centrifugal pressure, Bowl and spindle motion: critical speed.

List of Experiments

Application of computation tools, programming and simulation packages for the following,

1. Introduction to Lab:
   a) Calculate Reynolds Number and determine type of flow pattern
   b) Determine heat transfer coefficient and heat transfer area for shell and tube heat exchanger
2. Design of vessel shell under internal pressure.
3. Design of vessel head under internal pressure.
4. Design of vessel under external pressure.
5. Program to calculate are of reinforcing pad (area compensation)
6. Design of flange and selection of bolt
7. Pipe system flexibility analysis.
8. Design of tall column for its complete height.
9. Design of shell of storage vessel.

Suggested Text Books

1. Brownell L. E. and Young E. H., "Process Equipment Design", Wiley, 2004.
2. Bhattacharya B. C., "Introduction of Chemical Equipment Design", CBS Publishers, 2003.
3. Sinnott, R.K. "Chemical Engineering Design Volume-6", 4/e", Elsevier Indian reprint, 2006 (Coulson & Richardson's Chemical Engineering Series).
4. I.S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards.1969 (Reaffirmed 1977)

Weblink: https://archive.nptel.ac.in/courses/103/107/103107143/

Suggested Reference Books

1. Moss, D.R., "Pressure Vessel Design Manual", 3rd Ed., Gulf Publishers, 2004
2. Annartone D., "Pressure Vessel Design", Springer, 2007
3. M.V.Joshi "Process Equipment Design 2/e", Macmillan India, 1981(reprint 1985).

NCH 303 CHEMICAL REACTION ENGINEERING-II

L	T	P	C
3	1	0	4

Assessment:

End Semester: 50 marks

Course Objective

Main purpose of this course is to introduce the basic concepts of heterogeneous reactions (fluid-fluid and fluid-solid) and develop rate equations considering mass transfer as well. This course will also focus on basic concepts of catalysis, kinetics and mechanistic aspects of catalysts and design and rating of catalytic reactors.

Course outcomes:

Students completing the course will be able to

CO1	Understand kinetics and design of fluid-fluid reactions	Apply, Evaluate
CO2	Understand kinetics and design of fluid-solid reactions.	Apply, Evaluate
CO3	Explain methods for catalyst preparation, characterization, catalyst poisoning, mechanisms of catalytic reactions.	Analyze, Evaluate
CO4	Design solid catalytic reactors.	Apply, Analyze, Evaluate
CO5	Understand deactivating catalysts.	Understand, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2							1	3	2	1
CO2	3	2	2	2	2							1	3	2	1
CO3	2	3	3	3								1	2	1	1
CO4	3	3	3	3								1	3	2	2
CO5	3	2	3	3								1	3	2	1
Avg	2.8	2.6	2.8	2.6	2							1	2.8	1.8	1.2

Module 1 (10 hours)

Introduction to heterogeneous reactions, Fluid-fluid reactions: kinetics, the rate equation, The rate equation of straight mass transfer (Absorption) from gas to liquid, Rate equation for Mass Transfer and Reaction, Instantaneous reaction with respect to mass transfer- Different cases, Review of the Role of the Hatta modulus, Clues to Kinetic Regime from Solubility Data, Fluid-fluid reactors Design: Factors to consider in selecting a contactor, Straight mass transfer - Plug Flow Gas/Plug Flow Liquid Countercurrent flow in a Tower, Mass Transfer along with not very slow reaction: Different cases.

Module 2 (8 hours)

Fluid-solid reactions: kinetics, Selection of a model, Progressive-conversion model, Shrinking-core Model, Comparison of Models with real situation, Shrinking core model for spherical particles of unchanging size, Diffusion through gas film controls, Diffusion through ash layer controls, Chemical reaction controls, Rate of reaction for shrinking spherical particles, Chemical reaction controls, film diffusion controls, Extensions, Particles of different shape, Combination of resistances, Limitations of shrinking core model, Determination of the rate controlling step, Fluid-particle reactors: Design, Particles of a single size, plug flow of solids, Uniform Gas composition, Mixture of particles of different but unchanging size, Plug flow of solids, Uniform gas composition, Mixed flow of particles of a Single Unchanging size, Uniform Gas Composition, Mixed flow of a size mixture of particles of Unchanging size, Uniform Gas Composition, Instantaneous Reactions.

Module 3 (8 hours)

Nature of catalysis, Adsorption isotherms, Physical properties of catalysts, preparation, testing and characterization of solid catalysts, catalyst selection, catalyst poisoning and mechanisms of catalytic reactions.

Module 4 (8 hours)

Reaction and diffusion within porous catalysts, effectiveness factor, heat effects during reaction, Experimental methods for finding rates, design of solid catalytic reactors.

Module 5 (6 hours)

Mechanisms of catalyst deactivation, the rate and performance equation and design

Suggested Text Books

1. Levenspiel, O., "Chemical Reaction Engineering", 3rd edition, John Wiley, 1998.
2. Smith, J.M., "Chemical Engineering Kinetics", 3rd edition, McGraw-Hill 1990.

Suggested Reference Books

1. Carberry, J.J., "Chemical and Catalytic Reaction Engineering", Dover Books on Chemistry, 2001.
2. Froment, G.F., Bischoff, K.B. and De Wilde, J., "Chemical Reactor Analysis and Design" John Wiley & Sons, Incorporated, 2010.

NCH 305 MASS TRANSFER OPERATIONS-II

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
2	1	2	4

Course Objectives:

Course Objectives: To teach the students different separation techniques such as distillation, adsorption, liquid liquid extraction and solid liquid extraction

Course outcomes:

Students completing the course will be able to

CO1	Differentiate between flash, steam, batch, and vacuum distillation and explain their respective characteristics.	Identify, Explain, Differentiate
CO2	Calculate the extent of separation achieved for continuous binary or multicomponent system.	Recognize, Explain, Calculate
CO3	Evaluate liquid-liquid extraction and calculate number of theoretical stages required for a given extent of separation.	Recognize, Evaluate, Calculate
CO4	Evaluate solid-liquid extraction processes and calculate the number of theoretical stages required for a given extent of separation in solid-liquid extraction for cross current and countercurrent flows	Recognize, Evaluate, Calculate
CO5	Calculate the extent of adsorption for stage-wise and continuous contact adsorption operations and evaluate ion exchange processes.	Calculate, Evaluate
CO6	Conduct various experiments to apply the concepts of Mass Transfer Operation	Identify, Explain, Conduct

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2							2	2	3	2
CO2	3	3	3	3	2							2	2	3	2
CO3	3	3	3	3	2							2	2	3	2
CO4	3	3	3	3	2							2	2	3	2
CO5	3	3	3	3	2							2	2	3	3
CO6	3			3	2		2	2	3	2	2	1	2	3	1
Avg.	3	3	3	3	2		2	2	3	2	2	1.83	2	3	2

Module 1 (6 hours)

Distillation: Pressure-composition, Temperature-composition, Enthalpy-composition diagrams for ideal and non-ideal solutions; Raoult's law and its application; Maximum and minimum boiling mixtures; Concept of relative volatility; Single Stage Distillation-Differential distillation, Flash vaporization; Vacuum, molecular and steam distillations. Principles of azeotropic and extractive distillation.

Module 2 (8 hours)

Continuous Distillation of Binary Mixtures: Multistage contact operations, Characteristics of multistage tower, McCabe-Thiele method, Ponchon-Savarit method, Concept of theoretical or ideal stage; Reflux ratio-maximum, minimum and optimum reflux ratio, Use of open steam, Tray efficiency, Determination of height and diameter of distillation column, Binary batch rectification with constant reflux and variable distillate composition, constant distillate composition and variable reflux, Introduction to multicomponent distillation system.

Module 3 (6 hours)

Liquid-Liquid Extraction: Applications; Ternary liquid-liquid equilibria; Triangular graphical representation; Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation,

Module 4 (5 hours)

Solid-Liquid Extraction: Applications; Solid-liquid equilibrium; Equipment used in solid liquid extraction; Single and multistage crosscurrent contact and countercurrent operations; Overall stage efficiency; Determination of number of stages, Supercritical extraction: principles and applications.

Module 5 (5 hours)

Adsorption: Description of adsorption processes and their application, Types of adsorptions, Nature of adsorbents; Adsorption isotherms and adsorption hysteresis; Stagewise and continuous contact adsorption operations, Determination of number of stages, Equipments; Ion exchange, Equilibrium relationship; Principle of ion-exchange, techniques and applications.

List of Experiments

1. Determination of V-L-E diagram by measuring composition of binary and ternary components at different temperatures and vacuum levels apart from atmospheric pressure operation.
2. Verification of *Rayleigh equation* in a binary batch distillation process
3. To Study the performance of continuous distillation column.
4. Determination and Verification of yield of oil by steam distillation unit.
5. Determination of Liquid Equilibrium and construction of tie lines in triangular diagram
6. To Study the performance of solvent extraction packed bed or Rotating Disc Contactor (RDC).
7. Determination of efficiency and effect of one of the parameters on extraction in a micro channel
8. Determination of efficiency and effect of one of the various parameters on the yield of oil in leaching.
9. Determination of efficiency and effect of one of the various parameters for removal of dissolved contaminant in water by adsorptive separation in activated carbon bed columns.
10. Determination of performance and efficiency of separation of membrane set up for removal of contaminants.

Suggested Text Books

1. Treybal, R.E. “Mass Transfer Operations”, 3rd ed. New York: McGraw-Hill, 1980.

2. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi 2013.

Suggested Reference books

1. Sherwood, T.K., Pigford, R.L. and Wilke, C.R. "Mass Transfer" McGraw Hill 1975.
2. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi 2012.
3. Dutta, B.K., Principles of Mass Transfer and Separation Processes. PHI Learning Private Limited, 2007.

NCH 307 TRANSPORT PHENOMENA

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives

This course provide knowledge and coupling between three transport phenomena such as momentum, heat and mass with applications in various inter-disciplines related to chemical engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Introduction of Elementary concept for understanding the analogy of three transport phenomena's. Review of basic concepts of molecular transport phenomena.	Understand, Apply, analyze
CO2	Develop understanding of Newtonian and Non-Newtonian Fluids and Solve Equations of Change Under Laminar Flow Conditions.	Create, Apply, Evaluate
CO3	Formulate and solve the equation of change for isothermal system and Velocity distribution with more than one Independent variable respectively.	Create, Analyze, Evaluate
CO4	Building the concept of conservation of thermal energy balance and solve problem related to heat and mass transport.	Apply, Create
CO5	Apply the shell balance, conservation equations and boundary conditions on different systems of transport phenomena.	Understand

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PS
CO1	3	3	3	3	3							2	1	3	1
CO2	3	3	3	3	3							2	1	3	1
CO3	3	3	3	3	3							2	1	3	1
CO4	3	3	3	3	3							2	1	3	1
CO5	3	3	3	3	3							2	1	3	1
Avg	3	3	3	3	3							2	1	3	1

Module 1 (6 hours)

General Overview: Time derivatives, Foundation methodologies (dimensional analysis and solving partial differential equation), Boundary layer concept and boundary conditions. Molecular Transport Phenomena: Molecular transport of momentum, heat and mass, law of molecular transport, Newton's law of viscosity, Fourier's law of conduction and Fick's law of diffusion. Transport coefficients- viscosity, thermal conductivity and mass diffusivity.

Module 2 (6 hours)
Newtonian and Non-Newtonian Fluids: Time independent, time-dependent and viscoelastic fluids, constitutive equations and rheological characteristics.
Shell momentum balances and velocity distributions in laminar flow. Discuss case of flow of a falling film, circular tube, an annulus, and immiscible fluids, etc.

Module 3 (6 hours)
The equation of change for isothermal system: Navier-Stokes equations describing fluid flow, and use them to solve problems in which flow velocity varies in just one direction.
Velocity distribution problems with more than one Independent variable. Time–dependent flow of Newtonian fluids, solving flow problems using stream function, flow near solid surfaces by boundary layer theory. Turbulence phenomena

Module 4 (6 hours)
Fundamental laws of conservation of thermal energy. Define the heat transfer, Conductivity and its dependence on temperature and pressure. Shell energy balances, Application in heat flow problems. Heat transfer by radiation, and coupled with conduction as a boundary condition.

Module 5 (6 hours)
Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity. Shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with chemical reaction. Momentum, energy and mass transport in boundary layer with relevant analogies

Suggested Text books

1. Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., John Wiley & Sons, Inc. 2002
2. James, W., Wicks, C.E, Wilson, R.E. and Rorrer, G.L. "Fundamentals of Momentum, Heat, and Mass Transfer". 4th Edn. John Wiley and Sons Inc., New York: January 2000. ISBN: 9780471381495.
3. Geankoplis, C.J., "Transport Processes and Separation Process Principles includes Unit Operations", 4th Ed., Prentice-Hall of India 2013

Suggested Reference Books

1. Brodkey, R.S. and Hershey H.C., "Basic Concepts of Transport Phenomena", Vol. 1 and 2, Brodkey Publishing 1998 & 2003
2. Bannet, C.O. and Myers J.E., "Momentum Heat and Mass Transfer" Tata McGraw Hill.

3. Cussler E.L., “Diffusion: Mass Transfer in Fluid Systems”, 2nd Edn., Cambridge University Press. 2009

NCH 309 CHEMICAL TECHNOLOGY

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives:
To study process technology, material requirements, production trends and conditions, preparation of process flow sheets, design aspects, engineering and environmental problems of various chemical industries.

Course outcomes:
Students completing the course will be able to

CO1	Provide an overview of chemical process industries, identifying unit operations and processes used. Explain raw materials, industrial processes, and engineering challenges in Chloro-alkali, Cement, Sulphur, and Phosphorous industries.	Understand, Apply, Analyze, Evaluate
CO2	Develop understanding of raw materials, processes, and engineering challenges in Electro-chemical, Coal, and Industrial gases industries.	Understand, Analyze Evaluate
CO3	Study raw materials, in-depth processes, and engineering challenges in Petroleum and Petrochemicals industries.	Understand, Analyze, Evaluate
CO4	Explain raw materials, comprehensive processes, and engineering challenges in Natural products industries.	Apply, Understand, Analyze
CO5	Study raw materials, processes, and engineering challenges in fertilizer, Polymer, and synthetic fiber industries.	Understand, Apply, Create

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1			3	2		2	2	2	3	3	3	3
CO2	3	1	1			3	2		2	2	2	3	3	3	2
CO3	3	1	1			3	2		2	2	2	3	3	3	2
CO4	3	1	1			3	2		2	2	2	3	3	3	2
CO5	3	1	1			3	2		2	2	2	3	3	3	2
Avg	3	1	1			3	2		2	2	2	3	3	3	2.2

Module 1 (8 hours)
Overview of chemical process industries with reference to Indian resources. Study different unit operations and unit processes used for manufacturing chemicals. Cement manufacturing,

Sulphur, Common salt, Caustic soda and Chlorine, Soda Ash, Hydrochloric acid, Sulfuric acid, Phosphoric acid and Super- Triple phosphates.

Module 2 (7 hours)
Electrochemical Industries, Coal and Industrial Gases: Coal (electricity production processes), Oxygen, Nitrogen, Hydrogen, Carbon dioxide, Synthesis gases.

Module 3 (10 hours)
Petroleum and Petrochemicals: Crude oil distillation, Thermal conversion processes (cracking, coking and vis-breaking), Catalytic conversion processes (fluid catalytic cracking, catalytic reforming, hydro cracking, alkylation, isomerization and polymerization), Petrochemicals Products (ethylene, propylene, formaldehyde, methanol).

Module 4 (7 hours)
Natural products industries: Production of Sugar from sugar cane, Oil & fats, Fermentation products such as Alcohol, Acetic acid, etc and Paper & Pulp industry.

Module 5 (8 hours)
Polymerization industries: Synthetic and natural fibers: Nylon, Dacron, natural and synthetic rubber, vulcanization and reclaiming of rubber, SBR, Thermosetting and Thermo Plastics (PVC, Polyethylene, Polyurethane, Teflon). Fertilizers: Ammonia, Nitric acid, Urea and other nitrogen fertilizers, mixed fertilizers.

Suggested Text Books

1. Rao M.G. and Sittig, M. "Dryden’s Outlines of Chemical Technology for the 21st Century", Affiliated East-West Press, New Delhi. 2002.
2. Austin G.T., "Shreve’s Chemical Process Industries", Fifth edition, Tata McGraw Hill, NY. 2012

Suggested Reference Books

1. Faith, W.L., Keyes, D.B. and Clark, R.L., “Industrial Chemicals” John Wiley. 1975
2. Kirk and Othmer, "Encyclopaedia of Chemical Technology" Wiley, 2004.
3. Kent, J.A., "Riegel's Handbook of Industrial Chemistry,” CBS Publishers. 1997
4. Mall, I.D., "Petrochemical Process Technology", Macmillan India Ltd., New Delhi. 2007

III B.Tech. Chemical Engineering Semester-VI

NCH 302 PROCESS CONTROL AND INSTRUMENTATION

L	T	P	C
3	1	2	4

Assessment:

Sessional: 50 marks

End Semester:50 marks

Course Objective: Objective is to introduce the fundamentals of process control, controllers, stability and frequency response along with different process instruments used in chemical industries. The course will teach the students, how to obtain dynamic response of closed loop systems, stability analysis in transient and frequency domains. The course will also introduce about the instruments used for measurement of temperature, pressure, flow, level, viscosity.

CO1	Demonstrate understanding of process control and differentiate between open and closed loop systems.	Understand, Apply
CO2	Evaluate and analyze the transient response of simple control systems.	Apply, Evaluate, analyze
CO3	Apply the concepts of stability and frequency response in control systems.	Analyze, Evaluate, create
CO4	Acquire knowledge on different measurement methods used in industrial processes.	Understand, Apply, Evaluate, analyze
CO5	Apply different measurement devices in Chemical industries.	Apply, evaluate, analyze
CO6	Conduct various experiments to apply the concepts of process control	Apply, evaluate, analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	1	3									2	
CO2	3	3		3	3		3							3	2
CO3	3	2	3	3	3		3					3	3	3	3
CO4	3	3		3	3									1	1
CO5	3	3	3	2	3		2					1		3	3
CO6	3			3	2			2	3	2	2	1	2	3	1
Avg	3	2.8	3	2.5	2.83		2.66	2	3	2	2	1.66	2.5	2.5	2

Module 1 (8 hours)

Introduction to Process control systems, Use of Laplace & Inverse Laplace Transformation in study of Process Dynamics & Control. Dynamic behavior of First order system and First order systems in series. Second & higher order systems, Linearization of nonlinear systems, Transportation & Transfer Lag.

Module 2 (8 hours)

Classification of control systems, Regulator & Servo control, Feed Forward & Feed backward control, Negative & Positive Feedback Control, Modes of control action, Controllers & Final control Elements, Reduction of Block & Signal Flow Diagrams, and Transient response of simple control systems

Module 3 (8 hours)

Response of closed loop, Concept of stability, Stability Criterion, Routh test for stability, Introduction to frequency response, Introduction to control system design by frequency response (Bode Plot, Zeigler Nichols controller settings), Introduction to Controller Tuning.

Module 4 (8 hours)

Characteristics of measurement system, classification, performance characteristics, dynamic calibration, errors, statistical error analysis, Temperature measurement

Module 5 (8 hours)

Measurement of pressure: Manometers, Elastic pressure transducers, Measurement of Vacuum, Flow measurement, Level measurement, Density and viscosity measurement.

List of Experiments:

1. To calibrate and study the response of bimetallic thermometer.
2. To study the response of a liquid level tank system.
3. To calibrate the P/I converter.
4. To calibrate the given manometer for level measurement.
5. To determine the viscosity of given samples by constant stress rotational viscometer.
6. To study and calibrate diaphragm control valve.
7. To study the response of first order system in series using two tank liquid level system (Non-interacting system) to step input.
8. To study the response of first order system in series using two tank liquid level system (interacting system).
9. To calibrate a thermocouple using a glass bulb thermometer.
10. To assess the accuracy of a pressure gauge with a dead weight gauge tester.

Suggested Text Books

1. Coughnour and Koppel, "Process System Analysis and Control", McGraw-Hill, New York, 1986
2. Stephanopoulos, G. "Chemical Process Control", Prentice-Hall of India Pvt Ltd., New Delhi, 1990.
3. Singh, S.K., "Industrial Instrumentation and Control", Prentice-Hall of India, 2016.
4. Eckman, D.P., "Industrial Instrumentation", Wiley Eastern Ltd., New York, 1990

Suggested Reference Books

1. Sarkar, P.K. "Process Dynamic and Control", Prentice-Hall of India, 2014
2. Considine, D.N. "Process Instrumentation and Controls Books", McGraw-Hill 2008
3. Patranabis, D."Principles of Industrial Instrumentation", Tata McGraw Hill, 2008.

NCH 304 PLANT DESIGN AND ECONOMICS

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
2	1	0	3

Course Objectives

The objective of this course is to acquire basic understanding of design parameters, complete knowledge of configuration and design procedures for commonly used process equipment in Heat transfer, Mass transfer and other operations. To gain the knowledge of cost and plant economics including depreciation, capital investment, cash flows, profitability evaluation and techno-economic feasibility

Course Outcomes:

Students completing the course will be able to

CO1	Analyze, synthesize and design processes for process heat exchangers.	Analyze, Apply
CO2	Integrate and apply techniques and knowledge acquired in heat and mass transfer, fluid mechanics, instrumentation and control to design condensers, reboilers, jacketed and coiled vessels.	Understand, Apply, Evaluate
CO3	Integrate and apply techniques and knowledge acquired to design distillation and packed column.	Analyze, Evaluate, Apply
CO4	Understanding capital investment and cash flow, estimation of operating and production cost for process plants.	Evaluate, Analyze
CO5	Understanding depreciation, evaluating the profitability of process industry projects using different methods of profitability analysis, replacement costs; Optimizing production rates and evaluation of optimum conditions of operations.	Understand, Evaluate, Apply

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3		1	2		1	2	3	3	1
CO2	3	3	3	3	3	3		1	2		1	2	3	3	1
CO3	3	3	3	3	3	3		1	2		1	2	3	3	1
CO4	3	3	3	3	2	2		1	3		1	3	2	1	
CO5	3	3	3	3	2	2		1	3		1	3	2	1	
Avg	3	3	3	3	2.6	2.6		1	2.4		1	2.4	2.6	2.2	1

Module 1 (6 hours)

Introduction , Basic design procedure and theory, Heat exchanger analysis: effectiveness NTU method, Overall heat-transfer coefficient, Fouling factors (dirt factors),Shell and tube exchangers: construction details, Heat-exchanger standards and codes, Tubes, Shells, Tube-sheet layout (tube count), Shell types (passes), Shell and tube designation, Baffles, Support plates and tie rods, Tube sheets (plates), Mean temperature difference (temperature driving force), Shell and tube exchangers: general design considerations, Fluid allocation: shell or tubes, Shell and tube fluid velocities, Stream temperatures, Pressure drop, Fluid physical properties, Tube-side heat-transfer coefficient and pressure drop (single phase),Heat transfer, Tube-side pressure drop, Shell-side heat-transfer and pressure drop (single phase), Flow pattern, Design methods, Kern's method, Bell's method, Shell and bundle geometry, Effect of fouling on pressure drop, Pressure-drop limitations.

Module 2 (6 hours)
Condensers, Heat-transfer fundamentals, Condensation outside horizontal tubes, Condensation inside and outside vertical tubes, Condensation inside horizontal tubes, Condensation of steam, Mean temperature difference, De superheating and sub-cooling Condensation of mixtures Pressure drop in condensers, Design of forced-circulation reboilers, Design of thermo siphon reboilers, Design of kettle reboilers, Heat transfer to vessels, Jacketed vessels, Internal coils, Agitated vessels.

Module 3 (6 hours)
Design methods for binary distillation systems, Basic equations, McCabe-Thiele method, Low product concentrations, The Smoker equations, Batch distillation, Steam distillation, Plate efficiency, Prediction of plate efficiency. Approximate column sizing, Plate contactors, Selection of plate type, Plate construction, Plate hydraulic design, Plate-design procedure. Plate pressure drop, Down comer design. Design of packed columns for absorption/stripping, Types of packing, Packed-bed height- Prediction of the height of a transfer unit (HTU), Prediction of the number of transfer units (NTU), Column diameter (capacity), Column internals.

Module 4 (6 hours)
Cost Estimates: Factors affecting investment and production costs, Methods for estimating capital investment, Estimation of total product cost, cash flow and cumulative cash flow diagram Cost indexes, estimating equipment cost by scaling, Turnover ratio, types of interest, Simple and Compound interest, nominal and effective interest rates, continuous interest, Cash flow pattern - Discrete cash flow & Continuous cash flow.

Module 5 (6 hours)
Depreciation: Straight line method, Declining balance method, Double declining balance method, sum-of-the-digit method, Sinking-fund method, evolution of depreciation method, Profitability, Methods of profitability evaluation for replacements. alternative investments, practical factors in alternative investment and replacement studies, Taxes and insurance, breakeven chart for production schedule and its significance for optimum analysis, optimum production rates in plant operation and for minimum cost per unit of production

Suggested Text Books
1. Sinnott R. K., "Chemical Engineering Design", Vol 6, Fourth Edition, Butterworth-Heinemann. 2006
2. Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India.2006
3. I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers", Bureau of Indian Standards.2007

4. Peters M. S. and Timmerhaus K. D., “Plant Design and Economics For Chemical Engineers”, 5th Ed., McGraw Hill, International Ed.2004.

Suggested Reference Books

1. Ludwig E. E., “Applied Process Design for Chemical and Petrochemical Plants”, Vol. 2, 3rd Ed., Gulf Publishers.1997

NCH 306 PROCESS MODELING AND SIMULATION

L	T	P	C
3	1	2	5

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course explores the basic concepts and steady state equations of simple systems in chemical process industries. It deals with the techniques for derivation of system model equations, data analysis and visualization. The basic objective is to develop the tools to analyze the system and to visualize the effect of various process inputs on system performance and state variables. The course aims to present the basic idea and concept on process model with detailed analysis and solution of model equations for steady and unsteady operation.

Course Outcomes:

Students completing the course will be able to

CO1	Model deterministic systems and differentiate between nonlinear and linear models.	Remember, Understand
CO2	Numerically simulate linear and non-linear ordinary differential equations for deterministic systems	Understand, Apply
CO3	Estimate and validate a model based upon input and output data.	Understand, Apply, Evaluate
CO4	Create a model prediction based upon new input and validate the output data	Understand, Analyze, Evaluate
CO5	Develop steady state models for flash vessels, equilibrium staged processes, distillation columns, absorbers, strippers, CSTR, heat exchangers and packed bed reactors.	Understand, Apply, Analyze, Evaluate, Create
CO6	Demonstrate the knowledge of various simulation packages and available numerical software libraries.	Understand, Apply, Create

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	2	3							2			
CO2	3	2	1	2	3							3			
CO3	3	2	2	2	3							2	1	2	1
CO4	3	2	2	2								2	2	3	2
CO5	3	3	2	2								3	2	3	2
Avg	2.83	2.33	1.83	2	3			3	3	3		2.33	2	2.75	2

Module 1 (12 hours)

Introduction to mathematical modeling; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models: Linear vs. Non-linear, Lumped parameter vs. Distributed parameter; Static vs. Dynamic, Continuous vs. Discrete; Numerical Methods: Iterative convergence methods, Numerical integration of ODE- IVP and ODE-BVP.

Module 2 (7 hours)

Concept of degree of freedom analysis: System and its subsystem, System interaction, Degree of freedom in a system e.g. Heat exchanger, Equilibrium still, Reversal of information flow, Design variable selection algorithm, Information flow through subsystems, Structural effects of design variable selection, Persistent Recycle.

Module 3 (7 hours)

Simple examples of process models; Models giving rise to nonlinear algebraic equation (NAE) systems, - steady state models of flash vessels, equilibrium staged processes distillation columns, absorbers, strippers, CSTR, heat exchangers, etc.; Review of solution procedures and available numerical software libraries.

Module 4 (7 hours)

Steady state models giving rise to differential algebraic equation (DAE) systems; Rate based approaches for staged processes; Modeling of differential contactors – distributed parameter models of packed beds; Packed bed reactors; Modeling of reactive separation processes; Review of solution strategies for Differential Algebraic Equations (DAEs), Partial Differential Equations (PDEs), and available numerical software libraries. Introduction to unsteady state models and their applications.

Module 5 (7 hours)

Simulation and their approaches, Modular, Sequential, Simultaneous and Equation solving approach, Simulation softwares and their applications, Review of solution techniques and available numerical software libraries. Review of thermodynamic procedures and physical property data banks.

List of Experiments

1. Solve a non-linear algebraic equation using Newton Raphson method.
2. Solve a differential equation using Runge Kutta method.

3. Calculate pressure drop in a pipe.
4. Calculate the minimum fluidization velocity.
5. Calculate the terminal velocity.
6. Solve a system of non-linear equations,
7. Calculate the molar volume of saturated liquid water and saturated water vapour using van der Waals, Redlich-Kwong and Peng-Robinson cubic equation of state.
8. Solve a system of simultaneous ordinary differential equations.
9. Solve for outlet temperatures in a series of stirred tanks with coil heater.
10. Solve for reactor height and conversion in a non-isothermal plug flow reactor (PFR).
11. Solve for concentration profiles of A, B and C in the series reaction A→B→C.

Suggested Text Books

1. Luyben, W.L., "Process Modeling, Simulation, and Control for Chemical Engineering", Mc Graw Hill. 1998
2. Rudd, D.F. and Watson, C.C. "Strategy of Process Engineering", Wiley International. 2003
3. Denn, M.M. "Process Modelling", Wiley, New York, 1990.

Suggested Reference Books

1. Jana, A.K. "Chemical Process Modelling and Computer Simulation", PHI, 2011.
2. Holland, C.D. "Fundamentals of Modelling Separation Processes", Prentice Hall, 1975.
3. Hussain, Asghar, "Chemical Process Simulation", Wiley Eastern Ltd., New Delhi, 1986.

NCH 308 PLANT SAFETY AND ENVIRONMENTAL ASPECTS

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective: Study of Plant Safety is an essential requirement of the chemical process industries. Knowledge of plant safety is indispensable while working in plant to prevent accidents and damages. A safety management, audit and risk analysis skill prepares the plant operators and managers to emerge to a safe protocol and minimize potential damages to personnel, process equipment, and the environment. This course will give an overview of the safety regulations and practices, plant hazards and their control, risk management principles and techniques and accident analysis. The environmental aspects of various industries are also discussed to clear the comprehensive approach of the subject objective

CO1	Introduction and Identification of key concepts of safety, hazards, risk assessment and its management in process plant	Understand, Evaluate
CO2	Develop understanding of severity of incidents and importance of toxicological studies	Analyze, Remember
CO3	Understand and interpret a hazard and operability study (HAZOP) for the hazard identification, chances of occurring and consequences.	Understand, Apply
CO4	Awareness about the various government/investigating agency such as EPA, OSHA, NSC for the analysis of safety related to environmental and human reliability	Remember, Apply
CO5	Demonstrate the root cause of the incident and study the plant safety based on environmental/technical aspects, and problems. Majorly in mineral, thermal power plant, metallurgical and petroleum industry, etc.	Understand, Apply, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2				3	3	3			3	3	2	3	3
CO2	3	2				3	3	3			3	3	2	3	3
CO3	2	2	2	3	3	3	3	3			3	3	2	3	3
CO4	2	2				3	3	3			3	3		3	3
CO5	3	2	3	3		3	3	3			3	3	3	3	3
Avg	2.6	2	2.5	3	3	3	3	3			3	3	2.25	3	3

Module 1 (5 hours)
Introduction, key concepts: Safety, Hazard, and Risk, Nature of the accident process, inherent safety. OSHA, fatal accident, fatality rate; Review of major chemical industry accidents: Flixborough Disaster, Seveso Disaster, Bhopal Disaster. Toxicological studies and TLVs.

Module 2 (8 hours)
Industrial Hygiene: Regulations, Identification, evaluation and control. Material safety data sheets. Introduction to source models. Fire triangle, flammability characteristics of liquids and vapor, estimation of flammability limits, LOC and inerting, Ignition energy, autoignition, autooxidation, adiabatic compression. Detonation and deflagration, VCE, BLEVE, Energy of a mechanical and chemical explosion. Inerting, vacuum and pressure purging, static electricity and its control. Explosion proof equipment and instruments.

Module 3 (7 hours)
Identification of reactive chemical hazards, relief concepts and types, relief systems. Introduction to relief sizing. Hazard Identification and Risk assessment, Hazard and Operability study (HAZOP); procedure and application. Probability theory and interaction between process units. Fault tree and event tree analysis;

Module 4 (4 hours)

Process safety strategies, managing safety, safety reviews and accident investigations, process uncertainties, reliability engineering and economics of loss prevention, designs for process safety.
Safety laws and regulations: Agencies involved as NFPA, OSHA, EPA and National Safety Council for safety management and environmental related issues.

Module 5 (6 hours)
Environmental aspects of plant safety: Environmental laws related to various industries. Protections against fire, explosions and toxic hazards; Process and plant safety; Introduction to safety audits.
Environmental health and safety guidelines: Occupational health and safety impacts of petroleum industry, coal processing, cement and lime, ceramic, fertilizer, textile, thermal power plant; metal, plastic and rubber industry.

Suggested Text Books:

1. Crowl D.A. and Louvar, J.F. "Chemical Process Safety: Fundamentals with Applications", 3rd Edition, Pearson, 2014.
2. Lees' Loss Prevention in the Process Industries, 4th Edition, Butterworth-Heinemann, 2012.

Suggested Reference:
1. International Finance Corporation (World Bank Group): Environmental, Health, and Safety guidelines. (www.ifs.org)

NCH 310 MATERIALS SCIENCE AND ENGINEERING

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives: At the end of the course the student will have an understanding of science and engineering aspect of materials. The major focus shall be on the structure, properties, processing, and application of common as well as advanced engineering materials.

CO1	Materials selection, Structure & imperfections.	Understand, Analyze
CO2	Corrosion, Structural & functional properties of materials	Understand, Analyze, Apply
CO3	Different engineering & advanced materials	Understand, Analyze, Apply
CO4	Different synthesis technologies & characterization of materials	Understand, Analyze, Apply

CO5	Economic & environmental issues, life cycle analysis	Understand, Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	1								2		2	
CO2	3	2	3	1			2					2	2	2	
CO3	3	2	3	2			3					2	2	2	1
CO4	3	2	3	3	3		3					2	2	2	2
CO5	2	2	3	2			3	2			2	2	2	2	3
Avg	2.6	2	2.6	1.8	3		2.75	2			2	2	2	2	2

Module 1 (6 hours)

Historical perspective of Materials Science, Classes of engineering materials- engineering requirement of materials -selection of materials, Structure and Imperfections in Crystals: Crystal structure Crystal geometry, structure of solids, methods of determining structures. Imperfection in crystals - types of imperfection. Point imperfection, diffusion in solids - self diffusion Fick's law, Applications of diffusion.

Module 2 (6 hours)

Properties and Corrosion of Material: Structural and Functional property, mechanical (Elastic and plastic properties), electrical and magnetic properties (Dia, para, Ferro, Antiferro and ferrimagnetism), Deformation of materials - corrosion, theories of corrosion, control and prevention of corrosion.

Module 3 (7 hours)

Engineering materials - ferrous & non-ferrous metals - Metals and alloys, Iron and steel Iron carbon equilibrium diagram, Non-Metals: Inorganic materials: Ceramics, Glass and refractories - organic materials: wood, plastics, and rubber and wood, Advanced materials (Biomaterials, nanomaterials and composites) with special reference to the applications in chemical Industries.

Module 4 (7 h ours)

Synthesis routes, Sol-gel technique, Nonaqueous Sol–gel route for Metal Oxide nanoparticles, hydrothermal synthesis, co-precipitation, preparation of nanocomposites, Characterization of Materials- Importance of Characterization of Materials, Structural and Functional Characterizations. Principles and application of different characterization techniques

Module 5 (4 hours)

Economic considerations, Environmental and societal considerations, Recycling issues, Life cycle analysis and its use in design.

Suggested Text Books:

1. Callister, William D. "Materials Science and Engineering", 7th Edition, John Wiley & Sons, Inc. 2007

2. Hajra Choudhury, S.K. "Material Science and Processes", 1st Edition, 1977. Indian Book Distribution Co., Calcutta 1977

Suggested Reference Books:

1. Van Vlack, Lawrence H. "Elements of Material Science and Engineering", Addison-Wesley Co.1971.
2. Raghavan, V. "Materials Science and Engineering", Prentice Hall. 2004

OPEN ELECTIVE -I

NCH 466 INDUSTRIAL POLLUTION CONTROL AND WASTE MANAGEMENT

L	T	P	C
2	0	0	2

Assessment:

Sessional: 50 marks

End Semester: 50marks

Course Objective:

To learn the essential principles used in industrial pollution abatement and understand important issues in industrial pollution abatement and pertinent environmental acts and legislations.

Course Outcomes:

Students completing the course will be able to

CO1	Demonstrate comprehensive understanding of various types of pollution from chemical industries and various regulations pertinent to air, solid and water pollution.	Understand, Apply
CO2	Suggest process modifications in order to reduce pollution and waste from a chemical industry by employing recycle and reuse.	Apply, Evaluate
CO3	Design gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers for air pollution control.	Analyze, Evaluate
CO4	Perform design calculations for anaerobic and aerobic reactors for biological treatment of waste water.	Apply, Evaluate
CO5	Identify the best way to dispose, minimize or utilize hazardous solid waste from chemical industries and understand the ethical issues and societal impact of releasing pollutants in environment.	Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2		1		3	3					2	3	3	3
CO2	3	2		1		3	3					2	3	3	3
CO3	2	2	2	2	2	3	3					2	3	3	3
CO4	2	2	2	3	2	3	3					2	3	3	3
CO5	2	2	2	3		3	3	3				2	3	3	3
Avg	2.2	2	2	2	2	3	3	3				2	3	3	3

Module 1 (7 hours)

Introduction: Industrial Pollution and types of pollution from chemical process industries, Characterization of emission and effluents, Global consideration of environmental pollution, Environmental legislation - Water Act 1974, Air Act 1981, Environmental Protection Act 1986; Standards for liquid effluents from chemical process industries, air quality, nuclear radiation emission, noise emission.

Module 2 (8 hours)

Pollution Prevention: Process modification, Alternative raw material, Recovery of by product from industrial emission/effluents, Recycle and reuse of waste, Energy recovery and waste utilization, Material and energy balance for pollution minimization, Water minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.

Module 3 (10 hours)

Air Pollution Control: Air pollutants classification, Equipments for controlling particulate and gaseous pollutants, lapse rate, atmospheric stability, Dispersion models, Plume behavior, Stack design, Design of gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers, Air pollution control for petroleum refineries and cement plants.

Module 4 (7 hours)

Water Pollution Control: Waste water characteristics, Primary, secondary and tertiary treatments for wastewater, Anaerobic and aerobic treatment biochemical kinetics, Design of trickling filter, activated sludge systems, ponds and lagoons and aeration systems, Water pollution control for petroleum refineries, fertilizer industry, pulp and paper industry.

Module 5 (8 hours)

Solid Waste Management: Characterization of solid wastes-hazardous and non-hazardous wastes, Waste disposal and management laws and guidelines, Non-hazardous industrial wastes-treatment, disposal, utilization and management, Value-extraction from the wastes, Handling, storage and disposal of hazardous wastes, Waste disposal for nuclear power plants.

Suggested Text Books

1. Metcalf & Eddy, “Wastewater Engineering-Treatment and Reuse”, Revised by G. Tchobanoglous, F. L. Burton, and H. D. Stensel, 4th edition. Tata McGraw-Hill, 2003.

2. Mahajan, S.P., "Pollution Control in Process Industries", Tata McGraw-Hill, 1985

3. Peavy, H.S., Rowe, D.R.s and Tchobanoglous, G., "Environmental Engineering", McGraw-Hill edition, 1985

Suggested Reference Books

1. Kreith, F. and Tchobanoglous, G., "Handbook of Solid Waste Management", 2nd Ed., Mc Graw Hill, 2002

2. Pichtel, J., "Waste Management Practices: Municipal, Hazardous and Industrial", 2^{nd} Ed., CRC Press, 2005.

3. Conway, R.A. and Ross R.D., "Handbook of Industrial Waste Disposal", Van-Nostrand Reinhold, 1980.

4. Vallero, D., "Fundamentals of Air Pollution", 4th Ed., Academic Press, 2007.

Final B.Tech. Chemical Engineering Semester-VII

OPEN ELECTIVE - II

NCH ENERGY RESOURCES AND UTILIZATION

Assessment:

L	T	P	C
2	0	0	2

Sessional: 50 marks

End Semester: 50 marks

Course Objective

To understand and analyze the present and future energy demand of the world and the nation and techniques to exploit the available renewable and non-renewable energy sources such as solar, bio fuels, wind energy, tidal energy, nuclear energy and energy from fossil fuels.

Course Outcomes

Students completing the course will be able to

CO1	Understand the energy demand and resources to fulfill the demand of the world and the nation.	Understand
CO2	Effectively utilize available renewable and non-renewable energy resources.	Understand, Apply
CO3	Explain modern energy conversion techniques.	Understand, Apply
CO4	Evaluate different energy technologies based on efficiency, impacts and other factors.	Understand, Apply, Analyze, Evaluate

CO5	Evaluate different ways to conserve energy in different contexts.	Apply, Analyze, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	1			2	1				2	3	3	3
CO2	3	3	3	1		2	2	1				2	3	3	2
CO3	3	3	3	1			2	1				2	3	3	1
CO4	3	3	3	1		2	2	1				2	3	3	2
CO5	3	3	3	1		2	2	1				2	3	3	2
Avg	3	3	3	1		2	2	1				2	3	3	2

Module 1 (6 hours)

Energy Scenario: Indian and global, energy crisis, Classification of various energy sources, Renewable and non-renewable energy sources, Remedial measures to some energy crisis. Energy Conservation: Biogas plants and their operation, Biomass and its conversion routes to gaseous and liquid fuels, Wind energy.

Module 2 (6 hours)

Fuel cell; Solar Energy: Photo thermal and photovoltaic conversion and utilization methods, Solar water heating, Solar cooking, Solar drying and its use for other industrial processes, solar cells: their material and mode of operation; Direct and indirect methods solar energy storage: Sensible heat and latent heat storage materials, Solar ponds; Bio energy: Biogas plants and their operations; Wind energy: its potential and generation by wind mills.

Module 3 (6 hours)

Hydroelectric potential: its utilization & production; Geothermal energy: its potential status and production; Nuclear energy: Status, Nuclear raw materials, Nuclear reactors and other classification, Generation of Nuclear power, Nuclear installations in India and their capacity of generation, Limitations of nuclear energy, Reprocessing of spent nuclear fuel; Cogeneration of fuel and power; Energy from tidal and ocean thermal sources; Magneto hydrodynamic power generation (MHD) systems.

Module 4 (6 hours)

Coal its origin and formation, Coal analysis, Coal classification, Coal preparation, Coal washing and Coal blending, Coal carbonization, Treatment of coal gas and recovery of chemical from coal tar, Coal gasification, liquid fuel synthesis from coal, Coal bed methane (CBM).

Module 5 (6 hours)

Petroleum crude, Types of crude, Emergence of petroleum products as energy, Gaseous Fuels: Natural gas, Water gas, Producer gas, LPG, Bio-gas, Coke oven gas, Blast furnace gas, LNG, CNG, Gas hydrates, GTL Technology (gas to liquid conversion), Biodiesel.

Suggested Text Books

1 Brame, J.S.S., and King, J.G., and Arnold, E. "Fuel Solid, Liquid and Gases", 4^{th} Ed., Edward Arnold 1967.

Suggested Reference Books

1 Sukhatme, S.P, "Solar Energy - Principles of Thermal Collection and Storage", 2nd Edn., Tata McGraw- Hill., 1996.

OPEN ELECTIVE – III

NCH PROCESS UTILITIES

L	T	P	C
2	0	0	2

Assessment:
Sessional: 50 marks
End Semester: 50 marks

Course Objective: To learn about various utilities used in chemical process industries such as water, compressed air, vacuum, heating medium, steam, insulation and refrigerants. To make students familiar with the equipments used to generate, deliver and maintain these utilities namely boilers, compressors, blowers, vacuum pumps and air filters,

Course Outcomes

Students completing the course will be able to

CO1	Know the various process utilities and their importance in chemical plants, Water resources and water treatment for industrial use	Understand, Apply
CO2	Select a suitable process heating system for chemical plants; Design a steam generation and distribution system for a chemical plant	Understand, Apply, Evaluate
CO3	Handling and use of process heat transfer fluids	Understand, Apply, Evaluate
CO4	Select a proper insulator and insulation thickness for high, intermediate, low and sub-zero temperatures	Understand, Analyze, Evaluate, Apply
CO5	Select a suitable pressure and vacuum system and piping system under pressure or vacuum for chemical plants	Understand, Analyze, Evaluate, Apply

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	1			2		1		1	2	3	3	3

CO2	3	3	3	1		2	2		1		1	2	3	3	2
CO3	3	3	3	1			2		1		1	2	3	3	1
CO4	3	3	3	1		2	2		1		1	2	3	3	2
CO5	3	3	3	1		2	2		1		1	2	3	3	2
Avg	3	3	3	1		2	2		1		1	2	3	3	2

Module 1 (6 hours)

Utilities, their role and importance in chemical plants; Water- Sources of water and their characteristics; Requisites of industrial water and its uses; Methods of water treatment-Chemical softening, Demineralization; Resins used for water softening; Reverse osmosis and membrane separation; Effects of impure boiler feed water & its treatments-Scale & sludge formation, Corrosion, Priming & foaming, Caustic embrittlement; Reuse and conservation of water; Water resource management.

Module 2 (7 hours)

Types of electrical process heating system- Dielectric heating, Resistance heating, Induction heating, Infrared heating, Properties of steam; Problems based on enthalpy calculation for wet steam, dry saturated steam, superheated steam; Steam generation, distribution and utilization; Types of steam generator / boilers: water tube & fire tube; Solid fuel fired boiler; Waste gas fired boiler; Waste heat boiler; Fluidized bed boiler; Scaling, trouble shooting, preparing boiler for Inspection; Design of efficient steam heating systems; steam economy, Steam condensers and condensate utilization, Expansion joints, flash tank design, Steam traps-Characteristics, selection and application.

Module 3 (6 hours)

Heat-transfer fluids: Heat-transfer fluid systems-Liquid-phase, vapour-phase systems; Heat-transfer fluids-Steam, synthetic organic fluids, Silicone fluids, Glycol-based fluids, Water, Paraffinic and mineral oils, Molten salts, Desirable properties of a heat-transfer fluid- Thermal properties, Containment properties, Stability properties, Fire safety, Environmental and toxicological properties, Selection of proper heat-transfer fluid-Liquid or vapour phase heat transfer, Maximum temperature, Minimum temperature, Vapour pressure, Thermal stability, Heat-transfer fluid degradation, Heat-transfer mist explosion.

Module 4 (5 hours)

Importance of thermal insulation for meeting the process requirement, Insulation materials and their effect on various materials of equipment, piping, fitting and valves etc., Insulation for high, intermediate, low and sub zero temperatures, including cryogenic insulation.

Module 5 (6 hours)

Pressure and Vacuum Systems: Compressors, blowers and vacuum pumps and their performance characteristics; Methods of developing vacuum and their limitations, material handling under vacuum, Piping systems; Lubrication and oil removal in compressors and pumps, Air filters, Air and gas leakage, Inert gas systems, Compressed air for process, Instrument air, Storage and Movement of Utilities within Plant.

Suggested Text Books

1. Nordell, Eskel, “Water Treatment for Industrial and Other Uses”, Reinhold Publishing Corporation, New York. 1961.
2. Balleney, P.L. “Thermal Engineering”, Khanna Publisher, New Delhi, 1978
3. Powel, S.T. “Industrial Water Treatment”, McGraw Hill, New York, 1964
4. Chattopadhya, P“Boiler Operations”, Tata McGraw Hill, New Delhi, 1998
5. Ananthanarayan, P.N. “Refrigeration & Air Conditioning”, Tata McGraw Hill, 2005

Suggested Reference Books

1. Perry, R.H. and Green, D.W., Perry’s Chemical Engineer’s Handbook, McGraw Hill, New York, 2019
2. R. C. Patel, R.C. and C. J. Karmchandani, C.J. “Elements of Heat Engines” Vol –II, III, Acharya Book Depot., Vadodara, 1997
3. Goodall, P.M., “The Efficient Use of Steam” IPC Science and Technology 1980.

ELECTIVE I (NCH 312-318)

NCH 312 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives

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

Course Outcomes:

Students completing the course will be able to

CO1	Solve problems of ordinary differential equations	Apply, Evaluate
CO2	Solve problems using power series methods	Apply, Evaluate
CO3	Solve problems of Bessel’s equations	Apply, Evaluate
CO4	Solve problems involving matrices and determinants	Apply, Evaluate
CO5	Solve problems of partial differential equations	Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3	-	-	-	-	-	-	2	1	3	
CO2	3	3	3	3	3	-	-	-	-	-	-	2	2	1	
CO3	3	3	3	2	3	-	-	-	-	-	-	2	1	2	
CO4	3	3	3	2	3	-	-	-	-	-	-	2	1	2	
CO5	3	3	3	3	3	-	-	-	-	-	-	2	2	2	
Avg	3	3	3	2.4	3							2	1.4	2	

Module 1 (6 hours)

Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear coefficients, Exact equations, Linear equation of first order, Bernoulli’s equation, Other integrating factors, Integration of Exact equations, Equations of first order and higher degree, Clairaut’s equation, Singular solutions, Equations with missing terms, General properties of Linear equations, Linear equations with constant coefficients, Determination of the complementary function, exponential functions, Determination of the particular integral, the Euler equation, Simultaneous Linear Differential equations.

Module 2 (6 hours)

Power series method, theory of the power series method, Legendre’s equation, Legendre’s Polynomials, Frobenius Method

Module 3 (6 hours)

Bessel’s equation, Bessel Functions Jv(x), Bessel Functions Jv(x) for any $v \geq 0$. Gamma Function, Solution J-v(x) of the Bessel Equation, Backbones of Bessel’s Theory, Jv(x) with v= ± 1/2, ± 3/2, ± 5/2.

Module 4 (6 hours)

Definition of matrix, Some special definitions and operations involving matrices, Determinants, Theorems on determinants, Inverse of a matrix, Orthogonal and unitary matrix. Orthogonal vectors, System of linear equations, Systems on n equations with n unknowns, Cramer’s Rule, eigen values and eigen vectors.

Module 5 (6 hours)

Definition of partial differential equations, types of partial differential equations and solution of partial differential equations.

Suggested Text Books

1 Mickley, Reid and Sherwood, “Applied Mathematics in Chemical Engineering”, Tata McGraw Hill, New Delhi (1981).

2 Kreyszig, E. "Advanced Engineering Mathematics", 8th edition, John Wiley and Sons 1999.

3 Spiegel, M.R. "Advanced Mathematics for Engineers and Scientists", Schaum Outline Series, McGraw Hill, 1971.

NCH 314 DESIGN OF EXPERIMENTS

Assessment:

L	T	P	C
3	**0**	**0**	**3**

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

Main objective of this course is to introduce various standard experimental designs and methods to analyze the data. To analyze and design the parameters of the systems such that the measure of performances are optimized.

Course Outcomes:

Students completing the course will be able to

CO1	Understand the importance of randomization and replication of experimental data set.	Understand, Apply,
CO2	Estimate statistical variance and perform analysis of variance, regression analysis, correlation analysis on a given experimental data.	Apply, Evaluate
CO3	Design full factorial and two factor complete factorial experiments and analyse the data.	Analyze, Evaluate
CO4	Understanding optimization and gradient optimization method.	Apply, Evaluate
CO5	Response surface designs and mixture experiments.	Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	3	3				1		1	1	2	3	1
CO2	3	3	3	2	3				1		1	1	2	3	1
CO3	3	2	3	3	3				2		1	1	2	2	1
CO4	2	2	3	3	3				2		1	1	2	2	2
CO5	2	2	3	2	2				2		1	1	3	3	2
Avg	2.4	2.2	2.8	2.6	2.8				1.6		1	1	2.2	2.6	1.4

Module 1 (6 hours)

Introduction to statistics for engineers: Simplest discrete and continuous distributions, Statistical inference, Statistical estimation, tests and estimates on statistical variance, Analysis of variance, Regression analysis (Simple linear, multiple, polynomial, nonlinear), Correlation analysis (Correlation in linear regression, correlation in multiple linear regression). Generalized matrix method for regression model.

Module 2 (6 hours)

Introduction to design of experiments, Preliminary examination of subject of research, Screening experiments. Basic experiment-mathematical modeling, Introduction to ANOVA, completely randomized design, randomized completely block design, latin square design

Module 3 (6 hours)

Complete factorial experiment, two factor complete factorial experiment, 2^n factorial experiment, Fractional factorial design, Box Wilson design. Statistical analysis: Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models.

Module 4 (6 hours)

Experimental optimization of research subject: Problem of optimization, Deterministic and Stochastic optimization problems. Gradient optimization method, efficiency of gradient method, canonical analysis.

Module 5 (6 hours)

Response surface methodology, central composite design. Box Benken design for fitting response surface, Mixture experiments, Steps of Mixture experiments.

Suggested Text Bookss

1 Lazic, Z.R. "Design of Experiments in Chemical Engineering: A Practical Guide, Wiley 2005.

NCH 316 PROCESS OPTIMIZATION

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives

The primary goal of this course is to provide an overview of state-of-the-art optimization algorithms, the theoretical principles that underpin them, and to provide students with the modeling skills necessary to describe and formulate optimization problems and their use for solving several types of practically relevant optimization problems arising in process systems engineering and society in general.

Course Outcomes:
Students completing the course will be able to

CO1	Identify different types of optimization problems	Understand, Apply
CO2	Explain different optimization techniques.	Apply, Evaluate
CO3	Solve various multivariable optimization problems.	Analyze, Evaluate
CO4	Solve problems by using Linear Programming.	Apply, Evaluate
CO5	Solve optimization problems of staged and discrete processes, understand the concept of specialized & Non-traditional Algorithms.	Understand, Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3							2	2	3	2
CO2	3	3	2	2	3							2	3	3	1
CO3	3	3	3	2	3							1	3	3	2
CO4	3	3	3	2	3							1	2	3	2
CO5	3	3	2	3	3							2	3	2	2
Avg	3	3	2.6	2.4	3							1.6	2.6	2.8	1.8

Module 1 (6 hours)
Introduction to process optimization: formulation of various process optimization problems and their classification. Basic concepts of optimization, convex and concave functions, necessary and sufficient conditions for stationary points.

Module 2 (10 hours)
Optimization of one dimensional functions, unconstrained multivariable optimization- direct search methods. Bracketing methods: Exhaustive search method, Bounding phase method Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

Module 3 (10 hours)
Multivariable Optimization: Unrestricted objective function, Problems with restricted variables: Equality constraints, Inequality constraints, Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent)

method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Direct search for constraint minimization: Variable elimination method, complex search method.

Module 4 (8 hours)
Linear Programming: Graphical solution, Primal Simplex method, Artificial starting solution, Dual Simplex method, Primal-Dual relationship, Duality, Sensitivity analysis. Revised Simplex method.

Module 5 (6 hours)
Transportation problem, Optimization of staged and discrete processes. Dynamic programming, Introduction to Specialized & Non-traditional Algorithms.

Suggested Text Books

1. Edgar, T.F. and Himmelblau, D.M. "Optimization of Chemical Processes", Mc Graw Hill, International editions, Chemical Engineering Series, 1989.
2. Beveridge, G.S. and Schechter, R.S. "Optimization Theory and Practice", Mc Graw Hill, New York, 1970

Suggested Reference Books

1. Taha, H.A. " Operation Research: An Introduction", 10^{th} Edition, Pearson, 2017. 2017.

NCH 318 ADVANCED CONTROL SYSTEM

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives:
To make the students understand the basic concepts of advanced process control schemes, solve controller tuning problems, design various types of controllers used in chemical process industries.

Course Outcomes:

Students completing the course will be able to

CO1	Design of feedback control systems using frequency response techniques.	Understand, Apply
CO2	Solve problems of controller tuning using online trial and error method, Ziegler-Nichol’s, Cohen and Coon methods	Understand, Apply
CO3	Design of Advanced Control Schemes involving large dead time or inverse response in feedback control systems.	Analyze, Evaluate
CO4	Design of controllers for interacting loops.	Apply, Understand, Evaluate
CO5	Decoupling and design of non-interacting control loops such as those found in distillation, heat exchangers etc.	Understand, Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2				2		2		3	2	2
CO2	3	3	3	3	2				2			1	3	3	2
CO3	2	3	3	3	1				1				3	3	1
CO4	3	3	3	2	2				1		1	1	3	3	2
CO5	3	3	3	3					2		1		3	3	3
Avg	2.8	3	3	2.8	1.75				1.6		1.33	1	3	2.8	2

Module 1 (8 hours)

Feedback Control Schemes: Concept of feedback control. Dynamics and analysis of feed-back-controlled processes. Stability analysis. Design of Feedback Controller, and its applications. Design of Feedback Control Systems using Frequency Response Techniques.

Module 2 (8 hours)

Controller Tuning: Controller tuning, Tuning rules, Online trial and error method, Ziegler-Nichol’s method, process reaction curve (PRC), Cohen and Coon formulae based on PRC, Integral error criterion. Discrete- Time control systems: Sampling and Z-Transform, Open-Loop and Closed-Loop response.

Module 3 (8 hours)

Analysis and Design of Advanced Control Systems: Feedback control of systems with large dead time or inverse response, Cascade control, Feedforward-Feedback control, Ratio control, Adaptive control, Inferential Control, Control systems with multiple loops.

Module 4 (8 hours)

Multiple-Input, Multiple-Output (MIMO) Systems: Introduction to MIMO systems, generation of alternative loop configurations, extension to interacting systems. Multivariable process control: Design of controllers for interactions, Loop interaction, Decoupling of interacting loops.

Module 5 (8 hours)

Multi loop multivariable control: Process and control loop interaction., Ratio control, Singular Value Decomposition (SVD), Relative Gain Array (RGA). Decoupling and design of non-interacting control loops. Example -Design of controller and control structure for common industrial processes such distillation, heat exchangers etc.

Suggested Text Books

1. Coughnowr and Koppel, "Process Systems Analysis and Control", McGraw-Hill, NewYork, 1986.
2. Stephanopolous, G. "Chemical Process Control", Prentice-Hall of India Pvt. Ltd., New Delhi, 1990.
3. Sarkar, P.K. “Process Dynamics and Control”, Prentice Hall India, 2014.

Suggested Reference Books

1. Considine, D.N. “Process Instrumentation and Controls Handbook”, Considine, McGraw Hill. 1990
2. Savas, E.S. "Computer Control of Industrial Processes", McGraw-Hill, London, 1965.
3. Smith, C.A., Armando B. and Corripio, A.B. “Principals and Practice of Automatic Process Control”, 2nd Edn., John Willy & Sons, 1997

ELECTIVE II (NCH 401-407)

NCH 401 ADVANCED SEPARATION PROCESSES

Assessment:

L	T	P	C
3	1	0	4

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To understand the governing mechanism and driving forces of various advanced separation processes such as azeotropic distillation, extractive distillation, molecular distillation, reactive distillation, absorption with chemical reaction, supercritical fluid extraction, membrane separation and reverse osmosis; and to perform process and design calculations for these processes.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the importance of modern separation techniques in various applications.	Understand, Apply,
CO2	Design novel membranes for intended applications.	Apply, Evaluate

CO3	Design supercritical fluid extraction processes.	Analyse, Evaluate
CO4	Perform preliminary calculations for multicomponent separation systems including azeotropic and extractive cases.	Understand, Apply, Evaluate
CO5	Calculate the rate of reactive absorption processes	Understand, Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3							2		3	2	2
CO2	3	3	3	3	2							1	3	3	2
CO3	2	3	3	3	1								3	3	1
CO4	3	3	3	2	2						1	1	3	3	2
CO5	3	3	3	3	2						1		3	3	3
Avg	2.8	3	3	2.8	1.75						1.3	1	3	2.8	2

Module 1 (8 hours)

Multicomponent distillation – Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes, Azeotropic distillation, Extractive distillation, Molecular distillation, Reactive distillation.

Module 2 (8 hours)

Absorption with chemical reaction, Enhancement factor, Simultaneous diffusion and chemical reaction near an interface – Film theory, Penetration theory, Surface renewal theory for a first-order irreversible reaction; Effect of reversibility of the chemical reaction on the mass-transfer rate; Computation of reaction effect for a few chemical situations – absorption of CO_2 and H_2S from a gas stream into aqueous solution of KOH etc.

Module 3 (8 hours)

Supercritical fluid extraction: Supercritical fluids, Phase equilibria, Industrial applications. Important supercritical processes: Decaffination of coffee, Extraction of oil from seeds, Residuum oil supercritical extraction (ROSE), Supercritical fluid chromatography, Supercritical fluid reactions etc.

Module 4 (8 hours)

Classification of membrane processes; Liquid permeation membrane processes or dialysis: Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis. Gas permeation membrane processes: Types of membranes and permeabilities for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes), Types of flow in gas permeation, Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes, Effect of processing variables on gas separation by membranes.

Module 5 (8 hours)

Reverse osmosis membrane processes: Osmotic pressure of solution, flux equation, Types of equipment and Complete mixing model; Effect of operating variables; Concentration polarization; Permeability constants. Ultrafiltration membrane processes: Types of equipment, flux equation, effects of processing variables

Suggested Text Books

1 Geankoplis, C.J., “Transport Processes and Unit Operations”, Prentice-Hall of India Pvt. Ltd., New Delhi 2000.

2 Sherwood, T.K., Pigford, R.L. and Wilke, C.R., “Mass Transfer”, McGraw-Hill, New York 1975.

Suggested Reference Books

1 Treybal, R.E., Mass-Transfer Operations”, McGraw-Hill, New York 1980.

NCH 403 CONCEPTUAL DESIGN OF CHEMICAL PROCESSES

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Objective of this course is to introduce students to the systematic procedure for the conceptual design of chemical processes. The goal of a conceptual design is to find the best process flow sheet and estimate the optimum design conditions. The course addresses an introduction to engineering economics, including a discussion of various measures of profitability, design of a gas absorber, recycle structure and flow sheet, compressor design, design of minimum-energy heat exchanger networks, cost diagram and the quick screening of process alternatives.

Course Outcomes:

Students completing the course will be able to

CO 1	Estimate capital and operating costs, total capital investments, total product costs.	Understand, Analyze
CO 2	Understand input-output structure of flow sheet, equilibrium limitations.	Understand, Analyze
CO 3	Design heat exchanger networks, minimum heating and cooling requirements, minimum number of exchanges, area estimates.	Apply, Analyze, Evaluate

CO 4	Estimate the cost diagram and the quick screening of process alternatives.	Analyze, Evaluate
CO 5	Approximate optimum design conditions.	Analyze, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2						2		3	2	2
CO2	3	3	3	3	2							2	3	3	2
CO3	2	3	3	3	1								3	3	1
CO4	3	3	3	2	2						1	2	3	3	2
CO5	3	3	3	3							1		3	3	3
Avg	2.8	3	3	2.8	1.75						1.33	2	3	2.8	2

Module 1 (8 hours)

Creative aspects of Process Design; A hierarchal approach to conceptual design; Engineering Economics –Cost information required, Estimating capital and Operating costs, Total capital investments and Total product costs, Time value of money, Measures of process profitability.

Module 2 (8 hours)

Economic Decision Making: Design of a Gas Absorber – Flow sheet, Material and Energy Balances, and stream costs, Rules of thumb. Input-output structure of the flow sheet: Decisions for the Input-Output Structure; Design variables, Overall Material Balances, and Stream Costs.

Module 3 (8 hours)

Recycle structure of the flow sheet - Recycle material balances, Reactor heat effects, Equilibrium limitations. Separation system – General structure, Vapor recovery system, Liquid separation system: column sequencing.

Module 4 (8 hours)

Heat exchanger networks – minimum heating and cooling requirements, minimum number of exchangers, area estimates, Design of minimum-energy heat exchanger networks.

Module 5 (8 hours)

Cost diagram and the quick screening of process alternatives; Preliminary process optimizations – Design variables and Economic Trade-offs, Cost models for process units, A cost model for a simple process.

Suggested Text Book:

1. Douglas J.M., Conceptual Design of Chemical Processes, McGraw-Hill, 1988.

NCH 405 ENERGY RESOURCES AND ENERGY CONSERVATION

L	T	P	C
3	**1**	**0**	**4**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Main purpose of this course is to introduce various conventional (coal and petroleum) and non-conventional energy resources (solar, nuclear, wind, tidal, geothermal), ways of harnessing energy from these sources and its distribution and utilization. This course also focuses on various approaches for energy conservation in a chemical industry.

Course Outcomes

Students completing the course will be able to

CO1	Demonstrate understanding of the different types of renewable and non-renewable energy technologies that are currently available and how they are used to provide energy.	Understand, Apply
CO2	Identify strengths and limitations associated with different energy technologies.	Apply, Evaluate
CO3	Realize that for sustainability of natural resources, our primary global energy resource profile must shift toward renewable resources.	Analyse, Evaluate
CO4	Evaluate different energy technologies based on efficiency, impacts and other factors.	Apply, Evaluate
CO5	Evaluate different ways to conserve energy in different contexts and the social and environmental impacts of renewable and non-renewable energy use.	Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	2	3	-	-	-	-	3	3	2	2
CO2	3	1	1	1	-	2	3	-	-	-	-	3	3	3	2
CO3	3	1	1	1	-	2	3	-	-	-	-	3	3	3	1
CO4	3	1	1	1	-	2	3	-	-	-	-	3	3	3	2
CO5	3	1	1	1	-	2	3	-	-	-	-	3	3	3	3
Avg	3	1	1	1		2	3					3	3	2.8	2

Module 1 (8 hours)

Energy scenario, classification of energy sources, need for conserving energy, government initiative for conserving energy (Role of bureau of energy efficiency, energy conservation bill 2001), energy efficiency based on first and second laws of thermodynamics; Thermodynamic analysis of processes.

Module 2 (8 hours)

Coal - coal analysis, coal classification, coal preparation, coal washing and coal blending, coal carbonization, coal gasification, liquid fuel synthesis from coal; Crude petroleum -chemistry, composition, classification; Crude oil distillation, composition, properties and application of liquid fuels - gasoline, kerosene, ATF, diesel, fuel oil; Gaseous fuels: natural gas, water gas, producer gas, L.P.G., bio-gas, coke oven gas, blast furnace gas, LNG, CNG, CBM, gas hydrates.

Module 3 (8 hours)

Nuclear energy: nuclear raw materials, nuclear reactors, electricity generation from nuclear power, nuclear installations in India and their generation capacities; Solar Energy: solar thermal and photovoltaic conversion and utilization methods, Solar cells, their material and mode of operation; Solar thermal energy storage - sensible heat and latent heat storage materials, chemical energy storage; Solar ponds.

Module 4 (8 hours)

Biomass: conversion routes to gaseous and liquid fuels; Biodiesel; Wind energy: basic principles of wind energy conversion, performance of wind mills, electricity generation from wind; Hydroelectric energy - potential and production; Geothermal energy - potential and production; Ocean energy: ocean thermal energy conversion (OTEC), tidal power plants.

Module 5 (8 hours)

Equipment-oriented approaches for energy conservation - fired heater, boiler, evaporators, distillation column, absorption/stripping column, dryer, liquid-liquid extraction column; Waste heat recovery: sources of waste heat, feasibility of waste heat recovery, types of heat recovery equipments, applications; Energy conservation opportunities in chemical process utilities - steam systems, compressed air systems, insulation; Cogeneration-A plausible approach for energy conservation

Suggested Text Books

1. Brame, J.S.S., King, J.G., and Arnold, E. "Fuel Solid, Liquid and Gases" Edward Arnold 1967.

2. Sukhatme, S.P, "Solar Energy - Principles of Thermal Collection and Storage", 2nd Edn., Tata McGraw- Hill., 1996.

3. Murphy, W.R. and Mckay, G., "Energy Management" Elsevier, 2003

Suggested Reference Books

1. Boyle "Renewable Energy: Power for a sustainable future" 3rd Ed., Oxford 19942012.

2. Rao, S. and Parulckar, B.B. "Energy Technology", 3rd Edn., Khanna Publisher.

NCH 407 PIPELINE TRANSPORTATION OF OIL & GAS

Assessment:

L	T	P	C
3	1	0	4

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

The primary goal of this course is to provide an overview of state-of-the-art pipeline design, and the theoretical principles that underpin them. The aim is to provide students with the skills necessary to describe and formulate design problems and their use for solving several types of practically relevant pipeline design problems arising in pipeline industries.

Course Outcomes:

CO1	Understand the fundamentals for calculating the properties of compressible and non-compressible fluids	Remember, Understand
CO2	Apply the various equations and concepts for calculating pressure drop in compressible and non-compressible fluids	Apply, Evaluate
CO3	Understanding the process of laying, constructing, and operating of pipelines	Apply, Evaluate
CO4	Apply the knowledge of pumps and compressors used for oil and gas pipeline operations.	Apply, Evaluate, Analyze
CO5	Develop an understanding in problems incurred in operating the cross-country pipelines and methods to mitigate them	Understand, Analyze, Create

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	1						1	3	2	1
CO2	3	3	3	3	2	1						1	3	3	1
CO3	2	3	3	3	1	1						1	3	3	1
CO4	3	3	3	2	2							1	3	3	1
CO5	3	3	3	3								1	3	3	1
Avg	2.8	3	3	2.8	1.75	1						1	3	2.8	1

Module 1 (8 hours)

Modes of Transporting Oil & Gas, Importance of Pipelines, Pipeline Systems, Design Life of Pipelines, Size and Cost of Pipelines, History of Pipelines in India, Major Codes and Standards in Pipeline, NPS Chart, Gases: Volume/Specific Gravity/Viscosity/Average Molecular Weight Compressibility Factor/Average Pressure Calculation/Heating Value Liquids:

Mass/Volume/Specific Weight/API Gravity(Dependency on Temperature)/Specific Gravity of Blended Liquids/Viscosities of Liquid Mixtures(Variation with Temperature)/Bulk Modulus/Vapor Pressure, Design if piping and pipeline systems

Module 2 (10 hours)

Pressure Drop Calculations: A Incompressible fluids: Converting Pressure to Head Velocity of Liquid in Pipelines, Pressure Drop Equations (Hagen Williams Equation, Shell MIT Equation, Miller Equation) Looping and Branching in Pipeline (Gas and Liquid) B. Compressible fluids: Gas: Flow Equations, Generalized Flow Equation, Weymouth Equation, Panhandle A equation, Panhandle B Equation. Transmission Factor, Effect of Pipeline Elevation (Single Slope, Multiple Slope) Velocity of Gas in Pipeline, Erosional Velocity, Reynolds Number (gas pipeline), Friction Factor Calculations, optimum diameter calculations.

Module 3 (8 hours)

Pipeline Construction, Pipeline Laying, Pipe Specifications, Route Surveying, Trenching, Welding, Wrapping Pig launchers and receivers

Module 4 (8 hours)

Pumps and Compressors, Types of Pumps and Compressors, Pumps and Compressors Characteristics, Single and Multistage pumps and compressors, compressor location. Number of pumping stations

Module 5 (6 hours)

Pipeline issues and Mitigation Measures, Wax, Scaling, Condensate, Corrosion, Thermal Variations in Pipelines, Automation, and SCADA

Suggested Text Books

1. Menon, E.S. "Gas Pipeline Hydraulics", CRC Press, Taylor and Francis Group, Boca Raton, FL. 2005.
2. Menon, E.S. Liquid Pipeline Hydraulics", CRC Press, Taylor and Francis Group, Boca Raton, FL. 2005

Suggested Reference Books

1. E.W. McAllister, E.W. "Pipeline Rules of Thumb Handbook", Gulf Professional Pulishing, 2002.

ELECTIVE III (NCH 409-417)

TCH 409 PETROLEUM REFINING AND PETROCHEMICALS

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives:

Petroleum refining as well as petrochemical industries constitute a major part of chemical sector. Knowing the sources of crude petroleum, extraction of the crude petroleum, its refining to the useful petro-products and efficient transport to the end users through network are important tasks to the petroleum or chemical engineers. This course intends to form the foundation of the chemical engineers on basic fields of petroleum from extraction to the safe end use where refining is the most challenging. The course puts major thrust on all the techniques/processes of petroleum refining encompassing selection of the mass/heat transfer devices, their operation and basic design. The course also covers the feed stocks of petrochemical industries and manufacture important petrochemicals.

Course Outcomes:

Students completing the course will be able to

CO1	Understand the fundamental concepts related to crude petroleum such as origin, occurrence, composition, physico-chemical properties and distillation characteristics	Understand, Apply
CO2	Know the various laboratory tests carried out for the various petroleum products and understand about the crude oil distillation operation	Understand, Analyze
CO3	Understand the thermal and catalytic conversion processes of petroleum refineries	Apply, Analyze, Evaluate
CO4	Know the petrochemical feedstocks and manufacturing of C1 and C2 petrochemicals	Understand, Apply
CO5	Understand the manufacturing of C3, C4, aromatic and polymeric petrochemicals	Understand, Analyze,

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1								1		2	3	2	2
CO2	3	2	1				1			1		2	3	3	2
CO3	2	2	1			1	2			1		2	3	3	1
CO4	2	2	1			2	2			1		2	3	3	2
CO5	3	2	2	1						1		2	3	3	3
Avg	2.4	1.8	1.25	1		1.5	1.6			1		2	3	2.8	2

Module 1 (6 hours)

Origin and occurrence, composition, classification and physio-chemical properties of petroleum; Distillation Characteristics such as TBP,ASTM & EFV etc.

Module 2 (6 hours)

Quality Control of Petroleum Products. Classification of laboratory tests, distillation, vapour pressure, flash and fire points, octane number, performance number, cetane number, aniline

point, viscosity index, calorific value, smoke point, char value, viscosity, viscosity index, penetration tests, cloud and pour points, drop point of grease, melting and settling points of wax, softening point of Bitumen, induction period of gasoline.
Crude Oil Distillation: Desalting of crude oils, Atmospheric distillation of crude oil, Vacuum distillation of atmospheric residue.

Module 3 (6 hours)
Thermal Conversion Process: Thermal Cracking Reactions, Thermal Cracking, Visbreaking, Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of Green Coke.
Catalytic Conversion Process: Fluid catalytic cracking; Catalytic reforming; Hydrocracking Catalytic Alkylation, Catalytic Isomerization; Catalytic Polymerization.

Module 4 (6 hours)
Petrochemical feed stocks; C1 and C2 Petrochemicals: Methanol, Formaldehyde, Chloromethane etc. Ethylene, Ethylene Dichloride, Vinyl Chloride, Ethylene Oxide, Ethylene Glycol, Ethanol amines etc.

Module 5 (6 hours)
C3, C4, Aromatics and Polymers: Propylene, Butadiene, etc. BTX Separation, p-xylene, Styrene, p-terephthalic acid, etc. PVC, LDPE, LLDPE, HDPE, Polypropylene, Polypropylene Co-polymers , Polystyrene , SBR ,PBR, Polyesters etc.

Suggested Text Books:
1. Mall, I.D., "Petroleum Refining Technology", CBC Publishers. 2017
2. Prasad, R. "Petroleum Refining Technology", Khanna Publishers, Delhi 2000.
3. Wiseman, P. "Petrochemicals", John Wiley & Sons, 1986.

Suggested Reference Books:
1. Nelson, W.L. "Petroleum Refinery Engineering", McGraw Hill, New York, 1961.
2. Matar, S. "Chemistry of Petrochemical Processes", 2nd Ed., Gulf Publishing Company, 2000.
3. Gary, J.H. and Handwork, G.E. "Petroleum Refining Technology and Economics", 4th Edn., Dekker, 2001.
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NCH 411 NANOTECHNOLOGY

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course aims to provide a broad overview of fundamental principles and laws governing the properties at nanometer scale. Students will learn various top down and bottom up approaches for nanostructure synthesis and experimental techniques to characterize them. This course will also introduce various applications of nanotechnology in chemical engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Describe the basic science behind the novel and superior properties of materials at the nanometer scale	Remember, Understand
CO2	Demonstrate a comprehensive understanding of the state-of-the-art nanofabrication methods	Understand, Apply
CO3	Compare and select suitable techniques for characterization of a given nanomaterial	Remember, Understand, Apply
CO4	Explain how nanotechnology can be put to use in varied areas of science and engineering	Apply, Analyze
CO5	Evaluate the impact of nanotechnology on society and environment. Evaluate current constraints such as regulatory, ethical, political, social and economic; when putting nanotechnology to use.	Understand, Apply, Analyze, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1										3	3	2	2
CO2	3	2	1				1					2	3	3	2
CO3	3		1	1	3							2	3	3	1
CO4	2	1					1	1				3	3	3	2
CO5	2	1	1			1	1	1				2	3	3	3
Avg	2.4	1.25	1	1	3	1	1	1				2.4	3	2.8	2

Module 1 (6 hours)

Introduction to Nanotechnology - its emergence and challenges, Nanomaterials and its classification, Properties of individual nanoparticles, Methods of synthesis, Reactivity of nanoparticles, List of stable carbon allotropes extended, Synthesis of carbon Bucky balls, Fullerenes, Metallofullerenes, solid C60, Bucky onions, Nanotubes, Nanowires, Nano cones, Carbon nanostructures, Graphene.

Module 2 (6 hours)

Methods of synthesis of Nanomaterials: Bottom-up (building from molecular level) and top-down (breakdown of bulk/microcrystalline materials) approaches. Manufacturing of nanoscale materials: Chemical vapor deposition of carbon nano tubes, Plasma deposition of ultra-thin functional films on Nano materials, Solution based Synthesis of Nanoparticles, Vapour Phase

Synthesis & Synthesis with framework, Nanolithography, Dip Pen Lithography. Artificially Layered Materials: Quantum Well, Quantum Dots, Super lattices & Layered Structures, core shell nano structure.

Module 3 (6 hours)

Top down approach vs Bottom up approach, Optical Microscopy, Electron Microscopy, Secondary electron scattering, back scattering, Scanning Probe Microscopes, Focused Ion Beam Technique, X-ray imaging, Transmission Electron Microscope (TEM), Scanning Probe Microscope (SPM)- Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM).

Module 4 (6 hours)

Surface Tension and Interfacial Tension, Surfaces at Equilibrium, Surface Tension Measurement, Contact Angles, Colloidal Stability, Electrical Phenomena at Interfaces, Vander Waals Forces between Colloidal Particles, Photo catalysis Nanostructured materials, Self-assembly and Catalysis.

Module 5 (6 hours)

Nano biotechnology : Drug Delivery, Nano clay, Nanocomposites, Surface coatings, Self-cleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nano electronics, Nano machines & Nano devices, Nano hydrogel, Photocatalytic reactors, Nano clay Synthesis, Polymer nanocomposite, Waste Water Treatment, Societal, Health and Environmental Impacts, Introduction to industries which produces commercial nanomaterials.

Suggested Text Books

1. Hornyak, G.L., Dutta, J., Tibbals, H.F. and Rao, A.K. "Introduction to NanoScience", CRC Press of Taylor and Francis Group, 2008
2. Pools, C.P. and Owens, F.J., "Introduction to Nanotechnology", Wiley-Interscience, 2003.
3. Cao, G. "Nanostructures and Nanomaterials, Synthesis, Properties and Applications", Imperial College Press, 2004.

Suggested Reference Books

1 Bhusan B., Springer Handbook of Nanotechnology, 4^{th} Ed., 2017

NCH 413 BIO-PROCESS ENGINEERING

Assessment:
Sessional: 50 marks
End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives

This course will introduce students to key concepts of microbiology and biochemistry that underpin their application in biochemical engineering. Main objective of this course is to make students understand the basic structure and function of microbial cells, key aspects of biochemistry including macromolecules, enzymes and key metabolic pathways and processes. To introduce enzyme kinetics and immobilization techniques, models for microbial growth, design of bioreactors, downstream processing and product recovery in bioprocesses.

Course Outcome

On completion of this course, students will be able to

CO1	Describe and identify the main groups of microorganisms.	Remember, Analyze
CO2	Compare the different structures and growth modes of diverse microorganisms.	Understand, Apply
CO3	Describe key biochemical and cellular components and biochemical pathways	Remember
CO4	Explain how microorganisms and biochemical processes can be applied in engineered systems and processes.	Understand, Apply
CO5	Select a proper bioreactor and decide suitable operating conditions for aerobic and anaerobic systems.	Understand, Apply, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	2									3			
CO2	2	1										3			
CO3	2	2	1									3			
CO4	3	2	3	2			2				2	2	2	2	2
CO5	3	3	3	2			2				2	2	2	2	2
Avg	2.4	1.8	2.25	2			2				2	2.6	2	2	2

Module 1 (6 hours)

Introduction - principles of microbiology, structure of cells, microbes, bacteria, fungi, algae, chemicals of life - lipids, sugars and polysaccharides, amino acids, proteins, nucleotides, RNA and DNA, Principles of genetic Engineering.

Module 2 (6 hours)

The kinetics of enzyme catalyzed reactions - the enzyme substrate complex and enzyme action, simple enzyme kinetics with one and two substrates. Isolation and utilization of Enzymes -production of crude enzyme extracts, enzyme purification, Enzyme production intercellular and extra cellular enzymes.

Module 3 (6 hours)

Metabolic pathways and energetic of the cell, concept of energy coupling, Photosynthesis, Carbon metabolism, EMP pathway, TCA cycle and electron transport chain, aerobic and anaerobic metabolic pathways, transport across cell membranes, Synthesis and regulation of bio-molecules.

Module 4 (6 hours)

Microbial Growth: Continuum andStochastic Models, Factors affecting growth, Batch and Continuous cell growth, nutrient media, enrichment culture, culture production and preservation, Immobilization technology–Techniques of immobilization.

Module 5 (6 hours)

Introduction to bio-reactors, types, continuously stirred aerated tank bio-reactors, Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, Fermentation: methods and applications; downstream processing and product recovery in bio processes.

Suggested Text Books

1. Bailey, J.E. and Ollis, D.F. “Biochemical Engineering Fundamentals” McGraw Hill Book Company, 1986.
2. Shuler, M.L. and F. Kargi, F. “ Bioprocess Engineering (Basic Concepts)” Prentice Hall of India, 2003.

NCH 415 ELECTROCHEMICAL TECHNOLOGY

L	T	P	C
3	**0**	**0**	**3**

Assessment:
Sessional: 50 marks
End Semester: 50 marks

Course Objectives

This course introduces the principles of electrochemistry; the fundamentals of corrosion and related concepts, with a link to fundamental electrochemistry. Different methods of corrosion protection methods are discussed. Classification of electrochemistry processes are studied. Electrochemical reactors and electrodes used in industry are discussed.

Course Outcome

On completion of this course, students will be able to

CO1	Understand the basics of electrochemistry and the laws associated with it	Remember, Understand
CO2	Study the role of electrical double layer in electrochemical process	Remember, Analyze
CO3	Understand the fundamentals of corrosion and study the theories of corrosion. Illustrate the different methods of corrosion control and protection.	Understand, Apply, Evaluate
CO4	Study the classification and understanding the principles of electrochemistry process	Apply, Analyze

CO5	Understanding the fundamentals of electrochemical reactors and knowing its applications.	Understand, Apply, Analyze, Evaluate, Create

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	2									3			
CO2	2	1										3			
CO3	2	2	1				2					3			
CO4	3	2	3	2							2	2	2	2	2
CO5	3	3	3	2							2	2	2	2	2
Avg	2.4	1.8	2.25	2			2				2	2.6	2	2	2

Module 1 (6 hours)
Review fundamentals of electrochemistry: Basic elements of electrochemistry, devices used in electrochemistry. Theories and laws related to electrochemistry: Faraday's law, Nernst potential, galvanic cells, paleography. The electrical double layer, its role in electrochemical processes, electro capillary curve, Helmholtz layer, , Stern layer, fields at the interface.

Module 2 (6 hours)
Mass transfer in electrochemical systems, diffusion controlled electrochemical reaction, importance of convention and the concept of limiting current, over potential, primary, secondary current distribution, rotating disc electrode.

Module 3 (6 hours)
Introduction to corrosion, corrosion theories, derivation of potential, current relations of activities controlled and diffusion controlled corrosion process. Potential, pH diagram, forms of corrosion, definition, factors and control methods of various forms of corrosion, corrosion control measures, industrial boiler water corrosion control, protective coatings, vapor phase inhibitors, cathode protection.

Module 4 (6 hours)
Electro deposition, electro refining, electroforming, electro polishing, anodizing, selective solar coatings, primary and secondary batteries, fuel cells. types of fuel cell, working and performance analysis of fuel cell, advantages and limitations

Module 5 (6 hours)
Electrodes used in different electrochemical industries: Metals, Graphite, Lead dioxide, titanium substrate insoluble electrodes iron oxide, semi conducting type etc. Metal finishing, cell design- types of electrochemical reactors, merits of different type of electrochemical reactors.

Suggested Text Books
1. Picket, J"Electrochemical Engineering", Prentice Hall, 1977.
2. Newman, J.S., "Electrochemical Systems", Prentice Hall, 1973.
3. Barak, M. and Stevenge, U.K., "Electrochemical Power Sources Primary and Secondary Batteries", IEE energy series 980.
4. Mantell, C., "Electrochemical Engineering", McGraw Hill, 1972.

Suggested Reference Books

1. Hart, L. "Electrochemistry and Electrochemical Engineering", Library Press, 2018

NCH 417 PRINCIPLES OF POLYMER ENGINEERING

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To provide a broad and fundamental knowledge of the polymers and their chemical, physical and mechanical behavior. Emphasis is on the processing techniques like moulding and extrusion.

Course Outcomes:

Students completing the course will be able to

CO1	Connect properties of polymeric materials to their structures and explain how different material parameters and external factors affect the mechanical properties.	Remember, Understand
CO2	Decide which test methods are suitable for measurement of mechanical properties	Apply, Analyze, Evaluate
CO3	Correlate structure-processing-properties relationships for polymers, blends and composites	Understand, Apply, Analyze
CO4	Select a suitable processing and manufacturing technique for a given polymer.	Understand, Apply
CO5	Identify methods for rheological measurements and analysis of the rheological data using models for non-Newtonian fluids.	Understand, Apply, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	1	1							1	2	1	1	1
CO2	2	3	1	2							1	2	1	3	1
CO3	1	1	2	3							2	3	3	2	2
CO4	1	1	2	2							2	3	1	2	1
CO5	3	3	1	2							3	3	3	3	1
Avg	1.8	1.8	1.4	2							1.8	2.6	1.8	2.2	1.2

Module 1 (6 hours)

Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure of the crystal, Crystal shape, Crystallinity, Crystallization and melting, the glass transition temperature, Molecular conformation in the amorphous polymer, the freely jointed chain, the Gaussian chain, Molecular orientation.

Module 2 (6 hours)

Structure of an ideal rubber, Entropy elasticity, elasticity of a network, Stress-strain relationship, Engineering rubbers, The nature of viscoelasticity, Creep, Stress relaxation, Dynamic properties, Theory of linear viscoelasticity, Polymer selection: stiffness.

Module 3 (6 hours)

Yielding, Crazing, Linear elastic fracture mechanics, Elastic-plastic fracture mechanics, Brittle fracture of polymer, rubber toughening, Reinforced plastics, Forming of reinforced plastics, the mechanics of fiber reinforcement, Reinforced rubbers.

Module 4 (6 hours)

The flow properties of polymer melts, Cooling and solidification, Extrusion, Injection moulding, Compression and transfer moulding.

Module 5 (6 hours)

Materials selection, designing for manufacture, Designing for stiffness, Designing for strength, Case Histories.

Suggested Text Books

1 McCrum, N.G., Buckley, C.P. and Bucknall, C.B. “Principles of Polymer Engineeing”, 2nd Edition, Oxford University Press, 1997.

ELECTIVE IV (NCH 419-425)

NCH 419 GREEN CHEMISTRY

Assessment:

L	T	P	C
3	**0**	**0**	**3**

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To provide an idea on Green Technology with an approach towards the design, manufacturing and use of chemical products to reduce or eliminate the chemical hazards intentionally. Green Technology is a new and rapidly emerging branch of chemistry. The goal of Green Technology is to create better and safe chemicals while choosing the safest and the most efficient ways to synthesize them. The main goal of Green Technology is to eliminate hazards right at the design stage. The principles of Green Technology demonstrate how chemical production could be achieved without posing hazard to human health and environment.

Course Outcomes:

CO1	To understand the principles of green chemistry and engineering	Understand
CO2	To design processes that are benign and environmentally viable	Understand, apply
CO3	To understand the field of Green Technology and its approach towards the new discovery and innovation	Understand, apply, create
CO4	To create cleaner development mechanisms.	Understand, apply, create
CO5	To develop concepts on various energy efficient systems	Apply, analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3		3	3	3				3	3	2	3
CO2	3	3	3	3		3	3	3				3	3	2	3
CO3	3	3	3	3		3	3	3				3	3	2	3
CO4	3	3	3	3		3	3	3				3	3	2	3
CO5	3	3	3	3	2	3	3	3	2	1	2	3	3	2	3
Avg	3	3	3	3	2	3	3	3	2	1	2	3	3	2	3

Module 1 (5 hours)

Environmental Chemistry: Green Chemistry and Synthetic Chemistry, The twelve principles of green chemistry, Green technology-definition, importance, factors affecting green technology. Role of industry, government and institutions; industrial ecology, role of industrial ecology in green technology.

Module II (5 hours)

Environmentally benign processes: Solvent free techniques-Reaction on solid supports. Alternative solvents Ionic liquids-synthesis & applications; supercritical fluids-extraction, Microwave assisted synthesis, Ultrasound Chemistry, Photochemistry process, sono chemical and applications

Module II (6 hours)

Catalyst and Catalysis, Biocatalysis, Green Chemistry Using Bio Catalytic Reactions – Introduction - Fermentation and Bio transformations, Use of other catalysis techniques in organic synthesis, TiO_2, SiO_2, Graphene based oxide as a green photocatalyst and reactions.

Module IV (6 hours)

Cleaner development mechanisms, role of industry; reuse, reduce and recycle, raw material substitution; wealth from waste; carbon credits, carbon trading, carbon sequestration, eco labelling. Oxidation technology for waste water treatment-Cavitation, Fenton chemistry, photocatalysis and hybrid processes.

Module V: (8 hours)

Energy efficient process, selection of fuels, green manufacturing systems-Bio gasification: Biomethanation process, biogas digester types, Waste to energy. Biofuels, Physical and chemical characteristics of biofuels – Biomass, wood gas, bio methane; ethanol, biodiesel, Wood oil; Bio blends and its various applications. Biofuel economy; Biofuel roadmap of India - policy issues, regulatory issues and economic impact; Entrepreneurship in biofuel - Prospects & Challenges

Text Books:

1. Das, A.K. "Environmental Chemistry with Green Chemistry", Books and Allied (P) Ltd., Kolkata, India, 2012.
2. Ahluwalia, V.K. "Green Chemistry: Environmentally Benign Reactions", Ane Books India, New Delhi, India, 2006.
3. Nelson, D.L. and Cox, M.M. "Lehninger's Principles of Biochemistry" Macmillan Worth publisher, 2009.

Suggested Reference Books

1. Matlack, A.S. "Introduction to Green Chemistry", Marcel Dekker, Newyork, 2001.
2. Anastas, P.T. and Warner, J.C "Green Chemistry: Theory and Practice", Oxford University Press, 1998.
3. Clark, J.H. and Macquarrie, D.J. "Handbook of Green Chemistry and Technology", Wiley Blackwell Publishers, 2002

NCH 421 MICROCHEMICAL SYSTEM

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives

The objective of this course is to give basic understanding of engineering phenomena involved in microchemical systems and expose students to versatile applications of these systems in different areas of science and technology.

Course Outcome

On completing of this course, students will be able to

CO1	Describe concept of lab-on-a-chip and identify its significance and relevance	Remember, Understand
CO2	Explain fundamental transport processes relevant to micro scale devices	Understand, Apply
CO3	Compare and select various microfabrication methods and relevant materials	Understand, Apply, Analyze
CO4	Describe various aspects of design, simulation, and experimental methods at microscale	Understand, Apply

CO5	Explain and examine wide range of applications of microchemical systems	Apply, Analyze

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	1	2	1						2	3	1	
CO2	3	3	3	1	2	1	2					2	3	1	
CO3	3	3	3	1	2	1	2					2	3	1	2
CO4	3	3	3	1	2	1	2					2	3	1	2
CO5	3	3	3	1	2	1	2		3	3	2	2	3	1	2
Avg	3	3	3	1	2	1	2		3	3	2	2	3	1	2

Unit 1 (6 hours)
Introduction to microchemical systems, concept of lab-on-a-chip, advantages, limitations, interdisciplinary approach. Range of applications- basic and applied areas of science and engineering. Scale out approach, commercialized technologies.

Unit 2 (6 hours)
Transport phenomena at microscale. Concepts in microfluidics, Navier-Stokes equation, Multiphase flows, capillary action. Mixing and separation. Heat transfer in microchannels, electrokinetics

Unit 3 (6 hours)
Microfabrication techniques, Conventional and emerging techniques, photolithography, micromachining, etching. Soft lithography, materials in fabrication

Unit 4 (6 hours)
Design to implementation approach. Concepts and approach from design to realization, tools for design and simulation. Experimental methods and components-pumps, valves. Measurements at microscale, Pressure, flow rate, temperature measurements. Analytical techniques

Unit 5 (6 hours)
Applications and case studies. Miniaturized chemical systems, microreactors, drug delivery, point-of-care devices, sensors, environmental monitoring, biomedical diagnostics, energy applications

Suggested text books
1. Kirby, B.J., “Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices”, Cambridge University Press, 2010.

Suggested reference books
2. Nguyen, N. T., Werely, S. T., “Fundamentals and Applications of Microfluidics”, Artech house Inc., 2002.
3. Madou, M. J., “Fundamentals of Microfabrication”, CRC press, 2002.
4. Tabeling, P., “Introduction to Microfluidics”, Oxford University Press Inc., 2005

5. Colin, S., “Microfluidics”, John Wiley & Sons, 2009.

NCH 423 COLLOIDS & INTERFACE SCIENCE AND ENGINEERING

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To introduce the fundamentals of colloid and interface science; specifically the nature of various interparticle forces, how they can be calculated and applied. To understand the origins of surface tension, its measurement and how it can be modified by addition of surfactants. To understand factors determining colloidal stability and actual applications of colloidal phenomena in industries.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the concepts of surface and interfacial energies and tensions and how they can be measured	Remember, understand
CO2	Identify the nature of various interparticle forces between colloidal systems and how they can be calculated	Remember, understand
CO3	Evaluate when stable emulsions will be formed using DLVO and DLVO like theories	Analyze, evaluate
CO4	Select suitable surfactants for specific applications in nanofluids and advanced and functional materials	Understand, apply, analyze
CO5	Identify the ways in which wettability of surfaces can be manipulated for preparing superhydrophobic surfaces	understand, apply

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1										2	1	1	1
CO2	3	1										2	1	3	1
CO3	3	2	1				-					3	3	2	2
CO4	3	2	2	1			1					2	1	2	1
CO5	3	2	1				1					2	3	3	1
Avg	2.8	1.6	1.3	1			1					2.2	1.8	2.2	1.2

Module 1 (6 hours)

Effects of confinement and finite size, concepts of surface and interfacial energies and tensions, Apolar (van der Waals) and polar (acid-base) components of interfacial tensions. Young-Laplace equation of capillarity, examples of equilibrium surfaces, multiplicity, etc., Stability of equilibrium solutions, contact angle and Young's equation, Determination of aploar (van der Waals) and acid-base components of surface/interfacial tensions. Free energies of adhesion, kinetics of capillary and confined flow.

Module 2 (6 hours)

Intermolecular, nanoscale and interfacial forces in organic, polymeric, biological and aqueous systems, van der Waals, electrostatic double layer, acid-base interactions including hydrophobic attraction and hydration pressure

Module 3 (6 hours)

Gibb's treatment of interfaces, concept of excess concentration, variation of interfacial tension with surface concentration, Adhesion, wetting, nucleation, flotation, patterning of soft material by self-organization and other techniques.

Module 4 (6 hours)

DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement.

Module 5 (6 hours)

Stability of thin (< 100 nm) film, self-organization in confined systems, mesoscale patterning. Superhydrophobicity, functional coatings, structural colours, nano-adhesives, nano-composites.

Suggested Text Books

1. Hiemenz, P.C. "Principles of Colloid and Surface Chemistry", 2nd edition and onwards, Marshal Dekker 1986.

2. Adamson, A.W. "Physical Chemistry of Surfaces", 5th edition, Wiley,1990.

3. Hunter, R.J. "Foundations of Colloid Science", Clarendons, Oxford, Volume 1,1989.

4. Russel, W.B., Saville, D.A. and Schowalter, W.R. "Colloidal Dispersions", Cambridge University Press, 1989.

Suggested Reference Books

1. Israelachvili, J.N. "Intermolecular and Surface Forces", Academic Press, 1992 or later editions.

2. van Oss, C.J. “Interfacial Forces in Aqueous Media”, Marcel Dekker or Taylor Francis, 1994.

NCH 425 CORROSION SCIENCE AND ENGINEERING

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course introduces the principles of corrosion, common corrosion forms; the concept of corrosion measurement and monitoring methods, with a link to fundamental electrochemistry. Corrosion protection systems are discussed, with a broad overview of coating and surface treatment/engineering routes and material selection to reduce corrosion cost.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the industrial applications and economic benefits of corrosion control	Remember, Understand
CO2	Evaluate if corrosion can occur under specific operating conditions in a given equipment or construction	Apply, Analyze, Evaluate
CO3	Determine the probable corrosion type, estimate the corrosion rate and propose the most reasonable protection method as regards safety, price and environmental considerations	Understand, Apply
CO4	Select proper material, design and operating conditions to reduce the likelihood of corrosion in each equipment	Apply, Analyze, Evaluate
CO5	Perform troubleshooting and corrosion monitoring	Understand, Apply, Analyze, Evaluate, Create

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1										3	1	1	
CO2	2	2	1	1	2							2	1	3	
CO3	3	2	2	1	3							2	3	2	3
CO4	3	2	2	1	2							2	1	2	3
CO5	3	2	2	2	3		3					2	3	3	3
Avg	2.8	1.8	1.75	1.25	2.5		3					2.2	1.8	2.2	3

Module 1 (6 hours)

Basic aspects, introduction, classification, economics and cost of corrosion. EMF series, Galvanic series, corrosion theories, derivation of potential-current relationship of activation controlled and diffusion corrosion processes. Potential-pH diagrams: General aspects, Potential-pH diagrams for specific metals; Fe-H_2O system, application and limitations. Passivation definition, anodic passivation, theory of passivation, oxidation laws, effects of oxygen and alloying on oxidation rates.

Module 2 (6 hours)

Forms of corrosion - definition, factors and control methods of various forms of corrosion such as pitting, intergranular, crevice, stress corrosion, corrosion fatigue, hydrogen embrittlement, corrosion processes and control methods in fertilizers, petrochemical and petroleum refineries

Module 3 (6 hours)

Environmental aspects: Atmospheric corrosion- classification, factors influencing atmospheric corrosion, temporary corrosion, preventive methods, corrosion in immersed condition, effect of dissolved gases, salts, pH, temperature and flow rates on corrosion, Underground corrosion-corrosion process in the soil, factors influencing soil corrosion.

Module 4 (6 hours)

Corrosion control aspects: Electrochemical methods of protection-theory of cathodic protection, design of cathodic protection, sacrificial anodes, anodic protection. Corrosion inhibitors for acidic, neutral and alkaline media, cooling water system-boiler water system. Organic coating-surface preparation, natural synthetic resin, paint formulation and applications. Design aspects in corrosion prevention, corrosion resistant materials.

Module 5 (6 hours)

Corrosion Testing, monitoring and inspection, laboratory corrosion tests, accelerated chemical tests for studying different forms of corrosion. Electrochemical methods of corrosion rate measurements by DC and AC methods, corrosion monitoring methods, chemical and electrochemical removal of corrosion products.

Suggested Text Books

1. Banerjee, S.N. “An Introduction to Corrosion and Its Inhibition”, Oxonian Press Ltd., New Delhi 1985.
2. Shrier, L.L. “Corrosion Vol. I & II” 2nd Edn. George Nownons Ltd., Southhampton Street London, 1976.
3. Fontana, M.G. and Greene, N.D. “Corrosion Engineering”, 3rd Ed., McGraw Hill, New York , 2017
4. Uhlig, H.H. “Corrosion and Corrosion Control”. A Wiley- Inter Science. Publication John Wiley & Sons, New York. 1985

Suggested Reference Books

1 Munger, C.T. “Organic Coatings” 2020

2 Jain & Jain, “Engineering Chemistry”, 17^{th} Ed., Dhanpat Rai & Sons, New Delhi 2022.

ELECTIVE V (NCH 402-408)

NCH 402 MANAGEMENT OF R&D

L	T	P	C
3	**1**	**0**	**4**

Assessment:

Sessional: 50 marks

End Semester: 50marks

Course Objective:

This course will provide the candidate with the skills necessary to successfully manage a small corporate research and development department. Emphasis will be on identifying the unique characteristics of an R&D department in terms of its funding, its personnel, and mandate to be creative and productive.

Course Outcomes:

Upon successful completion of this course, the candidate will be able to:

CO 1	Develop understanding of importance of research and development.	Understand,
CO 2	Learn about work environment and management of R&D organisation. Define the unique characteristics of R&D in terms of its funding, people, and mandate to innovate.	Understand, Analyze, Apply
CO 3	Explain how to make the link between R&D and corporate strategy, and how R&D can respond to the challenges of globalization.	Remember, Evaluate, Apply
CO 4	Learn about the issue and importance of Human resource management in R&D.	Remember, Apply
CO 5	Study an R&D strategic plan and implementation of new project with quality management.	Analyze, Apply, Remember

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	3	3	2	2	2	3	1	3	2	2	1	
CO2	2	2	1	3		2				1	3	2	2	1	
CO3	2	2	1	3						1	3	2	2	1	
CO4	2	2	1	3				2	3	1	3	2	2	1	
CO5	2	2	1	3				2	3	1	3	2	2	1	
Avg	2	2	1	3	3	2	2	2			3		2	1	

Module 1 (6 hours)

Introduction: Meaning of Research and Development, The Structural Components of an R&D Organization, Management of R&D planning, organizing, staffing, scheduling, controlling, budgeting, Selection of R&D projects

Module 2 (6 hours)

The R&D team manager role, R&D Organizing for an Innovative Environment, The Provision of the Appropriate Support of R&D, A Financially Sound, Healthy, Safe and Quality Environment in R&D organizations.

Module 3 (6 hours)

Project management skills, The Protection of Intellectual Property, The Exploitation of Opportunities and Methodologies for evaluating the effectiveness of R&D, Research Productivity. Project Management of Innovation, Creativity and Nurturing of Innovation in R&D organization.

Module 4 (6 hours)

Human Resource Management in R&D and Innovation, training, motivation, communication, group dynamics, Timing of Entry, Technological Innovation Strategy, Types and Patterns of Innovation, Choosing Innovation Projects, Protecting Innovation, present Collaboration Strategies.

Module 5 (6 hours)

Issues relating to managing scientists and technologists as individual, in teams, and in large organizations. Information management for quality management. The Selection and Evaluation of R&D Projects. How to write the R&D projects.

Suggested Text Books

1. Schilling, M.A. "Strategic Management of Technology and Innovation" Fouth Edition, McGraw- Hill. 2012
2. Bamfield, P. "Research and Development in the Chemical and Pharmaceutical Industry", Third Edition. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim 2006 (ISBN: 3-527-31775-9)
3. Glasser, A. "Research and Development Management" Prentice-Hall 1982.

4. Bamfield, P. "Research and Development Management in the Chemical and Pharmaceutical industry" John Wiley & Sons 2006.

NCH 404 ENVIRONMENTAL IMPACT ASSESSMENT

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50marks

Course Objectives:

EIA process is a tool to do the assessment of proposed project or development practice taking into account positive and negative, economics and social impacts of the same. This course develop understanding of history, need, structure, involved methods and challenges which reduce the adverse impacts of any new developments.

Course outcomes:

Students completing the course will be able to

CO1	Define and Classify Environmental Impacts and the terminology. Understands the importance of environmental Impact assessment procedure as an integral part of planning process	Understand, Apply, Create
CO2	Detailed study of EIA methodology	Understand
CO3	Gain knowledge of Environmental Legislation and Life cycle Assessment to predict the Environmental impacts of project after conclusive various environmental attribute.	Analyze, Evaluate, Create
CO4	Prediction and Methods of Assessment of Impacts on Various aspects of Environment.	Understand, Analyze
CO5	Case studies and Create the EIA report for getting Environmental clearance	Understand, Apply

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2		1		3	3	1	1	1	2	3	3	2	3
CO2	1			1	3	3			1	1	2	3	3	2	3
CO3	1					3	3	1	1	1	2	3	3	2	3
CO4	1	2	3			3	3	1	1	1	2	3	3	2	3
CO5	1	2	3	1	3	3	3	1	1	1	2	3	3	2	3
Avg	1	2	3	1	3	3	3	1	1	1	2	3	3	2	3

Module 1 (6 hours)

Concepts of Environmental Impact Assessment: Environment; Environmental Impacts; Environmental Impact Analysis; Environmental Impact Assessment and Environmental Impact Statement; EIA- As an Integral Part of the Planning Process

Module 2 (6 hours)

EIA Methodologies: Environmental attributes -Criteria for the selection of EIA methodology, impact identification, impact measurement, impact interpretation and Evaluation, impact communication, Methods-Adhoc methods, Checklists methods, Matrices methods, Networks methods, and Overlays methods. EIA review- Baseline Conditions -Construction Stage Impacts, post project impacts; Environmental Monitoring Programme; Additional studies; Project Benefits; Environmental Cost Benefit Analysis

Module 3 (6 hours)

Environmental Legislation and Life cycle Assessment: Environmental laws and protection acts, Constitutional provisions-powers and functions of Central and State government, The Environment (Protection) Act 1986, The Water Act 1974, The Air act 1981, Wild Life act 1972, Guidelines for control of noise, loss of biodiversity, solid and Hazardous waste management rules. Life cycle assessment: Life cycle analysis, Methodology, Management, Flow of materials-cost criteria-case studies.

Module 4 (6 hours)

Prediction and Methods of Assessment of Impacts on Various aspects of Environment; Application of various models for the Prediction of impact on Air Environment, Water Environment, Noise Environment, Land and Soil Environment.

Module 5 (6 hours)

EIA notification September 2006 and amendments: Categorization of projects, Procedure for getting environmental clearance. Public participation in environmental decision making processes. Case studies on EIA for Industries and Infrastructure projects

Suggested Text Books / References

1. Whooten, R. “Environmental Impact Analysis Handbook” McGraw Hill publications 1980
2. Canter, L. “Environmental Impact Assessment” McGraw Hill publications Year?
3. Jain, R.K. “Environmental Impact Analysis – A Decision Making Tool” Stacey Publishers
4. Petts, J. “Handbook of Environment Impact Assessment” McGraw Hill 2017
5. Jain, R.K., Urban, L.V. and Stracy, G.S., “Environmental Impact Analysis”, Van Nostrand Reinhold Co., New York, 1991.
6. Rau, J.G. and Wooten, D.C., “Environmental Impact Assessment”, McGraw Hill Pub. Co., New York, 1996.

NCH 406 AIR POLLUTION MONITORING AND CONTROL

Assessment:

Sessional: 50 marks

L	T	P	C
3	1	0	4

End Semester: 50 marks

Course Objectives: To introduce various sources and classification of air pollutants. To understand various methods for air pollution monitoring and learn various dry and wet techniques for air pollution control at source.

Course Outcomes:

Students completing the course will be able to

CO1	Demonstrate comprehensive understanding of different types of air pollutants and various standards and acts regarding the air pollutants of global concern.	Understand, Apply
CO2	Select proper sampling and analysis method for a specific gaseous or particulate air pollutant.	Apply, Evaluate
CO3	Analyse plume behaviour and come up with a suitable stack design based on meteorological aspects of air pollution	Analyse, Evaluate
CO4	Select and design the most economical industrial dust collector for control of particulate emission at the source itself.	Apply, Evaluate
CO5	Design absorption columns for control of gaseous pollutants and three-way catalytic converters for pollution control from automobiles.	Apply, Evaluate

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	3	3	2			3	-	-	-	-	2	3	2	3
CO2	3	3	3	3			3	-	-	-	-	2	3	2	3
CO3	2	3	3	2			3	-	-	-	-	2	3	2	3
CO4	2	3	3	3			3	-	-	-	-	2	3	2	3
CO5	2	3	3	2			3	-	-	-	-	2	3	2	3
Avg	2.2	3	3	2.4			3					2	3	2	3

Module 1 (7 hours)

Air Pollutants - Sources and Classification, Effects of air pollutants on physical environment and living systems, Air pollution – Standards and acts, Global consideration of air pollution: Greenhouse effect, Chemical reactions in a contaminated atmosphere, urban air pollution, acid rain.

Module 2 (8 hours)

Air pollution monitoring, Sampling and analysis of gaseous and particulate air pollutants, Air pollution control by dilution of contaminants in atmosphere, Atmospheric stability, Lapse rate and Inversion, Meteorological aspects of air pollution: Dispersion models- Gaussian dispersion model, Plume behavior (Plume rise model), Stack design.

Module 3 (8 hours)

Air Pollution Control at Source - Source Correction methods - Particulate emission control: Dry techniques industrial dust collectors, cyclone and multiclone separators, bag filters, electrostatic precipitators, relative merits and demerits, choice of equipments, design aspects and economics.

Module 4 (9 hours)

Wet techniques for controlling particulate pollutants: wet dust collection, wet cyclone, empty scrubber, column (packed) scrubber, venturi scrubber, suitability, merits and demerits, design aspects and economics.

Module 5 (8 hours)

Techniques for Controlling Gaseous Pollutants: Absorption - absorbents and absorbers (plate towers and packed towers), Adsorption, Condensation - direct and contact, Combustion - Thermal, flare and catalytic. Pollution control from automobiles - three-way catalyst and catalytic converters.

Suggested Text Books:

1 Peavy, H.S., Rowe, D.R. and Tchobanoglous G., "Environmental Engineering, McGraw-Hill edition, 1985.

2 Rao, M.N. and Rao, H.V.N. "Air Pollution", Tata McGraw Hill, New Delhi, 1993.

3 Rao, C.S. "Environmental Pollution Control Engineering" 2nd Edition, New Age International Publishers, 2006.

Suggested Reference Books:

1 Sincero, P. and Sincero, G.A. "Environmental Engineering: A Design Approach", Prentice Hall of India Pvt Ltd, New Delhi.1996.

2 Verma, Y.B.G. and Brauer, H., "Air Pollution Control Equipments", Springer, Berlin, 1981

NCH 408 Energy Management

Assessment:
Sessional: 50 marks

L	T	P	C
3	0	0	3

Course Objectives: This course is developed the basic understanding of sustainability in terms of energy conservation for chemical process plants. Energy economics and performance indices help students to take practical decision which leads to the economically efficient performance of chemical plants. The application of energy management in present scenario helpful in all engineering filed.

Course outcomes:

Students completing the course will be able to

CO1	Introduction: Objective, scope and energy management of the course includes Energy Basics, Energy Demand Management, Conservation & Resource Development, Energy for Sustainable Development.	Understand, Apply, Create
CO2	Study about the energy economics, financial evaluation and economic performance indices.	Understand, Analyze Evaluate
CO3	Study about the need for Energy Management by Sector- Industry, Buildings & Houses, Transport, Electric Power, Energy forecasting techniques; Energy Integration, Energy Matrix.	Analyze, Evaluate, Create
CO4	Create understanding about the energy conservation for unit operations and equipment majorly used in chemical industries.	Understand, Analyze
CO5	Develop understanding of cogeneration concept for successfully implementation of financial energy conservation in all engineering practices.	Understand, Apply, Evaluate

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3		3		2	1	1	1	3	3	3	2	2
CO2	3	3	3		3			1	1	1	3	3	3	2	2
CO3	3	3	3	3	3			1	1	1	3	3	3	2	2
CO4	3	3	3	3	3	2	2	1	1	1	3	3	3	2	2
CO5	3	3	3	3	3	2	2	1	1	1	3	3	3	2	2
Avg	3	3	3	3	3	2	2	1	1	1	3	3	3	2	2

Module 1 (6 hours)

General principles of energy management and energy management planning, conducting energy audit (pre-audit, audit and post-audit), energy audit instruments, energy audit report, monitoring, evaluating and following up energy saving measures/ projects, case study. Energy efficiency analysis, management of heating, analysis of past trends plant data, closing the energy balance, laws of thermodynamics, measurements, and portable and on line instruments.

Module 2 (6 hours)

Energy Economics: Time value of money Present-Worth and Future Worth, discount rate, payback period, internal rate of return, life cycle costing. Economic performance indices: Payback – Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelized cost. Financial evaluation of energy projects, evaluation of proposals, profitability index, life cycle costing approach, investment decision and uncertainty.

Module 3 (6 hours)

Electrical Systems: Demand control, power factor correction, load scheduling/shifting, Motor drives- motor efficiency testing, energy efficient motors, motor speed control. Lighting-lighting levels, efficient options, fixtures, daylighting, timers, Energy efficient windows.

Module 4 (6 hours)

Steam Systems: Boiler efficiency testing, excess air control, Steam distribution & use- steam traps, condensate recovery, flash steam utilization, Thermal Insulation. Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & air conditioning systems. Waste heat recovery: recuperators, heat wheels, heat pipes, heat pumps

Module 5 (6 hours)

Cogeneration- Concept, options (steam/gas turbines/diesel engine based), selection criteria, control strategy. Heat exchanger networking- concept of pinch, target setting, problem table approach, composite curves. Demand side management. Financing energy Conservation

Suggested Text Books / References

1. Witte, L.C., Schmidt, P.S. and Brown, D.R. "Industrial Energy Management and Utilisation", Hemisphere Publ, Washington, 1988.
2. Dryden, I.G.C. (Editor) "Industrial Energy Conservation Manuals", MIT Press, Mass, 1982.
3. Turner, W.C. (Editor) "The Efficient Use of Energy", Butterworths, London, 1982.
4. Wayne C. Turner & Steve Doty "Energy Management Handbook", Wiley, New York, 1982.
5. National Productivity Council and Center for & Environmental Studies, "Technology Menu for Efficient Energy Use - Motor Drive Systems". Princeton Univ, 1993.

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