BANASTHALI VIDYAPITH

Master of Technology (Chemical Engineering)

Curriculum Structure

First Semester Examination, December, 2020
Second Semester Examination, April/May, 2021
Third Semester Examination, December, 2021
Fourth Semester Examination, April/May, 2022

BANASTHALI VIDYAPITH
P.O. BANASTHALI VIDYAPITH
(Rajasthan)-304022

July, 2020

108

No. F. 9-6/81-U.3
Government of India
Ministry of Education and Culture
(Department of Education)

New Delhi, the 25th October, 1983

N O T I F I C A T I O N

In exercise of the powers conferred by Section 3 of the University Grants Commission Act, 1956 (3 of 1956) the Central Government, on the advice of the Commission, hereby declare that Banasthali Vidyapith, P. O. Banasthali Vidyapith, (Rajasthan) shall be deemed to be a University for the purpose of the aforesaid Act.

Sd/-
(M. R. Kolhatkar)
Joint Secretary of the Government of India

N O T I C E

Changes in Bye-laws/Syllabi and Books may from time to time be made by amendment or remaking, and a Candidate shall, except in so far as the Vidyapith determines otherwise, comply with any change that applies to years she has not completed at the time of change.

Programme Educational Objectives

- To develop latitude of effectiveness in solving advanced/complex engineering problems and tasks using engineering, science and statistics principles.
- To develop longitude of not only opening careers in the branch of study as well as interdisciplinary and multidisciplinary fields with the help of compulsory and elective courses followed by one year of project work in Industry along with reading electives.
- To develop altitude of professionalism and function effectively in the complex modern work environment, both as individuals as well as in team, with the ability to assume leadership roles and achieve understanding and appreciation of ethical behavior, social responsibility and diversity.

Programme Outcomes

Each graduate will be able to

- Evaluate the impact of own work on society including ethical, economic, global and environmental aspects and deliver effective presentations of engineering results in written and oral formats.
- Apply life-long-learning skills and engineering knowledge in critically evaluating relevant literature and new technology systems and become effective leaders, capable of working in diverse environments.

Curriculum Structure
Master of Technology (Chemical Engineering)

First Year

Semester - I

Course	Code	Course Name	L	T	P	C*
CHE	304	Advanced Chemical Reaction Engineering	3	1	0	4
CHE	505	Advanced Process Control	4	0	0	4
CHE	501L	Advanced Chemical Engineering Lab	0	0	12	6
CHE	530P/	Term Paper-I/Minor Project-I	0	0	8	4
CHE	528P					
		Discipline Elective - I	4	0	0	4
		Discipline Elective - II	4	0	0	4
		Semester Total:	**15**	**1**	**20**	**26**

Semester - II

Course	Code	Course Name	L	T	P	C*
CHE	511	Computational Fluid Dynamics	4	0	0	4
CHE	517	Equipment Design	4	0	0	4
CHE	507L	Advanced Simulation Lab	0	0	12	6
CHE	531P/	Term Paper-II/Minor Project-II	0	0	8	4
CHE	529P					
		Discipline Elective – III	4	0	0	4
		Open Elective	4	0	0	4
		Semester Total:	**16**	**0**	**20**	**26**

Second Year

Semester - III

Course	Code	Course Name	L	T	P	C*
CHE	604P	Project (Part - I)	0	0	48	24
		Reading Elective - I	0	0	4	2
		Semester Total:	**0**	**0**	**52**	**26**

Semester - IV

Course	Code	Course Name	L	T	P	C*
CHE	605P	Project (Part - II)	0	0	48	24
		Reading Elective - II	0	0	4	2
		Semester Total:	**0**	**0**	**52**	**26**

List of Discipline Electives

Course	Code	Course Name	L	T	P	C*
CHE	512	Conceptual Design of Chemical Processes	4	0	0	4
CHE	513	Corrosion Science and Technology	4	0	0	4
CHE	524	Polymer Processing and Reaction Engineering	4	0	0	4
CHE	527	Supercritical Fluid Extraction	4	0	0	4
CHE	509	Bioenergy Engineering	4	0	0	4
CHE	510	Catalysis and Surface Chemistry	4	0	0	4
CHE	514	Cryogenic Engineering	4	0	0	4
CHE	519	Industrial Heat Treatment	4	0	0	4
CHE	515	Energy Conservation	4	0	0	4
CHE	408	Nano - Science and Technology	3	1	0	4
CHE	502	Advanced Chemical Engineering Thermodynamics	4	0	0	4
CHE	503	Advanced Heat Transfer	4	0	0	4
CHE	516	Environmental Safety and Impact Assessment	4	0	0	4
CHE	306	Computational Methods in Engineering	3	1	0	4
CHE	317	Advanced Mass Transfer	3	1	0	4
CHE	523	Pinch Technology	4	0	0	4
CHE	525	Process and Product Development	4	0	0	4
CHE	508	Advanced Transport Phenomena	4	0	0	4
CHE	518	Fluidization Technology	4	0	0	4
CHE	521	Natural and Synthetic Polymers	4	0	0	4
CHE	526	Processing of Alternative Fuels	4	0	0	4

List of Reading Electives						
Course	**Code**	**Course Name**	**L**	**T**	**P**	**C***
CHE	601R	Green Energy	0	0	4	2
CHE	602R	ISO Practices in Industry	0	0	4	2
CHE	603R	Life Cycle Assessment	0	0	4	2
CHE	606R	Safety in Process Industry	0	0	4	2
CHE	607R	Social Responsibilities of Industries	0	0	4	2
CHE	608R	Water and Land Pollution	0	0	4	2

*** L - Lecture hrs/week; T - Tutorial hrs/week; P-Project/Practical/Lab/All other non-classroom academic activities, etc. hrs/week; C - Credit Points of the Course**

Student can opt open (Generic) elective from any discipline of the Vidyapith with prior permission of respective heads and time table permitting.

Every Student shall also opt for:
Five Fold Education: Physical Education I, Physical Education II, Five Fold Education: Aesthetic Education I, Aesthetic Education II, Five Fold Education: Practical Education I, Practical Education II one each semester

Project Evaluation Scheme

Duration	Course Code		Course Name	L	T	P	C
2 Semesters (10 months) 1 July - 30 April	CHE	604P	Project (Part - I)	0	0	48	24
	CHE	605P	Project (Part - II)	0	0	48	24

Continuous Assessment (40 Marks)

1. Joining report, brief project outlay	- 10 Marks
2. Synopsis	- 10 Marks
3. Mid-term evaluation by Supervisor	- 10 Marks
4. Further evaluation by Supervisor	- 10 Marks
Total	**- 40 Marks**

End Semester Assessment (60 Marks)

1. Project Report	- 20 marks
2. Presentation	- 20 Marks
3. Viva-voce	- 20 Marks
Total	**- 60 Marks**

Five Fold Activities

Aesthetic Education I/II		Physical Education I/II	
BVFF 101	Classical Dance (Bharatnatyam)	BVFF 201	Aerobics
BVFF 102	Classical Dance (Kathak)	BVFF 202	Archery
BVFF 103	Classical Dance (Manipuri)	BVFF 203	Athletics
BVFF 104	Creative Art	BVFF 204	Badminton
BVFF 105	Folk Dance	BVFF 205	Basketball
BVFF 106	Music-Instrumental (Guitar)	BVFF 206	Cricket
BVFF 107	Music-Instrumental (Orchestra)	BVFF 207	Equestrian
BVFF 108	Music-Instrumental (Sarod)	BVFF 208	Flying - Flight Radio Telephone Operator's Licence (Restricted)
BVFF 109	Music-Instrumental (Sitar)	BVFF 209	Flying - Student Pilot's Licence
BVFF 110	Music-Instrumental (Tabla)	BVFF 229	Aeromodelling
BVFF 111	Music-Instrumental (Violin)	BVFF 210	Football
BVFF 112	Music-Vocal	BVFF 211	Gymnastics
BVFF 113	Theatre	BVFF 212	Handball
Practical Education I/II		BVFF 213	Hockey
BVFF 301	Banasthali Sewa Dal	BVFF 214	Judo
BVFF 302	Extension Programs for Women Empowerment	BVFF 215	Kabaddi
BVFF 303	FM Radio	BVFF 216	Karate - Do
BVFF 304	Informal Education	BVFF 217	Kho-Kho
BVFF 305	National Service Scheme	BVFF 218	Net Ball
BVFF 306	National Cadet Corps	BVFF 219	Rope Mallakhamb
		BVFF 220	Shooting
		BVFF 221	Soft Ball
		BVFF 222	Swimming
		BVFF 223	Table Tennis
		BVFF 224	Tennis
		BVFF 225	Throwball
		BVFF 226	Volleyball
		BVFF 227	Weight Training
		BVFF 228	Yoga

Every Student shall also opt for:
Five Fold Education: Physical Education I, Physical Education II,
Five Fold Education: Aesthetic Education I, Aesthetic Education II,
Five Fold Education: Practical Education I, Practical Education II
one each semester

Evaluation Scheme and Grading System

Continuous Assessment (CA) (Max. Marks)					End-Semester Assessment (ESA) (Max. Marks)	Grand Total (Max. Marks)
Assignment		Periodical Test		Total (CA)		
I	II	I	II			
10	10	10	10	40	60	100

In all theory, laboratory and other non classroom activities (project, dissertation, seminar, etc.), the Continuous and End-semester assessment will be of 40 and 60 marks respectively. However, for Reading Elective, only End semester exam of 100 marks will be held. Wherever desired, the detailed breakup of continuous assessment marks (40), for project, practical, dissertation, seminar, etc shall be announced by respective departments in respective student handouts.

Based on the cumulative performance in the continuous and end-semester assessments, the grade obtained by the student in each course shall be awarded. The classification of grades is as under:

Letter Grade	Grade Point	Narration
O	10	Outstanding
A+	9	Excellent
A	8	Very Good
B+	7	Good
B	6	Above Average
C+	5	Average
C	4	Below Average
D	3	Marginal
E	2	Exposed
NC	0	Not Cleared

Based on the obtained grades, the Semester Grade Point Average shall be computed as under:

$$SGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ---- + CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ---- + CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of courses (with letter grading) registered in the semester, CC_i are the course credits attached to the i^{th} course with letter

grading and GP_i is the letter grade point obtained in the i^{th} course. The courses which are given Non-Letter Grades are not considered in the calculation of SGPA.

The Cumulative Grade Point Average (CGPA) at the end of each semester shall be computed as under:

$$CGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ----+ CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ----+ CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of all the courses (with letter grading) that a student has taken up to the previous semester.

Student shall be required to maintain a minimum of 4.00 CGPA at the end of each semester. If a student's CGPA remains below 4.00 in two consecutive semesters, then the student will be placed under probation and the case will be referred to Academic Performance Review Committee (APRC) which will decide the course load of the student for successive semester till the student comes out of the probationary clause.

To clear a course of a degree program, a student should obtain letter grade C and above. However, D/E grade in two/one of the courses throughout the UG/PG degree program respectively shall be deemed to have cleared the respective course(s). The excess of two/one D/E course(s) in UG/PG degree program shall become the backlog course(s) and the student will be required to repeat and clear them in successive semester(s) by obtaining grade C or above.

After successfully clearing all the courses of the degree program, the student shall be awarded division as per following table.

Division	CGPA
Distinction	7.50 and above
First Division	6.00 to 7.49
Second Division	5.00 to 5.99
Pass	4.00 to 4.99

CGPA to % Conversion Formula: % of Marks Obtained = CGPA * 10

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Detailed Syllabus

MTECH I AND II SEMESTER COURSES

CHE 304 Advanced Chemical Reaction Engineering

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**3**	**1**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand mechanism of catalytic reactions and analysis of kinetic data.
- Understand yield and selectivity of reaction and diffusion in porous catalyst.
- Design catalytic reactors.
- Understand rector design for different type of reactions.

Section-A

Catalysts: Description methods of preparation and manufacture; catalyst characterization BET surface area, pore volume pore size distribution. Catalyst Reaction Kinetic Models: Physical and chemical adsorption; Determination of rate expressions using adsorption, surface reaction and desorption as rate-controlling steps.

Determination of global rate of reaction: Heterogeneous laboratory reactors; Determination of rate expressions from experimental data. Effect of Intrapellet Diffusion on Reaction Rates in Isothermal Pellets: concept of effectiveness factor, Thiele modulus, and experimental determination of effectiveness factor-Weisz- Prater criteria, Non-isothermal effectiveness factor.

Section-B

Packed bed catalytic reactors: suspended solid reactors, bubbling fluidized bed and circulating fluidized bed reactors.

Deactivating Catalyst: mechanism of deactivation, rate & performance equations.

Gas-liquid Reactions on solid catalyst: trickle bed, slurry reactors, three-phase fluidized beds, general rate equations & performance equations.

Section-C

Gas-liquid reactions on solid catalyst and packed bed catalytic reactors: trickle bed, slurry reactors, three-phase fluidized beds, general rate equations & performance equations.

Design of fixed bed catalytic reactor: isothermal, adiabatic, non-isothermal reactors: one dimensional, two dimensional approaches.

Recommended books:

1. Levenspiel, O. (1999). Chemical reaction engineering. John Wiley & Sons.
2. Fogler, H. S. (2010). Elements of Chemical Reaction Engineering. Pearson Education.
3. Smith, J. M. (1981). Chemical engineering kinetics. McGraw-Hill.

E-resource(s): https://nptel.ac.in

CHE 505 Advanced Process Control

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the basic principles and importance of process control in industrial process plants.

- Specify the required instrumentation and final elements to ensure that well-tuned control is achieved.
- Understand the use of block diagrams & the mathematical basis for the design of control systems.
- Design and tune process (PID) controllers.
- Use appropriate software tools for the modeling of plant dynamics and the design of well tuned control loops.

Section-A

Brief review on: 1^{st} and 2^{nd} order systems, block diagram; Open and closed loop transfer functions; P, PI, PD and PID controllers; Feedback, feedforward and cascade control systems; matrix algebra.

Advanced control systems: Process with large dead time, Dead time compensation, Selectie control system, Split-Range control, Ratio control, Adaptive control, Inferential control.

Section-B

Advanced control configurations for multiple input multiple output (MIMO) processes: Design questions for MIMO control systems, Degree of freedom and number of controlled and manipulated variables, Generation of Alternative loop configurations.

Interaction and decoupling of control loops: Interaction of Control loops, Relative gain array and the Selection of loops, Design of non-interacting control loops.

Section-C

Digital computer control loops: The digital computer, Computer-process interface for data acquisition and control.

Continuous to discrete time systems: Sampling continuous signals, Reconstruction of continuous signals from their discrete-time values, Conversion of continuous to discrete-time models.

z-transforms: Definition of z-transforms, z-transforms of basic functions, Properties of z-transforms, Inversion of z-transforms.

Recommended Books:

1. Stephanopoulos G. (2010). Chemical Process Control: An Introduction to Theory and Practice. New Delhi: PHI learning Private Limited.
2. Luyben, W. L. (1973). Process Modeling, Simulation and Control for Chemical Engineers. McGraw Hill.
3. Coughanowr D. R. (1991). Process System Analysis & Control. McGraw Hill.

E-resource(s): https://nptel.ac.in

CHE 501L Advanced Chemical Engineering Lab

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**12**	**6**

Learning Outcomes:

The students will be able to:

- Understand the kinetics of various kinds of reaction
- Determination of COD and BOD
- Operate spectrophotometer, HPLC, GC, etc.

Selected experiments are to be performed from the following list:

1. Kinetics of homogeneous reactions
2. Kinetics of heterogeneous reactions
3. Gas-solid reactions
4. Determination of Chemical Oxygen Demand (COD)
5. Determination of Biochemical Oxygen Demand (BOD)
6. Aeration of water/wastewater
7. Boiling heat transfer coefficient
8. Unsteady state heat transfer in solid

9. Determination of heat transfer coefficient in shell and tube heat exchanger
10. Mass transfer with chemical reaction
11. Heat and mass transfer coefficient in cooling tower
12. Bubble-cap distillation
13. Flow control
14. Temperature control
15. Control valve characteristics
16. UV spectrophotometer
17. Gas-liquid chromatography (GLC)
18. HPLC
19. Membrane characteristics
20. Two phase flow pressure drop
21. Collection efficiency of a Cyclone separator
22. Study of batch and continuous filtration process
23. Determination of mass transfer coefficient in a fluidized bed drier

CHE 511 Computational Fluid Dynamics

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Develop geometrical model of the flow

- To select appropriate boundary conditions
- Obtain solution of dynamic flows using different mathematical models

Section A

Introduction: What is CFD? How does a CFD code works?

Conservation laws of fluid motion and boundary conditions: Governing equations of fluid flow and heat transfer, Equations of state, Navier-Stokes equations for a Newtonian fluid, classification of physical behaviors, classification of fluid flow equations and Auxiliary conditions for viscous fluid flow equations.

Section B

Turbulence and its modeling: Transition from laminar to turbulent flow, Descriptors of turbulent flow, Characteristics of simple turbulent flows (Free turbulent flows , Flat plate boundary layer and pipe flow), Reynolds-averaged Navier–Stokes equations and classical turbulence models (Mixing length model, The k– model and Reynolds stress equation models).

Implementation of boundary conditions: Introduction, Inlet boundary conditions, Outlet boundary conditions, Wall boundary conditions and the constant pressure boundary condition.

Section C

The finite volume method for diffusion problems: Introduction, Finite volume method for one-dimensional steady state diffusion, Finite volume method for two-dimensional diffusion problems and Finite volume method for three-dimensional diffusion problems.

The finite volume method for convection-diffusion problems: Introduction, Steady one-dimensional convection and diffusion, the central differencing scheme, Properties of Discretization schemes (Conservativeness, Boundedness and Transportiveness).

The finite volume method for unsteady flows: Introduction, One-dimensional unsteady heat conduction and Discretization of transient convection–diffusion equation.

Recommended Books:

1. Versteeg H. K. & Malalasekera W. (2007). An introduction to computational fluid dynamics: the finite volume method. Longman scientific & technical publishers.

2. Ranade V. V. (2002). Computational flow modeling for chemical reactor engineering. San Diego: Academic Press.

E-resource(s): https://nptel.ac.in

CHE 517 Equipment Design

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Identify design parameters
- To design internal pressure vessels and external pressure vessels
- To design special vessels (e.g. tall vessels) and various parts of vessels (e.g. heads)

Section-A

Introduction: Types of materials and their basic characteristics, nature of design, general design considerations, codes and standards, design variables.

Design of heat exchangers: Codes and standards for heat exchangers. Shell and Tube Heat Exchanger- General design considerations- LMTD correction factor, fluid allocation, fluid velocities, stream temperatures, pressure drop, Shell side and tube side heat transfer coefficients. Plate Heat Exchanger- Advantages, disadvantages, design procedure, temperature correction factor, heat transfer coefficients, pressure drop.

Section-B

Mass transfer equipments design: Introduction to continuous distillation, process description, distillation column design for binary component: design variables, column sizing, plate efficiencies, plate hydraulic design, Packed column design- choice of packing, design procedure, prediction of the HTU, column internals.

Section-C

Design of mechanical separation equipment: Guide to gas-solid separator design: cyclone separator, Guide to Liquid-Gas Separator design: vertical and horizontal separator.

Process hazards and safety measures in equipment design: process hazards, hazard identification, risk analysis, pressure relief devices.

Recommended Books:

1. Joshi M. V. & Mahajani V. V. (1999) Process Equipment Design. Delhi: Macmillan India Ltd.
2. Sinnot R. K. (1998). Chemical Engineering Design. Elsevier.
3. Treybal R. E. (1995). Mass-Transfer Operations. McGraw Hill Education.
4. Bhattacharya B. C. (2001). Introduction to Chemical Equipment Design: Mechanical Aspects. Delhi: CBS Publishers and Distributors Pvt Ltd.
5. Crowl D. A. & Louvar J. A. (1995). Chemical process safety fundamentals with applications. New Delhi: Prentice Hall of India.

E-resource(s): https://nptel.ac.in

CHE 507L Advanced Simulation Lab

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**12**	**6**

Learning Outcomes:

The students will be able to:

- Develop and implement dynamic models in simulation software
- Investigate effect of operating parameters using simulator
- Develop complex network of process flow diagram

Selected experiments are to be performed from the following list using available softwares (MATLAB, ASPEN, AFT Fathom, ProSimulator, OLI Analyzer, ANSYS CFD, K-SPICE).

1. To write a computer code of Newton-Raphson method and simulate it
2. To write a code of solution of linear and nonlinear algebraic equations and simulate it
3. To write a code of Runge-Kutta method and simulate it
4. Heat exchanger control
5. Distillation column control
6. Design and steady state solution of distillation column
7. Steady state and dynamic simulation
8. Simulation of flow through channels
9. VLE/LLE

Discipline Electives

CHE 512 Conceptual Design of Chemical Processes

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Identify the mathematical constraints involved in process design.
- Identify other constraints such as local government policy, environment clearance, safety concern and economics which can change feasibility of a process.
- Carryout flow sheeting of the process

Section A

The design process: Steps involve in process design, Environmental protection and Safety consideration.

Developing a conceptual design and finding the best flowsheet: Input information, Batch vs. Continuous, Input output structure of the flowsheet and Recycle structure of the flowsheet.

Separation system: Introduction, General structure of the separation system, Selection of equipment (Absorption, Adsorption Membrane Separation, Distillation, Drying and Crystallization).

Section B

Capital cost estimation: Cost Indexes, Installation Cost, Process plant Cost and Process equipment cost.

Estimation of total capital investment: Order of Magnitude, Study Estimate, Preliminary Estimate.

Earning and profitability analysis: Working capital Investment, Manufacturing and Non-Manufacturing capital Investment, Total Production Cost, Time value of money, cash Flow, Depreciation and Rigorous Profitability Measures.

Section C

Energy integration: Introduction, First law and Second Law Analysis, minimum heating and minimum cooling load Networks for maximum Energy Recovery Minimum number of exchanger Optimum Approach Temperature, Grid diagram and Cascade diagram, Heat Integrated distillation Trains.

Interaction of process of process design and process control: Control System configuration, Qualitative Plant wide control system synthesis.

Scheduling of batch processes: Design of Single and Multiple product processing sequences.

Recommended Books:

1. Seider W. D. &Seader J. D. &Lewin D. R. (2012). Product & Process Design Principles. India: Wiley.
2. Peters M. S. &Timmerhaus K. D. (1989). Plant Design and Economics for chemical Engineering. McGraw Hill.
3. Smith R. (1989). Chemical Process Design. New York: McGraw Hill.
4. Sinnot R. K. (1989). An Introduction to Chemical Engineering Design. Oxford: Pergamon Press.

E-resource(s): https://nptel.ac.in

CHE 513 Corrosion Science and Technology

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the concept of thermodynamics and kinetics of aqueous corrosion
- Recognize the factors, forms and affecting parameters of corrosion
- Monitor, test and prevent corrosion

SECTION- A

Thermodynamics of Aqueous Corrosion: Electrode processes - electrode potential, free energy, emf series, potential measurements with reference electrodes, three electrode systems, computation and construction of Pourbaix diagrams of Fe, Al, Ni, and Zn, practical use of E-pH diagrams. Chemical vs. electrochemical mechanism of corrosion reactions, corrosion rate expressions.

Kinetics of Aqueous Corrosion: Corrosion current density and corrosion rate, exchange current density. Polarization - activation control, Tafel equation, mass transport control, mixed potential theory and behavior of galvanic couples in acidic environments, effect of oxidizer, combined polarization, factors affecting polarizations and rate of corrosion. Passivity, potentiostatic polarization curves, factors affecting passivity, mechanism of action of passivators.

SECTION-B

Factors Affecting Aqueous Corrosion: Effect of environmental variable - effect of pH, oxidation potential, temperature, velocity/fluid flow rate, concentration, biological effects. Effect of metallurgical variables - metals and their surfaces, alloys and their surfaces, effect of alloying on corrosion resistance, effect of heat treatment.

Forsm of Corrosion: General corrosion - atmospheric corrosion, galvanic corrosion, general biological corrosion. Localised corrosion - filiform corrosion, crevice corrosion, pitting corrosion, localized biological corrosion.

Metallurgically Influenced Corrosion: Inter granular corrosion, de-alloying. Mechanically assisted corrosion - erosion corrosion, fretting corrosion, corrosion fatigue. Environmentally induced cracking – mechanism of stress corrosion cracking and hydrogen embitterment.

SECTION-C

Prevention and Control of Corrosion: Corrosion control by design. Selection of corrosion resistant materials – alloying, stainless steel and brass. Oxidation resistant materials, control of high temperature oxidation. Cathodic and anodic protection methods. Use of inhibitors-types, applications. Corrosion in cold water pipes – Langalier saturation index.

Corrosion Monitoring: Introduction – On-stream monitoring – Electrical resistance, linear polarization, hydrogen test probe, ultrasonic testing, radiography and corrosion coupons. Off-stream monitoring equipments – Acoustic emission testing, eddy current inspection, liquid penetration inspection.

Corrosion Testing: Purpose and classification. Dimensional charge – Ultrasonic thickness measurements, eddy current, microscopic examination. Weight charge – Specimen preparation, test conditions and evaluation of results for overall corrosion, SCC, IGC. Electrochemical techniques – Polarization curves, Tafel extrapolation, linear polarization, AC impedance methods (EIS).

Recommended Books:

1. Jones, D. A. (1992). Principles and prevention of corrosion. Macmillan.
2. Fontana, M. G. (2005). Corrosion engineering. Tata McGraw-Hill Education.
3. Trethewey, K. R., & Chamberlain, J. (1995). Corrosion for science and engineering.
4. Schweitzer, P. A. (1989). Corrosion and corrosion protection handbook (Vol. 1). CRC Press.

E-resource(s): https://nptel.ac.in

CHE 524 Polymer Processing and Reaction Engineering

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Get idea about extrusion, blow molding, wire coating etc. and it's affecting parameters
- Carry out various molding techniques, problems and their solutions
- Understand the methods to achieve polymerization by various reactors

Section-A

Basic principles, description of different processing techniques such as extrusion, blow molding, wire coating, calendaring including equipment, detailed discussions of parameters affecting the processing, problems and troubleshooting during processing, compounding and mixing of polymers and additives.

Section-B

Description of different processing techniques such as molding compression, injection, transfer, reaction-injection, thermoforming including equipment details and discussion on parameters affecting the processing, problems and troubleshooting during processing, reinforced polymers and their processing.

Section-C

Review of RTD & macro and micro mixing in reaction vessels. Homogeneous continuously stirred tank, segregated continuous stirred tank reactor and laminar flow tubular reactor in case of ionic, free radical and step growth polymerization. Models of heterogeneous Polymerizations. Solution / precipitation, suspension and Emulsion Polymerization, Smith Ewart Model, Application to continuous emulsion polymerization. Co-ordination polymerization in fluidized bed reactor.

Recommended Books:

- Tadmor, Z., & Gogos, C. G. (1979). Principles of Polymer Processing John Wiley u. Sons, New York, Brisbane, Chichester, Toronto.
- Baird, D. G., &Collias, D. I. (2014). Polymer processing: principles and design. John Wiley & Sons.
- Gupta, S. K., & Kumar, A. (2012). Reaction engineering of step growth polymerization. Springer Science & Business Media.

E-resource(s): https://nptel.ac.in

CHE 527 Supercritical Fluid Extraction

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the properties and chemistry of supercritical fluids
- Perform the supercritical fluid extraction process
- Develop and apply the strategies of supercritical fluid extraction

SECTION-A

Introduction and Properties of Supercritical Fluids: Introduction, Scope of supercritical fluid extraction, Properties of Supercritical Fluids, Density, Diffusivity and viscosity of supercritical fluid, Solvating Strength, Modified Supercritical Fluids.

Solution Chemistry of Supercritical Fluids: Phase equilibria in near-critical solutions, Binary and ternary mixtures of carbon dioxide and certain solutes and the occurrence of two-phase holes, Critical and crossover phenomena in fluids and fluid mixtures, Phase separation by nucleation and by spinodal decomposition.

SECTION-B

Supercritical Fluid Extraction: Functional Group Solubility in Supercritical Fluids, Solubility Determination, Threshold Density, Solubility in Modified Fluids, Method of Sample Preparation, Conventional Sample Preparation, Preliminary Considerations, Types of Fluids and Pumps, Extraction Vessel, Restrictor.

Collection of the Extracted Material: Collection Efficiency, Importance of trapping, Importance of the Restrictor, Inert Solid Trap, Active Solid Sorbent, Liquid Solvent Trapping, Trapping using Modified Fluids.

SECTION-C

Extraction Strategies: Extraction Protocol, Factors Determining Extractability, Extraction Scenarios, Extraction Strategies, Extraction Profiles, Mechanics of Analytical SCFE, Extraction Aids, Matrix Problems, Modifier Introduction, Developing a Method, Quantification in SFE.

Applications of Supercritical Fluid Extraction: Environmental Applications, Pharmaceutical Applications, Application in polymers, Natural Product Applications, Food Applications, Destruction of toxic organic components using supercritical water oxidation, Conclusion.

Recommended Books:

1. Taylor, L. T. (1996). Supercritical fluid extraction (Vol. 4). Wiley-Interscience.
2. Kiran, E., Debenedetti, P. G., & Peters, C. J. (Eds.). (2012). Supercritical fluids: fundamentals and applications (Vol. 366). Springer Science & Business Media.
3. Martinez, J. L. (2007). Supercritical fluid extraction of nutraceuticals and bioactive compounds. CRC Press.
4. McHugh, M., & Krukonis, V. (2013). Supercritical fluid extraction: principles and practice. Elsevier.
5. King, J. W., & List, G. R. (Eds.). (1996). Supercritical fluid technology in oil and lipid chemistry. The American Oil Chemists Society.

CHE 509 Bioenergy Engineering

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- To judge the different options available given the nature of the feedstock.
- To apply the acquired knowledge to design biomass energy plants and to evaluate their performances.

SECTION – A

Introduction to microbiology and biochemical engineering: Microbial variety; Nomenclature of organisms; Classification of organisms; Cell structure; Gram +ve and Gram – ve bacteria; Growth medium; Enzyme kinetics; Enzyme immobilization technique; Cell counting techniques; Growth phases of microorganism; Factors affecting the growth of microorganisms; Fermentor; Bioproduct recovery and biosepararation.

Introduction to bioenergy: Overview; Needs and Benefits; Types of bioenergy; Bio-facilities; Conversion of biomass to biofuels.

Bioenergy from wastewater: Process of energy recovery-conversion to methane, Internal combustion engine, Fuel cell, Production of hydrogen; Microbial fuel cell; Future direction of research.

SECTION – B

Food waste to bioenergy: Anaerobic digestion (AD) – Biochemical principle of AD, Two phase AD (BIOCELL and HASL); Parameters affecting AD – pH, Composition, Loading rate, Retention time, Biodegradability, Lipid content, C/N ratio, Temperature; Biomethane production.

Energy from municipal solid waste (MSW) and landfill (LF): Sources of MSW; Solid state fermentation (SSF) – Process, Advantages/disadvantages, Affecting parameters; Case studies; Formation of LF gases; Landfill gas facility and utilization of energy; Landfill gas quality and quantity; Factors affecting biogas production; Landfill bioreactors. Future perspectives.

Biohydrogen: Types of waste materials; Processes – Dark fermentation, Photo fermentation, Hybrid process; Future research.

Biodiesel: Production of biodiesel – Blending, Microemulsion, Thermal cracking, Transesterification (reactor systems, mechanism, affecting factors); Conclusion.

SECTION – C

Algal biodiesel: Microalgae; Advantages; Technologies for algal biomass production – Phototrophic production (open pond, closed photobioreactor, hybrid systems), Heterotrophic production, Mixotrophic production; Biofuel productivity factors – Photosynthetic efficiency, Impact of strain, Lipid productivity; Co-processes in microalgal production; Recovery of microalgal biomass; Extraction and purification of algal biomass; Algal biomass to biodiesel; Other fuel generation from microalgae.

Conversion of lignocellulosic biomass: Preprocessing methods; Lignin recovery (Organosolv method); Application of lignin; Cellulose saccharification- Acidic hydrolysis, Enzymatic hydrolysis, Thermochemical transformation, Supercritical water treatment, Solid-acid catalyzed reaction; Conclusion.

Bioethanol: Biomass resources and production method; Ethanol production from waste materials; Microorganisms for ethanol fermentation – microorganism producing ethanol, Microorganisms synthesize hydrolytic enzymes; World status; Future aspects of research; Algal bioethanol – Characteristics and advantages, Sources of algae, Production of bioethanol from algal biomass, Future perspectives.

Recommended Books:

1. Khanal S. K., Rao Y. S. Zhang T. C., Lamsal B. P., Tyagi R. D. & Kao C. M. (1998). Bioenergy and Biofuel from Biowastes and Biomass. ASCE publication.

2. Vesilind P. A., Worrell W. A., Reinhart D. R. & Speight J. G. (1986). Synthetic Fuel Handbook: Properties, Process and Performance.Mc-Graw Hill Publishers.

3. Klass D. L. (1998) Biomass and Renewable Energy Fuels and Chemicals. Academic Press.

4. Sunggyu Lee S. & Shah Y. T. (2007). Biofuels and Bioenergy: Processes and Technologies. CRC Press.

CHE 510 Catalysis and Surface Chemistry

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand colloids, association of colloids and electro-kinetic effects
- Prepare, understand and analyze the properties of catalysis
- Characterize, select the catalyst and design the reactor

Section-A

Introduction: Basics of surface chemistry, surface tension and adsorption.

Surface & colloids: coagulation and kinetics of coagulation, spontaneous aging of colloids.

Aggregation process: Coalescence and particle growth, Stability of colloids, determination of change on colloids, size and shape of colloids.

Association of colloids: Self-assembly system, reversal of phase, emulsion (micro, macro and aerosols), emulsifying agents, theories of emulsification, gel, sol gel transformation.

Electro kinetic effect: Electrosmosis, electrophoresis, streaming potential, dorn effect, stabilization of surfactant solution.

Section-B

Catalysis: Emergence of Catalyst Technology, Basic Variables for Control of Chemical Reactions, Importance of Catalysis and Catalyst Technology, Impact on Society and Life Forms, Scope of Catalyst Technology, Fundamental Catalytic Phenomena, Steps in a Heterogeneous Catalytic Reaction, Reaction and Diffusion Resistances for a Catalytic Reaction, Kinetics of Catalytic Surface Reactions, Effects of Surface Structure and Support on Catalytic Activity.

Catalyst materials, properties and preparation: Catalyst Materials: Active Phase, Carriers, Promoters, Molecular Sieves and Zeolites, Catalyst Properties, Catalyst Engineering, Physical, Mechanical and Chemical Properties, Catalyst Preparation methods. New Concepts of Catalysis Design, Design of New Molecular Sieves, Design of Sophisticated Composite Catalysis Based on Nanostructures.

Section-C

Catalyst characterization and selection: Principles and Objectives of Catalyst Characterization, Determining Physical Properties of Catalysts, Determining Chemical Properties of Catalysts and Catalyst Selection Catalytic fixed Bed Reactor Design and Activity Testing Fundamentals of Reactor Design, Collecting, Analyzing and Reporting Data from Laboratory Reactors, Choosing Reactors in the Laboratory and Plant Design of Adiabatic, Iso-thermal, non-isothermal and non-adiabatic reactors.

Recommended Books:

1. Somorjai, G. A., & Li, Y. (2010). Introduction to surface chemistry and catalysis. John Wiley & Sons.
2. Atkins, P. & de Paula, J. (2006). Physical Chemistry 8th edition. Great Britain. Oxford University Press, 6, 791-830.
3. Upadhyay, S. K. (2007). Chemical kinetics and reaction dynamics. Springer Science & Business Media.
4. Froment, G. F., Bischoff, K. B., & De Wilde, J. (1990). Chemical reactor analysis and design (Vol. 2). New York: Wiley.
5. Smith, J. M. (1981). Chemical engineering kinetics.

CHE 514 Cryogenic Engineering

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand utilization of cryogenic engineering in the benefit of the society
- Understand working principles of various units such as cryo-coolers, gas liquefaction unit, refrigeration etc.

Section A

Gas Liquefaction Systems: Thermodynamically Ideal System, Joule - Thomson Effect, Adiabatic Expansion; Liquefaction Systems for Air, Neon, Hydrogen and Helium - Effect of component efficiencies on System Performance.

Section B

Gas Separation and Purification: Principles - Plate Calculations - Air, Hydrogen and Helium separation systems.

Cryogenic Systems: Ideal and practical systems - Cryogenic Fluid Storage and Transfer systems - Storage vessels , Insulation - Two Phase Flow in Cryogenic Transfer Systems - Cool Down Process Module IV

Section C

Cryogenic Fluid Vacuum Technology: Low Temperature Properties of Materials - Properties of Cryogenic Fluids - Pump Down Time - Applications of Cryogenic Systems - Super Conductive Devices, Rockets and Space Simulation, Cryogenics in Biological and Medicine - Cryo pumping.

Recommended Books:

1. Baron, R. (2003). Cryogenic System. New York: McGraw Hill
2. Timmerhaus, K. D. & Flynn, T. M. (2004). Cryogenic Process Engineering. Plenum Press.
3. Russel B. S. (2003). Cryogenic Engineering. Van Nostrand.
4. Yance R. W. & Duke W. M. (2009). Applied Cryogenic Engineering. John Willey.

CHE 519 Industrial Heat Treatment

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand details analysis of heating process, heating or cooling requirements and problems encountered during heat treatment
- Learn about how control material properties with-out using stress
- Identify solution using automation for time-temperature controlled treatment to change material properties

Section A

Time-temperature parameters of a heat treatment process; classification of heat treatment processes; heat treatment as applied to the products of steel-making industry, machine building and automobile industry, tool making industry, etc.

Section B

Heat treatment defects and their rectification, modernization of heat treatment processes for near net shape applications and surface treatments; energy efficiency in heat treatments; furnace atmospheres and their production, heating and cooling media and their characteristics.

Section C

Calculations on heating and cooling of charges; equipment of heat treatment shops and their selection; mechanization, automation, design and layout of heat treatment shops.

Recommended Books:

1. Dieter, G. E. (1999). Engineering Design: A Materials and Processing Approach. New York: McGraw hill.
2. Lakhtin Y. & Weinstein N. (1980). Engineering physical metallurgy and heat treatment. Central Books Ltd.
3. Avner S. H. (2016). Introduction to physical metallurgy. Delhi: TATA McGraw hill.
4. Bralla J. B. (1998). Design for manufacturability handbook. New York: McGraw hill handbooks.

E-resource(s): https://nptel.ac.in

CHE 515 Energy Conservation

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Carryout energy auditing, waste heat recovery and renewable energy resources.
- Carryout calculations related to pay-back, energy management, performs, energy conservation opportunities in various equipments, controllers and heat pumps.
- Understand concepts of non-conventional energy sources, designs and calculation will be explained.

Section-A

Introduction: Energy generation, utilization, economics and growth rates, ENCON: approach, modern techniques, benefits, trends, energy conservation in energy intensive industries: boilers, steam system, heating systems, furnaces.

Energy efficiency: Energy accounting; Overview of energy audit, monitoring and control.

Section-B

Waste heat recovery: benefits, measurement- classifying and storage of waste-heat, open and close waste-heat exchangers, the waste-heat exchanger equipment- heat exchangers, incinerators, regenerators and recuperators, economics of waste-heat recovery, various forms of energy storage- thermal, chemical, mechanical and electrical.

Section-C

Solar energy: Production and transfer of solar energy, general description and characteristics of solar collectors.

Energy from biomass: Sources of biomass, conversion of biomass into fuels- fermentation, pyrolysis, gasification, combustion, aerobic and anaerobic bio-conversion.

Wind energy: Principles of wind energy conversion, site selection considerations, types of wind power conversion systems.

Geothermal energy: Availability, system development and limitations, ocean thermal energy conversion.

Recommended Books:

1. Kreith F. & Goswami D. Y. (2003). Energy management and conservation handbook. CRC Press.
2. Turner W. C. & Doty S. (2005) Energy Management Handbook. The Fairmont Press Inc.

3. Rai G.D. (1997). Non-conventional Energy Sources. Khanna Publishers.

4. Smith Craig B. (2006). Energy Management Principles: Applications, Benefits, Savings. Pergamon.

5. Chakrabarti A. (2015). Energy Engineering And Management. Phi Learning Private Limited.

E-resource(s): https://nptel.ac.in

CHE 408 Nano-Science and Technology

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**3**	**1**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Objectives:

The students will be able to:

- Demonstrate the understanding of length scales concepts, nanostructures and nanotechnology
- Identify the principles of processing, manufacturing and characterization of nanomaterials and nanostructures
- Apply the electronic microscopy, scanning probe microscopy and nano-indentation techniques to characterize the nano-materials and nanostructures
- Evaluate and analyze the mechanical properties of bulk nanostructured metals and alloys, nano-composites and carbon nano-tubes

Section-A

Supramolecular chemistry: Definition and examples of the main intermolecular forces used in supramolecular chemistry. Self-assembly processes in organic systems.

Basic principles and fundamental properties: Size and Confinement Effects, Nanoparticle Morphology, Physical and Chemical Properties.

Section-B

Synthesis of nanomaterials: Introduction to nanomaterials, Equipment and processes needed to fabricate nano devices and structures such as bio-chips, power devices and opto-electronic structures. Top-down (Nanolithography, CVD), Bottom-up (Sol-gel processing, chemical synthesis). Wet deposition techniques, Self-assembly (Supramolecular approach).

Section-C

Different classes of nanomaterials: Metal and Semiconductor Nanomaterials, Quantum Dots, Wells and Wires, Molecule to bulk transitions Bucky balls and Carbon Nanotubes.

Instrumentation for nanoscale characterization: TEM, SEM and SPM technique, Fluorescence Microscopy and Imaging.

Recommended books:

1. Steed, J. W., & Atwood, J. L. (2013). *Supramolecular chemistry*. John Wiley & Sons.
2. Bréchignac, C., Houdy, P., & Lahmani, M. (Eds.). (2008). *Nanomaterials and nanochemistry*. Springer Science & Business Media.
3. Lehn, J. M. (1995). *Supramolecular chemistry* (Vol. 1). Germany: Vch, Weinheim.

E-resource(s): https://nptel.ac.in

CHE 502 Advanced Chemical Engineering Thermodynamics

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the importance and relevance of thermodynamics in life processes
- Analyze various situations and apply the concepts of thermodynamics to problem solving.
- Work with single and multiphase systems of pure materials and mixtures.

SECTION-A

Review of first and second law of thermodynamics, Maxwell equations, Joule-Thompson experiment, irreversibility and availability, exergy analysis. Phase transition, types of equilibrium and stability, multi-component and multi-phase systems, equations of state. Chemical thermodynamics, combustion. Third law of thermodynamics.

SECTION-B

Kinetic theory of gases: Introduction, basic assumption, molecular flux, equation of state for an ideal gas, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity. Transport phenomena-intermolecular forces, The Van der Waals equation of state, collision cross section, mean free path.

SECTION-C

Statistical thermodynamics: Introduction, energy states and energy levels, macro and microscales, thermodynamic probability, B-E, F-D, M-D statistics, distribution function, partition energy, statistical interpretation of entropy, application of statistics to gases-mono-atomic ideal gas.

Recommended Books:

1. Bejan, A. (2016). Advanced engineering thermodynamics. John Wiley & Sons.
2. Sandler, S. I. (2017). Chemical, biochemical, and engineering thermodynamics. John Wiley & Sons.
3. Sandler, S. I. (2017). Chemical, biochemical, and engineering thermodynamics. John Wiley &Sons.
4. Prausnitz, J. M., Lichtenthaler, R. N., & de Azevedo, E. G. (1998). Molecular thermodynamics of fluid-phase equilibria. Pearson Education.
5. Smith, J. M. & VanNess, A. (1975). Introduction to chemical engineering thermodynamics. Mc-Graw Hill.
6. Van Ness, H. C. (2015). Classical thermodynamics of non-electrolyte solutions. Elsevier.

E-resource(s): https://nptel.ac.in

CHE 503 Advanced Heat Transfer

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand flow behaviour in boundary layers
- Do analogs study between heat, mass and momentum
- Recognize factors affecting during transport of mass and energy
- Do make energy balances in boundary layers

Section-A

Introduction; molecular momentum transport; convective momentum transport; velocity distribution in laminar flow; Equations of change for isothermal systems; Equations of change, applications of equations of change; velocity distribution with more than one independent variables, stream functions and velocity potential, flow near solid surfaces, molecular energy transport, convective energy transport.

Section-B

Energy balances; convection; equation of change for non-isothermal systems; applications of equations of change; temperature distribution with more than one independent variable; molecular mass transport; convective mass transport; mass balances; concentration distribution in solids and laminar flow.

Section-C

Concentration distribution with more than one independent variable: boundary layer theory, turbulent flow, velocity distribution in turbulent flow; temperature distribution in turbulent flow; concentration distribution in turbulent flow.

Recommended Books:

1. Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2007). *Transport phenomena*. John Wiley & Sons.
2. Deen, W. M. (1998). *Analysis of transport phenomena* (Vol. 2). New York: Oxford University Press.
3. Welty, J. R., Wicks, C. E., Rorrer, G., & Wilson, R. E. (2009). *Fundamentals of momentum, heat, and mass transfer*. John Wiley & Sons.

E-resource(s): https://nptel.ac.in

CHE 516 Environmental Safety and Impact Assessment

	L	T	P	C
Max. Marks: 100				
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Develop the basic idea of impact assessment
- Able to predict the impact of air, water and noise pollution
- Assess and manage the environmental risk

Section-A

Introduction: Historical development of Environmental Impact Assessment (EIA), Definition and scope of EIA, Objectives of EIA, Basic EIA principles.

Impact study: Approach for environmental impact studies, EIA as planning tool, EIA methodology, Predictive model of impact assessment.

Section-B

Impact prediction and assessment for air, water and noise: Air: knowledge of air quality, Air quality standards, Sources of pollutants, Effects of pollutions, Conceptual approach for air impacts prediction.

Water: Information on water quality (Surface water and ground water), water quality standards, identification and prediction of impact and assessment.

Noise: Information on noise legislation and guidelines, Methodology for noise-impacts prediction, Assessment of impact significance.

Section-C

Environmental risk assessment (ERA) and management in EIA: Environmental risk assessment, treatment of uncertainty, key steps.

Management Plan: Impact prediction, evaluation and mitigation, Preparation of EIA plan for industrial project and functions, factors for consideration, managing the EIA process, Monitoring and auditing.

Recommended books:

1. Anjaneyulu, Y. (2003). Environmental Impact Assessment. B.S Publications.
2. Attri S. D. & Tyagi, A. (2010). Climate Profile of India. Ministry of Earth Sciences.
3. Glasson, J., Therivel, R. & Chadwick, A. (1998) Introduction to Environmental Impact Assessment.Routledge- Taylor & Francis Group.
4. Lawrence, D.P. (2003). Environmental Impact Assessment – Practical solutions to recurrent problems. Wiley-Interscience.
5. Petts, J. (1999). Handbook of Environmental Impact Assessment, Vol., I and II. Blackwell Science.

E-resource(s): https://nptel.ac.in

CHE 306 Computational Methods in Engineering

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**3**	**1**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Solve linear and nonlinear algebraic equations
- Approximate functional value, integration and ODE
- Solve the ODE and PDE

Section-A

Linear Algebraic Equations: Introduction, Gauss-Elimination, Gauss-Siedel and LU Decomposition methods. Thomas' algorithm. **Eigen Values and Eigen Vectors of Matrices:** Introduction, Fadeev-Leverrier's method, Power method, Householder's and Givens' method.

Nonlinear Algebraic Equations: Single variable and multivariable successive substitution method, Single variable and multivariable Newton-Raphson technique and Polynomial root finding methods: lin's and Lin Bairstow's Methods.

Section-B

Function Approximation: Least squares curve fit, Newton's interpolation formulae, Lagrangian interpolation, Pade approximation and Finite difference approximation.

Integration formulae: Trapezoidal rule, Simpson's 1/3 & 3/8 rule.

Ordinary Differential Equations: Initial Value Problems: Explicit Adams-Bashforth technique, Implicit Adams-Moulton technique and Runge-Kutta methods.

Section-C

Ordinary Differential Equations: Boundary Value Problems: Finite difference technique, Shooting Technique, Orthogonal Collocation using Legendre Polynomials.

Partial Differential Equations: Classification of PDE Solution of Heat equation using Finite difference technique (Method of lines).

Recommended books:

1. Gupta, S. K. (1995). Numerical methods for engineers. New Age International.

2. Hanna, O. T., & Sandall, O. C. (1995). Computational methods in chemical engineering. Prentice-Hall, Inc...

3. Sastry, S. S. (2012). Introductory methods of numerical analysis. PHI Learning Pvt. Ltd...

E-resource(s): https://nptel.ac.in

CHE 317 Advanced Mass Transfer

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**3**	**1**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand single stage binary distillation
- Understand distillation of binary mixture and LLE
- Understand leaching and crystallization

SECTION A

Distillation: Vapor-liquid equilibria: pressure-temperature-concentration phase diagram, enthalpy-concentration diagram; ideal and non-ideal solutions, Raoult's law and its application, relative volatility, maximum and minimum boiling mixtures.

Single stage binary distillation: flash vaporization, partial condensation, differential (Rayleigh) distillation, differential condensation, constant relative volatility, lever rule, steam distillation.

SECTION B

Continuous distillation of binary mixtures: ideal and non-ideal stages, definition of a point, stage and column efficiency; Ponchon Savarit method: adiabatic & non-adiabatic; McCabe Thiele method: plate calculations, feed plate location; use of open steam, tray efficiency, tray type (bubble cap, sieve & valve), flooding, tray layout, delta P. tray hydraulics, determination of column height and diameter; packed column.

Liquid-liquid extraction: principle, usefulness, ternary liquid equilibria, triangular coordinates, mixer rule, choice of solvent; Extractors: mixer settlers, spray & packed column, rotating disk contactor, sieve tray column.

SECTION C

Leaching: solid liquid equilibrium; Batch and continuous operations: single and multistage cross current and counter current operations, number of equilibrium stages; Equipments; percolation tank, agitated vessel, thinkers, classifiers, continuous counter current decantation.

Crystallization: nucleation & crystal growth rate, controlled growth of crystals, equilibrium yield of crystallization, heat and mass transfer rates in crystallization, classification of industrial crystallizers.

Recommended books:

1. Seader, J. D., Henley, E. J., & Roper, D. K. (1998). Separation process principles.
2. Taylor, R., & Krishna, R. (1993). Multicomponent mass transfer (Vol. 2). John Wiley & Sons.
3. Benitez, J. (2016). Principles and modern applications of mass transfer operations. John Wiley & Sons.
4. Holland, C. D. (1981). Fundamentals of multicomponent distillation. McGraw-Hill,.
5. Wankat, P. C. (2006).
6. Separation process engineering. Pearson Education.

E-resource(s): https://nptel.ac.in

CHE 523 Pinch Technology

	L	T	P	C
Max. Marks: 100				
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Explain the role of thermodynamics in process design
- Calculate the minimum heating and cooling requirements for a process
- Identify existing non-optimal arrangements of heat exchangers
- Calculate lower cost solutions for arrangements of heat exchangers
- Critically assess any design changes to process.

Section –A

Process Integration and its Building Blocks: Definition of Process Integration (PI), School of thoughts, Areas of application and Techniques available for PI, Onion diagram.

Pinch Technology: An Overview: Introduction, Basic concept, How it is different than energy auditing, Role of thermodynamic laws, Problem addressed by Pinch technology.

Key Steps of Pinch Technology: Data extraction, Targeting, Designing, Optimization-Super targeting. Basic Elements of Pinch Technology: Grid diagram, Composite curve, Problem table algorithm, Grand composite curve.

Section – B

Targeting of Heat Exchanger Network (HEN): Energy targeting, Area targeting, Number of units targeting, Shell targeting, cost targeting.

Designing of HEN: Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER), Design of multiple utilities and pinches, Design for threshold problem, Loops and Paths.

Heat Integration of Equipments: Heat engine, Heat pump, Evaporator, Drier, Refrigeration systems.

Section – C

Heat integration of Reactors: Heat integration characteristics of reactors; Appropriate placement of reactors, Use of the grand composite curve, Evolving reactor design to improve heat integration.

Heat integration of distillation column: Heat integration characteristics of distillation, Appropriate placement of distillation columns, Use of the grand composite curve for heat integration of distillation, Evolving the design of simple distillation columns to improve heat integration, Heat pumping in distillation.

Heat and Power Integration: Co-generation, Steam turbine, Gas turbine.

Recommended Books:

1. Shenoy, U. V. (1995). Heat exchanger network synthesis: process optimization by energy and resource analysis. Gulf Professional Publishing.
2. Douglas, J. M. (1988). Conceptual design of chemical processes (Vol. 1110). New York: McGraw-Hill.
3. Linnhoff, B. (1982). User guide on process integration for the efficient use of energy. AIChE J., 28, 000-000.
4. Smith, R., & Smith, R. (1995). Chemical process design (pp. 8-13). New York: McGraw-Hill.

CHE 525 Process and Product Development

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- To understand the basic concepts of process design, process development and product development.
- To apply material and energy balances for process development using process data.
- To apply algorithms for feasibility and optimization offlow sheet.
- To apply the scaling up processes.

Section A

Introduction: goal of industrial research and development, production structure of chemical industry, task of process development, creative thinking, preliminary database creation, preliminary process synthesis, examples.

Product Development: development of chemical product on laboratory scale, quality improvement, reproducibility etc. Case studies of products developed.

Chemical Production Plant and Its Components: about catalyst, reactors, product processing, pipelines pumps and compressors, product supply and storage, water disposal, measurement and control technology, plant safety, material selection.

Section B

Process Data: Chemical Data, Mass Balance, Physio-chemical data sources and estimation, Patenting and licensing situations, development cost, location, market situation, plant capacity, raw materials, waste disposals

Course of Process Development: Process development as an iterative process, Drawing up of an initial version of the process, checking the individual steps, Micro Plant: Link between the laboratory and the pilot plant, Testing the entire process on small scale.

Section C

Scaling up Process: Scaling up of process from laboratory to pilot plant and to industrial scale.

Process Evaluation: Batch Versus Continuous, Equilibrium Limitations, Process alternatives, Preparation of study report

Flow sheeting: Basic Flow Diagram, P&ID, Development of flow diagram.

Recommended Books:

1. Vogel, G. H. (2005). Process development: from the initial idea to the chemical production plant. John Wiley & Sons.
2. Perkins, J. D. (1989). Conceptual design of chemical processes JM Douglas. New York: McGraw Hill
3. Jordan, D. G. (1968). Chemical process development.
4. Seader, J. D., Seider, W. D., & Lewin, D. R. (2004). Product and process design principles: synthesis, analysis and evaluation. Wiley.
5. Turton, R., Bailie, R. C., Whiting, W. B., & Shaeiwitz, J. A. (2008). Analysis, synthesis and design of chemical processes. Pearson Education.

CHE 508 Advanced Transport Phenomena

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to

- Understand the fundamentals of transport process
- Pertain the isothermal, non isothermal and multi-component systems
- Analyze the transport equation and computational methods involving multiphase flow

SECTION A

Fundamentals of transport processes, basics of vector and tensor algebra, phenomenological equations and transport properties, analogies amongst momentum, heat, and mass transport; non-newtonian fluids and rheological behaviour. Basic transport equations for isothermal, non-isothermal and multicomponent systems; velocity, temperature and concentration distributions with more than one independent variables; velocity, temperature and concentration distributions in laminar and turbulent flow.

SECTION B

Macroscopic balances for isothermal, non-isothermal and multicomponent system and their applications in momentum, heat and mass transport problems; simultaneous momentum, heat and mass transfer with chemical reaction.

SECTION C

Analytical methods for solution of transport equations .Computational methods involve in multiphase flow, chemically reacting flows, turbulent mixing etc.

Recommended Books:

1. Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2002). Transport Phenomena 2nd Ed., John Wiley&Sons. Inc., Hoboken, NJ.

2. Deen, W. M. (1998). Analysis of transport phenomena (Vol. 2). New York: Oxford University Press.

3. Slattery, J. C. (1999). Advanced transport phenomena. Cambridge University Press.

4. Leal, L. G. (2007). Advanced transport phenomena: fluid mechanics and convective transport processes (Vol. 7). Cambridge University Press.

5. Geankoplis, C. J. (2003). Transport processes and separation process principles: (includes unit operations). Prentice Hall Professional Technical Reference.

E-resource(s): https://nptel.ac.in

CHE 518 Fluidization Technology

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the fluidization phenomena and operational regimes
- Design various types of gas distributors for fluidized beds and determine effectiveness of gas mixing at the bottom region.
- Analyze fluidized bed behavior with respect to the gas velocity
- Develop and solve mathematical models of the fluidized bed

Section-A

Introduction: the phenomenon of fluidization, liquid like behavior of a fluidized bed, comparison with other contacting methods, advantages and disadvantages of fluidized beds, fluidization quality, selection of a contacting mode for a given application.

Industrial applications of fluidized beds: coal gasification, gasoline from other petroleum fractions, synthesis reactions, metallurgical and other processes, physical operations, synthetic reactions, cracking of hydrocarbons, biofluidization.

Mapping of regimes and dense bed: fixed bed of particles, fluidization without carryover of particles, mapping of regimes, distributor types, gas entry regions, gas jet region.

Section-B

Bubbles in the fluidized bed: single rising bubbles, coalescence and splitting of bubbles, flow model for bubbling bed, two phase hypothesis.

Entrainment and elutriation from fluidized beds: freeboard behavior, location of the gas outlet of a vessel, Entrainment of tall vessel: the elutriation constant approach, relationship between k and Gs, experimental findings of k and k*, K-L approach.

High velocity fluidization: turbulent fluidized beds, fast fluidization.

Mixing, segregation and staging: vertical and horizontal movements of solids, segregation of particles.

Section-C

Mass and heat transfer in fluidized bed: dispersion of gas in beds, gas interchange between bubble and emulsion, mass transfer between particle and bed, heat transfer between fluidized bed and surfaces.

Circulation system: circuits for the circulation of solids, circulation rates, flow of gas-solid mixture in down-comers.

Fluidized bed reactor: reaction rates and reactor performance, reactor model for fine particle bubbling bed, intermediate and large size particle beds.

Recommended Books:

1. Kunii D. & Levenspiel O. (1991). Fluidization Engineering. Butterworth.
2. Gidaspow D. (1993). Multiphase Flow and Fluidization: Continuum and Kinetic Theory Description. Elsevier Science & Technology.
3. Gibilaro L.G. (2001). Fluidization dynamics. Butterworth Heinemann.

E-resource(s): https://nptel.ac.in

CHE 521 Natural and Synthetic Polymers

	L	T	P	C
Max. Marks: 100				
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Understand the basics of polymer
- Understand kinetics of polymerization
- Classify polymers, their reinforcement and additives

Section-A

Introduction To Polymer Science: history of polymers, types of polymers and polymerizations: polymer composition and structure, polymerization mechanism, nomenclature of polymers, nomenclature based on source, nomenclature based on structure, linear, branched, and crosslinked polymers, molecular weight, physical state, crystalline and amorphous behavior, determinants of polymer crystallinity, thermal transitions, applications of polymers, mechanical properties, elastomers, fibers, and plastics, surface characterization, stress–strain relationships, thermal analysis, particle size, rheology, chemical resistance.

Section-B

Kinetics of Polymerization: step-reaction polymerization or polycondensation reactions stepwise kinetics, general step-reaction polymerization, polycondensation mechanisms, ionic chain-reaction and complex coordinative, polymerization (addition polymerization), cationic polymerization, anionic polymerization, free radical chain polymerization (addition polymerization), initiators for free radical chain polymerization, mechanism for free radical, chain polymerization, chain transfer, kinetics of copolymerization, copolymerization.

Naturally Occurring Polymers: polysaccharides, cellulose, cellulose-regenerating processes, esters and ethers of cellulose, starch, other polysaccharides, proteins, nucleic acids, naturally occurring polyisoprenes, and polymer structure.

Section-C

Inorganic-Organic Polymers: sol-gel, addition polymers, coordination polymers, inorganic reaction mechanisms, condensation organometallic polymers. **Inorganic Polymers:** silicon dioxide (amorphous), silicates, high-temperature, superconductors, silicon dioxide in electronic chips, polymeric carbon—diamond, asbestos, polymeric carbon—graphite, ceramics, polysulfur, zeolites, silicon dioxide (crystalline forms)—quartz form. **Fillers and Reinforcements for Polymers:** Theory of the effect of fillers**,** fillers, reinforcements, coupling agents, composites, nanocomposites. **Plasticizers, Stabilizers, Flame Retardants and Other Additives:** plasticizers, antioxidants, heat stabilizers, ultraviolet stabilizers, flame retardants, microorganism inhibitors, colorants, curing agents, antistatic agents (antistats), chemical blowing agents, compatibilizers, impact modifiers, processing aids, lubricants, flame-retardant mechanisms.

Recommended Books:

1. Odian, G. (2004). Principles of polymerization. John Wiley &Sons.
2. CarraherJr, C. E. (2007). Seymour/Carraher's polymer chemistry. CRC press.

E-resource(s): https://nptel.ac.in

CHE 526 Processing of Alternative Fuels

Max. Marks: 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Note: The paper will contain three questions from every section aggregating nine questions. Candidates are required attempt total of six questions, taking two questions from each section.

Learning Outcomes:

The students will be able to:

- Predict the future of energy scenario and availability
- Understand basic characteristics of alternative fuels including alcohol, biodiesel and gaseous fuels
- Realize the importance of electric and solar power vehicles

Section A

Estimation of petroleum reserve, World Energy Scenario , Energy Survey of India; Oil industry background and history, Survey of oil consumption ;Availability of petroleum products – types – uses , Air craft fuels , Alternate fuels , list of alternate fuels, Need for alternate fuel – Availability of alternate fuels

Section B

Alternative fuels: Liquid and gaseous fuels, Physico-Chemical Characteristics.

alternative liquid fuels - alcohol fuels; Ethanol & Methanol. Fuel composition, Fuel Induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions. **Vegetable oil based fuels** Introduction, Various vegetable oils for engines, Biodiesel formulation techniques, trans-esterification, Application in diesel engines- Performance and Emission Characteristics. **Gaseous Fuels** Availability of CNG-automotive gasoline- composition- types- properties – additives-effect of emissions - modification required in engines – performance and emission characteristics of CNG and LPG in SI & CI engines. Performance and emission for LPG – Hydrogen – Storage and handling, performance and safety aspects. Biogas, Producer gas and natural gas; their characteristics, System development for engine application.

Section C

Electric and solar powered vehicles Layout of an electric vehicle – advantage and limitations, Specifications – System component, Electronic control system – High energy and power density batteries – Hybrid vehicle – Solar powered vehicles. Fuel cell vehicles.

Recommended Books:

1. Hordeski, M. F., & Pansini, A. J. (2007). Alternative fuels: the future of hydrogen. The Fairmont Press, Inc..
2. Thipse, S. S. (2010). Alternative fuels. Jaico, India.
3. Bechtold, R. (1997). Alternative fuels guidebook. SAE.

4. Maxwell, T. T., & Jones, J. C. (1994). Alternative fuels. Emissions, economics, and performance (Vol. 143).

5. Lee, S., Speight, J. G., & Loyalka, S. K. (2014). Handbook of alternative fuel technologies. CRC Press.

Reading Electives

CHE 601R Green Energy

Max. Marks: 100

L	T	P	C
0	0	4	2

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Identify the need of wind Energy and solar energy and the various components used in energy, generation and know the classifications.
- Understand the concept of Biomass energy resources and their classification, types of biogas Plants- applications.
- Compare Solar, Wind and bio energy systems, their prospects, advantages and limitations

Section-A

Green Chemistry: Introduction, Introduction to chemistry (atoms and elements), Chemical compounds and chemical bonds, Chemical reactions and equations, Physical properties and states of matter.

Green Science & Technology: Introduction, Definition, Concept, techniques involve and applications.

Introduction to Energy Sources: Petroleum in the World, Natural Gas as the Fastest Growing Primary energy, Source in the World, Coal as a Fuel and Chemical Feedstock, Introduction to Renewable and Bio-renewable Sources, Role of energy in economic development and social transformation.

Section-B

Biomass Energy: Introduction, Biomass Characterization, Biomass Fuel Analyses Biomass and its Conversion Technologies.

Fuel Cell Energy: Introduction, types of fuel cell system, Principle of working, construction and applications.

Solar Energy: Thermonuclear energy source, Planck's Law, Thermal radiation fundamentals,

Wind Energy: Introduction, Types of wind turbines, Power extraction by a turbine, Integration of wind energy converters to electrical networks - Applications of wind energy.

Section-C

Wave Energy: Concept of energy and power from waves, Wave characteristics (period and wave velocities), and Different wave energy conversion devices.

Tidal Energy: Principles of tidal power generation, components of power plant, Single and two basin systems, Estimation of energy.

Hydro-Energy: Introduction, types of hydro-energy systems, Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and turbines.

Recommended Books:

1. Twidell, J., & Weir, T. (2006). Renewable energy resources. Routledge
2. Manahan, S. E. (2006). Environmental science and technology: a sustainable approach to green science and technology. CRC Press.
3. Sharpe, D., Burton, T., Jenkins, N., & Bossanyi, E. (2013). Wind energy handbook. Wiley.

E-resource(s): https://nptel.ac.in

CHE 602R ISO Practices in Industry

Max. Marks: 100	**L**	**T**	**P**	**C**
	0	**0**	**4**	**2**

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Differentiate various ISO standards
- Implement ISO practices in environmental management
- Apply ISO standards in energy management system

Section-A

ISO-Quality Management System: Introduction; Quality management system, management responsibilities, contributing approach to quality. the ISO 9000:2006 specific terminology, the concept of quality products, development of concept "quality" and related industrial practices, ISO 9000 family of standards, requirements of the quality management system according to ISO 9001 standard; quality management system documentation.

Section-B

ISO-Environmental Management System: Introduction; general approach to developing an environmental management system, summary of requirements of ISO-14001, other ISO -14000 standards. Design and implementation of ISO-14001 (environmental management system), costing, audits and registration of environmental management system. Measurements systems in environmental managements; choosing suitable measuring instruments, calibration of measuring instruments, documentation. Quantification and effects of air and water pollution. Waste management; waste reduction and disposal. Monitoring process parameters values to minimize pollution risk.

Section-C

ISO-Energy Management System: Introduction to ISO-50001Energy Management System, Phases and Elements, Stages, Requirements, Management responsibilities, Management, Representative, A best practice using OAR and/or PAL for energy team meeting, QVS corporation management, QVS corporation energy policy.

Recommended Books:

1. Singhal, D., & Singhal, K. R. (2012). Implement ISO9001: 2008 Quality Management System: A Reference Guide. PHI Learning Pvt. Ltd..
2. Morris, A. S. (2004). ISO 14000 environmental management standards: engineering and financial aspects. John Wiley & Sons.
3. Howell, M. T. (2014). Effective implementation of an ISO 50001 energy management system (EnMS). ASQ Quality Press.

CHE 603R Life Cycle Assessment

Max. Marks: 100

L	T	P	C
0	0	4	2

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Get basic idea of life cycle assessment including its goal and scope
- Classify and implementation of LCA
- Interpret LCA, identify its significant issues, report preparation and review the LCA

Section-A

Introduction: Life cycle assessment, History, definition, standards, structure of LCA.

Goal and scope: System of a product, system boundary, unit process, functional unit.

Life cycle inventory: Data collection, databases, allocation, validation.

Section-B

Life cycle impact assessment: Impact categories, classification, normalization, weighting.

Life cycle impact assessment methodologies: Overview of methodologies, Eco-indicator99 method.

Section-C

Life cycle interpretation: limitation of LCA, Identification of significant issues, evaluation, reporting, critical review, LCA in practice, LCA and life cycle management, life cycle thinking, sustainability.

Recommended Books:

1. Scientific Applications International Corporation (SAIC), & Curran, M. A. (2006). Life-cycle assessment: principles and practice (pp. 1-80). Cincinnati, Ohio: National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency.
2. Guinée, J. B. (2002). Handbook on life cycle assessment operational guide to the ISO standards. The international journal of life cycle assessment, 7(5), 311-313.
3. Zbicinski, I. (2006). Product design and life cycle assessment (Vol. 3). Baltic University Press.

E-resource(s): https://nptel.ac.in

CHE 606R Safety in Process Industry

Max. Marks: 100

L	T	P	C
0	0	4	2

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Potential hazards and hazardous conditions in process industries
- Pay more attention on precaution to avoid accidents
- Make carful decisions during plant malfunction

Section-A

Introduction: Safety program, Accidents & loss statistics, risk perception, nature of the accident process, inherently safer design, safety and environment concern, major process hazards, accident model, personal safety, risk management.

Section-B

Pressure relief System: Source model, introduction, definition, relief concepts, types of relief systems, pressure relief devices and design.

Fire: The Fire triangle, flammability characteristics of liquids and vapors, combustion phenomena, ignition energy, MOC and inerting.

Explosions: Classification, explosion apparatus for vapor and dust, explosion characteristic, energy of chemical and mechanical explosion, TNO multi energy method.

Section-C

Hazard identification: Safety audit, hazard indices, hazard studies, HAZOP, scenario development.

Accident investigation: General investigation concept, cause of accident, evidence issues, evidence analysis, identification of root cause, management system for investigation.

Recommended Books:

1. Lees, F. (2012). Lees' Loss prevention in the process industries: Hazard identification, assessment and control. Butterworth-Heinemann.
2. Crowl, D. A., & Louvar, J. F. (2001). Chemical process safety: fundamentals with applications. Pearson Education.
3. Wentz, C. A. (1998). Safety, health, and environmental protection. McGraw-Hill Companies.
4. Sanders, R. E. (2015). Chemical process safety: learning from case histories. Butterworth-Heinemann.

E-resource(s): https://nptel.ac.in

CHE 607R Social Responsibilities of industries

Max. Marks: 100

L	T	P	C
0	0	4	2

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Understand the scope, value and philosophies of CSR activities
- Develop labor communities, techniques and processes in CSR
- Work for the betterment of working culture and industrial environment

Section-A

Industrial Social Work: Meaning, definition, scope, values and philosophy, social responsibilities industry, various approaches to social welfare, recent development in social work practice in industry, future of industrial social work with special reference to India.

Section-B

Social Case Work: Meaning, principles, techniques and process of use in the area of industrial social work as a method of practice in the industrial setting.

Community Organization: meaning and its use in Industries, labor community development.

Section-C

Corporate Social Responsibility (CSR): Concept, objective and scope, integrated approach to social work methods in the field of industrial social work.

Industrial Environment: meaning and nature, roles, responsibilities of industrial social work in the growth and development of a balanced industrial environment, social service organizations for industrial workers.

Recommended Books:

Alao, K. A., Kobiowu, S. V., & Adebowale, O. F. (2010). Fundamentals of educational and counseling psychology. Strategic Insight Publishing.

E-resource(s): https://nptel.ac.in

CHE 608R Water and Land Pollution

Max. Marks: 100

L	T	P	C
0	0	4	2

Note: The Question paper will contain eight questions and candidate will be required to attempt any five questions.

Learning Outcomes:

The students will be able to:

- Predict impact of pollution on future and can take appropriate action for prevention
- Identify causes of water and land pollution
- Recognize the conventional techniques which can help in reducing pollution

Section-A

Freshwater pollution: Types and sources; Sampling Methods; Water Quality Parameters.

Types and sources of water pollution: Biological pollutants; Inorganic; Organic; Heavy metals; Pesticides; Radioactive pollutants), Various sources Effluent standards, Drinking water standards, Characteristics of Domestic Waste and Characteristics of agricultural Waste.

Consequences of water pollution: Effect on health on biosphere and on economy.

Sampling methods: Purpose of sampling, different types of samples, collection methods and various instruments used, Methods involved in estimation of parameter for Pollution levels. Concept of dissolved O2, BOD, COD; Prevention of water pollution (Water treatment processes & Sewage treatment

Section-B

Marine water pollution: Types, sources and consequences; Specifications for disposal of sewage and industrial waste into sea; Disposal of sewage & wash water from MVcargo & ships.

Soil pollution: Types, sources and consequences; Sampling Methods; Specifications for disposal of sewage & effluent on land for irrigation & ground water recharge. Methodology of wastewater disposal on land in India; Impact of usage of land for solid waste disposal both municipal solid waste & industrial solid wastes (fly ash from thermal power station, lime sludge from pulp & paper mills); Disposal of hazardous solid waste (heavy metals, toxic organic compounds) on land & its impact on soil pollution. Deterioration of soil due to mining activities Case study of restoration of land due to disposal to fly ash and dumping overburden & tailing in iron ore extraction.

Section-C

Solid waste pollution: Types, sources and consequences. Classification of wastes (Domestic, Industrial, Municipal, Hospital, Nuclear, Agriculture), Transfer and transport, Recycle, Reuse, Recovery, Conversion of solid wastes energy / Manure, Disposal methods (Generation, Sea disposal, Land disposal, Waste disposal on farm crops for irrigation purpose).

Radioactive pollution: Types, sources and consequences, Sampling methods; Models of radioactive decay.

Detection of nuclear radiations: G. M. Counter, Scintillation counter, semiconductor detector; Interaction of radiation's with matter: Biological effects of ionizing radiations: ICRP recommendations.

Recommended Books:

1. Eisenbud, M., & Gesell, T. F. (1997). Environmental radioactivity from natural, industrial and military sources: from natural, industrial and military sources. Elsevier.
2. Arnikar, H. J. (1997). Essentials of Nuclear Chemistry: Critique of a review. Current science, 72(5).
3. Arnikar, H. J. (1995). Essentials of nuclear chemistry (No. 1653). New Age International.
4. Enger, E. D., Smith, B. F., & Bockarie, A. T. (2000). Environmental science: A study of interrelationships. Boston: McGraw-Hill.

E-resource(s): https://nptel.ac.in

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