Department of Chemical Enigeering

1.	MAN-001	Mathematics-1	BSC	4
2.	CYN-001	Physical Chemistry	BSC	4
3.	CEN-105	Introduction to Environmental Science	GSC	3
4.	HS-001A	Communication Skills (Basic)	HSSC	2
5.	HS-001B	Communication Skills (Advance)	HSSC	2
6.	HSN-002	Ethics and General Awareness	HSSC	2
7.	CHN-101	Introduction to Chemical Engineering	DCC	2
8.	CHN-103	Computer Programming and Numerical Analysis	ESC	4
9.	CHN-102	Material and Energy Balance	DCC	4
10.	CHN-104	Fluid Dynamics	DCC	4
11.	CHN-106	Thermodynamics and Chemical Kinetics	DCC	4
12.	CYN-002	Organic and Inorganic Chemistry	BSC	4
13.	MAN-002	Mathematical Methods	BSC	4
14.	EEN-112	Electrical Science	ESC	4
15.	CHN-112	Energy Engineering	ESC	4
16.	CHN-201	Heat Transfer	DCC	4
17.	CHN-203	Mechanical Operations	DCC	4
18.	CHN-205	Chemical Engineering Thermodynamics	DCC	4
19.	CHN-207	Transport Phenomena	DCC	4
20.	CHN-202	Mass Transfer-I	DCC	3
21.	CHN-204	Reaction Engineering	DCC	5

22.	CHN-206	Chemical Technology	DCC	3
23.	CHN-291	Equipment Design*	DCC	4
24.	CHN-301	Mass Transfer-II	DCC	4
25.	CHN-303	Process Dynamics & Control	DCC	4
26.	CHN-305	Process Equipment Design*	DCC	4
27.	CHN-210	Industrial Instrumentation	DCC	2
28.	CHN-302	Engineering Analysis and Process Modeling	DCC	4
29.	CHN-304	Process Economics and Plant Design	DCC	3
30.	CHN-306	Process Utilities & Safety	DCC	3

1.	CHN-411	Polymer Physics and Rheology*	DEC	4
2.	CHN-413	Novel Separation Techniques*	DEC	4
3.	CHN-415	Heterogonous Catalysis & Reactor Design*	DEC	4
4.	CHN-417	Industrial Safety & Hazards Management	DEC	4
5.	CHN-419	Probability and System's Reliability	DEC	4
6.	CHN-421	Petroleum Refining	DEC	4
7.	CHN-423	Microfluidics*	DEC	4
8.	CHN-425	Nanotechnology in Chemical Engineering*	DEC	4
9.	CHN-427	Clean Technology in Process Industries	DEC	4
10.	CHN-429	Waste-to-Energy*	DEC	4
11.	CHN-431	Fuel Cells Fundamentals*	DEC	4
Spring Semester				
1.	CHN-412	Modeling of Dynamics System*	DEC	4
2.	CHN-414	Advanced Process Control*	DEC	4
3.	CHN-416	Design of Piping System	DEC	4
4.	CHN-418	Advances in Fluid Mechanics*	DEC	4

5.	CHN-420	Advances in Heat Transfer*	DEC	4
6.	CHN-422	Petrochmicals	DEC	4
7.	CHN-424	Industrial Pollution Abatement	DEC	4
8.	CHN-426	Fertilizer Technology	DEC	4
9.	CHN-428	Polymer Science and Engineering		

Chemical Enigeering Department Elective Course

Autumn Semester				
1.	CHN-321	Biochemical Engineering	DEC	4
2.	CHN-323	Computer Application in Chemical Engineering	DEC	4
3.	CHN-325	Process Integration	DEC	4
Spring Semester				
1.	CHN-322	Optimization of Chemical Engineering Processes	DEC	4
2.	CHN-324	Computational Fluid Dynamics	DEC	4
3.	CHN-326	Fluidization Technology	DEC	4

Category 1

Autumn Semester				
1.	CHN-321	Biochemical Engineering	DEC	4
2.	CHN-323	Computer Application in Chemical Engineering	DEC	4
3.	CHN-325	Process Integration	DEC	4
Spring Semester				
1.	CHN-322	Optimization of Chemical Engineering Processes	DEC	4
2.	CHN-324	Computational Fluid Dynamics	DEC	4
3.	CHN-326	Fluidization Technology	DEC	4

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: CHN-101 Course Title: **Introduction to Chemical Engineering**

2. Contact Hours: **L: 2** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **0** **Practical** **0**

4. Relative Weightage**: CWS** **0** **PRS** **0** **MTE** **0** **ETE** **100** **PRE** **0**

5. Credits**:** **2** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce the basic features and concepts of Chemical Engineering to the students.

10. Details of Course:

Module No.	Contents	Contact Hours
1.	**Introduction:** Framework of chemical industry and its classification, production routes, concepts of synthesis and segmentation, definition of chemical engineering, historical perspective and contribution; job description and attributes of a chemical engineer, chemical engineering and its seamless integration with other sciences and engineering disciplines; Societal needs and life cycle of technology, market forces; Economic scale of production; Waste utilization and recycle, sustainable technology, process integration and intensification; Employment opportunities, knowledge resources and software tools; Frontiers & future roadmap ; Challenges of chemical engineering practice-safety, economics, ethics, regulation and IP.	**7**
2.	**Chemical Process Industries**: Evolution of chemical industries, Technological developments in major challenges; Chemical industries structure and segments of chemical industry, raw material and production pattern; Basic principles of chemical processes, unit processes and unit operations and various routes to produce chemicals; Petroleum, petrochemical and fertilizer industry integration; Cleaner and greener technologies.	**7**
3.	**Basic Tools of Chemical Engineering:** Physico-chemical and biological sciences; Mathematics and computation; Thermodynamics and kinetics, Material and Energy balances; Transport phenomena; Equilibrium and rate based processes; Reaction engineering and reactors; Various transport processes; Efficiency and economics of processes. Measuring instruments, automation and control, concept of scale-up- lab to industrial, nano to terrestrial; Dimensional analysis and semi-empiricis; Degree of freedom analysis; Concept of design, modelling and simulation.	**8**

4.	**Applications of Various tools and Examples:** Flash unit and blending system; Coal combustion and gasification; Boiler and steam generation; Biomethanation and alcohol production; Petroleum fractionation and petrochemicals; Chemical vapour deposition; Nano-devices and drug delivery systems; Accidents and safety; Web-based learning and educational videos of refineries, petrochemical plants and fertilizer units; Important developments and milestones in chemical engineering.	**6**
	Total	**28**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Denn Morton M., "Chemical Engineering; An Introduction", Cambridge, University Press.	2012
2.	Himmelblau D.M. and Riggs J.B., **"**Basic Principles and Calculations in Chemical Engineering". 7th Edition., Prentice Hall.	2003
3.	Austin G .T., "Shreve's chemical process industries", McGraw-Hill Book Company, 5TH Edition.	1984
4.	Groggins, P.H., "Unit processes in organic synthesis", Tata McGraw Hill Education Private Limited, 5th Edition.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-102** Course Title: **Material and Energy Balance**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory : 3** **Practical : 0**

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE : 25** **ETE: 50** **PRE: 0**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of principles of material and energy balances applied to chemical engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Units and dimension in chemical engineering**,** units conversion of dimensional equations, stoichiometric and composition relations, concept of degrees of freedom and linear independence of a set of equations.	**5**
2.	**Material Balance:** Concept of material balance, open and closed systems, steady state and unsteady state, multiple component system, selection of a basis, problem solving strategy.	**4**
3.	**Material Balance without Chemical Reaction for Single and Multiple Units:** Conservation of mass/atom, material balance for systems without chemical reactions involving single unit and multiple units.	**5**
4.	**Material Balance with Chemical Reaction for Single and Multiple Units:** Concept of excess reactant, extent of reaction, material balance for systems with chemical reactions involving single unit and multiple units.	**6**
5.	**Recycle, Bypass, Purge and Industrial Applications:** Calculations for a cyclic processes involving recycle/ purge/ bypass, material balances involving gases, vapors, liquids and solids and use of real gas relationships, material balance involving gases, vapors, liquids & solids and uses of real gas relationships, vapor-liquid equilibrium and concepts of humidity & saturation, analysis of systems with bypass, recycle and purge, analysis of processes involving condensation, crystallization and vaporization.	**7**

6.	**Energy Balance:** Conservation of energy with reference to general energy balance with and without chemical reactions, chemical engineering problems involving reversible processes and mechanical energy balance.	**4**
7.	**Applications of Energy Balance:** Calculations of heat of change of phase (solid – liquid & liqid – vapor), heat of reaction, heat of combustion, heat of solutions and mixing, determination of temperatures for adiabatic and non-adiabatic reactions, use of psychometric and enthalpy- concentration diagrams.	**6**
8.	**Simultaneous Material and Energy Balances:** Degrees of freedom analysis for multicomponent systems, combined steady state material and energy balances for units with multiple sub-systems.	**3**
9.	**Unsteady State Material and Energy Balances:** Transient materials and energy balances involving with and without chemical reactions.	**2**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Himmelblau D.M. and Riggs J. B.," Principles and Calculations in Chemical Engineering", 8th Ed., Prentice Hall of India.	2012
2.	Felder R.M. and Rousseau R.W., "Elementary Principles of Chemical Processes", 3rd Ed.., John Wiley.	2005
3.	Bhatt B.I. and Vora S.M., "Stoichiometry", 5th Ed., Tata McGraw-Hill	2010
4.	Narayanan K.V. and Lakshmikutty B., "Stoichiometry and Process Calculations", Prentice Hall of India.	2006
5.	Hougen D.A., Watson K.M. and Ragatz R.A., "Chemical Process Principles", Part-I, 2nd Ed., CBS Publishers.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-103** Course Title: **Computer Programming and Numerical Analysis**

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **15** **PRS** **15** **MTE** **30** **ETE** **40** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: ESC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce object oriented programming using C++ language and numerical analysis

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Computer Fundamentals:** Introduction to computer systems - CPU organization, ALU, registers, memory and input-output devices; Number system: binary and hexadecimal; Fixed and Floating point numbers; Errors and Approximations	**4**
2.	**Basic Programming in C++:** Concepts of algorithm & flow charts; Input/output, constants, variables, expressions and operators; Naming conventions and styles; Conditions and selection statements; Looping and control structures; File input/output, header files, string processing; Preprocessor directives such as #include, #define, #ifdef, #ifndef; Compiling and linking.	**6**
3.	**Modular Programming**: Functions (void and value returning), parameters, scope and lifetime of variables, passing by value, passing by reference, passing arguments by constant reference; Design of functions and their interfaces, recursive functions; Function overloading and default arguments; Library functions; Matters of style, naming conventions, comments	**6**
4.	**Aggregate Data-types**: Arrays and pointers; Structures; Dynamic data and pointers, dynamic arrays.	**4**
5.	**Object Oriented Programming**: Classes and Objects; Constructors and Destructors; Operator Overloading and Type Conversions; Inheritance: extending classes; Pointers; Virtual Functions; Polymorphism; Manipulating Strings; Use of Pointers in linked arrays.	**8**
6.	**Solution of Linear and Non-Linear Equation:** Direct methods	**6**

	such as Gaussian elimination and Thomas algorithm for tri-diagonal systems; Iterative methods such as Jacobi method and Gauss-Seidel method; Single variable using Bisection method and Newton-Raphson method; Application of Newton-Raphson to two variables	
7.	**Numerical Interpolation, Differentiation and Integration**: Difference tables, forward, central and backward difference interpolation; Interpolating polynomials; Differentiation formulas; Trapezoidal rule, Simpson's rule	**4**
8.	**Solution of Ordinary Differential Equations**: Initial value problems (IVPs), Euler Method and Runge-Kutta method	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Balaguruswamy, E., "Object Oriented Programming with C++", Tata McGraw Hill Education, 5th Edition.	**2011**
2.	Lafore, R., "Object Oriented Programming with C++", Pearson, 4th Edition.	**2008**
3.	Dietel, H. M. and Dietel, P. J., "C++ How to Program", Prentice Hall, 8th Edition.	**2011**
4.	Sastry, S. S., "Introductory Methods of Numerical Analysis", PHI Learning, 5th Edition.	**2012**
5.	Chapra, S. C., "Applied Numerical Methods with MATLAB for Engineers and Scientists", Tata McGraw Hill Education, 3rd Edition.	**2012**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-104** Course Title: **Fluid Dynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 3**

4. Relative Weightage**: CWS: 15** **PRS: 15** **MTE: 15** **ETE: 40** **PRE: 15**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**: Nil**

9. Objective: To present the fundamental insights of fluids and their static and dynamic behaviors and fluid machineries, etc

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Fundamental concepts of fluids; Fluid statics, kinematics and dynamics; Properties of fluids.	**3**
2	**Fluid Statics:** The basic equation of fluid statics; Pressure - depth relationship; Pressure forces on plane and curved surfaces; Buoyancy and stability; Forces on immersed and submerged bodies; Pressure measurements; Pressure in accelerated rigid body motions.	**6**
3	**Elementary Fluid Kinematics:** Lagrangian and Eulerian descriptions; Flow visualization – streamline, pathline, streakline and timeline, contours and profile plots; Description and classification of fluid motions; Rotational, irrotational, inviscid and potential flows; Deformation of fluids; System and control volume representation; Reynolds transport theorem.	**6**
4.	**Dynamic Analysis of Flow:** Conservation of mass, linear and angular momentum, and energy; Bernoulli theorem; Flow deformation relationships, Navier-Stokes equations.	**6**
5.	**Dimensional Analysis, Similitude and Modeling:** Dimensional homogeneity and analysis; Methods of finding dimensionless numbers; Selection of variables, Rayleigh and Buckingham's π method; Common dimensionless numbers and their physical significance; Model and Prototypes; Complete and incomplete similarity.	**3**
6.	**Internal Incompressible Viscous Flow:** General characteristics of pipe flow – laminar, turbulent, entrance region, fully developed; Fully developed laminar/turbulent flow in pipe, duct and orifice – shear stress	**7**

	distribution and velocity profiles; Energy correction factors; Energy and hydraulic grade lines; Major and minor losses in pipes, fittings, non-circular ducts; vena contracta; Friction factor, pipe roughness; Moody chart.	
7.	**Flow Measurements:** Flow rate and velocity measurements – Pitot tube, orifice meter, venturimeter, rotameter, notches and weirs, etc.	**2**
8.	**Fluid Handling Machinery:** Classification; Positive-displacement pumps and compressors, centrifugal pumps and compressors, Axial flow pumps and compressors, compressor efficiency. Characteristics of pumps; Selection of pumps.	**6**
9.	**Agitation and Mixing:** Agitated vessels; Blending and mixing; Suspension of solid particles; Dispersion operations; Agitator selection and scale up.	**3**
Total		**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Nevers N.D., "Fluid Mechanics For Chemical Engineers", 3rd Ed., McGraw Hill Higher Education.	2005
2.	Cengel Y.A. and Cimbala J.M. "Fluid Mechanics: Fundamentals and Applications", 2nd Ed. McGraw-Hill	2010
3.	Balachandran P. "Engineering Fluid Mechanics", PHI Learning Pvt Ltd., New Delhi	2012
4.	Munson B.R., Young D.F., Okiishi T.H. and Huebsch W.W., "Fundamentals of Fluid Mechanics", 6th Ed., Willey	2010
5.	White F.M. "Fluid Mechanics", 7th Ed. Tata McGraw-Hill	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-106** Course Title: **Thermodynamics and Chemical Kinetics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**: Nil**

9. Objective: To provide basic knowledge of thermodynamics and chemical kinetics to chemical engineering students.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Thermodynamic system, surroundings, state, process, properties, equilibrium, heat and work.	**02**
2.	**Properties of Pure Simple Compressible Substance:** P-V-T surface, P-V, T-V and T-P diagrams. Equations of state for ideal and real gases. Virial equation of state, van der Waals and Redlich-Kwong equations of state; Use of Thermodynamic tables.	**06**
3.	**First Law of Thermodynamics:** Energy balance for closed systems. Various forms of energy balance. Specific heat, internal energy, enthalpy, and specific heat of ideal gases. Application of first law to non-flow isochoric, isobaric, isothermal, and adiabatic and polytropic processes. Conservation of mass for a control volume, mass and volume flow rates, mass balance for steady flow processes, flow work, steady flow energy equation. Application to various practical systems viz. nozzles, diffusers, etc. Transient Analysis.	**05**
4.	**Second Law of Thermodynamics:** Second law, reversible and irreversible processes, Clausius and Kelvin Planck statements. Carnot cycle, Clausius inequality, entropy as a property, principle of increase of entropy. Calculation of entropy change.	**06**
5.	**Thermodynamic Cycles:** Otto, Diesel, Rankine cycles and their applications.	**03**
6.	**Rate Expression and Reaction Mechanism:** Use of pseudo steady state approximation to get rate expression from mechanism, temperature-dependence of reaction rate-collision theory, transition state theory, thermodynamics and Arrhenius law.	**04**

7.	**Interpretation of Kinetic Data of Batch Reactors:** Constant volume and variable volume batch reactions, Integral and differential methods of analysis of data of uni, bi and tri-molecular irreversible reactions. Reversible reactions, homogeneously catalysed, auto-catalysed, series and parallel reactions. Estimation of rate constants and its temperature-dependence.	**08**
8.	**Solid-Catalysed Fluid Reactions:** Characterization of catalyst, Physical and chemical adsorption, various reaction steps, Langmuir-Hinshelwood kinetics.	**04**
9.	**Kinetics of Bio-Chemical Reactions:** Kinetics of enzyme catalysed reactions, substrate and product inhibition, effect of temperature and pH on enzyme catalysed reactions.	**04**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors / Books / Publishers**	**Year of Publication/ Reprint**
1.	Çengel Y.A. and Boles M.A., "Thermodynamics: An Engineering Approach", 6th Ed., McGraw Hill.	2008
2.	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
3.	Borgnakke C. and Sonntag R.E., "Fundamentals of Thermodynamics", 7th Ed., John Wiley and Sons.	2009
4.	Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., John Wiley.	2000
5.	Fogler H.S., "Elements of Chemical Reaction Engg.", 4th Ed., Prentice Hall of India.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemistry**

1. Subject Code: **CYN-002** Course Title: **Organic and Inorganic Chemistry**

2. Contact Hours **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs): **Theory: 3** **Practical : 0**

4. Relative Weightage : **CWS: 15** **PRS: 15** **MTE: 30** **ETE: 40** **PRE: 0**

5. Credits: 4 6. Semester: **Spring** 7.Subject Area: **BSC**

8. Pre-requisite: **Nil**

9. Objective: To impart basic knowledge of organic and inorganic chemistry.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Heteroatoms in Organic Chemistry:** Introduction to heterocyclic chemistry, aromaticity, reactivity and synthesis of thiophene, pyridine, furan and pyrrole.	**6**
2.	**Stereochemistry and Reaction Mechanisms:** Stereochemistry of addition at carbon-carbon double bond, addition of bromine to cis-, and trans- butene, oxidation across the double bond through peroxides and permanganate, Diels Alder reaction [4+2] and [2+2] cycloaddition reactions. Aromatic nucleophilic substitution mechanisms (S_NAr, S_N1 and arynes), reactivity and reactions.	**8**
3.	**Synthesis and Characterization** of some important compounds such as benzocaine, saccharin, salbutamol and thyroxine. Introduction to mass spectroscopy and NMR spectroscopy for structural prediction of organic compounds.	**9**
4.	**Novel Polymers:** Stereochemical control of synthesis, molecular mass of polymers, polyurethanes, conducting polymers, doping, Shirakawa experiments, oxidation of aniline, bipolymers, and plastics.	**5**
5.	**Coordination Chemistry:** Comparison of the stability of octahedral and tetrahedral complexes on the basis of crystal field stabilization energy, factors affecting the magnitude of Δ, applications of crystal field theory, variation of hydrated ionic radii and hydration enthalpy/stability of complexes, Jahn-Teller effect–definition and examples from d^9 and high-spin d^4 systems, static and dynamic Jahn-Teller effects.	**7**

6.	**Organometallic Chemistry:** Factors affecting M-C bond formation, synthesis, reactions and structures including spectroscopic features of metal carbonyls, transition metal-π alkene complexes- synthesis, reactions, bonding and stability. Applications of organometallic compounds in catalytic processes such as hydroformylation, hydrogenation, catalytic decarbonylation, olefin metathesis and enantioselective hydrogenation of alkenes.	**7**
	Total	**42**

List of Experiments:

i)	Determination of sodium carbonate in baking/washing soda.
ii)	Determination of Zn by EDTA- complexometric titration.
iii)	Solvent less synthesis- Wittig reaction.
iv)	Determination of the equivalent weight of an organic acid.
v)	Identification of functional groups in an organic compound.
vi)	Characterization of an organic compound by UV-Vis and IR spectra.
vii)	Synthesis of a polymer.
viii)	Determination of λ_{max} and concentration of $KMnO_4/K_2Cr_2O_7$ spectrophotometrically.
ix)	Determination of ligand field strength of ligands.
x)	Synthesis of potassium trisoxalatochromate(III).
xi)	Preparation of p-nitroacetanilide and determination of melting point, and matching with known sample.
xii)	Synthesis of an azo dye and its application in textiles.
xiii)	Test of carbohydrate as osazone
xiv)	Determination of calcium in chalk/toothpaste.

11. Suggested Books:

S.No.	**Name of Authors / Books / Publishers**	**Year of Publication/ Reprint**
1.	Morrison R. T. and Boyd R.N., " Organic Chemistry", 6th Ed., Prentice Hall of India.	2001
2.	Clayden, J., Greeves, N., Warren, S., and Wothers, P., "Organic Chemistry" Oxford University Press	2009
3.	Lee, J.D., "Concise Inorganic Chemistry", 5th Ed., Chapman & Hall.	2010
4.	Huheey, J .E., K eiter, E.A., K eiter, R .L. and M edhi, O .K. " Inorganic Chemistry: P rinciples of S tructure and Reactivity", 4th Ed., P earson Education	2009
5.	March, J, Organic Chemistry: Reaction Mechanism and Structures, 6th Ed, John Wiley & Sons	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-112** Course Title: **Energy Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical:0**

4. Relative Weight**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7. Subject Area**: ESC**

8. Pre-requisite**: Nil**

9. Objective: To introduce different resources of energy, their exploitation and energy audit & conservation for modern society

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction**: Energy resources spectrum, renewable and non renewable energy sources, consumption pattern in various sectors, efficiency of energy resources, load demand and economics	6
2.	**Coal**: Classification, properties, proximate and ultimate analyses, heating value, combustion, carbonization, liquefaction and gasification, electricity generation from coal	6
3.	**Petroleum:** Origin and processing, various type of fuels, properties and handling	5
4.	**Gaseous fuel:** CNG, LNG and LPG	2
5.	**Solar energy:** Solar insolation, flat plate and focusing collectors, solar space heating and cooling, solar pond, solar cells and storage	6
6.	**Biomass energy**: Biomass types, characterization, pyrolysis, gasification, biochemical conversion routes, biogas, fuel alcohol, biodiesel	6
7.	**Other sources**: Hydrogen as a future fuel, fuel cells and environmental implications of these fuels	4
8.	**Energy audit:** Mapping of distribution of energy supply and demand and identification of energy intensive areas.	4
9.	**Energy conservation measures:** Waste heat recovery, use of low grade streams, vapour recompression, improvement in heat exchanger efficiency, pinch technology for optimum heat utilization	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Twidel, J. and Tony W., Renewable Energy Resources, Second Edition, Taylor & Francis	2006
2..	Kreith F., Goswami D. Y., Energy Management and Conservation, CRC Press	2008
3.	Sukhatme S., J Nayak J., Solar Energy: Principles of Thermal Collection and Storage, 3/ed, Tata McGraw-Hill Publishing Company Ltd	2008
4.	Harker J.H. and Backhusrt J.R., Fuel and Energy, Academic Press Inc	1981
5.	Miller Bruce G., Coal Energy Systems, Elsevier Academic Press, Paris	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-321** Course Title: **Biochemical Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weight **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To introduce microbiology, enzymes, unit operations in biochemical processes and design of bioreactors.

10. Detail of Course:

S.No	Contents	Contact Hours
1	**Introduction:** Aspects of microbiology, cell theory, structure of cells, classification of microorganisms, influence of environmental parameters on microorganisms; Chemical composition of the cell, carbohydrates, proteins, enzymes and chemicals of life	**8**
2	**Metabolism and Energetics:** Assimilatory and dissimilatory processes, metabolism of the cells, metabolic pathways.	**4**
3	**Enzymes and microbial kinetics:** Mono and multi substrate enzyme kinetics, modulation and regulation of enzyme activity, enzyme reactions in heterogeneous systems, fermentation kinetics, monod model and monod chemostate, Cell-growth-cycle phase for batch cultivation, modelling of batch growth, product synthesis kinetics, overall kinetics, thermal death kinetics of cells and spores, batch and continuous sterilization.	**10**
4	**Unit Operations in Biochemical Processes:** Agitation and aeration in microbial system, gas liquid microbial cell mass transfer, determination of oxygen rates, k_L and k_{La} in batch and continuous bioreactor, scale up of bioreactor. Heat balance and heat transfer correlations for biotechnical systems, filtration and drying. Immobilization of cells and enzymes.	**10**
5	**Analysis and Design Bioreactors:** Classification and characterization of different bioreactors, bioreactor: batch and continuous- tubular, CSTR and tower reactors. Aerobic and anaerobic fermentation, process design and operation of typical aerobic and anaerobic fermentation processes, manufacture of	**10**

	microbial product e.g. antibiotics, alcohol/wine etc. Use of immobilized enzymes and whole cells for industrial processes.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books/Authors	Year of Publication
1.	Bailey J.E and Ollis D.F., "Biochemical Engineering Fundamentals", 2nd Ed., McGraw Hill.	1987
2.	Doble M. and Gummadi S.N., "Biochemical Engineering", Prentice Hall.	2007
3.	Schuler M. L. and Kargi F., "Bio Process Engineering", 2nd Ed., Prentice Hall.	2002
4.	Aiba, S., Humphrey A. E., and N. F. Millis, "Biochemical Engineering".	1973
5.	Clark D. S. and Blanch H. W., "Biochemical Engineering", CRC press	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-323** Course Title: **Computer Applications in Chemical Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **Practical**

4. Relative Weight: **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**:4** 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide knowledge of advanced numerical methods and their applications to chemical engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Review of solution methods of non linear single variable equations, polynomials (determination of quadratic factors), linear set of simultaneous equations, ill conditioned matrix, and set of nonlinear equations using Newton's and globally convergent methods	**8**
2.	Solution of homogeneous set of linear equations using eigen values and eigen vectors with application to chemical engineering problems.	**3**
3.	Review of numerical differentiation and numerical integration methods, quadratures and their applications to numerical integration.	**4**
4.	Review of single step and multiple step methods to solve initial value ordinary differential equations problems, estimation of error and its propogation in single step and multiple step methods, step size selection and adaptable step size Runga-Kutta methods, stiff ODE's and Gear's class of methods.	**8**
5.	Boundary value problems (BVP) - shooting methods for linear system, finite difference methods, regular perturbation method, method of weighted residuals and orthogonal collection methods to solve first and higher order BVP in ODE's application to chemical engineering systems, concept of finite element.	**10**
6.	Review of finite difference techniques to solve partial difference equations (PDE's), similarity transformation, method of weighted residuals, orthogonal collocation to solve PDEs with their application to chemical engineering systems.	**9**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Finlayson B. A., "Introduction to Chemical Engineering Computing", 7th Ed.., Wiley Interscience publication.	2006
2.	Gerald C. F. and Wheatly P. O.; "Applied Numerical Analysis", 7th Ed., Addison Wesley.	2003
3.	Rice R.G. and Do D. D., "Applied Mathematics for Chemical Engineers", Wiley.	1995
4.	Beers K. J., "Numerical Methods for Chemical Engineering: Applications in Matlab", Cambridge University Press.	2006
5.	Constantinides A. and Mostoufi N., "Numerical Methods for Chemical Engineers with MATLAB Applications", Prentice Hall.	1999
6.	Cutlip M. B. and Shacham M.., "Problem Solving in Chemical and Biochemical Engineering with POLYMATH, EXCELL and MATLAB", 2nd Ed., Prentice Hall.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-325** Course Title: **Process Integration**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.):**Theory:3** **Practical:0**

4. Relative Weight: **CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**:** 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To introduce the concept of pinch technology in integration of unit operations in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Process Integration and its Building Blocks:** Definition of Process Integration (PI), School of thoughts, Areas of application and Techniques available for PI, Onion diagram.	**6**
2.	**Pinch Technology – An Overview:** Introduction, Basic concept, How it is different than energy auditing, Role of thermodynamic laws, Problem addressed by Pinch technology.	**7**
3.	**Key Steps of Pinch Technology:** Data extraction, Targeting, Designing, Optimization-Supertargteing.	**5**
4.	**Basic Elements of Pinch Technology:** Grid diagram, Composite curve, Problem table algorithm, Grand composite curve.	**5**
5.	**Targeting of Heat Exchanger Network (HEN):** Energy targeting, Area targeting, Number of units targeting, Shell targeting, cost targeting.	**5**
6.	**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.	**6**
7.	**Heat Integration of Equipments:** Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Drier, Refrigeration systems.	**4**
8.	**Heat and Power Integration:** Co-generation, Steam turbine, Gas turbine.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Kemp I. C., "Pinch Analysis and Process Integration: A user Guide on Process Integration for the Efficient Use of Energy", 2nd Ed., Butterworth-Heinemann.	2007
2.	Smith R.., "Chemical Process Design and Integration", 2nd Ed., Wiley.	2005
3.	Shenoy U. V., "Heat Exchanger Network Synthesis", Gulf Publishing Company.	1995
4.	El Halwagi M. M., "Process Integration", 7th Ed., Academic Press.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-322** Course Title: **Optimization of Chemical Engineering Processes**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of optimization methods used in Chemical Engineering.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Optimization and calculus based classical optimization techniques.	**5**
2.	**One Dimensional Minimization Methods:** Elimination methods-equally spaced points method, Fibonacci method and golden section method; Interpolation methods-quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods.	**6**
3.	**Linear Programming:** Graphical representation, simplex and revised simplex methods, duality and transportation problems.	**7**
4.	**Multivariable Non-Linear Programming:** Unconstrained-univariate method, Powell's method, simplex method, rotating coordinate method, steepest descent method, Fletcher Reeves method, Newton's methods Marquardt's method and variable metric (DFP and BFGS) methods; Constrained- complex method, feasible directions method, GRG method, penalty function methods and augmented Lagrange multiplier method.	**9**
5.	**Dynamic Programming:** Multistage processes- acyclic and cyclic, sub-optimization, principle of optimality and applications.	**4**

6.	**Geometric Programming (GP):** Differential calculus and Arithmetic- Geometric inequality approach to unconstrained GP; Constrained GP minimization; GP with mixed inequality constraints and Complementary GP.	**6**
7.	**Emerging Optimization Techniques:** Genetic algorithm, simulated annealing, particle swarm and ant colony optimization.	**5**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Rao S. S., ''Engineering optimization: Theory and Practice", 4th Ed., Wiley	2009
2.	Edgar T. F., Himmelblau D. M. and Lasdon L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill.	2001
3.	Ravindran A., Ragsdell K. M. and Reklaitis G. V., " Methods and Application'' 2nd Ed., Wiley	2006
4.	Venkataraman P., " Applied Optimization with MATLAB Programming'',2nd Ed., Wiley	2009
5.	Beveridge G.S.G. and Schechter R.S., " Optimization: Theory and Practice'', McGraw Hill	1970

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-324** Course Title: **Computational Fluid Dynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 25 50 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9.Objectives: To provide an understanding of physical models to study hydrodynamics in engineering systems.

10.Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts of Fluid Flow:** Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, simplified flow models such as incompressible, inviscid, potential and creeping flow, flow classification.	5
2.	**Grid Generation:** Structured and unstructured grids, choice of suitable grid, grid transformation of equations, some modern developments in grid generation in solving the engineering problems.	3
3.	**Finite Difference Method (FDM):** Discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, applications to the engineering problems.	15
4.	**Finite Volume Method:** Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, application to the engineering problems.	9
5.	**Case studies:** Case studies using FDM and FVM: Flow and heat transfer in pipes and channels, square cavity flows, reacting flow, reactive flow, multiphase flow, Heat Transfer in Rotary Kiln Reactors, Fluid mixing, etc. Essence of Finite element method (FEM) .	10
	Total	42

11.Suggested Books:

S. No.	Authors / Name of Books / Publisher	Year of Publication
1.	Fletcher C.A.J. "Computational Techniques for Fluid Dynamics, Vol. 1: Fundamental and General Techniques", Springer-Verlag.	1998
2.	Fletcher C.A.J. "Computational Techniques for Fluid Dynamics, Vol. 2: Specific Techniques for Different Flow Categories", Springer-Verlag .	1998
3.	Anderson. J.D., "Computational Fluid Dynamics", McGraw Hill.	1995
4.	Ghoshdastidar P.S., "Computer Simulation of Flow and Heat Transfer", Tata McGraw Hill.	1998
5.	Patankar S.V., "Numerical Heat Transfer and Fluid Flow", Taylor and Francis.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-326** Course Title: **Fluidization Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To provide knowledge about the principle of fluidization engineering and its applications in process industries.

10. Details of Course:

S.No.	Topic	Contact Hours
1.	**Introduction:** Importance of fluidization in process industry, comparison of fluidized beds with other modes of contacting, advantages and disadvantages, industrial applications. Terminology for fluid-particle systems	4
2.	**Mechanics of flow around single particles**: Flow around single particle, force balance, Review of packed beds- force balance and Ergun equation, Fixed bed of particles of mono and mixed sizes, and varying shapes.	4
3.	**Mechanics of homogenous fluidization:** Homogenous fluidized beds, minimum fluidization velocity-measurement, prediction and correlations, stability aspects- qualitative and quantitative-wave propagation.	7
4.	**Heterogeneous fluidization:** Geldart classification and mapping of regimes, bubbling bed (heterogeneous fluidized) bed models, Davidson model for a bubble in a fluidized bed, and its implications, turbulent and fast fluidization-mechanics, flow regimes and design equations. Entrainment and elutriation, pneumatic transport, Free boards behavior, slugging, spouted beds, dilute and dense phase transport-circulating fluidized beds.	13
5.	**Complexities in fluidized bed operation:** Mixed particle system-mixed sized particles,Particles of different densities and shapes, particle to particle and particle to gas heat transfer.Mass transfer in fluidized systems, mixing in fluidized systems-measurements and mixing models, reactions in fluidized beds and models, FCC reactor introduction.	9

6.	**Modern techniques of analysis:** Modern experimental techniques-flow visualization and quantitative measurements, modern simulation techniques-CFD models.	5
	Total	42

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Kunii D. and Levenspiel O., "Fluidization Engineering", 2nd Ed., Butterworth-Heinemann.	1991
2.	Davidson D. and Harrison J. F., "Fluidization Engineering", 2nd Ed., Academic Press.	1992
3.	Yang W. C., "Handbook of Fluidization and Fluid Particle Systems", 3rd Ed., CRC.	2003
4.	Rhodes, M., Introduction to Particle Technology, 2nd Ed., Wiley.	2008
5.	Jackson, R., The Dynamics of Fluidized Particles, Cambridge University Press.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-411** Course Title: **Polymer Physics and Reoholgy**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To understand the static and dynamic properties of polymers in solutions, melts, and gels.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Polymer structure, properties and universality; The basic approach of polymer physics.	**2**
2.	**Mathematical and Statistical Preliminaries:** Probability distribution (Gausian, Poisson), Binomial and multinomial distributions, Large N limit, Stirling's approximation, Discrete and continuous Fourier Transform.	**4**
3.	**Brief Recap of Thermodynamics and Statistical Mechanics:** The laws of thermodynamics; Internal energy, free energy and entropy. Introduction to statistical mechanics.	**4**
4.	**Properties of an Isolated Polymer Chain:** Conformations, bond rotation and polymer size: the random walk model (Ideal chain), effect of short range interactions (freely-rotating chain, hindered rotation etc.), Stiffness measures: concept of statistical segment length (persistence length/ Kuhn length), Radius of gyration, The Gaussian chain model, Probability distribution for polymer conformation: Self-avoiding chains and the excluded-volume effect; Real polymeric systems; Molecular weight distributions and polydispersity.	**8**
5.	**Statistical Thermodynamics of Polymer solutions:** Lattice model for a binary fluid mixture; Flory-Huggins theory for polymer	**8**

	solutions; Osmotic pressure; Flory Chi parameter and Theta temperature; Phase behavior of polymer solution and blends; Good solvents, Poor solvents and Theta solvents; Excluded volume effect revisited; Coil-Globule transition; Concentration regimes; Chain size in concentrated solutions and melts.	
6.	**Continuum Aspects of Rheology:** Introduction to various rheological response functions: viscosity, modulus and compliance; Normal stress differences; Stress relaxation and Creep response; Dynamic response functions (storage and loss moduli); Linear vs. Non-linear response; Intrinsic viscosity of polymer solutions; steady shear and elongational flows; Introduction to Rheometry; Phenomenological models to illustrate viscoelastic effects; Some commonly used continuum constitutive relations for polymer solutions; Differential and Integral representations.	**8**
7.	**Molecular Theories of Dynamics and Rheology of Polymer Solutions:** Polymer chains as an entropic spring; Theory of rubber elasticity; General theory of Brownian motion; Microscopic expression for stress tensor; Dilute solutions: The bead-spring model for a polymer; Rouse theory; Hydrodynamic interactions and the Zimm model; Concentrated polymer solutions and melts; Entanglement and reputation model.	**8**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Publication year**
1.	Rubinstein M. and Colby R. H., Polymer Physics, Oxford.	2004
2.	Doi M., Introduction to Polymer Physics, Oxford.	1996
3.	Teraoka I., Polymer Solutions: An Introduction to Physical Properties, Wiley.	2002
4.	Larson R. G., The Structure and Rheology of Complex Fluids, Oxford.	1998
5.	Doi M. and Edwards S. F., The Theory of Polymer Dynamics.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-413** Course Title: **Novel Separation Techniques**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide knowledge of various advanced separation techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Separation processes in chemical and biochemical industries, categorization of separation processes, equilibrium and rate governed processes.	**8**
2.	**Bubble and Foam Fractionation:** Nature of bubbles and foams, stability of foams, foam fractionation techniques, batch, continuous, single stage and multistage columns.	**8**
3.	**Membrane Separation:** Physical factors in membrane separation, osmotic pressure, partition coefficient and permeability, concentration polarization, electrolyte diffusion and facilitated transport, macro-filtration, ultra-filtration, reverse osmosis and electro-dialysis, gas separation using membrane structure and production.	**14**
4.	**Special Processes:** Liquid membrane separation, critical extraction, pressure swing adsorption and freeze drying of pervaporation and permeation; Nanoseparation.	**12**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Seader J. D. and Henley E. J. "Separation Process Principles", 2nd Ed., Wiley-India.	2006
2.	King C. J., "Separation Processes", Tata McGraw Hill.	1982
3.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", 2nd Ed., CRC.	2007
4.	Khoury F. M., "Multistage Separation Processes", 3rd Ed., CRC.	2004
5.	Wankat P. C., "Separation Process Engineering", 2nd Ed., Prentice Hall.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-415** Course Title: **Heterogenous Catalysis and Reactor Design**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide the knowledge of Heterogeneous Catalysis & Reactor Design.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definitions, catalytic properties, classification of catalysts, steps in catalytic reaction, adsorption isotherm, chemisorptions, synthesizing rate law, mechanism and rate limiting steps, deducing a rate law from the experimental data, finding a mechanism consistent with experimental observation, evaluation of rate law parameter,	6
2.	**Solid catalysis:** Catalyst synthesis, impregnation, sol-gel, catalyst characterization by BET, TPR, XTD, TPD, chemisorptions, FTIR, XPS etc., catalyst promoters and inhibitors, catalyst poisoning, types of catalyst deactivation, kinetics of catalytic deactivation, temperature-time trajectories, moving bed reactors, straight through transport reactors.	8
3.	**Rate equations for fluid solid catalytic reactions:** Rates of adsorption, desorption, surface reaction, rate equations in terms of fluid phase concentration at the catalyst surface, qualitative analysis of rate equations, quantitative interpretation of kinetics data.	8
4.	**Diffusion and reaction:** external diffusion effects on heterogeneous reaction, diffusion and reaction in spherical pellets, internal effectiveness factor, falsified kinetics, overall effectiveness factor, estimation of diffusion-and reaction limited regimes, Wisz-Prater criterion for internal diffusion, Mears criterion for external diffusion, interpellet heat and mass transfer, mass and heat transfer with reaction, mass transfer and reaction in a packed bed, multiphase reactors, slurry reactors, trickle bed reactors.	10

5.	**Modeling of chemical reactors:** Approach, aspects of mass, heat and momentum balance, specific continuity equation, energy equation, momentum equation, modeling of fixed bed reactor, pseudo homogeneous models, heterogeneous models, modeling of fluidized bed reactors.	**10**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Froment G. F., Bischoff K. B., Wilde J. D., "Chemical Reactor Analysis and Design", John Wiley & Sons, Inc, 3rd edition.	2011
2.	Smith J.M., "Chemical Engineering Kinetics", McGraw-Hill International Editions, 3rd edition.	1981
3.	Carberry J. J., "Chemical and Catalytic Reaction Engineering", Courier Dover Publications, N.Y.	2001
4.	Lee H. H., "Heterogeneous Reactor Design", Butterworth – Heinemann.	1984
5.	Ramchandran P. A. and Chaudhari R. V., " Three Phase Catalytic Reactors", Gordon And Breach.	1983

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-417** Course Title: **Industrial Safety and Hazards Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide a comprehensive coverage of safety and hazards aspects in industries and the management of hazards.

10. Details of Course:

S.No.	Topic	Contact Hours
1.	**Introduction:** Industrial processes and hazards potential, mechanical electrical, thermal and process hazards. Safety and hazards regulations, industrial hygiene and the Factories Act, and Environment protection Acts and rules.	9
2.	**Toxicology:** Hazards identification-toxicity, fire, static charge, noise and dust concentration. Material safety data sheet, hazards indices-Dow and Mond indices, HAZOP and HAZAN.	6
3.	**Reliability Engineering and Hazards Assessment:** Probabilistic failure distribution, failure of standard and complex systems, failure data analysis and failure modeling. Event data, fault tree and event tree analysis, scenario development and consequence modeling, risk criteria.	10
4.	**Fire and Explosion:** Shock wave propagation, vapor cloud explosion (VCE) and boiling liquid expanding vapor explosion (BLEVE), mechanical and chemical explosion, multiphase reactions, transport effects and global rates.	7
5.	**Relief Systems:** Preventive and protective management from fires and explosion-inerting, static electricity passivation, ventilation, and sprinkling, proofing, relief systems-relief valves, flares, scrubbers.	7
6.	**Cases Studies:** Flixborough and Bhopal accidents.	3
	Total	42

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Crowl D. A. and Louvar J. F., "Chemical Process Safety: Fundamentals with Applications", 2nd Ed., Prentice Hall.	2001
2.	Mannan S., "Lee's Loss Prevention in the Process Industries", Vol. I, 2nd Ed., Butterworth Heinemann.	2004
3.	Mannan S., "Lee's Loss Prevention in the Process Industries", Vol. II, 2nd Ed., Butterworth Heinemann.	2004
4.	Mannan S., "Lee's Loss Prevention in the Process Industries", Vol.III, 2nd Ed., Butterworth Heinemann.	2004
5.	Tweeddale M., "Managing Risk and Reliability of Process Plant", Gulf Professional Publishing	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-419** Course Title: **Probability and System's Reliability**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **0** **25** **50** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To demonstrate quantitative evaluation of system's reliability, maintainability, availability and safety to support decision making.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Interpretation of random data, mean and variance, probability distributions: normal, binomial, Poisson, Weibull distribution, etc.; Interpretation of failure data; Equal likelihood and Boolean algebra, probability of union, joint and marginal probability, conditional probability, distribution function.	**4**
2.	**Monte Carlo Simulation:** Pseudo random number; Frequency distribution; Simple programming for simulation of random event; Basics of Monte Carlo simulation and its applications.	**5**
3.	**Failure Models:** Reliability functions and hazard rate, failure distribution and bathtub curve, failure data for estimation of mean time to failure (MTTF), MTBF, MTTR, mean time to restore, applications of exponential, binomial, multinomial and Poisson's distributions.	**8**
4.	**Reliability of complex systems:** Application of failure distribution to series and parallel components; *k*-out-of-*n* parallel and standby units; Reliability and availability formulation.	**7**
5.	**Markov analysis:** Load sharing systems; Standby systems and three-state devices; Reparability of single equipment system.	**5**
6.	**Failure Analysis and Confidence Limit:** Data source and data bank; Confidence limit on failure frequency; Representation of event and failure data, fault tree and event tree analysis; Scenario development and consequence modeling, Risk criteria.	**8**
7.	**Application of Reliability Engineering:** Reliability predictions; Reliability in design and lifecycle costing; Maintenance activity and policymaking.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Ebeling C. E., "An Introduction to Reliability and Maintainability Engineering" Tata McGraw-Hill.	2008
2.	Mannan S., and O'Connor M. K. (Eds.), "Reliability Engineering" in Less' Loss Prevention in the Process Industries, Vol-1, 3rd Ed., Butterworth-Heinemann.	2004
3.	Walpole R. E., Myers R. H., Myers S. L., Ye K., "Probability & Statistics for Engineers & Scientists", 9th Ed., Prentice Hall	2012
4.	Nikolaidis E., Ghiocel D. M., and Singhal S,, "Engineering Design Reliability Handbook", CRC Press.	2005
5.	Tweeddale M., "Managing Risk and Reliability of Process Plant", Gulf Professional Publishing	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-421** Course Title: **Petroleum Refining**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To introduce petroleum refining processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Indian and Global Petroleum Industries: an overview., emerging crude oil quality and fuel norms, natural gas, shale gas and gas hydrates, changing scenario in crude oil and natural gas availability.	3
2.	**Origin, Occurrence and Composition of Petroleum:** Origin and occurrence of petroleum crude, drilling of crude oil and natural gas, composition of crude oil and natural gas, classification and physical properties of petroleum, evaluation of crude oil and petroleum products.	3
3	**Evaluation of crude oil and petroleum products:.** Short term and Long term evaluation Composition of crude oil, TBP Assay, ASTM distillation, Evaluation crude oil base and other properties, Product quality analysis and fuel norms.	4
3.	**Crude Oil Distillation Processes**: Pretreatment of crude, atmospheric and vacuum distillation process., effects of crude characteristics and operating variables in Crude oil distillation. Processing of high TAN crude oil.	5
4	**Thermal Conversion Process:** Thermal Cracking Reactions, Thermal Cracking, Visbreaking, Coking Processing, Delayed, Fluid And Flexi Coking, Petroleum Coke.	6
5	**Catalytic Conversion Process:** Fluid Catalytic Cracking (FCC), Hydrocracking, Catalytic Reforming, Alkylation, Isomerization and Polymerization.	8
6.	**Lubricating Oil, Wax and Bitumen:** Lube refini8ng concept,	5

	Dewaxing, deasphalting, lube hydro-finishing, bitumen and asphalt processing.	
7.	**Finishing and Sweetening processes :** Desulfurization and hydro-desulfurisation of petroleum products., Sweetening Processes, Desulphurisation of sour water, sulphur recovery.	**4**
8	**Future refining trend s:** Biofuel, gas to liquid technology, carbon foot prints in petroleum refining, concept of Petrochemical refinery, gas refinery and Biorefinery.	**4**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Nelson W. L., "Petroleum Refinery Engineering" 4th Ed.., McGraw Hill.	1987
2.	Wauquier J. P., "Petroleum Refining 2 Separation Processes", Vol:1-5, IFP, Technip Ed.	1998
3.	Meyers R. A., "Hand book of Petroleum Refining Processes", 3rd Ed., The McGraw-Hill Publication Data.	2004
4.	Dawe R. A., "Modern Petroleum Technology- Part I", by Institute of Petroleum (IP), John Wiley.	2002
5.	Prakash Surinder " Refining Processes Hand book" Elsevier	2003
6	Hobson,G.D." Modern Petroleum technology Volume I & II" Wiley	1984
7	Bhaskar rao, B.K. "Modern Oetroleum refining processes" Oxford &IBH Publishing Co Pvt.Ltd.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-423** Course Title: **Microfluidics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite: CH-104 and CH-103

9. Objectives: To understand the fundamental insights of Microfluidics and microfluidic flows.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Microfluidics; Relationships among microfluidics, nanotechnology and MEMS; Scientific and commercial aspects; Milestones of microfluidics – Device and technology developments; Microfluidics and chemical engineering; Astonishing microfluidics system in nature; Different aspects of microfluidics; Scaling of micromechamical devices	3
2	**Fundamental Physics:** Ranges of forces of microscopic origin; Microscopic scales intervening in liquids and gases; Physics of miniaturization; Miniaturization of electrostatic, electromagnetic, mechanical, thermal and chemical analysis systems; New flow regimes in microfluidics; Continuum hypothesis – molecular magnitude, mixed flow regimes and experimental evidences; Modeling of microfluidic flows; Simulation approaches of microfluidic systems	4
3	**Hydrodynamics of Microfluidic Systems**: Hypothesis of hydrodynamics; Hydrodynamics of gases in mircosystems; Slip flow and models – general slip conditions, comparison of slip models; Microhydrodynamics; Microfluidics involving inertial effects; Interfacial phenomena; Microfluidics of drops, bubbles and emulsions	5
4.	**Shear-Driven Microfluidics:** Couette flow- slip, transition and free molecular flow regimes; Velocity and shear stress models; Oscillatory Couette flow – steady and unsteady flow; Grooved channel flow	5
5.	**Pressure-Driven Microfluidics:** Slip flow regimes – isothermal and adiabatic compressible flows; Entry flows and effects of roughness; Transitional and free-molecular regimes – Burnett equations; Unified flow	5

	model;	
6.	**Thermal Effects in Microfluidics:** Heat conduction in gases, liquids and solids; Ghost effect; Thermal creep (transpiration); Gas flow at moderate Knudson numbers	4
7.	**Electrokinetic flows in Microfluidics:** Electrokinetic effects; Electrical double layer, Potential distribution; Flow characterization and governing equations; Electroosmotic flows – Channel flow, time-periodic flow, EDL/bulk flow interface velocity matching conditions, slip conditions, drag models, Joule heating, applications; Electrophoresis – Classification and governing equations, Taylor dispersion, charged particles in pipe; Dielectrophoresis and its applications	8
8.	**Surface Tension-Driven Flows:** Basic concepts; General form of Young's equations; Governing equations for thin films; Dynamics of capillary spreading; Thermocapillary pumping; Electrocapillary	3
9.	**Computational fluid dynamics (CFD) Analysis and Application of some Microfluidic Devices**: Basic aspects of computational tools; Applications of CFD methods on various microfluidic flow problems of micromanipulations and separations using electric fields, surface tension effects, etc.	5
Total		42

11.Suggested Books:

S. No.	Name of Books/Authors/Publications	Publication Year
1.	Tabeling P., "Introduction to Microfluidics", Oxford University Press.	2010
2.	Kandlikar S., Garimella S., Li D., Colin S. and King M.R. "Heat Transfer and Fluid Flow in Minichannels and Microchannels", Elseveir.	2006
3.	Nguyen N.-T. and Wereley S. "Fundamental and Applications of Microfluidics", 2nd Ed. Artech House, London.	2006
4.	Kirby B.J. "Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices" Cambridge University Press,	2010
5.	Gad-el-Hak, M. "The MEMS Handbook: Volume 1 – MEMS Introduction and Fundamentals" 2nd Ed., CRC Press.	2006
6.	Karniadakis G., Beskok A. and Aluru N. "Microflow and Nanoflow: Fundamentals and Simulations" Springer.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-425** Course Title: **Nanotechnology in Chemical Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce selected topics in Nanotechnology to Chemical Engineers.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Nanotechnology and its historic perspective; Foundation of Nanotechnology in Chemistry, Physics and Biology; Nanostructures in Nature.	**4**
2.	**Nano-structures and Nano-materials:** Shape and structure of nano-materials: nano-particles, nano-wires and nano-films; Crystal structure and Space lattices; Special nano-materials such as quantum dots, semiconductor nano-particles, Bio-macromolecules, self assembling nanostructures, nano-structured thin films and nano-composites.	**6**
3.	**Nano-scale Characterization Techniques**: X-Ray Diffraction; Brunauer-Emmett-Teller (BET), Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Auger Electron Spectroscopy (AES), X-Ray Photo-electron Spectroscopy (XPS), Electron Energy Loss Spectroscopy (EELS).	**6**
4.	**Nano-scale Manufacturing Techniques**: Bottom-up Approach: Sol-Gel Synthesis, Hydrothermal Growth, Thin-Film Growth, Physical Vapour Deposition, Chemical Vapour Deposition; Top-Down-Approach: Ball Milling, Micro-fabrication, Lithography, Ion-Beam Lithography.	**6**
5.	**Properties of Nano-structures**: Crystal defects, surfaces and interfaces in nanostructures, ceramic interfaces, Super-hydrophobic surfaces; Thermodynamics of Nanostructures; Diffusion Kinetics; Properties: Optical, Emission, Electronic transport, Photonic, Refractive Index, Dielectric, Mechanical, Magnetic, Non-linear optical, Catalytic and Photo-catalytic.	**8**
6.	**Chemical Engineering Aspects:** Flow of Nano-fluids in Micro-	**12**

	channel; Heat Transfer from Nano-fluids: Convective and Radiative; Surface energy, Colloidal and Catalytic Behaviour of Nano-particles: Gold Nano-particles; Nano-particulate Suspensions; Membrane Nanotechnology; Nano-engineered Catalysts and Polymers; Nano-material Filters.	
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors/ Publishers**	**Year of Publication/ Reprint**
1.	Rao, M. S. R. and Singh, S., "Nanoscience and Nanotechnology: Fundamentals to Frontiers", Wiley India Pvt. Ltd., I Edition.	**2013**
2.	Ashby, D. M., Ferreira, P. and Schodek, D. L., "Nanomaterials, Nanotechnologies and Design: an Introduction to Engineers and Architects", Butterworth-Heinemann. I Edition.	**2009**
3.	"Handbook of Nanotechnology", Eds: Bhushan, B., Springer, 3rd Edition.	**2010**
4.	"Advances in Numerical Heat Transfer: Nanoparticle Heat Transfer and Fluid Flow", Vol.4, Eds: Minkowwycz, W. J., Sparrow, E. M. and Abraham, J. P., CRC Press.	**2013**
5.	Ferry, D. K., Goodnick, S. M. and Bird, J., "Transport in Nanostructure", Cambridge University Press, 2nd Edition.	**2009**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-427** Course Title: **Clean Technology in Process Industries**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To expose the students to newer clean technologies for chemical processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Environmental impact of chemicals and chemical production, life cycle assessment, waste minimization techniques, sustainable development.	3
2.	**Evaluation of Conventional Technologies:** Evaluation of present process technologies for ammonia, sulphuric acid, caustic soda, pulp and paper, plastics and polymers synthesis. Analysis of raw materials, intermediates, final products, by-products and wastes.	8
3	**Alternate Technologies:** Alternative raw materials, low temperature and low pressure and low energy consuming routes for the manufacture of caustic soda, leather, plastics, pulp and paper and rayon.	8
4	**Minimization of water and heat consumption:** Process Integration and water pinch technology for minimizing water and heat consumption; data extraction, minimum fresh water target with and without reuse: limiting water profile, concentration-composite curve, concentration-interval diagram, block diagram, grid diagram, mass-content diagram, network design, network evolution: lop identification and loop breaking.	9
5	**Process Modification and energy production from waste:** Process modification waste utilization and energy production from solid waste, recycling and reuse of water, solid waste management.	8
6	**Advanced Technologies:** Development of biodegradable and end-products of polymers and plastics, CO_2 capture, sequestration and utilization.	6
	Total	42

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication
1	Jacob A. Moulijn, Michiel Makkee, Annelies E. van Diepen, "Chemical Process Technology'', John Wiley and Sons Ltd.	2013
2	George T. Austin, "Shreve's Chemical Process Industries", Tata McGraw Hill Education	2012
3	Gerard Kiely, " Environmental Engineering'', Tata McGraw-Hill Education	2007
4	J. Mann and Y.A. Liu, "Industrial Water Reuse and Wastewater Minimization", McGraw-Hill Professional", Ist Edn.	1999
5	Mahmoud M. El-Halwagi, Sustainable Design Through Process Integration: Fundamentals and Application to Industrial Pollution Prevention, Resource Conservation, and Profitability Enhancement, Elsevier Science & Technology	2011
6	Roberto Solaro, Emo Chiellini, Biodegradable Polymers and Plastics, Springer	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-429** Course Title: **Waste-to-Energy**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To deal with the various types of wastes available and technological options of their exploitation for obtaining useful energy.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction**: Introduction to energy from waste, characterization and classification of wastes, availability of agro based, forest, industrial, municipal solid waste in India vis-a-vis world, proximate & ultimate analyses, heating value determination of solid liquid and gaseous fuels.	8
2.	**Waste to energy options I**: Incineration, pyrolysis, gasification, hydrogen production, storage and utilization, anaerobic digestion, composting: gas generation and collection in landfills,	7
3.	**Waste to energy options II**: Industrial liquid effluents and their energy potential, anaerobic reactor configuration for fuel gas production, separation of methane and compression.	7
4.	**Densification:** Densification of agro and forest wastes, technological options, combustion characteristics of densified fuels, usage in boilers, brick kilns and lime kilns.	6
5.	**Power generation:** Steam and gas turbine based power generation, cogeneration, IC engines, IGCC and IPCC concepts, supercritical boilers.	6
6.	**Biodiesel:** Biodiesel production from waste/discarded oils, characterization of biodiesel, usage in CI engines with and without retrofitting.	6
7.	**Case studies:** Two industrial case studies where waste materials are used to supplement energy needs.	2
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science.	1984
2..	Hall, D.O. and Overeed, R.P.," Biomass - Renewable Energy", John Willy and Sons.	1987
3.	Harker, J.H. and Backhusrt, J.R., "Fuel and Energy", Academic Press Inc.	1981
4.	Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store.	2011
5.	Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-431** Course Title: **Fuel Cell Fundamentals**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide the comprehensive knowledge of Fuel cells fundamentals and applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Fuel cell definition, Fuel cells versus batteries, type of fuel cell, basic fuel cell operation, fuel cell performance, advantages and disadvantages of fuel cell, overview of fuel cell system, fuel cell stack, thermal management subsystem, fuel delivery and processing subsystem, hydrogen storage, generation and delivery.	**8**
2.	**Working principle and application:** Phosphoric acid fuel cell (PAFC), polymer electrolyte membrane fuel cell (PEMFC), alkaline fuel cell (AFC), molten carbon fuel cell (MCFC), solid-oxide fuel cell (SOFC), performance characterization of fuel cell system.	**4**
3.	**Fuel cell thermodynamics:** Thermodynamic potential, heat potential of a fuel, enthalpy of reaction, temperature dependency of enthalpy, working potential of fuel, relationship between Gibbs free energy and electrical work, relationship between Gibbs free energy and voltage, standard electrode potential, reversible voltage variation of reversible voltage with temperature, pressure and concentration, real and ideal fuel cell efficiency.	**8**
4.	**Reaction kinetics in fuel cell:** Electrode kinetics, electrochemical reaction, heterogeneous electrochemical process, current rate, current amount and current density, activation energy in current transfer reaction, net rate of reaction calculation, potential and rate: Butler-Volmer equation, how to improve kinetic performance, catalyst electrode design.	**7**
5.	**Transport in fuel cell system:** Ion transport in an electrolyte, electron transport, gas-phase mass transport, diffusive transport in electrode, convective transport in flow structures.	**4**
6.	**Fuel cell characterization:** Overview of characterization techniques, basic fuel cell test station, current voltage measurement, Ex Situ characterization techniques, porosity, BET, gas permeability, fuel processing subsystem, steam reforming, partial oxidation, auto-thermal reforming, gasification, water-gas	**9**

	shift reactors, carbon Monoxide clean up, thermal management.	
7.	**Environmental impact:** Life cycle assessment, emission, climate change, greenhouse effect.	**2**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Ohayre R.P., Cha Suk-Won, Colella W. G., Prinz F. B., "Fuel Cell Fundamentals", John Wiley & Sons, Inc.	2009
2.	Larminie J., Dicks A., Fuel Cell System Explained", John Wiley & Sons	2003
3.	Mench M. M., " Fuel Cell Engines", John Wiley & Sons, Inc.	2008
4.	Zhao, T.S.; Kreuer, K.D., "Advances in fuel cells", Elsevier, 2007.	2007
5.	Linden, D., "Handbook of Batteries and Fuel Cells", McGraw-Hill.	1984

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-412** Course Title: **Modeling of Dynamic Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To provide the knowledge of modeling of chemical engineering equipment under dynamic conditions.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review:** Modeling fundamentals, formulation of dynamic models, material, energy and momentum balances.	**4**
2.	**Numerical Methods:** Use of Runge-Kutta and Gear's methods for solution of staged separation problems, finite difference approximation of partial differential equations and their solutions.	**7**
3.	**Process Dynamics Fundamentals:** Review of first order and second order dynamics for different inputs and applications to chemical engineering systems.	**5**
4.	**Modeling of Separation Processes:** Dynamic modeling of batch extraction, flash distillation and equilibrium stage concept, modeling of multistage systems for extraction, absorption, and distillation columns involving multicomponents, use of two-point implicit method for solution of staged separation problems such as evaporator system, continuous distillation column, batch-distillation column.	**11**
5.	**Modeling of Reactor Systems:** Dynamic modeling of batch reactor, semi batch reactor, stirred tank reactor and plug flow reactor with and without heat transfer, modeling of one dimensional and two dimensional fixed bed reactor, fluidized bed reactor and bioreactor.	**11**
6.	**Modeling of Heat Transfer Systems:** Dynamics of the metal jacket	**4**

	wall, heat exchanger dynamics.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Holland C.D. and Liapis A. I., "Computer Methods for Solving Dynamic Separation Problems", McGraw Hill.	1983
2.	Ingham J., Dunn I. J., Heinzle E., Prenosil J. E. and Snape J. B., "Chemical Engineering Dynamics", 3rd Ed., Wiley.	2007
3.	Munsif H. P., "Dynamic Modeling of a Multicomponents, Highly Nonideal Distillation Column", AIChE.	1995
4.	Bequette B. W., "Process Dynamics: Modeling, Analysis and Simulation", Prentice Hall.	1998
5.	Esfandiari R.S., Lu Bei, "Modeling and Analysis of Dynamic Systems", 2nd Ed., CRC Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-414** Course Title: **Advanced Process Control**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To provide the advanced knowledge of process control.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Feed Back Control:** Review of open loop and closed dynamics, stability using root-locus, and frequency response method, time-integral performance criteria of controllers and tuning methods.	**7**
2.	**Advanced Control Systems:** Control of systems with inverse response, dead time compensator, cascade control, selective control, split-range control, feed forward and ratio control, internal model, adaptive and inferential control.	**11**
3.	**Multivariable Control Systems:** Alternative control configurations, interaction and decoupling of loops, relative gain-array method, control for complete plants	**7**
4.	**State Space Methods:** State variables, description of physical systems, transition and transfer function matrices, use in multivariable control for interacting systems.	**5**
4.	**Digital Control Systems:** Review of Z transform**,** elements of digital control loop, sampling and reconstruction of signals, conversion of continuous to discrete-time models, discrete time response and stability, design of controllers and control algorithms.	**12**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Coughanowr D.R. and LeBlanc S. "Process System Analysis and Control", 3rd Ed., McGraw Hill.	2008
2.	Stephanopoulos G. "Chemical Process Control – An Introduction to Theory and Practice", Prentice-Hall of India.	1990
3.	Seborg D.E., Edgar T. F. and Mellichamp D. A., "Process Dynamics Control", 2nd Ed., John Wiley	2004
4.	Bequette B. W., "Process Control: Modeling, Design and Simulation", Prentice Hall of India	2003
5.	Ogunnaike B. A. & Ray W. H., "Process Dynamics Modeling & Control", Oxford University Press	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-416** Course Title: **Design of Piping Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To provide knowledge of design and engineering problems of piping in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Flow of Fluids:** Frictional loss in pipe and ducts, equivalent resistance of fittings, valves and bends, carrying capacity of pipes, network; pressure drop and diameter calculations of pipe carrying steam, water, oil and gases, optimum pipe line diameter calculations and optimum pipe network design.	**9**
2.	**Vapor Liquid Piping:** Flow pattern, piping design for two-phase flow; design of piping for reboiler and condenser systems.	**4**
3.	**Hydraulic Transport:** Design of homogenous and heterogeneous slurry transport line; correlations for various flow regimes.	**4**
4.	**Pneumatic Transport:** Conveying systems, solid gas flow pattern in vertical, horizontal and inclined pipe lines; concept of saltation and choking velocities, pressure drop calculations in different pipe lines carrying gas solid mixture; Design of feeding systems for pneumatic transport of solids.	**8**
5.	**Pipes and Fittings:** Standard sizes, wall thickness, tolerances, design of flanges and other fittings.	**2**
6.	**Strength and Failure of Materials:** Stable and unstable deformation, plasticity, plastic instability, design assumptions, stress evaluation and design limits, codes and standards. Local components of pipe bends, branch connections and bolted flange connections.	**8**
7.	**Simplified Methods for Flexibility Analysis:** Thermal expansion loops, code rules, approximate solutions and flexibility analysis by model tests.	**7**

	Approaches to reducing expansion effects, expansions joints.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Deutsch D. J., "Process Piping Systems", Chemical Engineering, McGraw Hill.	1980
2.	Marcus R. D., Leung L. S. Klinzing G. E. and Rizk F., "Pneumatic Conveying of Solids", Chapman and Hall.	1990
3.	Nayyar M. L., "Piping Handbook", 7^{th} Ed., McGraw Hill.	2000
4.	Boterman R. and Smith P., "Advanced Piping Design", Gulf Publishing Company.	2008
5.	Smith P., "The Fundamentals of Piping Design: Drafting and Design Methods for Process Applications", Gulf Publishing Company.	2007

NDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-418** Course Title: **Advances in Fluid Mechanics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To emphasize on physical concepts and mathematical formulation of typical fluid mechanics problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition and properties of Fluids, Continuum hypothesis, Elementary concepts in tensor analysis and index notation	**5**
2.	**Fluid kinematics:** Lagrangian and Eulerian viewpoints, substantial derivative, decomposition of motion, vorticity, elementary motions in linear shear flow	**3**
3.	**Basic conservation laws:** Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum and energy conservation equations, Navier-Stokes equations, Non-Newtonian liquids, No slip condition	**5**
4.	**Laminar flow examples:** steady flow between parallel plates, pipe flow, flow between concentric cylinders, flow due to oscillating plate; Hele-Shaw flows, start-up flows.	**6**
5.	**Irrotational flows:** Motivation, Inviscid flows: Euler equation, Bernoulli's Equation, Velocity potential, application of complex variables and stream function, Source and Sink; Vortex flow, Doublet, Superposition of basic plane potential flows,	**4**
6.	**Boundary layer theory**: Boundary layer approximation, different measures of boundary layer thickness, flow past a flat plate, Von Karman momentum equation, Flow separation, Entry flow into a duct, low past circular cylinder and sphere, secondary flows	**6**
7.	**Flow Instability**: Concept of small-disturbance stability, method of	**3**

	normal modes, Squire's theorem, Orr-Somerfield equation, some results of parallel viscous flows	
8.	**Turbulence**: Characteristics of turbulent flows, averages, correlations and spectra, averaged equations of motion, kinetic energy budget, turbulence production and cascade	**5**
9.	**Special topics:** Introduction to compressible flows/geo-physical fluid dynamics/bio-fluid mechanics .	**5**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Publication year**
1.	Kundu P. K. and Cohen I.M., "Fluid Mechanics, 4th Ed., Academic Press.	2008
2.	Panton R. L., "Incompressible flows", 3rd Ed., Wiley.	2005
3.	Robert F. W., McDonald A. T., Introduction to Fluid Mechanics, Fourth Edition, John Wiley & Sons	1995
4.	Muralidhar K. and Biswas G., Advanced Engineering Fluid Mechanics, 2nd Edition, Narosa	2005
5.	Frank M. White, Fluid Mechanics, Tata McGraw-Hill, New Delhi, Sixth Edition	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-420** Course Title: **Advances in Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To equip the students with the knowledge of Advance Heat transfer processes.

10. Details of the Course:

S.No.	Content	Contact Hours
1.	**Heat Transfer during phase change:** Different types of boiling phenomena(Nucleate, Sub-cooled, Pool and Film boiling. Boiling outside a tube & tube bundle and flow boiling inside tube under forced convection; Film-wise and drop-wise condensation, condensation outside a tube and tube bundle and inside a tube , flow condensation inside tube under forced convection, Augmentation of heat transfer coefficient during boiling and condensation.	12
2.	**Heat Pipes:** Constant Conductance Heat Pipes (CCHPs), Variable Conductance Heat Pipes (VCHPs), Pressure Controlled Heat Pipes (PCHPs), Diode Heat Pipes , Rotating Heat Pipes, Capillary pumped loop heat pipe, Micro Heat Pipes, Heat Pipe Heat Exchanger	06
4.	**Heat Conduction:** 1-Dimensional Planar, Radial steady state conduction with thermal energy generation, Heat transfer from extended surfaces and fin optimization, Multidimensional steady state and transient heat conduction, Advanced Electronics cooling	06
5.	**Heat Convection:** Introduction to convection, thermal boundary layer and its analogies, Forced convection inside tubes, correlation for laminar and turbulent forced convection; Forced convection for external flow over plates, cylinders, tube bundles. Heat Transfer in nano-fluids. Jet impingement Heat Transfer, Combined free and forced convection. Heat transfer in packed and fluidized beds.	09
6.	**Heat Radiation:** Introduction to thermal radiation, surface radiation properties, Wien's displacement law, Stefan-Boltzmann Law, Krichhoff's	09

	law, Gray Surfaces View Factor, Black body Radiation Exchange, Radiation Exchange in n Enclosure, Multimode Heat Transfer	
	Total	42

11. Suggested Books:

S.No.	Name of Authors/Books/Publishers	Year of publication
1.	Kreith, F. and Bohn, M.S., "Principles of Heat Transfer", 6th ED., Thomson Learning	2007
2.	Kays, W.M., Crawford, M.E. and Weigand , B., "Convective Heat & Mass Transfer", 4th Ed., MacGraw Hill	2004
3.	Siegel, R., and Howell, J.K., "Thermal Radiation Heat Transfer", Taylor & Francis	2002
4.	F.P. Incropera & D.P.DeWitt, "Fundamentals of Heat & Mass Transfer", 6th Ed., Wiley	2007
5.	Ryan McGlen, Peter Kew and David Reay, "Heat Pipes, Fifth Edition: Theory, Design and Applications", 5th Ed., Butterworth-Heinemann	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-422** Course Title: **Petrochemicals**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To provide in-depth knowledge to petrochemicals manufacture.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to petroleum and petrochemical industries, structure of petrochemical industry, product profile of petrochemicals, profile of Indian petrochemical industries, basic building blocks for petrochemical production.	**4**
2.	**Raw Materials:** Raw materials for organic chemicals-coal, biomass, petroleum and natural gas, Natural gas, NGL,, shale gas, coal bed methane, gas hydrate. Evaluation of crude oil and Petrochemical feed stocks- Naphtha, Kerosene, and Pyrolysis gasoline.	**4**
3.	**Methane and Synthesis Gas Derivatives:** Steam reforming and partial oxidation, gasification, product profile of synthesis gas,methanol, formaldehyde, chlorinated methane.	**4**
4.	**Production of Olefins:** Steam cracking of naphtha and natural gas. Advances in steam cracking, emerging Technologies for production of olefins	**4**
5.	**Treatment & Up-gradation of C_4 and C_5 Cuts:** Up gradation of C_4 and C_5 streams from crackers, MTBE, TAME. Recovery of butadiene and isoprene, cyclppentadiene	**3**
6.	**Aromatics Production:** Catalytic reforming, aromatic separation, aromatic conversion processes, Cyclar process.	**4**
7.	**Ethylene , Propylene and their derivatives:** Sources of ethylene and propylene, product profile **of** Ethylene and propylene, ethylene oxide, ethylene glycol, vinyl chloride, acetaldehyde, propylene oxide, glycol and isopropyl alcohol, acrylonitrile, cumene. C4 and c5 derivatives: Butadiene, Butane and butenes, Isobutylene,	**6**

	1,4-Butanediol, Chloroprene, Isoprene.	
8.	**Aromatic Derivatives: Phenol, a**niline, phthalic anhydride, caprolactum, terephthalic acid, DMT, maleic anhydride, linear alkyl benzene, cyclohexane,	**5**
9.	**Polymers, Elastomers and Synthetic fibre :** Polymer, elastomers and synthetic fiber: Polyolefins, PVC, Poly butadiene and Styrene butadiene rubber, caprolactam and nylon, polyester, acrylic fibre, polyurethane	**8**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Chaval A. and Lefebvre G., "Petrochemical Processes" Part-I, 2nd Ed., Technip .	1986
2.	Chaval A. and Lefebvre G., "Petrochemical Processes" Part-II, 2nd Ed., Technip .	1986
3	Wiseman,P. "Petrochemicals" Ellis Horward.	1986
4.	Chaskar rao, B.K." "Petrochemicals" 2nd Ed.,Khanna Publishers.	1998
5	Mall I. D., "Petrochemical Process Technology", 1st Ed., Macmillan India Ltd.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-424** Course Title: **Industrial Pollution Abatement**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To impart knowledge about various industrial pollutants and their control techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Environment and environmental pollution from chemical process industries, characterization of emission and effluents, environmental Laws and rules, standards for ambient air, noise emission and effluents.	**7**
2.	**Pollution Prevention:** Process modification, alternative raw material, recovery of by/co-products from industrial emissions/effluents, recycle and reuse of waste, energy recovery and waste utilization. Material and energy balance for pollution minimization. Water use minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.	**10**
3.	**Air Pollution Control:** Particulate emission control by mechanical separation and electrostatic precipitation, wet gas scrubbing, gaseous emission control by absorption and adsorption; Design of cyclones, ESP, fabric filters and absorbers.	**8**
4.	**Water Pollution Control:** Physical treatment, pre-treatment, solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation.	**6**
5.	**Biological Treatment:** Anaerobic and aerobic treatment biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying.	**6**
6.	**Solids Disposal:** Solids waste disposal – composting, landfill, briquetting / gasification and incineration.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Tchobanoglous G., Burton F. L. and Stensel H.D., "Waste Water Engineering: Treatment and Reuse", 4th Ed., Tata McGraw Hill	2003
2.	Vallero D., "Fundamentals of Air Pollution", 4th Ed., Academic Press.	2007
3.	Eckenfelder W. W., "Industrial Water Pollution Control", 2nd Ed., McGraw Hill.	1999
4.	Kreith F. and Tchobanoglous G., "Handbook of Solid Waste Management", 2nd Ed., Mc Graw Hill.	2002
5.	Pichtel J., "Waste Management Practices: Municipal, Hazardous and Industrial", CRC.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-426** Course Title: **Fertilizer Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: To impart in-depth knowledge of fertilizer technology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Macro- and micro-nutrients, fertilizer grades, development of fertilizer industry, different types of fertilizers, their demand and production in India. Global fertilizer industry . physical and chemical properties of fertilizers.	**5**
2	**Raw material:** Coal, natural gas, naphtha, Rock phosphate, potash, sulphur as fertilizer feed stock, their availability, future trend. Energy resources.	**4**
3.	**Nitrogenous Fertilizers: S**ynthesis gas production by steam reforming. partial oxidation, gasification of coal, pretreatment, in primary reformer, shift converters, CO_2 removal and final gas purification. design considerations and developments. **Ammonia Synthesis:** Different types of reactors, their design consideration, operation and comparison of various processes. Advances in ammonia synthesis, design considerations and developments.	**9**
4.	**Urea and other Nitrogenous Fertilizers:** Various processes for urea synthesis and major variables, synthesis of urea, calcium ammonium nitrate, ammonium sulphate, ammonium chloride, major operating variables. Prilling and granulation technology	**6**
5.	**Phosphatic Fertilizers:** Raw material and limitation in their use, uncertainties in their availability and their impact on the existing plants and future planning;, sulphuric acid, phosphoric acid, single and triple	**8**

	super-phosphates	
6.	**Potash Fertilizers:** Availability of potash, methods of production of potassium chloride and potassium sulphate. **Complex N-P-K Fertilizers:** Mono- and di-ammonium phosphates, nitro phosphate urea ammonium phosphate, mixed fertilizers, granulation techniques. **Biofetriliser, Slow release fertilizers**	**6**
7	**Energy & environment:** Energy consumption and energy conservation measures., Fertilizer plant emission and effluents and standards , pollution control strategies. In nitrogenous and phosphatic fertilizer industry.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1	Sauchelli,V. ,"Fertilizer nitrogen. Its chemistry and technology, Reinhold Publishing	1984
2.	Mortvedt J. J., "Fertilizer Technology and Applications", Meister publication company.	1999
3.	United Nations and Industrial Development Organization, "Process Technologies for Phosphate Fertilizers", University Press of Pacific.	2003
4.	United Nations and Industrial Development Organization, "Process Technologies for Nitrogen Fertilizers", University Press of Pacific.	2003
5	Sundram, K.P "Handbook of fertilizer technology" The fertilizer association of India 6^{th} Ed.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH- 428** Course Title: **Polymer Science and Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DEC**

8. Pre-requisite: Nil

9. Objective: The objective of the course is to present in-depth study of polymer science and engineering.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Chemistry of Polymerisation Reaction:** Functionality, polymerization reactions, polycondensation, addition free radical and chain polymerization, copolymerization, block and graft polymerizations, stereo specific polymerization.	**10**
2.	**Polymerisation Kinetics:** Kinetics of radial, chain and ionic polymerization and co-polymerisation systems.	**6**
3.	**Molecular Weight Estimation:** Average molecular weight, number average and weight average, theoretical distributions, methods for the estimation of molecular weight.	**8**
4.	**Polymerisation Processes:** Bulk, solution, emulsion and suspension polymerization. Thermoplastic composites, fibre reinforcement fillers, surface treatment, reinforced thermoset composites-resins, fibers additives, fabrication methods.	**10**
5.	**Rheology:** Simple rheological equations, simple linear viscoelastic models-Maxwell, Voigt, materials response time, temperature dependence of viscosity.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Name of Book / Authors / Publisher	Year of Publication
1	Kumar A. and Gupta R., "Fundamentals of Polymer Engineering",CRC.	2003
2	Fried J., "Fundamentals of Polymer Science", Prentice Hall.	2004
3.	Williams, D.J., "Polymer Science & Engg." Prentice Hall.	1971
4	Billmayer Jr., W., "Textbook of Polymer Science" Wiley Tappers.	1984
5.	Rodriguez F.," Principles of Polymer Systems", 5th Ed. CRC Press.	2003

Courses for Minor Specialization

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-102** Course Title: **Material and Energy Balance**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of principles of material and energy balances applied to chemical engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Units and dimension in chemical engineering**,** units conversion of dimensional equations, stoichiometric and composition relations, concept of degrees of freedom and linear independence of a set of equations.	**5**
2.	**Material Balance:** Concept of material balance, open and closed systems, steady state and unsteady state, multiple component system, selection of a basis, problem solving strategy.	**4**
3.	**Material Balance without Chemical Reaction for Single and Multiple Units:** Conservation of mass/atom, material balance for systems without chemical reactions involving single unit and multiple units.	**5**
4.	**Material Balance with Chemical Reaction for Single and Multiple Units:** Concept of excess reactant, extent of reaction, material balance for systems with chemical reactions involving single unit and multiple units.	**6**
5.	**Recycle, Bypass, Purge and Industrial Applications:** Calculations for a cyclic processes involving recycle/ purge/ bypass, material balances involving gases, vapors, liquids and solids and use of real	**7**

	gas relationships, material balance involving gases, vapors, liquids & solids and uses of real gas relationships, vapor-liquid equilibrium and concepts of humidity & saturation, analysis of systems with bypass, recycle and purge, analysis of processes involving condensation, crystallization and vaporization.	
6.	**Energy Balance:** Conservation of energy with reference to general energy balance with and without chemical reactions, chemical engineering problems involving reversible processes and mechanical energy balance.	**4**
7.	**Applications of Energy Balance:** Calculations of heat of change of phase (solid – liquid & liqid – vapor), heat of reaction, heat of combustion, heat of solutions and mixing, determination of temperatures for adiabatic and non-adiabatic reactions, use of psychometric and enthalpy- concentration diagrams.	**6**
8.	**Simultaneous Material and Energy Balances:** Degrees of freedom analysis for multicomponent systems, combined steady state material and energy balances for units with multiple sub-systems.	**3**
9.	**Unsteady State Material and Energy Balances:** Transient materials and energy balances involving with and without chemical reactions.	**2**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Himmelblau D.M. and Riggs J. B.," Principles and Calculations in Chemical Engineering", 8th Ed., Prentice Hall of India.	**2012**
2.	Felder R.M. and Rousseau R.W., "Elementary Principles of Chemical Processes", 3rd Ed.., John Wiley.	**2005**
3.	Bhatt B.I. and Vora S.M., "Stoichiometry", 5th Ed., Tata McGraw-Hill	**2010**
4.	Narayanan K.V. and Lakshmikutty B., "Stoichiometry and Process Calculations", Prentice Hall of India.	**2006**
5.	Hougen D.A., Watson K.M. and Ragatz R.A., "Chemical Process Principles", Part-I, 2nd Ed., CBS Publishers.	**1995**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-104** Course Title: **Fluid Dynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 3

4. Relative Weight: **CWS** 15 **PRS** 15 **MTE** 15 **ETE** 40 **PRE** 15

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To present the fundamental insights of fluids and their static and dynamic behaviors and fluid machineries, etc

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Fundamental concepts of fluids; Fluid statics, kinematics and dynamics; Properties of fluids.	3
2	**Fluid Statics:** The basic equation of fluid statics; Pressure - depth relationship; Pressure forces on plane and curved surfaces; Buoyancy and stability; Forces on immersed and submerged bodies; Pressure measurements; Pressure in accelerated rigid body motions.	6
3	**Elementary Fluid Kinematics:** Lagrangian and Eulerian descriptions; Flow visualization – streamline, pathline, streakline and timeline, contours and profile plots; Description and classification of fluid motions; Rotational, irrotational, inviscid and potential flows; Deformation of fluids; System and control volume representation; Reynolds transport theorem.	6
4.	**Dynamic Analysis of Flow:** Conservation of mass, linear and angular momentum, and energy; Bernoulli theorem; Flow deformation relationships, Navier-Stokes equations.	6
5.	**Dimensional Analysis, Similitude and Modeling:** Dimensional homogeneity and analysis; Methods of finding dimensionless numbers; Selection of variables, Rayleigh and Buckingham's π method; Common dimensionless numbers and their physical significance; Model and	3

	Prototypes; Complete and incomplete similarity.	
6.	**Internal Incompressible Viscous Flow:** General characteristics of pipe flow – laminar, turbulent, entrance region, fully developed; Fully developed laminar/turbulent flow in pipe, duct and orifice – shear stress distribution and velocity profiles; Energy correction factors; Energy and hydraulic grade lines; Major and minor losses in pipes, fittings, non-circular ducts; vena contracta; Friction factor, pipe roughness; Moody chart.	7
7.	**Flow Measurements:** Flow rate and velocity measurements – Pitot tube, orifice meter, venturimeter, rotameter, notches and weirs, etc.	2
8.	**Fluid Handling Machinery:** Classification; Positive-displacement pumps and compressors, centrifugal pumps and compressors, Axial flow pumps and compressors, compressor efficiency. Characteristics of pumps; Selection of pumps.	6
9.	**Agitation and Mixing:** Agitated vessels; Blending and mixing; Suspension of solid particles; Dispersion operations; Agitator selection and scale up.	3
Total		42

11. List of Practicals:

1. Stokes law/Viscosity measurement
2. Friction losses in pipes
3. Friction losses in fittings
4. Flow meters (Orificemeter, Venturimeter, Rotameter)
5. Pitot tube
6. Notches/Weirs
7. Bernauli's experiemnt
8. Reynold's experiemnt
9. Flow through porous media/Darcy's law validation
10. Centrifugal pump characteristics in series and parallel arrangements
11. Reciprocating pump characteristics

12. Suggested Books:

S. No.	Name of Books/Authors/Publications	Publication Year
1.	Nevers N.D., "Fluid Mechanics For Chemical Engineers", 3rd Ed., McGraw Hill Higher Education.	2005
2.	Cengel Y.A. and Cimbala J.M. "Fluid Mechanics: Fundamentals and Applications", 2nd Ed. McGraw-Hill	2010
3.	Balachandran P. "Engineering Fluid Mechanics", PHI Learning Pvt Ltd., New Delhi	2012
4.	Munson B.R., Young D.F., Okiishi T.H. and Huebsch W.W., "Fundamentals of Fluid Mechanics", 6th Ed., Willey	2010
5.	White F.M. "Fluid Mechanics", 7th Ed. Tata McGraw-Hill	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-106** Course Title: **Thermodynamics and Chemical Kinetics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of thermodynamics and chemical kinetics to chemical engineering students.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Thermodynamic system, surroundings, state, process, properties, equilibrium, heat and work.	02
2.	**Properties of Pure Simple Compressible Substance:** P-V-T surface, P-V, T-V and T-P diagrams. Equations of state for ideal and real gases. Virial equation of state, van der Waals and Redlich-Kwong equations of state; Use of Thermodynamic tables.	06
3.	**First Law of Thermodynamics:** Energy balance for closed systems. Various forms of energy balance. Specific heat, internal energy, enthalpy, and specific heat of ideal gases. Application of first law to non-flow isochoric, isobaric, isothermal, and adiabatic and polytropic processes. Conservation of mass for a control volume, mass and volume flow rates, mass balance for steady flow processes, flow work, steady flow energy equation. Application to various practical systems viz. nozzles, diffusers, etc. Transient Analysis.	05
4.	**Second Law of Thermodynamics:** Second law, reversible and irreversible processes, Clausius and Kelvin Planck statements. Carnot cycle, Clausius inequality, entropy as a property, principle of increase of entropy. Calculation of entropy change.	06
5.	**Thermodynamic Cycles:** Otto, Diesel, Rankine cycles and their applications.	03
6.	**Rate Expression and Reaction Mechanism:** Use of pseudo steady state approximation to get rate expression from mechanism, temperature-dependence of reaction rate-collision theory, transition state theory, thermodynamics and Arrhenius law.	04
7.	**Interpretation of Kinetic Data of Batch Reactors:** Constant volume and variable volume batch reactions, Integral and differential methods of analysis of data of uni, bi	08

	and tri-molecular irreversible reactions. Reversible reactions, homogeneously catalysed, auto-catalysed, series and parallel reactions. Estimation of rate constants and its temperature-dependence.	
8.	**Solid-Catalysed Fluid Reactions:** Characterization of catalyst, Physical and chemical adsorption, various reaction steps, Langmuir-Hinshelwood kinetics.	04
9.	**Kinetics of Bio-Chemical Reactions:** Kinetics of enzyme catalysed reactions, substrate and product inhibition, effect of temperature and pH on enzyme catalysed reactions.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Çengel Y.A. and Boles M.A., "Thermodynamics: An Engineering Approach", 6th Ed., McGraw Hill.	2008
2.	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
3.	Borgnakke C. and Sonntag R.E., "Fundamentals of Thermodynamics", 7th Ed., John Wiley and Sons.	2009
4.	Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., John Wiley.	2000
5.	Fogler H.S., "Elements of Chemical Reaction Engg.", 4th Ed., Prentice Hall of India.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-201** Course Title: **Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 3

4. Relative Weight: **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** -

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge about heat transfer and its processes used in Chemical Process Industries

10. Details of Course:

S. No.	Contents	Contact Hour
1.	**Introduction**: Heat transfer modes, their rate equations.	**2**
2.	**Radiation**: Mechanism of radiation and its laws, black and grey body behavior, shape factors- determination using equations and charts, relationship between shape factors, heat transfer between non-black bodies, concept of surface- and space- resistance with concept of insulated and large surfaces, use of radiation shields, radiation through absorbing and transmitting gases.	**7**
3.	**Conduction**: Use of extended surfaces, two-dimensional steady state conduction, Thermal insulation- materials for cold and hot applications and thickness calculations, introduction to transient conduction, Biot number, use of Heisler charts.	**6**
4.	**Convection**: Concept and significance of boundary layer, boundary layer similarity and analogy, convection coefficients, free and forced convection, empirical correlations- internal and external flows.	**6**
5.	**Heat Exchangers**: Types and selection, overall heat transfer coefficient, parallel and counter current flow, LMTD, F_T	**4**

	correction factor, analysis and design using effectiveness-NTU method.	
6.	**Boiling**: Characteristics, nucleate pool- and forced convection-boiling, boiling mechanism and curve, heat transfer correlations, heat pipes.	**4**
7.	**Condensation**: Mechanism and types of condensation of vapor with and without non-condensable gases, Nusselt equation for film wise condensation on vertical surfaces and its extension to inclined and horizontal surfaces and tubes, condensation number, film condensation inside horizontal tube.	**5**
8.	**Evaporator**: Classification and use of evaporators in process industries, effect of boiling point rise and hydrostatic head on evaporator performance, liquor flow sequences, calculations for multiple effect evaporator system.	**4**
9.	**Crystallization**: Mechanism, crystallization from mixed solutes, particle size distribution of crystals and parameters effecting it, some major types of crystallizers, crystallizer calculations.	**4**
	Total	**42**

11. List of Practicals:

1. Open Pan Evaporators with/without Agitator
2. Coil Tank Evaporator with/without Agitator
3. Hair Pin Heat Exchanger
4. Shell and Tube Heat Exchanger
5. Floating Head Heat Exchanger
6. Fin Tube Heat Exchanger
7. Heat Transfer in Natural Convection
8. Heat Transfer in Forced Convection
9. Two Phase Heat Transfer
10. Temperature Distribution in Metallic Rods
11. Drop-wise and Film-wise Condensation
12. Emissivity Measurement
13. Stefan Boltzmann's Apparatus
14. Single Effect Evaporator
15. Clasius Clayperon Equation
16. Gibbs Duhem Equation

12. Suggested Books:

S. No.	Name of Authors/ Books/ Publisher	Year of Publication
1.	Holman J.P., " Heat Transfer", 10th Ed., McGraw Hill	**2009**
2.	Bergman T.L., Lavine A.S., Incropera F.P. and DeWitt D.P., "Introduction to Heat Transfer", 6th Ed., Wiley	**2011**
3.	Cengel Y.A. and Ghajar A.J., "Heat and Mass Transfer: Fundamentals and Applications", 4th Ed., McGraw Hill	**2010**
4.	Kreith F., Manglik R.M. and Bohn M., "Principles of Heat Transfer", 7th Ed., Cengage Learning	**2010**
5.	Hewitt G.F., Shires G.L. and Bott T.R., "Process Heat Transfer", Begell House.	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-203** Course Title: **Mechanical Operations**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 2

4. Relative Weight: **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** -

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite: **Nil**

9. Objective: To impart Knowledge on particle size analysis, size reduction, separation of solid particles from fluids and flow through porous media.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Particles Size Analysis:** Sieve analysis, size distribution, size averaging and equivalence, size estimation in sub-sieve range, effectiveness of screen.	4
2.	**Size Reduction:** Theory of crushing and grinding, laws of crushing and grinding, crushing and grinding equipment and their selection.	4
3.	**Storage of Solids:** Angle of slide and repose, design of bins, silos, and hoppers, Jansen's equation.	4
4.	**Particle Mechanics:** Motion of particle in fluid, effect of particle shape, Stoke's law, hindered settling, jigging and classification.	4
5.	**Sedimentation and Flotation:** Gravity and centrifugal sedimentation, design of sedimentation tank and continuous thickeners, mechanism of flotation, flotation agents and flotation equipment.	6
6.	**Flow Through Packed Beds:** Characteristics of packings, flow of a single fluid through a packed bed, problem of channeling and wetting, counter current gas- liquid flow through packed beds, loading and flooding characteristics, industrial applications.	6
7.	**Fluidization:** Fluidization characteristics, aggregative and particulate fluidization, voidage and minimum fluidization velocity, voidage correlation, liquid-solid and gas-solid fluidization	5

	characteristics, industrial applications of fluidization.	
8.	**Filtration:** Flow through filter cake and medium, washing and drying of cake, filter aids, selection of filtration equipment, constant rate and constant pressure filtration.	**5**
9.	**Conveying of Solids:** Pneumatic and hydraulic conveying of solids, general characteristics and flow relations, mechanical conveyers.	**4**
	Total	**42**

11. List of Practicals:

1. Plate and frame filter press
2. Rotary drum filter
3. Flow through packed Bed
4. Flow through Fluidized bed
5. Batch Sedimentation
6. Crushing and grinding experiments through ball mill, pulvliser and Jaw crusher
7. Particle size analysis
8. Elutration
9. Continuous thickener

12. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication
1.	Backhurst, J. R. and Harker J. H.,"Coulson and Richardson Chemical Engineering", Vol. II",5th Ed., Butterworth-Heinemann.	2002
2.	Brown G.G. and Associates,"Unit Operations",CBS Publishers.	1995
3.	McCabe W.L., Smith J.C and Harriott P., "Unit Operations of Chemical Engineering", 7th Ed. , McGraw Hill.	2005
4.	Geankoplis C.J., Transport Processes and Separation Process Principles, 4th Ed.,Prentice Hall.	2003
5.	Narayanan C.M. & Bhattacharya B.C., "Mechanical Operation for Chemical Engineers –Incorporating Computer Aided Analysis", Khanna Publishers.	1992

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-205** Course Title: **Chemical Engineering Thermodynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-106**

9. Objective: To apply the laws of thermodynamics in solving problems related to flow processes and phase equilibrium of heterogeneous and reacting systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review:** Laws of thermodynamics, PVT behavior of fluids – Gibb's phase rule, cubic equations of state and generalized correlations.	2
2.	**Thermodynamic Properties of Homogeneous Fluids:** Fundamental property relations, Maxwell's relations, Residual properties and their estimation, two phase systems, thermodynamic diagrams and tables, generalized property correlation for gases.	7
3.	**Thermodynamic Properties of Mixtures or Solutions:** Property relationships for systems of variable composition; chemical potential, partial molar properties, fugacity and fugacity coefficients – pure species and species in a mixture, fugacity in ideal solutions, activity coefficients, excess properties.	7
4.	**Applications of Solution Thermodynamics:** VLE-qualitative behavior, Duhem's theorem, simple models for VLE (Raoult's law, modified Raoult's law, etc.). Liquid properties from VLE. Activity coefficients from experimental data – Margules, Van-Laar, and Wilson equations. Property changes of mixing, heat effects in mixing processes.	8
5.	**Phase Equilibria:** Importance of phase equilibria in process industries, equilibrium and stability, vapour-liquid equilibria (VLE) for miscible, partially miscible and immiscible systems, their phase diagrams, azeotropes. VLE calculations at low and high pressures, analysis of multi-component, multiphase systems.	6
6.	**Chemical Reaction Equilibria:** Reaction coordinate, application of equilibrium criteria to chemical reactions, standard Gibbs energy change and the equilibrium constant, effect of temperature on equilibrium constant, evaluation of equilibrium	6

	constant and composition. Calculation of equilibrium compositions for single reactions; Phase rule and Duhem's theorem for reacting systems.	
7.	**Thermodynamic Analysis of Processes:** Work and free energy, availability, analysis of mixing, separation processes, heat exchange, lost work calculations.	6
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
2	Sandler S.I. "Chemical, Biochemical and Engineering Thermodynamics", 4th Ed., John Wiley.	2006
3	Kyle B.G., "Chemical and Process Thermodynamics", 3rd ed., Prentice Hall.	1999
4	Narayanan, K.V., "Chemical Engineering Thermodynamics", Prentice Hall.	2007
5.	Koretsky M.D., "Engineering and Chemical thermodynamics", John Wiley.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-207** Course Title: **Transport Phenomena**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-104**

9. Objective: To provide knowledge of momentum, heat and mass transport in Chemical engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**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. Estimation of transport coefficients and temperature/pressure dependence.	8
2.	**Non-Newtonian Fluids:** Time independent, time-dependent and viscoelastic fluids, constitutive equations and rheological characteristics.	4
3.	**Equations of Change Under Laminar Flow Conditions:** Equation of continuity, motion, mechanical energy, energy and mass transport. Simple shell balance method for momentum, heat, and mass transport, velocity distribution in circular conduits and parallel plates. Generalized form of equations and simplifications.	8
4.	**Turbulence Phenomena:** Basic theory of turbulence, time averaging, intensity and correlation coefficients, isotropic turbulence. Equations of continuity, motion and energy for turbulent condition. Reynolds stresses. Phenomenological theories of turbulence, velocity profile in circular conduits. Temperature distribution in turbulent flow.	7

5.	**Methods of Analysis of Transport Problems:** General integral balance using macroscopic concepts, integral balance for mass, momentum, energy and mechanical energy.	**5**
6.	**Convective Transport:** Free and forced convective heat transfer and mass transfer.	**4**
7.	**Transport Past Immersed Bodies**: Laminar and turbulent boundary layers, Momentum, heat and mass transfer during boundary layer flow past a flat plate and flow over a sphere. Drag coefficient correlations.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., John Wiley & Sons, Inc.	2002
2.	Geankoplis C.J., "Transport Processes and Separation Process Principles includes Unit Operations", 4th Ed., Prentice-Hall of India.	2003
3.	Cussler E.L., "Diffusion: Mass Transfer in Fluid Systems", 2nd Ed., Cambridge University Press.	1997
4.	Deen W. M., " Analysis of Transport Phenomena", Oxford University Press	1998
5.	Brodkey R. S. and Hershey H. C., "Basic Concepts of Transport Phenomena", Vol. 1 and 2, Brodkey Publishing.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-202** Course Title: **Mass Transfer-I**

2. Contact Hours: **L: 2** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 3

4. Relative Weight: **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** -

5. Credits**:** 3 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-102**

9. Objective: To provide the basic knowledge of equilibrium mass transfer operations used in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Types and classification of separation processes and methods: distillation, absorption, extraction, drying, humidification, leaching, adsorption, membrane separation.	**2**
2.	**Staged Contact Operation:** Ideal stage concept; single and multi-staged operations in co-, cross- and counter- current modes for gas-liquid, liquid-liquid, and fluid-solid systems; Systems under different reflux and operating conditions, multiple stream systems, minimum ratio of gas to liquid, solvent to feed; analytical calculation of stages for simple counter current flow; Kremser-Brown-Souder equation; analytical and graphical calculation of stages at total and minimum reflux conditions. Overall tray efficiency, Murphree tray efficiency, and point efficiency.	**9**
3.	**Vapor–liquid Separation Processes:** Single stage equilibrium contact vapor liquid system; Equilibrium or flash distillation, batch or differential distillation, steam distillation; Distillation with reflux; Multistage distillation; McCabe–Thiele and Ponchon–Savarit methods; Calculation for number of theoretical stages, total and minimum reflux ratio using McCabe–Thiele method, q-line location, special cases for rectification using McCabe–Thiele method; Distillation efficiencies of tray towers.	**9**

4.	**Liquid–liquid and Liquid–solid Separation Processes:** Equipment for extraction and leaching processes; Single-stage liquid–liquid extraction and leaching; Single stage liquid -liquid extraction; Design of perforated plate extraction towers. Continuous multistage countercurrent extraction and leaching processes, countercurrent-stage extraction with immiscible liquids.	**8**
	Total	**28**

12. List of Practicals:

1. Batch Distillation
2. Steam Distillation
3. Liquid-liquid Extraction
4. Solid-liquid Leaching
5. Distillation in Packed Bed
6. Vapour-liquid Equilibrium
7. Partial Molar volume
8. Sieve Plate Distillation

12. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", CRC Press.	2007
2.	Treybal R.E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
3.	Brown G. G. and Associates, "Unit Operations", CBS Publishers.	1995
4.	McCabe W.L., Smith J.C. and Harriott P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw Hill.	2001
5.	Foust A. S., Wenzel L. A., Clump C. W., Maus L. and Andersen L. B., "Principles of Unit Operations", 2nd Ed., Wiley-India.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-204** Course Title: **Reaction Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 4/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 4

4. Relative Weight: **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** -

5. Credits**:** 5 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-102 and CH-106**

9. Objective: To provide the comprehensive knowledge of reaction engineering and chemical reactors.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction** : Review of rate equations	2
2.	**Ideal Reactors:** Design equations for ideal reactors, namely batch, CSTR, plug Flow	4
3.	**Design for Single Reaction:** Design equation for single reaction systems using batch- and semi batch- reactors, CSTR, PFR and recycle reactor, auto catalytic reactions, reactor choice for single reaction.	7
4.	**Design for Multiple Reactions:** Parallel and series reactions, quantitative treatment of product distribution and of reactor size for different types of ideal reactors, selectivity and yield factors, reactor choice for multiple reactions.	6
5.	**Non-isothermal Operation and Stability of Reactors:** Non-isothermal design of ideal reactors, hot spot in tubular reactor, auto-thermal process, steady state multiplicity optimal temperature progression for first order reversible reaction.	5
6.	**Non-ideal Flow:** Residence time distribution **(**RTD) theory, role of RTD in determining reactor behavior, age distribution (E) of fluid, experimental methods for finding E, relationship between E and F curve, models for non ideal flow – single parameter and multi parameter models (axial dispersion, tanks in series), performance estimation of reactor using reactor models.	8
7.	**Solid and Catalytic Reactions:** Solid reactions-shrinking core model, catalytic reactions-homogeneous and heterogeneous**,** steps in solid catalyzed reaction, rate limiting steps, effect of external resistance, effect of diffusion on reaction, Thiele	10

	modulus and effectiveness factor, performance equations for catalytic reactors (packed bed, fluidized bed), product distribution in multiple reactions, basic equations for trickle bed and moving bed reactors.	
	Total	**42**

11.List of Practicals:

1. Isothermal Batch Reactor
2. Isothermal Semi-batch Reactor
3. Isothermal Stirred Tank Reactor
4. Cascade of Continuous Stirred Tank Reactor (CSTR)
5. Plug Flow Reactor (PFR)
6. R.T.D. Studies in a Packed Bed Reactor
7. Decomposition of $CaCO_3$

12**. Suggested Books:**

S. No.	Name of Books / Authors	Year of Publication
1.	Fogler H.S., "Elements of Chemical Reaction Engg." 4th Ed., Prentice Hall of India.	2010
2.	Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., Wiley-INDIA	2008
3.	Butt, J.B., " Reaction Kinetics and Reactor Design" 2nd Ed., CRC Press	2000
4.	Froment G.F., Bischoff K.B., De Wilde J.D., " Chemical Reactor Analysis and Design", 3rd Ed., John Wiley & Sons, Inc.	2011
5.	Doraiswamy, L.K. and Uner, D., "Chemical Reaction Engineering: Beyond the Fundamentals", CRC Press	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CH-301** Course Title: **Mass Transfer-II**

2. Contact Hours: **L: 3** **T: 1** **P: 3/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 3

4. Relative Weight: **CWS** 15 **PRS** 15 15 40 15

5. Credits**:** 5 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-202 and CH-207**

9. Objective: To provide the basic knowledge of diffusional mass transfer operations used in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Diffusion Phenomena and Interphase Mass Transport:** Molecular diffusion in fluids and solids, Knudsen diffusion, multicomponent diffusion and effective diffusivity; Mass transfer coefficients-individual and overall, mass transfer theories-film, penetration and surface renewal.	**8**
2.	**Continuous Contact Operation:** Application of diffusion phenomena in distillation, absorption and extraction; Concept of NTU and HTU, evaluation of NTU for dilute and concentrated systems, approximate expressions for NTU. Typical procedure for solution of absorption, extraction and distillation in packed columns.	**8**
3.	**Simultaneous Heat and Mass Transfer:** Humidification and drying- introduction and concepts; Design of cooling towers and dehumidification systems, determination of NTU; Drying–mechanism, drying applications and equipment; Batch and continuous drying; Calculations for batch and continuous dryers.	**8**
4.	**Fluid–solid Separation Processes:** Adsorption and ion exchange: Adsorbents and ion-exchange materials; Equilibrium relations for adsorbents and ion exchange materials; Batch adsorption; Fixed bed	**8**

	adsorption, break-through curve; Design of adsorbers and ion exchangers.	
5.	**Membrane Separation Processes:** Types and classification of membrane processes; Liquid and gas permeation processes; Complete mixing and cross-flow models for gas separation by membranes; Counter- and co- current flow for gas separation using membranes; Applications of membrane separation processes.	**6**
6.	**Mass Transfer with Chemical Reaction:** Enhancement of mass transfer due to chemical reaction; Gas-liquid reactions in agitated tanks; Determination of interfacial area and mass transfer coefficient.	**4**
	Total	**42**

11.List of Practicals:

1. Diffusion of Vapors in Air
2. Batch Drier
3. Rotary Drier
4. Cooling Tower
5. Wetted-wall Column
6. Absorption in Sieve Plate Column
7. Fluidized Bed Drier
8. Batch Adsorption Isotherm
9. Batch Adsorption Kinetics
10. Adsorption Breakthrough Curve Modeling

12. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", CRC Press.	2007
2.	Treybal R.E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
3.	Brown G. G. and Associates, "Unit Operations", CBS Publishers.	1995
4.	McCabe W.L., Smith J.C. and Harriott P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw Hill.	2001
5.	Wankat P. C., "Separation Process Engineering", 2nd Ed., Prentice Hall.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electrical Engineering**

1. Subject Code: **EEN-112** Course Title: **Electrical Science**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**

4. Relative Weight**:** **CWS: 15** **PRS: 15** **MTE: 30** **ETE: 40** **PRE: 0**

5. Credits**: 4** 6. Semester**: Both** 7. Subject Area**: ESC**

8. Pre-requisite**: NIL**

9. Objective: To introduce the students to the fundamentals of Electrical Engineering concepts of network analysis, principles of electrical machines, basics of electrical measurement and measuring instruments.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Energy Resources and Utilization:** Conventional and non-conventional energy resources; Introduction to electrical energy generation from different resources, transmission, distribution and utilization.	**5**
2.	**Network Fundamentals**: Types of Sources and elements, Kirchoff's Laws, Mesh and Node Analysis of D.C. Networks, Network Theorems: Thevenin's Theorem, Norton's Theorem, Superposition Theorem, Maximum Power Theorem, Star-Delta Transformation.	**5**
3.	**A.C. Fundamentals**: Concept of phasor, impedance and admittance; Mesh and Node analysis of AC networks; Network theorems in AC networks; Active and reactive power in AC circuits; Resonance in series AC circuits; Power factor correction.	**4**
4.	**Three-phase A.C. Circuits**: Analysis of 3-phase balanced start-delta circuits, Power in 3-phase Circuits.	**2**
5.	**Measurement of Electrical Quantities**: Measurement of Voltage, Current, and Power; Measurement of 3 phase power; Energy meters.	**5**
6.	**Single Phase Transformer**: Introduction to magnetic circuit concepts, Basic constructional features, operating principle, phasor diagram, equivalent circuit, voltage regulation; Eddy current and Hysteresis losses, efficiency; Open circuit and Short Circuit tests.	**5**

7.	**D.C. Machines**: Principle of operation, constructional features; Emf and torque equations; Types of excitation; Generator characteristics; Starting and speed control of D.C. motors.	**5**
8.	**AC Machines**: Three-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting and speed control; Single-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting methods.	**5**
9.	**Industrial Applications and Control: V**arious industrial loads, traction, heating, lighting; Concept of power electronic control of AC and DC motors.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Mukhopadhyaya P., Pant A.K., Kumar V. and Chittore D.S., "Elements of Electrical Science", M/s Nem Chand & Brothers.	1997
2.	Vincent Del Toro, "Electrical Engineering Fundamentals", Prentice Hall of India.	2002
3.	Dubey G. K., "Fundamentals of Electric Drives", 2nd Ed., Narosa Publishing House.	2007
4.	Alexander C.K., Sadiku M.N.O., "Fundamentals of Electric Circuits", McGraw Hill, 5th Edition.	2012
5.	Chapman, Stephen, J., "Electric Machinery Fundamentals", McGraw Hill Book Company.	1985
6.	Hughes Edward, "Electrical & Electronic Technology", Pearson Publishing, 8th edition.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-002** Course Title: **Mathematical Methods**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory : 3** **Practical : 0**
4. Relative Weightage**:** **CWS: 25** **PRS: 0** **MTE : 25** **ETE : 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: BSC**
8. Pre-requisite**: Nil**
9. Objective: To provide knowledge of essential mathematical tools applied in solving ordinary and partial differential equations, initial and boundary value problems.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Ordinary Differential Equations:** Solution of linear differential equations with constant coefficients. Euler-Cauchy equations, Solution of second order differential equations by changing dependent and independent variables. Method of variation of parameters, Introduction to series solution method.	**10**
2.	**Partial Differential Equations:** Formation of first and second order partial differential equations. Solution of first order partial differential equations: Lagrange`s equation, Four standard forms of non-linear first order equations .	**6**
3.	**Laplace Transform:** Laplace and inverse Laplace transform of some standard functions, Shifting theorems, Laplace transform of derivatives and integrals. Convolution theorem, Initial and final value theorem. Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function. Applications of Laplace transform.	**10**
4.	**Z - Transform:** Z – transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem. Application of Z- transform to solve difference equations.	**5**
5.	**Fourier series:** Trigonometric Fourier series and its convergence. Fourier series of even and odd functions. Fourier half-range series. Parseval`s identity. Complex form of Fourier series.	**5**
6.	**Fourier Transforms:** Fourier integrals, Fourier sine and cosine integrals. Fourier transform, Fourier sine and cosine transforms and their elementary properties. Convolution theorem. Application of Fourier transforms to BVP.	**6**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Kreyszig, E., "Advanced Engineering Mathematics", Johan Wiley & Sons	2011
2.	Jain, R. K. and Iyenger, S. R. K., "Advanced Engineering Mathematics", Narosa Publishing House	2009
3.	Amarnath, T., "An Elementary Course in Partial Differential Equations", Narosa Publishing House (II Edition)	2012
4.	Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications	1992
5.	Rao, K. S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. (II Edition)	2010
6.	Sneddon, I. N., " Elements of Partial Differential Equations", McGraw-Hill Book Company	1988
7.	Simmons, G. F. and Krantz, S. G., Differential Equations:Theory, Technique and Practice" , Tata McGraw-Hill Edition	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-201** Course Title: **Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical: 3**

4. Relative Weight**:** **CWS:20** **PRS:20** **MTE :20** **ETE:40** **PRE:-**

5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge about heat transfer and its processes used in Chemical Process Industries

10. Details of Course:

S. No.	Contents	Contact Hour
1.	**Introduction**: Heat transfer modes, their rate equations.	**1**
2.	**Radiation**: Mechanism of radiation and its laws, black and grey body behavior, shape factors- determination using equations and charts, relationship between shape factors, heat transfer between non-black bodies, concept of surface- and space- resistance with concept of insulated and large surfaces, use of radiation shields, radiation through absorbing and transmitting gases.	**8**
3.	**Conduction**: Use of extended surfaces, two-dimensional steady state conduction, Thermal insulation- materials for cold and hot applications and thickness calculations, introduction to transient conduction, Biot number, use of Heisler charts.	**6**
4.	**Convection**: Concept and significance of boundary layer, boundary layer similarity and analogy, convection coefficients, free and forced convection, empirical correlations- internal and external flows.	**6**
5.	**Heat Exchangers**: Types and selection, overall heat transfer coefficient, parallel and counter current flow, LMTD, F_T correction factor, analysis and design using effectiveness-NTU method.	**4**
6.	**Boiling**: Characteristics, nucleate pool- and forced convection-boiling, boiling mechanism and curve, heat transfer correlations, heat pipes.	**4**
7.	**Condensation**: Mechanism and types of condensation of vapor with and without non-condensable gases, Nusselt equation for film wise condensation on vertical surfaces and its extension to inclined and horizontal surfaces and tubes, condensation number,	**5**

	film condensation inside horizontal tube.	
8.	**Evaporator**: Classification and use of evaporators in process industries, effect of boiling point rise and hydrostatic head on evaporator performance, liquor flow sequences, calculations for multiple effect evaporator system.	**4**
9.	**Crystallization**: Mechanism, crystallization from mixed solutes, particle size distribution of crystals and parameters effecting it, some major types of crystallizers, crystallizer calculations.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/ Publisher	Year of Publication
1.	Holman J.P., " Heat Transfer", 10th Ed., McGraw Hill	2009
2.	Bergman T.L., Lavine A.S., Incropera F.P. and DeWitt D.P., "Introduction to Heat Transfer", 6th Ed., Wiley	2011
3.	Cengel Y.A. and Ghajar A.J., "Heat and Mass Transfer: Fundamentals and Applications", 4th Ed., McGraw Hill	2010
4.	Kreith F., Manglik R.M. and Bohn M., "Principles of Heat Transfer", 7th Ed., Cengage Learning	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-203** Course Title: **Mechanical Operations**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical:2**

4. Relative Weight**: CWS:20** **PRS:20** **MTE:20** **ETE:40** **PRE:0**

5. Credits**:4** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite: **Nil**

9. Objective: To impart Knowledge on particle size analysis, size reduction, separation of solid particles from fluids and flow through porous media.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Particles Size Analysis:** Sieve analysis, size distribution, size averaging and equivalence, size estimation in sub-sieve range, effectiveness of screen.	**4**
2.	**Size Reduction:** Theory of crushing and grinding, laws of crushing and grinding, crushing and grinding equipment and their selection.	**4**
3.	**Storage of Solids:** Angle of slide and repose, design of bins, silos, and hoppers, Jansen's equation.	**4**
4.	**Particle Mechanics:** Motion of particle in fluid, effect of particle shape, Stoke's law, hindered settling, jigging and classification.	**4**
5.	**Sedimentation and Flotation:** Gravity and centrifugal sedimentation, design of sedimentation tank and continuous thickeners, mechanism of flotation, flotation agents and flotation equipment.	**6**
6.	**Flow Through Packed Beds:** Characteristics of packings, flow of a single fluid through a packed bed, problem of channeling and wetting, counter current gas- liquid flow through packed beds, loading and flooding characteristics, industrial applications.	**6**
7.	**Fluidization:** Fluidization characteristics, aggregative and particulate fluidization, voidage and minimum fluidization velocity, viodage correlation, liquid-solid and gas-solid fluidization characteristics, industrial applications of fluidization.	**5**
8.	**Filtration:** Flow through filter cake and medium, washing and drying of cake, filter aids, selection of filtration equipment, constant rate and constant pressure filtration.	**5**
9.	**Conveying of Solids:** Pneumatic and hydraulic conveying of solids, general characteristics and flow relations, mechanical conveyers.	**4**
	Total	**42**

11. Suggested books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication
1.	Backhurst and Harker ,"Coulson and Richardson Chemical Engineering", Vol. II",5th Ed., Butterworth-Heinemann.	2002
2.	Brown G.G. and Associates,"Unit Operations",CBS Publishers.	1995
3.	McCabe W.L., Smith J.C and Harriott P., "Unit Operations of Chemical Engineering", 7th Ed. , McGraw Hill.	2005
4.	Geankoplis C.J., Transport Processes and Separation Process Principles, 4th Ed.,Prentice Hall.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-205** Course Title: **Chemical Engineering Thermodynamics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory: 3** **Practical:0**
4. Relative Weight**:** **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: DCC**
8. Pre-requisite**:** **CHN-106**
9. Objective: To apply the laws of thermodynamics in solving problems related to flow processes and phase equilibrium of heterogeneous and reacting systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review:** Laws of thermodynamics, PVT behavior of fluids – Gibb's phase rule, cubic equations of state and generalized correlations.	2
2.	**Thermodynamic Properties of Homogeneous Fluids:** Fundamental property relations, Maxwell's relations, Residual properties and their estimation, two phase systems, thermodynamic diagrams and tables, generalized property correlation for gases.	7
3.	**Thermodynamic Properties of Mixtures or Solutions:** Property relationships for systems of variable composition; chemical potential, partial molar properties, fugacity and fugacity coefficients – pure species and species in a mixture, fugacity in ideal solutions, activity coefficients, excess properties.	7
4.	**Applications of Solution Thermodynamics:** VLE-qualitative behavior, Duhem's theorem, simple models for VLE (Raoult's law, modified Raoult's law, etc.). Liquid properties from VLE. Activity coefficients from experimental data – Margules, Van-Laar, and Wilson equations. Property changes of mixing, heat effects in mixing processes.	8
5.	**Phase Equilibria:** Importance of phase equilibria in process industries, equilibrium and stability, vapour-liquid equilibria (VLE) for miscible, partially miscible and immiscible systems, their phase diagrams, azeotropes. VLE calculations at low and high pressures, analysis of multi-component, multiphase systems.	6
6.	**Chemical Reaction Equilibria:** Reaction coordinate, application of equilibrium criteria to chemical reactions, standard Gibbs energy change and the equilibrium constant, effect of temperature on equilibrium constant, evaluation of equilibrium constant and composition. Calculation of equilibrium compositions for single reactions; Phase rule and Duhem's theorem for reacting systems.	6
7.	**Thermodynamic Analysis of Processes:** Work and free energy, availability, analysis of mixing, separation processes, heat exchange, lost work calculations.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
2	Sandler S.I. "Chemical, Biochemical and Engineering Thermodynamics", 4th Ed., John Wiley.	2006
3	Kyle B.G., "Chemical and Process Thermodynamics", 3rd ed., Prentice Hall.	1999
4	Narayanan, K.V., "Chemical Engineering Thermodynamics", Prentice Hall.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-207** Course Title: **Transport Phenomena**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory: 3** **Practical:0**
4. Relative Weight**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**:4** 6. Semester**: Autumn** 7. Subject Area**: DCC**
8. Pre-requisite**: CHN-104**
9. Objective: To provide knowledge of momentum, heat and mass transport in Chemical engineering systems.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**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. Estimation of transport coefficients and temperature/pressure dependence.	**8**
2.	**Non-Newtonian Fluids:** Time independent, time-dependent and viscoelastic fluids, constitutive equations and rheological characteristics.	**4**
3.	**Equations of Change Under Laminar Flow Conditions:** Equation of continuity, motion, mechanical energy, energy and mass transport. Simple shell balance method for momentum, heat, and mass transport, velocity distribution in circular conduits and parallel plates. Generalized form of equations and simplifications.	**8**
4.	**Turbulence Phenomena:** Basic theory of turbulence, time averaging, intensity and correlation coefficients, isotropic turbulence. Equations of continuity, motion and energy for turbulent condition. Reynolds stresses. Phenomenological theories of turbulence, velocity profile in circular conduits. Temperature distribution in turbulent flow.	**7**
5.	**Methods of Analysis of Transport Problems:** General integral balance using macroscopic concepts, integral balance for mass, momentum, energy and mechanical energy.	**5**
6.	**Convective Transport:** Free and forced convective heat transfer and mass transfer.	**4**
7.	**Transport Past Immersed Bodies**: Laminar and turbulent boundary layers, Momentum, heat and mass transfer during boundary layer flow past a flat plate and flow over a sphere. Drag coefficient correlations.	**6**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., John Wiley & Sons, Inc.	2002
2.	Geankoplis C.J., "Transport Processes ans Separation Process Principles includes Unit Operations", 4th Ed., Prentice-Hall of India.	2003
3.	Cussler E.L., "Diffusion: Mass Transfer in Fluid Systems", 2nd Ed., Cambridge University Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-202** Course Title: **Mass Transfer-I**
2. Contact Hours: **L: 2** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): **Theory :2** **Practical :3**
4. Relative Weight**: CWS: 20** **PRS:20** **MTE:20** **ETE:40** **PRE:00**
5. Credits**:3** 6. Semester**: Spring** 7. Subject Area**: DCC**
8. Pre-requisite**: CHN-102**
9. Objective: To provide the basic knowledge of equilibrium mass transfer operations used in process industries.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Types and classification of separation processes and methods: distillation, absorption, extraction, drying, humidification, leaching, adsorption, membrane separation.	**2**
2.	**Staged Contact Operation:** Ideal stage concept; single and multi-staged operations in co-, cross- and counter- current modes for gas-liquid, liquid-liquid, and fluid-solid systems; Systems under different reflux and operating conditions, multiple stream systems, minimum ratio of gas to liquid, solvent to feed; analytical calculation of stages for simple counter current flow; Kremser-Brown-Souder equation; analytical and graphical calculation of stages at total and minimum reflux conditions. Overall tray efficiency, Murphree tray efficiency, and point efficiency.	**9**
3.	**Vapor–liquid Separation Processes:** Single stage equilibrium contact vapor liquid system; Equilibrium or flash distillation, batch or differential distillation, steam distillation; Distillation with reflux; Multistage distillation; McCabe–Thiele and Ponchon–Savarit methods; Calculation for number of theoretical stages, total and minimum reflux ratio using McCabe–Thiele method, q-line location, special cases for rectification using McCabe–Thiele method; Distillation efficiencies of tray towers.	**9**
4.	**Liquid–liquid and Liquid–solid Separation Processes:** Equipment for extraction and leaching processes; Single-stage liquid–liquid extraction and leaching; Single stage liquid -liquid extraction; Design of perforated plate extraction towers. Continuous multistage countercurrent extraction and leaching processes, countercurrent-stage extraction with immiscible liquids.	**8**
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", CRC Press.	2007
2.	Treybal R.E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
3.	Brown G. G. and Associates, "Unit Operations", CBS Publishers.	1995
4.	McCabe W.L., Smith J.C. and Harriott P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-204** Course Title: **Reaction Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 4/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical:4**

4. Relative Weight**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:00**

5. Credits**: 5** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**: CHN-102 and CHN-106**

9. Objective: To provide the comprehensive knowledge of reaction engineering and chemical reactors.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction** : Review of rate equations	**2**
2.	**Ideal Reactors:** Design equations for ideal reactors, namely batch, CSTR, plug Flow	**4**
3.	**Design for Single Reaction:** Design equation for single reaction systems using batch- and semi batch- reactors, CSTR, PFR and recycle reactor, auto catalytic reactions, reactor choice for single reaction.	**7**
4.	**Design for Multiple Reactions:** Parallel and series reactions, quantitative treatment of product distribution and of reactor size for different types of ideal reactors, selectivity and yield factors, reactor choice for multiple reactions.	**6**
5.	**Non-isothermal Operation and Stability of Reactors:** Non-isothermal design of ideal reactors, hot spot in tubular reactor, auto-thermal process, steady state multiplicity optimal temperature progression for first order reversible reaction.	**5**
6.	**Non-ideal Flow:** Residence time distribution **(**RTD) theory, role of RTD in determining reactor behavior, age distribution (E) of fluid, experimental methods for finding E, relationship between E and F curve, models for non ideal flow – single parameter and multi parameter models (axial dispersion, tanks in series), performance estimation of reactor using reactor models.	**8**
7.	**Solid and Catalytic Reactions:** Solid reactions-shrinking core model, catalytic reactions-homogeneous and heterogeneous**,** steps in solid catalyzed reaction, rate limiting steps, effect of external resistance, effect of diffusion on reaction, Thiele modulus and effectiveness factor, performance equations for catalytic reactors (packed bed, fluidized bed), product distribution in multiple reactions, basic equations for trickle bed and moving bed reactors.	**10**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Fogler H.S., "Elements of Chemical Reaction Engg." 4th Ed., Prentice Hall of India.	2010
2.	Levenspiel O., "Chemical Reaction Enginering", 3rd Ed., Wiley-INDIA	2008
3.	Butt, J.B., " Reaction Kinetics and Reactor Design" 2nd Ed., CRC Press	2000
4.	Froment G.F., Bischoff K.B., De Wilde J.D., " Chemical Reactor Analysis and Design", 3rd Ed., John Wiley & Sons, Inc.	2011
5.	Doraiswamy, L.K. and Uner, D., "Chemical Reaction Engineering: Beyond the Fundamentals", CRC Press	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-206** Course Title: **Chemical Technology**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory:3** **Practical: 0**
4. Relative Weight**:** **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**:3** 6. Semester**: Spring** 7. Subject Area**: DCC**
8. Pre-requisite**:** **Nil**
9. Objective: To study process technology, availability of raw materials, production trends, preparation of flow sheets, engineering and environmental problems of various chemical industries.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Introduction:** Overview of chemical process industries	**2**
2.	**Coal and Industrial Gases:** Coal and coal chemicals, syn gas, nitrogen, oxygen, hydrogen and carbon dioxide.	**6**
3.	**Nitrogeneous and Phosphatic Fertlisers:** Ammonia, nitric acid, nitrogenous fertilisers, sulphuric acid, phosphoric acid, phosphatic fertilisers and mixed fertilisers.	**7**
4.	**Chlor-Alkali Industries:** Common salt, caustic soda, chlorine, hydrochloric acid and soda ash.	**3**
5.	**Pulp and Paper:** Raw materials**,** pulping processes, recovery of chemicals, stock preparation and paper making.	**3**
6.	**Petroleum Industry:** Origin, occurrence and characteristics of crude oil, crude oil distillation, residue upgradation and secondary conversion processes.	**7**
7.	**Petrochemicals:** Olefin and aromatic production, methanol, formaldehyde, ethylene oxide, ethylene glycol**,** acetaldehyde, acetic acid, propylene oxide, propylene glycol, acrylonitrile, maleic anhydride, butadiene, nitrobenzene, styrene, linear alkyl benzene, phenol and bis- phenol.	**8**
8.	**Polymer and Synthetic Fibre:** Introduction to polymers, polyethylene, polypropylene, polyvinyl chloride, styrene butadiene rubber, polybutadiene, polyester, polyamide, acrylic fibre and viscose rayon.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Book / Authors / Publisher	Year of Publication
1.	Austin G. T., "Shreve's Chemical Process Industries", Fifth edition, Tata McGraw Hill, NY.	1984
2	Kent J.A., "Riegel's Handbook of Industrial Chemistry," **CBS** Publishers.	1997
3.	Gopala Rao M. & Marshall Sittig, "Dryden's Outlines of Chemical Technology for the 21st Century", Affiliated East –West Press, New Delhi.	2002
4.	Mall I. D., "Petrochemical Process Technology", Macmillan India Ltd., New Delhi.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Department of Chemical Engineering**

1. Subject Code: **CHN-291** Course Title: **Equipment Design***

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory:4** **Practical:0**

4. Relative Weight**: CWS:15** **PRS:25** **MTE:20** **ETE:40** **PRE:0**

5. Credits**:4** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge about mechanical design of chemical process equipments.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Mechanics of Materials:** Stress, strain, biaxial stress, stress-strain relationship for elastic bodies, theories of failure, thermal stresses, membrane stresses in shells of revolution, thin and thick cylinder.	**08**
2.	**Pressure Vessel:** Selection of type of vessels, material of construction selection and design considerations. Introduction of codes for pressure vessel design, classification of pressure vessels as per codes. Design of cylindrical and spherical shells under internal and external pressure; Pipe thickness calculation under internal and external pressure; Selection and design of closures and heads, design of jacketed portion of vessels. Compensation of openings. Design of high pressure monoblock and multilayer vessels. Inspection and testing of pressure vessels.	**13**
3.	**Flanges:** Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges.	**05**
4.	**Tall Tower Design:** Design of shell, skirt, bearing-plate and anchor bolts for tall tower used at high wind and seismic conditions.	**06**
5.	**Supports:** Design of lug and leg supports. Design of saddle supports including bearing plates and anchor bolts.	**04**
6.	**Storage Tanks:** Introduction to Indian standards codes**,** filling and breathing losses; classification of storage tanks; optimum length to diameter ratio, design of liquid and gas storage tanks with and without floating roof.	**06**
	Total	**42**

* Note: This is an OPEN BOOK EXAMINATION. The students are allowed to consult IS Codes, Text books, Reference books and bound lecture notes certified by the examiner concerned

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Brownell L. E. and Young H. E., “Process Equipment Design”, John Wiley.	2004
2.	Bhattacharya B. C., “Introduction of Chemical Equipment Design”, CBS Publisher.	2003
3.	I.S.:2825-1969, “Code for Unfired Pressure Vessels”.	1969
4.	I.S.:803-1974, “Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks”.	1984
5.	Moss D. R., ”Pressure Vessel Design Manual”, 3rd Ed., Gulf	2004
6.	Megyesy E.F., "Pressure Vessel Handbook", 12th Ed., Pressure Vessel Publishing.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-301** Course Title: **Mass Transfer-II**

2. Contact Hours: **L: 3** **T: 1** **P: 3/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical :3**

4. Relative Weight**: CWS:20** **PRS: 20** **MTE:20** **ETE:40** **PRE:0**

5. Credits**: 5** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**: CHN-202 and CHN-207**

9. Objective: To provide the basic knowledge of diffusional mass transfer operations used in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Diffusion Phenomena and Interphase Mass Transport:** Molecular diffusion in fluids and solids, Knudsen diffusion, multicomponent diffusion and effective diffusivity; Mass transfer coefficients-individual and overall, mass transfer theories-film, penetration and surface renewal.	**8**
2.	**Continuous Contact Operation:** Application of diffusion phenomena in distillation, absorption and extraction; Concept of NTU and HTU, evaluation of NTU for dilute and concentrated systems, approximate expressions for NTU. Typical procedure for solution of absorption, extraction and distillation in packed columns.	**8**
3.	**Simultaneous Heat and Mass Transfer:** Humidification and drying- introduction and concepts; Design of cooling towers and dehumidification systems, determination of NTU; Drying–mechanism, drying applications and equipment; Batch and continuous drying; Calculations for batch and continuous dryers.	**8**
4.	**Fluid–solid Separation Processes:** Adsorption and ion exchange: Adsorbents and ion-exchange materials; Equilibrium relations for adsorbents and ion exchange materials; Batch adsorption; Fixed bed adsorption, break-through curve; Design of adsorbers and ion exchangers.	**8**
5.	**Membrane Separation Processes:** Types and classification of membrane processes; Liquid and gas permeation processes; Complete mixing and cross-flow models for gas separation by membranes; Counter- and co- current flow for gas separation using membranes; Applications of membrane separation processes.	**6**
6.	**Mass Transfer with Chemical Reaction:** Enhancement of mass transfer due to chemical reaction; Gas-liquid reactions in agitated tanks; Determination of interfacial area and mass transfer coefficient.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", CRC Press.	2007
2.	Treybal R.E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
3.	Brown G. G. and Associates, "Unit Operations", CBS Publishers.	1995
4.	McCabe W.L., Smith J.C. and Harriott P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-303** Course Title: **Process Dynamics & Control**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): **Theory: 3** **Practical:3**
4. Relative Weight**:** **CWS: 20** **PRS: 20** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: DCC**
8. Pre-requisite**:** **CHN-102 and CHN-207**
9. Objective: To acquaint the students about the dynamics and control strategies chemical process systems.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** The concept of process dynamics and control, review of Laplace transform methods, Laplace transform of disturbances and building functions, dynamic model building of simple systems.	**5**
2.	**Linear Open Loop System:** Physical examples of first order systems and their response for step, impulse and sinusoidal inputs, linearization of non linear models, response of first order system in series, examples of second order systems and their response, estimation of system parameters.	**8**
3.	**Linear Closed Loop System:** The control system and its elements, closed loop transfer functions, transient response of simple control systems, concept of stability and use of Routh – Hurwitz test for stability.	**8**
4.	**Controllers:** Modes of control action, control system and its closed-loop transfer function.	**3**
5.	**Root Locus Method :** Root locus treatment, response from root locus and its application to control system design.	**4**
6.	**Frequency Response:** Introduction to frequency response, Bode diagrams of simple systems, Bode stability criterion, control system design by frequency response, use of gain and phase margins.	**5**
7.	**Process Application :** Controller tuning rules, control of complex chemical processes and equipment, control valve sizing, introduction to real time computer control of process equipment.	**5**
8.	**Advanced Control Methods :** Introduction to state-space method, feed forward and ratio control, inferential control, control using digital computers-an introduction.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Coughanowr D.R. and LeBlanc S. "Process System Analysis and Control", 3rd Ed., McGraw Hill.	2008
2.	Stephanopoulos G. "Chemical Process Control – An Introduction to Theory and Practice", Prentice-Hall of India.	1990
3.	Seborg D. E., Edgar T. F. and Mellichamp D. A., "Process Dynamics Control", 2nd Ed., John Wiley.	2004
4.	Bequette B. W., "Process Control – Modeling, Design and Simulation", Prentice-Hall of India.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-305** Course Title: **Process Equipment Design***

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory: 4** **Practical: 0**

4. Relative Weight**: CWS: 15** **PRS: 25 MTE: 20** **ETE: 40** **PRE: 0**

5. Credits**:4** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**: CHN-201, CHN-202 and CHN-208**

9. Objective: To provide knowledge about process design principles of heat and mass transfer equipment involved in chemical plants.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Shell-Tube Heat Exchangers:** Basic design procedure of heat transfer equipment, overall heat transfer coefficient and fouling factors, shell & tube heat exchangers – construction details, selection algorithm, design codes, mean temperature difference, general design considerations, tube-side heat transfer coefficient and pressure drop, shell-side heat transfer coefficient and pressure drop, various design methods, CAD of shell & tube heat exchangers, mechanical and fabricational aspects. Drawing of heat exchangers.	**11**
2.	**Condensers:** Design of condensers for single vapors, heat transfer coefficient correlations for condensation inside and outside of tubes of the vertical and horizontal condensers, design of desuperheater-cum-condenser and condenser-cum-sub-cooler, condensation of mixtures, pressure drop in condensers.	**7**
3.	**Reboilers, Vaporizers and Evaporators**: Pool boiling, convective boiling, selection of reboilers, & vaporizers, design of reboilers, vaporizers and evaporators, drawing of evaporators.	**5**
4.	**Distillation Column:** Basic design consideration of distillation column, degree of freedom analysis, various design methods of distillation column, general design consideration of multicomponent distillation, plate efficiency, tray hydraulics of sieve and valve – trays. Drawing of distillation column.	**9**
5.	**Packed Columns:** Type of packing, packed bed height, column diameter, column internals, design methods, Design of liquid-liquid extraction equipment.	**6**
6.	**Miscellaneous Equipment:** Design of Crystalizers, Agitated vessels and selection of agitators, design of gas-liquid separators and mixing equipment.	**4**
		42

* Note: This is an OPEN BOOK EXAMINATION. The students are allowed to consult IS Codes, Text books, Reference books and bound lecture notes certified by the examiner concerned

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", 2nd Ed., Butterworth-Heinemann.	2012
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 & Tube Type Heat Exchangers.	1983
4.	Hewitt G.F., Shires G. L. and Bott T. R., "Process Heat Transfer", Begell House.	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Department of Chemical Engineering**

1. Subject Code: **CHN-210** Course Title: **Industrial Instrumentation**
2. Contact Hours: **L: 2** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory: 2** **Practical:0**
4. Relative Weight**: CWS:25 PRS :0 MTE:25 ETE:50 PRE:0**
5. Credits**:2** 6. Semester**: Spring** 7. Subject Area**: DCC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge about the instruments used in chemical industries and their principles.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Measurement and its classification by physical characteristics, direct and inferential measurement, on and off line measurement.	**2**
2.	**Static and Dynamic Characteristics of Instruments:** Types of errors and uncertainties in instrumentations; Static performance parameters– accuracy, repeatability, precision, threshold, sensitivity, resolution, linearity, range and span, hysteresis, dead band, drift, backlash, etc.; Dynamic characteristics of instruments– response to periodic, transient, and random signal inputs; Compensation.	**6**
3.	**Sensor and Transducers:** Classification, principles and applications.	**4**
4.	**Building Blocks of an Instrument:** Transducer, amplifier, signal conditioner, signal isolation, signal transmitter, display, data acquisition modules, I/O devices, signal convertors, interfaces.	**4**
5.	**Process Instrumentation:** Working principles, merits and demerits of transducers/instruments employed for the measurement of flow, level, force, pressure, temperature, density, viscosity, humidity, pH value, turbidity, etc.	**9**
6.	**Miscellaneous Instruments:** Indicating, transmitting and recording type instruments. Instrumentation symbols and P&ID diagrams. P&ID diagram for equipments like distillation column, heat exchange, etc.	**3**
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Dunn W.C., "Fundamentals of Industrial Instrumentation and Process Control", Tata McGraw Hill.	2009
2.	Nakra B. C. and Chaudhry K. K., "Instrumentation, Measurement and Analysis", II Ed., Tata McGraw Hill.	2004
3.	Andrew W. G., "Applied Instrumentation in the Process Industries", Vol. I, 1^{st} – 3^{rd} Ed., Gulf Publishing Company.	1993
4.	Johnson C., "Process Control Instrumentation Technology", 8^{th} Ed., Prentice Hall	2005
5.	Liptek, B.G., "Instrument Engineers' Handbook: Process Control and Optimization", Volume II, Taylor and Francis, CRC press.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-302** Course Title: **Engineering Analysis and Process Modeling**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory :3** **Practical: 0**

4. Relative Weight: **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**:4** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**:** **CH-202 and CH-207**

9. Objective: To provide the basic concepts of modeling and simulation of separation processes and reacting systems

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction :** Introduction to process modeling and simulation, tools of simulation, approaches for simulation, planning of calculation in a plant simulation.	**3**
2.	**Parameter Estimation:** Parameter estimation techniques in theoretical as well as numerical models.	**3**
3.	**Models:** Models, need of models and their classification, models based on transport phenomena principles, alternate classification of models, population balance, stochastic, and empirical models, unit models.	**10**
4.	**Models of Heat Transfer Equipment:** Development of detailed mathematical models of evaporators, use of Newton-Raphson method for solving evaporator problems.	**4**
5.	**Models of Separation Processes:** Separation of multicomponent mixtures by use of a single equilibrium stage, flash calculation under isothermal and adiabatic conditions, tridigonal formulation of component-material balances and equilibrium relationships for distillation, absorption and extraction of multicomponents, Thiele and Geddes method plus θ –method and K_b method, models of absorbers , strippers and extractors.	**12**
6.	**Models of Reactors:** Classification of fixed bed reactor models, one dimensional and two dimensional fixed bed reactor models, fluidized bed reactor models, bioreactor models.	**6**
7.	**Process Simulation:** Simulation of chemical process equipment, program development and numerical solution.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Denn M. M., "Process Modeling", Longman.	1986
2.	Holland C. D., "Fundamentals and Modeling of Separation Processes", Prentice Hall.	1975
3.	Luyben W. L., "Process Modeling Simulation and Control for Chemical Engineers", 2nd Ed., McGraw Hill.	1990
4.	Najim K., "Process Modeling and Control in Chemical Engineering", CRC.	1990
5.	Aris R., "Mathematical Modeling, Vol. 1: A Chemical Engineering Perspective (Process System Engineering)", Academic Press.	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-304** Course Title: **Process Economics and Plant Design**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical:0**

4. Relative Weight**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**:3** 6. Semester**: Spring** 7. Subject Area**: DCC**

8. Pre-requisite**: Nil**

9. Objective: To provide the fundamentals of economics, scale up methods and design strategies of plants.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Time Value of Money:** Interest; Compounding and Discounting Factors; Loan Payments; Cash Flow Pattern: Discrete Cash Flow, Continuous Cash Flow.	**3**
2.	**Methods for Calculating Profitability:** Methods that do not consider the time value of money; Methods that consider the time value of money; Alternative Investments by Different Profitability Methods; Effect of Inflation on Profitability Analysis; Methods of Profitability Evaluation for Replacements.	**6**
3.	**Depreciation**: Straight Line, Declining Balance, Double Declining Balance, sum-of-the-years-digit, Sinking Fund.	**4**
4.	**Analysis of Cost Estimates**: Factors Affecting Investment and Production Costs; Capital Investment; Types of Capital Cost Estimates; Methods for Estimating Capital Investment; Estimation of Revenue; Estimation of Total Product Cost; Gross Profit; Net Profit and Cash Flow; Contingencies.	**7**
5.	**Optimum Design and Design Strategy**: Procedure with one, two and more variables; Optimum Production Rates in Plant Operation; Case Studies; Linear Programming: Simplex Algorithm, Dynamic Programming for Optimization; Application of Lagrange Multipliers; Method of Steepest Ascent or Descent.	**10**
6.	**Plant Location and Layout:** Factors for Selection of Plant Location; Site Selection and Preparation; Plant Layout and Installation.	**4**
7.	**Scale-Up**: Pilot Plants and Models; Principle of Similarity; Dimensional Analysis; Empirical and Semi-empirical Model Building; Regime Concept: Static Regime, Dynamic Regime; Similarity Criteria and Scale Equations for Important Equipments.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Peters, M. S., Timmerhaus, K. D. and West, R. E., "Plant Design and Economics for Chemical Engineers", McGraw Hill, 5th Edition.	2002
2.	Towler, G. and Sinnott, R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann, 2nd Edition.	2012
3.	Couper, J. R., "Process Engineering Economics (Chemical Industries)", CRC Press, 1st Edition.	2003
4.	Zlokarnik, M., "Scale-up in Chemical Engineering", Wiley-VCH, 2nd Edition.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-306** Course Title: **Process Utilities & Safety**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**
4. Relative Weight**: CWS: 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits**: 3** 6. Semester**: Spring** 7. Subject Area**: DEC**
8. Pre-requisite**: Nil**
9. Objective: To provide the knowledge of the requirement of process utilities and safety aspects in the process industry.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Utilities in process industries; primary and secondary utilities, and their importance.	**2**
2.	**Heat Transfer Media:** Classification, characteristic properties, selection criteria for industrial applications.	**3**
3.	**Steam:** Steam generation, modern boilers, steam handling, condensate removal; Steam traps-classification, characteristics and selection; Condensate and flash steam utilization.	**4**
4.	**Water:** Raw water and its characteristics, treatment and conditioning for use in process industries and for boiler, cooling, etc.; Recycling and reuse of water.	**4**
5.	**Air:** Use of air in process industries for conveying, drying and instrumentation; design of air receivers.	**3**
6.	**Piping Network:** Design of pipelines (sizing) and piping networks for water, steam, condensate and air.	**4**
7.	**Process Safety:** Process safety, accident and loss statistics, nature of the accident/hazardous processes; Hazardous Substance classification and Hazardous Substance Rules, 1986; Factories Act 1949.	**5**
8.	**Toxicology:** Toxic materials, dose-response relationships and predictive models for response; Threshold dose concentration and its definition. Material safety data sheet and industrial hygiene evaluation.	**5**
9.	**Source models and Dispersion:** Source models for liquids and vapors, Dispersion, Ventilation and dispersion for toxic releases.	**3**
10.	**Fire and Explosion:** Flammability characteristics, fire and explosion, Ignition sources and static electricity. Preventing fires and explosions by inerting. purging, ventilation, sprinkler systems, etc.; Prevention of static electricity hazards.	**6**
11.	**Prevention and Control for Safety:** Relief's – classification and selection for vapour/gas, liquid and run-away reaction services.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Geiringer P. L., "Handbook of Heat Transfer Media", Reinhold Publishing Corporation.	1977
2.	Goodall P. M., "The Efficient Use of Steam", Editor: Westbury House.	1980
3.	Lorch, "Handbook of Water Purification", Editor: McGraw Hill Book Company.	1981
4.	Crowl D. A. and Louvar J. F., "Chemical Process Safety: Fundamentals with Applications", 2nd Ed., Prentice Hall.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **DEPARTMENT OF CIVIL ENGINEERING**

1. Subject code: **CEN-105** Course Title: **Introduction to Environmental Studies**
2. Contact Hours: **L: 3 T: 0 P: 0**
3. Examination Duration (Hrs): **Theory:** 3 **Practical:** 0
4. Relative Weightage: **CWS:** 15 **PRS:** 0 **MTE:** 35 **ETE:** 50 **PRE:** 00
5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **GSC**
8. Pre-requisite: **Nil**
9. Objective: To introduce fundamentals of environmental pollution and its control.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Overview: Environment and Natural Processes; Development (Resource Utilization & Waste G eneration); Environmental issues; Concept of Sustainable D evelopment; Issues affecting f uture development (population, urbanization, health, water scarcity, energy, climate change, toxic chemicals, finite resources etc.); Environmental units	6
2.	Air –Water i nteraction: (Liquid ph ase-gas pha se e quilibrium) H enry's Law Constant with units, Dimensionless Henry's Law Constant	3
3.	Water –Soil I nteraction: Carbonate S ystem (Alkalinity a nd buffering capacity); Major ions in water; Natural Organic Matter (NOMs); Water quality parameters; Physical processes (Mass Balance): Spatio-temporal variation i n qua lity of r iver w ater, l ake w ater, gr ound water; Water quality standards	9
4.	Wetlands, water treatment and wastewater treatment .	6
5.	Air resources: Atmosphere; Air pollutants; Emissions and control of air pollutants; Atmospheric meteorology and dispersion; Transport of air (global, r egional, lo cal); A ir/ a tmospheric stability; P lume sha pe; Gaussian modeling; Air quality standards	9
6.	Land pollution and solid waste management	3
7.	Ecosystem: Structure and function; Energy flow in ecosystem; Material flow in ecosystem; Biodiversity and ecosystem health; Bio-amplification and bio-magnification	3
8.	Hazardous Waste: Definition; Classification; Storage and management; Site remediation; Environmental Risk: assessment, and management	3
Total		**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Davis M . L . a nd C ornwell D . A ., " Introduction to E nvironmental Engineering", McGraw Hill, New York 4/e	2008
2.	Masters G . M., Joseph K . a nd N agendran R . "Introduction t o Environmental E ngineering a nd S cience", P earson E ducation, New Delhi. 2/e	2007
3.	Peavy H. S., R owe D.R. and T chobanoglous G., "Environmental Engineering", McGraw Hill, New York	1986
4.	Mines R . O. and L ackey L . W. "" Introduction t o Environmental Engineering", Prentice Hall, New Yark	2009
5.	Miheicic J. R . a nd Z immerman J . B . " E nvironmental E ngineering: Fundamentals, Sustainability, Design" John Wiley and Sons, Inc.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities & Social Sciences**

1. Subject Code: **HS-001A** Course Title: **Communication Skills (Basic)**

2. Contact Hours: **L: 1** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 00 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 2 6. Semester: **Autumn/Spring** 7. Subject Area: **HSS**

8. Pre-requisite: **NIL**

9. Objective:
The course intends to build the required communication skills of the students having limited communicative abilities, so that they may communicate effectively in real-life situations

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Understanding the Basics of Communication Skills: Listening, Speaking, Reading & Writing, Scope and Importance	**01**
2.	Grammar & Composition: Time and Tense, Agreement, Active-Passive, Narration, Use of Determiners, Prepositions & Phrasal Verbs	**05**
3.	Vocabulary Building & Writing: Word-formation, Synonyms, Antonyms, Homonyms, One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words	**02**
4.	Introduction to Sounds (Vowels & Consonants) Organs of Speech, Place and Manner of Articulation, Stress & Intonation, Listening Comprehension (Practical Sessions in Language Laboratory)	**02**

5.	Speaking, Countering Stage-fright and Related Barriers to Communication.	**02**
6.	Reading and Comprehension: Two lessons to be identified by the department.	**02**
	Total	**14**

List of Practicals:

1. Ice-breaking Exercises
2. Assignments on Time and Tense, Agreement, Active-Passive
3. Laboratory Session on Narration, Use of Determiners, Prepositions & Phrasal Verbs, Revisionary Exercises & Quiz
4. Laboratory Session on Synonyms, Antonyms, Homonyms
5. Assignments and Practice Sheets on One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words
6. Laboratory Session on Practice of sounds, Intonation and Stress, Listening Comprehension
7. Individual presentation, debates, Extempore & Turncoats
8. Exercises in Composition and Comprehension

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Murphy, Raymond. *Intermediate English Grammar*, New Delhi, Cambridge University Press.	**2009**
2.	Quirk, Randolph & Sidney Greenbaum. *A University Grammar of English*, New Delhi, Pearson.	**2009**
3.	McCarthy, Michael & Felicity O' Dell. *English Vocabulary in Use*, New Delhi, Cambridge University Press	**2010**
4.	Jones, Daniel. *The Pronunciation of English*, New Delhi, Universal Book Stall.	**2010**
5.	Birchfield, Susan M. *Fowler's Modern English Usage*, New Delhi, OUP.	**2004**
6.	Llyod, Susan M. *Roget's Thesaurus of English Words and Phrases.* New Delhi: Penguin.	**2010**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities & Social Sciences**

1. Subject Code: **HS-001B** Course Title: **Communication Skills (Advanced)**

2. Contact Hours: **L: 1** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 00 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 2 6. Semester: **Autumn/Spring** 7. Subject Area: **HSS**

8. Pre-requisite: **NIL**

9. Objective: The course intends to train the learners in using both verbal and non-verbal communication effectively.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Advanced Communication Skills: Scope, Relevance, & Importance	01
2.	Soft Skills: Interpersonal Communication; Verbal & Non-verbal, Persuasion, Negotiation, Neuro-Linguistic Programming	03
3.	Communication and Media (Social and Popular), The Social and Political Context of Communication, Recent Developments and Current Debates in Media	04
4.	Cross-cultural and Global Issues in Communication: Race, Ethnicity, Gender & Diaspora	03
5.	Rhetoric and Public Communication, Audience Awareness, Emotionality	03
	Total	14

List of Experiments:

1. Discussion on the Process of Communication in Personal and Professional Life
2. Group Discussion, Case Studies and Role-Play
3. Assignments on E-mail Etiquette, Social Networking, Blog Writing, Discussions on Current Issues
4. Non-Verbal Communication in Cross-Cultural Situations, Case Studies, Group Discussions and Readings on Topics Related to Race, Ethnicity , Gender and Diaspora
5. Individual Presentations (Audience Awareness, Delivery and Content of Presentation)

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Rentz, Kathryn, Marie E. Flatley & Paula Lentz. *Lesikar's Business Communication CONNECTING IH A DIGITAL WORLD*, McGraw-Hill, Irwin	**2012**
2.	Bovee, Courtland L & John V. Thill. *Business Communication Today*. New Delhi, Pearson Education	**2010**
3.	McMurrey, David A. & Joanne Buckley. *Handbook for Technical Writing*, New Delhi, Cengage Learning.	**2009**
4.	Jones, Daniel. *The Pronunciation of English*, New Delhi, Universal Book Stall.	**2010**
5.	Allan & Barbara Pease. *The Definitive Book of Body Language,* New York, Bantam	**2004**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities and Social Sciences**

1. Subject Code: **HSN-002** Course Title: **Ethics and Self-awareness**

2. Contact Hours: **L: 01** **T: 0 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 2** **Practical 0**

4.Relative Weight**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credit **02** 6. Semester**: Autumn** 7. Subject Area**: HSSC**

8. Pre-requisite**: NIL**

9. Objective: To introduce the concepts pertaining to ethical and moral reasoning and action and to develop self - awareness.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Definition of Ethics; Approaches to Ethics: Psychological, Philosophical, Social.	**1**
2	**Psycho-social theories of moral development**: View of Kohlberg; Morality and Ideology, Culture and Morality, Morality in everyday context.	**3**
3	**Ethical Concerns**: Work Ethics and Work Values, Business Ethics, Human values in organizations.	**3**
4	**Self-Awareness**: Self Concept: Johari Window, Self and Culture, Self Knowledge, Self-Esteem; Perceived Self-control, Self-serving bias, Self-presentation, Self-growth: Transactional Analysis and Life Scripts.	**4**
5.	**Self Development**: Character strengths and virtues, Emotional intelligence, Social intelligence, Positive cognitive states and processes (Self-efficacy, Empathy, Gratitude, Compassion, and Forgiveness).	**3**
	Total	**14**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication
1.	Hall, Calvin S., Lindzey, Dardner., & Cambell, John B.,"Theories of Personality",Hamilton Printing Company.	1998
2.	Car Alan, "Positive Psychology: The Science of Happiness and Human Strengths", Brunner-Routledge.	2004
3.	Leary M.R., "The Curse of Self: Self-awareness, Egotism and the Quality of Human Life", Oxford University Press.	2004
4.	Louis P. P., "The Moral Life: An Introductory Reader in Ethics and Literature", Oxford University Press.	2007
5.	Corey, G., Schneider Corey, M., & Callanan, P., "Issues and Ethics in the Helping Professions", Brooks/Cole.	2011
6.	Snyder, C.R., Lopez, Shane, J., & Pedrotti, J.T., "Positive Psychology" Sage, 2nd edition.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-101** Course Title: **Introduction to Chemical Engineering**

2. Contact Hours: **L: 2** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **0** **Practical** **0**

4. Relative Weightage**: CWS** **0** **PRS** **0** **MTE** **0** **ETE** **100** **PRE** **0**

5. Credits**:** **2** 6. Semester**: Autumn** 7. Subject Area**: DCC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce the basic features and concepts of Chemical Engineering to the students.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction:** Framework of chemical industry and its classification, production routes, concepts of synthesis and segmentation, definition of chemical engineering, historical perspective and contribution; job description and attributes of a chemical engineer, chemical engineering and its seamless integration with other sciences and engineering disciplines; Societal needs and life cycle of technology, market forces; Economic scale of production; Waste utilization and recycle, sustainable technology, process integration and intensification; Employment opportunities , knowledge resources and software tools; Frontiers & future roadmap ; Challenges of chemical engineering practice- safety, economics, ethics, regulation and IP.	**7**
2.	**Chemical Process Industries**: Evolution of chemical industries, Technological developments in major challenges; Chemical industries structure and segments of chemical industry, raw material and production pattern; Basic principles of chemical processes, unit processes and unit operations and various routes to produce chemicals; Petroleum, petrochemical and fertilizer industry integration; Cleaner and greener technologies.	**7**
3.	**Basic Tools of Chemical Engineering:** Physico-chemical and biological sciences; Mathematics and computation; Thermodynamics and kinetics, Material and Energy balances; Transport phenomena; Equilibrium and rate based processes; Reaction engineering and reactors; Various transport processes; Efficiency and economics of processes. Measuring instruments, automation and control, concept of scale-up- lab to industrial, nano to terrestrial; Dimensional analysis and semi-empiricis; Degree of freedom analysis; Concept of design, modelling and simulation.	**8**
4.	**Applications of Various tools and Examples:** Flash unit and blending system;	**6**

	Coal combustion and gasification; Boiler and steam generation; Biomethanation and alcohol production; Petroleum fractionation and petrochemicals; Chemical vapour deposition; Nano-devices and drug delivery systems; Accidents and safety; Web-based learning and educational videos of refineries, petrochemical plants and fertilizer units; Important developments and milestones in chemical engineering.	
	Total	**28**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Denn Morton M., "Chemical Engineering; An Introduction", Cambridge, University Press.	2012
2.	Himmelblau D.M. and Riggs J.B., **"**Basic Principles and Calculations in Chemical Engineering". 7th Edition., Prentice Hall.	2003
3.	Austin G.T., "Shreve's chemical process industries", McGraw-Hill Book Company, 5^{TH} Edition.	1984
4.	Groggins, P.H., "Unit processes in organic synthesis", Tata McGraw Hill Education Private Limited, 5th Edition.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-103** Course Title: **Computer Programming and Numerical Analysis**

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **15** **PRS** **15** **MTE** **30** **ETE** **40** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: ESC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce object oriented programming using C++ language and numerical analysis

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Computer Fundamentals:** Introduction to computer systems - CPU organization, ALU, registers, memory and input-output devices; Number system: binary and hexadecimal; Fixed and Floating point numbers; Errors and Approximations	**4**
2.	**Basic Programming in C++:** Concepts of algorithm & flow charts; Input/output, constants, variables, expressions and operators; Naming conventions and styles; Conditions and selection statements; Looping and control structures; File input/output, header files, string processing; Preprocessor directives such as #include, #define, #ifdef, #ifndef; Compiling and linking.	**6**
3.	**Modular Programming**: Functions (void and value returning), parameters, scope and lifetime of variables, passing by value, passing by reference, passing arguments by constant reference; Design of functions and their interfaces, recursive functions; Function overloading and default arguments; Library functions; Matters of style, naming conventions, comments	**6**
4.	**Aggregate Data-types**: Arrays and pointers; Structures; Dynamic data and pointers, dynamic arrays.	**4**
5.	**Object Oriented Programming**: Classes and Objects; Constructors and Destructors; Operator Overloading and Type Conversions; Inheritance: extending classes; Pointers; Virtual Functions; Polymorphism; Manipulating Strings; Use of Pointers in linked arrays.	**8**
6.	**Solution of Linear and Non-Linear Equation:** Direct methods	**6**

	such as Gaussian elimination and Thomas algorithm for tri-diagonal systems; Iterative methods such as Jacobi method and Gauss-Seidel method; Single variable using Bisection method and Newton-Raphson method; Application of Newton-Raphson to two variables	
7.	**Numerical Interpolation, Differentiation and Integration**: Difference tables, forward, central and backward difference interpolation; Interpolating polynomials; Differentiation formulas; Trapezoidal rule, Simpson's rule	**4**
8.	**Solution of Ordinary Differential Equations**: Initial value problems (IVPs), Euler Method and Runge-Kutta method	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Balaguruswamy, E., "Object Oriented Programming with C++", Tata McGraw Hill Education, 5th Edition.	**2011**
2.	Lafore, R., "Object Oriented Programming with C++", Pearson, 4th Edition.	**2008**
3.	Dietel, H. M. and Dietel, P. J., "C++ How to Program", Prentice Hall, 8th Edition.	**2011**
4.	Sastry, S. S., "Introductory Methods of Numerical Analysis", PHI Learning, 5th Edition.	**2012**
5.	Chapra, S. C., "Applied Numerical Methods with MATLAB for Engineers and Scientists", Tata McGraw Hill Education, 3rd Edition.	**2012**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Mathematics Department**

1. Subject Code: **MAN-001** Course Title: **Mathematics I**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** **CWS** 25 **PRS** 00 25 50 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: BSC**

8. Pre-requisite**:** **None**

9. Objective: **To provide essential knowledge of basic tools of Differential Calculus, Integral Calculus , Vector Calculus and Matrix Algebra for degree students.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Matrix Algebra:** Elementary operations and their use in getting the Rank, Inverse of a matrix and solution of linear simultaneous equations. Orthogonal, Symmetric, Skew-symmetric, Hermitian, Skew-Hermitian, Normal & Unitary matrices and their elementary properties. Eigen-values and Eigenvectors of a matrix, Cayley-Hamilton theorem, Diagonalization of a matrix.	**8**
2.	**Differential Calculus:** Limit, Continuity and differentiability of functions of two variables, Euler's theorem for homogeneous equations, Tangent plane and normal. Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Error approximations. Extrema of functions of two or more variables, Lagrange's method of undetermined multipliers	**12**
3.	**Integral Calculus:** Review of curve tracing and quadric surfaces, Double and Triple integrals, Change of order of integration. Change of variables. Gamma and Beta functions. Dirichlet's integral. Applications of Multiple integrals such as surface area, volumes, centre of gravity and moment of inertia..	**12**
4.	**Vector Calculus:** Differentiation of vectors, gradient, divergence, curl and their physical meaning. Identities involving gradient, divergence and curl. Line and surface integrals. Green's, Gauss and Stroke's theorem and their applications.	**10**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	E. Kreyszig, Advanced Engineering Mathematics, 9th edition, John Wiley and Sons, Inc., U.K.	2011
2.	R.K. Jain and S.R.K. Iyenger, Advanced Engineering Mathematics, 2nd Edition, Narosa Publishing House.	2005
3.	M.D. Weir, J. Hass, F.R. Giordano, Thomas' Calculus, 11th Edition, Pearson Education.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemistry**

1. Subject Code: **CYN-001** Course Title: **Physical Chemistry**

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**: CWS** 10 **PRS** 15 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester**: Autumn** 7. Subject Area**: BSC**

8. Pre-requisite: **Nil**

9. Objective: To provide a theoretical and experimental knowledge of fundamental physical chemistry to engineering students.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Quantum Chemistry:** Postulates, commuting and non-commuting operators, Schrödinger equation, particle in a one-, two- and three dimensional box and their implications, H-atom - radial and angular wave functions, shapes of orbitals (s, p and d), application of quantum chemistry concepts to hydrogen-like atoms and their atomic spectra.	**7**
2.	**Chemical Equilibria:** Description of equilibrium, feasibility of chemical reaction, Gibbs-Helmholtz equation, phase transition - Clapeyron equation, Clausius- Clapeyron equation, free energy changes in reversible processes, chemical potential, partial molar quantities, activity coefficient and fugacity, basic concepts of statistical thermodynamics.	**6**
3.	**Reaction Dynamics:** Collision theory of bimolecular reactions and its drawbacks, potential energy surfaces, transition state theory using partition functions, thermodynamic formulation of transition state theory and mapping of transition states using ultrafast processes.	**6**
4.	**Photochemistry:** Laws of photochemistry, photophysical and photochemical processes and their quantum efficiencies, spontaneous and stimulated processes. Franck-Condon principle, photosensitizers - photosynthesis and solar cells.	**6**

5.	**Catalysis:** Homogeneous catalysis – kinetics of acid, base and enzyme catalyzed reactions with suitable examples. Heterogeneous catalysis – surface phenomena, porosity, derivation of Langmuir adsorption isotherm, Langmuir-Hinshelwood and Rideal-Eley mechanisms, comparison of rates of homogeneous and heterogeneous reactions based on activated complex theory.	**6**
6.	**Spectroscopy:** Interaction of electromagnetic radiation with matter, instrumental spectroscopic techniques (AAS, ICP, UV-Vis and IR spectroscopy), application of spectroscopy techniques to atomic and molecular systems.	**6**
7.	**Solid-State Chemistry:** Bonding in solids, diffraction methods – scattering of X-rays from a crystal, structure factor and systematic absences, methods of synthesis of solids–ceramic, sol-gel, hydrothermal, microwave and sonochemical.	**5**
	Total	**42**

List of Experiments:

i)	Determination of iron in iron ore using potassium dichromate (internal indicator method).
ii)	Heat of neutralization of a strong base by a strong acid.
iii)	Determination of surface excess concentration of 1-butanol in aqueous solution.
iv)	To study the kinetics of a redox reaction.
v)	Blue printing using sunlight.
vi)	pH metry/ potentiometry titrations a) Strong acid – strong base; b) Strong acid – weak base c) Weak acid – strong base; d) Redox titration: Fe^{2+} or Mn^{2+}
vii)	Acid base titrations using conductivity meter. a) Strong acid – strong base; b) Strong acid – weak base c) Weak acid – strong base.
viii)	Spectrophotometry: Determination of [Fe (III)] by colorimetry.
ix)	Determination of hardness of water by EDTA- complexometry titration.
x)	Determination of the composition of mixtures of liquids using viscometry.
	.

11.**Suggested Books**:

S. No.	Authors/ Title/ Publisher	Year of Publication
1.	Silbey R.J. and Alberty R.A., "Physical Chemistry", 3rd Ed, John Wiley & Sons, Inc.	**2003**
2.	Atkins P. and Paula J. Physical Chemistry, 8th Ed., Oxford University Press.	**2006**

3.	West A.R., Solid State Chemistry and its Applications, Wiley-India Edition	**2003**
4.	Levine, I. N, Quantum Chemistry, Pearson Education	**2000**
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