INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN- 501** Course Title: **Numerical Methods in Chemical Enginering**

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

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

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

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

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 in chemical engineering, polynomials (determination of quadratic factors), linear set of simultaneous equations, ill conditioned matrix, and set of non-linear 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.	**4**
4.	Review of single step and multiple step methods to solve initial value problems (IVB), estimation of error and its propagation 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 method, regular perturbation method, Galerkin, 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,	**9**

	orthogonal collocation to solve PDEs with their application to chemical engineering systems.	
	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- 502** Course Title: **CAD of Mass Transfer Equipment**

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

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

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

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

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge about design principles and CAD of various mass transfer equipment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Design Principles and Methods:** Ideal-liquid-solution models, non-ideal thermodynamic property models, and activity-coefficient models for liquid phase. Design variables and their influence on multi-component separation processes, short cut design methods for absorption, stripping, extraction and distillation column.	12
2.	**Multicomponent Separation Processes and CAD of Staged-Columns:** Separation of multicomponent mixtures by use of a single equilibrium stage, flash calculation under isothermal and adiabatic conditions, tridiagonal formulation of component material balances and equilibrium relationships for distillation, absorption and extraction of multicomponent systems. Design of absorbers, distillation columns, strippers and extractors.	16
3.	**Tray Hydraulics:** Tray hydraulics and design considerations for various trays.	6
4.	**Packed Columns:** CAD of packed absorber, extractor and distillation	8

	column using different packings. CAD of pressure-swing adsorption system.	
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Sinnott R.K. and Towler G., "Chemical Engineering Design", 5th Ed., Butterworth-Heinemann.	2009
2.	Seader J.D. and Henley E.J., "Separation Process Principles", 2nd Ed., Wiley.	2006
3.	Holland C.D., "Fundamentals and Modeling of Separation Processes", Prentice Hall.	1975
4.	Stichlmair J.G. and Fair J.R., "Distillation Principles and Practices", Wiley.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN- 503** Course Title: **Advanced 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**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide advanced concepts of momentum, mass and heat transfer operations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Review of basic principles and equations of change in transport of momentum, heat and mass; Viscosity, thermal conductivity and diffusivity; Shell balance for simple situations to obtain shear stress, velocity, heat flux, temperature, mass flux and concentration distributions.	**8**
2.	**Equations of Change**: Equations of continuity, motion, mechanical energy, angular momentum, energy, and equation of continuity for multicomponent mixture. Use of the equations of change in solving problems of momentum, heat and mass transport, dimensional analysis of the equation of change.	**8**
3.	**Distributions with More than One Independent Variable**: Unsteady state flow, heat and mass transfer problems, creeping flow around a sphere, flow through a rectangular channel, unsteady heat conduction in slabs with and without changing heat flux, heat conduction in laminar in compressible flow, potential flow of heat in solids, unsteady state diffusive mass transport, steady state transport of mass in binary boundary layers.	**8**
4.	**Transport of Mass, Momentum and Heat under Turbulent Flow Conditions**: Velocity, temperature and concentration distributions in	**6**

	smooth cylindrical tubes for incompressible fluids, empirical equations for various transport fluxes and momentum.	
5.	**Interphase Transport in Isothermal and Non-Isothermal Mixtures**: Definitions of friction factor and heat and mass transfer coefficients; Heat and mass transfer in fluids flowing through closed conduits and packed beds; Mass transfer accompanied with chemical reaction in packed beds; Combined heat and mass transfer by free and forced convection; Transfer coefficients at high net mass transfer rate.	**6**
6.	**Macroscopic Balances**: Momentum, heat and mass balances and their application, use of macroscopic balances in steady and unsteady state problems; Cooling and heating of a liquid in stirred tank, start-up of a chemical reactor.	**6**
Total		**42**

11. Suggested Books:

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1.	Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., Wiley.	1994
2.	Leal L.G., "Advanced Transport Phenomena**:** Fluid Mechanics and Convective Transport Processes", Cambridge University Press.	2007
3.	Dean W.M., "Analysis of Transport Phenomena", Oxford University Press.	1998
4.	Brodkey R.S. and Hershey H.C., "Transport Phenomena – A Unified Approach", Brodkey.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN- 505** Course Title: **Chemical Reactor Analysis**

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**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide advanced knowledge of reaction kinetics and chemical reactors.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Review of design of ideal isothermal homogeneous reactors for single and multiple reactions.	**6**
2.	Residence time distribution (RTD) of ideal reactors, interpretation of RTD data, flow models for non-ideal reactors – axial dispersion, N tanks in series, and multiparameter models, diagnosing the ills of reactors, influence of RTD and micromixing on conversion.	**9**
3.	Adiabatic and non-adiabatic operations in batch and flow reactors, optimal temperature progression, hot spot in tubular reactor, autothermal operation and steady state multiplicity in continuously stirred tank reactor (CSTR) and tubular reactors, introduction to bifurcation theory.	**11**
4.	Introduction to multiphase catalytic reactors, effectiveness factor, selectivity, catalyst deactivation, use of pseudo-homogeneous models for design of heterogeneous catalytic reactors (fixed and fluidized beds).	**8**
5.	Gas-liquid-solid reactors, hydrodynamics and design of bubble column, slurry and trickle-bed reactors.	**6**
6.	Introduction to laboratory reactors.	**2**
Total		**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Ed., Prentice-Hall.	2006
2.	Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., Wiley.	1999
3.	Froment G.F. and Bischoff K.B., "Chemical Reactor Analysis and Design", 2nd Ed., Wiley.	1990
4.	Doraiswamy L.K. and Sharma M.M., "Heterogeneous Reactions Analysis. Vol. 1: Gas-Solid and Solid-Solid Reactions", Wiley.	1984
5.	Doraiswamy L.K. and Sharma M.M., "Heterogeneous Reactions Analysis. Vol. 2: Gas-Solid and Solid-Solid Reactions", Wiley.	1984

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN- 507** Course Title: **CAD of Heat Transfer Equipment**

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

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

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

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

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge about design principles and computer aided design of various heat transfer equipment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic design procedure of heat transfer equipment, overall heat transfer coefficient and dirt factors, shell and tube heat exchangers – construction details, selection algorithm, design codes, mean temperature difference.	**4**
2.	**Heat Exchangers:** General design considerations of shell and tubes of heat exchangers, thermo -physical properties, design of double pipe heat exchangers, tube-side heat transfer coefficient and pressure drop, shell-side heat transfer coefficient and pressure drop by using Kern, Bell and Heat Transfer Research Incorporation (HTRI) methods, CAD of shell and tube heat exchangers; Mechanical and fabricational aspects.	**13**
3.	**Condensers:** CAD of condensers for single vapours, desuperheater-cum-condenser and condenser-cum-sub-cooler, condensers for multicomponent vapours with and without non-condensables.	**6**
4.	**Reboilers, Vaporizers and Evaporators:** Pool boiling, convective boiling, selection and CAD of reboilers, vaporizers and evaporators.	**6**

5.	**Compact Heat Exchangers:** CAD of special heat transfer equipment like plate heat exchangers, finned tube heat exchangers, bayonet heat exchangers, spiral heat exchangers, suction heater, coiled and jacketed heating vessels.	**9**
6.	**Fired Heaters and Furnaces:** CAD of fired heaters and furnaces.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Sinnott R.K. and Towler G., "Chemical Engineering Design", 5th Ed., Butterworth-Heinemann.	2009
2.	Serth R.W., "Process Heat Transfer Principles and Applications", Elsevier.	2007
3.	Hewitt G.F., Shires G.L. and Bott T.R., "Process Heat Transfer", Begell House.	1994
4.	I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers".	1967

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-511** Course Title: **Air Pollution Control Engineering**

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

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

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

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

8. Pre-requisite: **Nil**

9. Objective: To provide comprehensive knowledge of air pollution problems, pollution control strategies and design of equipment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Basic criteria and strategies for the selection and design of air pollution control equipment, various efficiency equations; Particle size distribution and analysis.	**2**
2.	**Design of Settling Chambers:** Design with respect to laminar and turbulent flow; overall efficiencies and economic sizing of settling chambers.	**4**
3.	**Design of Cyclones:** Pressure drop calculation in a cyclonic flow; Design of cyclones and multi-clones for laminar, turbulent and modified flow for various sizes particle distributions; Design of standard centrifugal and reverse flow cyclone collectors; Estimation of pressure drop, power requirement and cost of single and multi-clone separators.	**6**
4.	**Design of Fabric Filters:** Design of single layer and multilayer fabric systems; Design of cylindrical fabric system; Calculation of overall collection efficiencies and pressure drop for single and multilayer filters; Design of bag filters and bag houses.	**4**
5.	**Design of Electrostatic Precipitators:** Basic principles of operation; Design of single and multi stage Electrostatic Precipitators for parallel plate electrodes and cylindrical electrodes; Particle charging and diffusion charging; Design for low dust system and high dust system.	**5**
6.	**Design of Particulate Scrubbers:** Interception, inertial impaction and	**7**

	diffusion to a spherical drop and overall efficiencies for multiple drops; Design of spray chambers: single and multiple stages; Design of jet and venture scrubber.	
7.	**Design of Absorption System;** Absorption of gases by moving drops; Henry's law and diffusion inside the drop; Gas scrubbers; Absorption towers.	**4**
8.	**Design of Adsorption System:** Principles of adsorption; Fixed-bed adsorbers; Moving-bed adsorbers.	**4**
9.	**Design of Combustion System:** Chemistry and thermodynamics of combustion; Combustion chamber design; Design of flammable mixtures and flares; Catalytic afterburners.	**3**
10.	**Design of Condensation System:** Thermodynamic Properties of pollutants; Direct-contact condensers; Surface heat exchangers; Condensation of steam-pollutant mixtures on surface condensers; Condensation of air-pollutant mixtures on surface condensers.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Cheremisinoff N.P., "Handbook of Air Pollution Prevention and Control", Butterworth-Heinemann.	2002
2.	Wang L.K. and Pereira N.C., "Advanced Air and Noise Pollution Control", Humana Press.	2005
3.	Stern A.C., "Air Pollution", Vol. I, II, and III, Academic Press.	1968
4.	Brauer H. and Varma Y.B.G., "Air Pollution Control Equipment", Springer – Verlag.	1981
5.	Chermisihoff N.P. and Young R.A., "Air Pollution Control and Design Handbook", Part I and II, Marcel Deckker.	1977

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-512** Course Title: **Solid and Hazardous Waste Management**

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**: PCC**

8. Pre-requisite**:** Nil

9. Objective: To provide comprehensive knowledge of treatment, utilization and management of industrial, municipal and hazardous solid wastes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Characterization:** Characterization of industrial and municipal solid wastes - hazardous and non-hazardous wastes. Overview of hazardous waste, battery waste, electronic waste, etc. Solid waste disposal and management – standards, laws and guidelines. Hazardous waste regulations, national and international codes; Authorisation procedure and generator requirement.	**6**
2.	**Solid Waste Collection, Handling and Transportation:** Generation, collection, handling, separation, storage, transfer and processing of solid waste, recycling of solid waste; Segregation of hazardous and non-hazardous wastes. Identification and characterisation of various kinds of hazardous wastes, introduction to toxicology, evaluation of health risks associated with exposure to hazardous wastes.	**10**
3.	**Solid and Hazardous Wastes Processing:** Physico-chemical method, biological methods, thermal methods; Recycling and reprocessing, handling and processing of sludge; Utilization of municipal solid wastes for landfill, biogasification and manure production; Recent technological advances in composting and	**12**

	thermal gasification. Processing of and value-winning from electronic wastes, battery wastes, ferrous and non-ferrous wastes, heavy metal containing spent catalysts, spent caustic and tannery wastes.	
4.	**Landfill**: Site selection and design criteria; Closure, restoration and rehabilitation of landfills. Remediation of hazardous waste landfill; Common treatment facility concept for hazardous wastes.	**6**
5.	**Case Studies:** Solid and hazardous waste management in sugar, distillery, pulp and paper, fertilizer, petroleum and petrochemical industries; Management of spent catalysts. Mercury emission and control in thermal power plants and cement plants.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Tchobanglais G., Theisen H. and Vigil S.A., "Integrated Solid Waste Management: Engineering Principles and Management Issues", McGraw Hill.	1993
2.	Pichtel J., "Waste Management Practices: Municipal, Hazardous and Industrial", CRC Press.	2005
3.	Shah K.L., "Basics of Solid and Hazardous Waste Management Techniques", Prentice Hall.	1999
4.	Tedder D.W. and Pohland F.G. (editors), "Emerging Technologies in Hazardous Waste Management", American Chemical Society.	1990
5.	Conway R.A. and Ross R.D., "Handbook of Industrial Waste Disposal", Van-Nostrand Reinhold.	1980
6.	Side G.W., "Hazardous Materials and Hazardous Waste Management", Wiley.	1993

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-513** Course Title: **Water Pollution Control Engineering**

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

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

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

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

8. Pre-requisite: **Nil**

9. Objective: To provide comprehensive knowledge of industrial wastewater problems, control strategies and design of treatment units.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Characterisation and monitoring of industrial and municipal waste water, recycling and reuse of wastewater. Basic philosophy and selection of water pollution treatment plants; Design criteria: hydraulic loading rate, organic loading rate, residence time, dilution rate.	**5**
2.	**Physico-Chemical Treatment Methods**: Sedimentation, coagulation, flocculation, thickening, floatation.	**4**
3.	**Biological Treatment Fundamentals**: Microbial metabolism, bacterial growth kinetics; Biological nitrification, denitrification and phosphorus removal; Anerobic fermentation and aerobic treatment.	**6**
4.	**Aerobic Suspended and Attached Growth Biological Treatment Processes**: Aerated lagoon, activated sludge systems, trickling filter, sequential batch reactor, fluidized bed bioreactors.	**7**
5.	**Anaerobic Suspended and Attached Growth Biological Treatment Processes**: UASB and hybrid UASB reactors, bio-towers.	**4**

6.	**Advanced Treatment Processes**: Membrane processes- reverse osmosis, ultrafiltration, nanofiltration and electrodialysis; Wet air oxidation, adsorption and ion-exchange; Wet-land and root-zone treatment of industrial and municipal wastes; Design of sludge drying beds, thermal and biological processes for sludge and land fillings.	**10**
7.	**Case Studies**: Waste water treatment and disposal strategies in petroleum, petrochemical, fertilizer, distillery, pulp and paper industries.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Tchobanoglous G., Burton F.L., Stensel H.D., "Metcalf and Eddy Inc.- Waste Water Engineering Treatment and Reuse", Tata McGraw-Hill.	2003
2.	Henze M., van-Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D., "Biological Wastewater Treatment: Principles, Modelling and Design", IWA publishing.	2008
3.	Arceivala S.J. and Asolekar S.R., "Wastewater Treatment for Pollution Control and Reuse", 3rd Ed., Tata McGraw Hill.	2007
4.	Sincero A.P. and Sincero G.A., "Environmental Engineering – A Design Approach", Prentice-Hall.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-515** Course Title: **System Approach to Environmental Engineering**

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

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

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

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

8. Pre-requisite: **Nil**

9. Objective: To provide basic concepts of modeling, simulation and optimization of environmental processes by system approach.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Basics understanding of system, systems approach and systems engineering; Principles of systems analysis; Basic approaches for model creation – analytical, empirical and hybrid. Types of models – discrete, continuous, deterministic, stochastic; Concepts of mathematical modeling, simulation and optimization.	**9**
2.	System dynamics simulation approach for formulating and analysis of environmental engineering problems; system dynamics simulation tool.	**7**
3.	Formulation and solution to the linear and non-linear problems and computer based programming tools. Basics of single objective optimization and multi-	**8**

	objective analysis.	
4.	Systems analysis for environmental pollution control, control models for air, water and solid, total and global environmental models. Mathematical models for water pollution control, sludge disposal systems, air pollution abatement and determination of optimum abatement policies.	**10**
5.	Basic concepts of Pinch Technology and its application in Water Targeting in Process and Chemical Industries.	**8**
	Total	**42**

11. Suggested Books:

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1.	Simonovic S.P., "Managing water resources: Methods and tools for a systems approach", Earthscan, London, Sterling VA.	2009
2.	Rich L. G., "Environmental Systems Engineering", McGraw-Hill.	1973
3.	Ray B. T., "Environmental Engineering", PWS Publishing.	1995
4.	Sincero A.P. and Sincero G.A., "Environmental Engineering – A Design Approach", Prentice-Hall.	1996
5.	Aris R., "Mathematical Modeling, Vol. 1: A Chemical Engineering Perspective (Process System Engineering)", Academic Press.	1999
6.	De Neufville, R., "Applied Systems Analysis: Engineering Planning and Technology Management", McGraw Hill.	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-517** Course Title: **Biochemical Engineering**

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**:** Autumn 7. Subject Area**: PCC**

8. Pre-requisite**:** Nil

9. Objective: To provide comprehensive knowledge of biochemical engineering principles and their application.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Biochemical engineering fundamentals, role of biochemical engineering in the biochemical product synthesis, bioprocess economics.	**2**
2.	**Microbiology:** Cell theory, structure of microbial cells, classification of microorganisms, RDNA technology, genetically engineered microbes (GEMS).	**5**
3.	**Biochemistry:** Chemical composition of microbial cells; properties, classification and metabolism of lipids, proteins, carbohydrates and enzymes, metabolic stoichiometry and energetics.	**5**
4.	**Kinetics of Enzyme Catalysed Reactions:** Simple enzyme kinetics with mono and multi substrates, determination of elementary step rate constant; Modulation and regulation of enzyme activity, factors influencing enzyme activity, immobilization of enzymes.	**5**
5.	**Microbial Fermentation Kinetics:** Bacterial growth cycle, mathematical modeling of batch and continuous fermentations with and without recycles, bioreactors in series, product synthesis kinetics, over all kinetics, thermal death kinetics of spores and cells, transient growth kinetics,	**8**

	deviation from Monod model, comparison between batch and continuous fermentation	
6.	**Sterilization:** Sterilization and pasteurization, batch and continuous sterilization of media, plate and direct injection sterilization; Thermal death kinetics of spores, cells and viruses.	**4**
7.	**Aeration and Agitation**: Gas-liquid mass transfer, oxygenation of fermentation broth; bubble and mechanical aeration and agitation, design and power requirement of gassed and un-gassed systems for various impellers, hold-up**.**	**3**
8.	**Scale-up of Bioreactors:** Dimensionless numbers for scale-up, design estimation of various scale-up parameters, power estimation for gassed and ungassed systems.	**4**
9.	**Aerobic and Anaerobic Fermentations**: Design and analysis of typical aerobic and anaerobic fermentation processes, manufacture of antibiotics, alcohol and other fermentation products.	**3**
10.	**Downstream Processing:** Use of filtration, centrifugation, adsorption, membrane separation processes, electrophoresis chromatography.	**3**
	Total	**42**

11. Suggested Books:

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1.	Bailey J.E. and Olis 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., "Bioprocess Engineering", 2nd Ed., Prentice Hall.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-561** Course Title: **Computational Fluid Dynamics**

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**: Autumn** 7. Subject Area**: PEC**

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

9. Objective: 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 of change for transfer processes, 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 for solving 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 engineering problems.	**9**
4.	**Finite Volume Method (FVM):** Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, application to engineering problems.	**11**
5.	**Special Topics:** Case studies using FDM and FVM, flow and heat transfer in pipes and channels, square cavity flows, reactive flow, multiphase flow, rotary kiln reactors, packed and fluidized bed reactors, furnaces and fire systems. Overview of finite element method (FEM).	**14**
Total		**42**

11. Suggested Books:

S. No.	Authors / Name of Book / 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.	Ferziger J.H. and Peric M., "Computational Methods for Fluid Dynamics", 3rd Ed., Springer.	2002
6.	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-562** Course Title: **Modeling of Chemical Engineering Systems**

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**:** PEC

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

9. Objective: To provide basic concepts of modeling and simulation of chemical engineering systems.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Introduction:** Introduction to process modeling and simulation.	**3**
2.	**Models:** Models, need of models and their classification, models based on transport phenomena principles, scaling, alternate classifications of models, population balance, stochastic, and empirical models. Unit models of simple chemical engineering systems and their block diagrams	**10**
3.	**Modeling of Chemical Engineering Systems:** Reactors - fixed bed, fluidized bed and bioreactors (aerobic and anaerobic); Evaporators, cyclone separators, electrostatic precipitators; Stack dispersion modeling; Modeling of safety systems.	**16**
4.	**Process Simulation:** Techniques of digital simulation. Lumped parameter systems, stability, model analysis, discretization, and discrete to continuous systems. Newton's and globally convergent methods for set of nonlinear equations; Use of Runge-Kutta and Gear's methods for solution of staged separation problems, finite difference approximation of partial differential equations and their solutions.	**13**
	Total	**42**

11. Suggested Books:

S.	Authors / Name of Book / Publisher	Year of

No.		Publication
1.	Denn M.M., "Process Modeling", Longman.	1986
2.	Luyben W.L., "Process Modeling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw Hill.	1990
3.	Najim K., "Process Modeling and Control in Chemical Engineering", CRC Press.	1990
4.	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-563** Course Title: **Process Integration**

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**: Autumn** 7. Subject Area**: PEC**

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

9. Objective: To introduce concept of process integration in chemical and allied industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Process integration (PI) and its building blocks, available techniques for implementation of PI, application of PI.	**6**
2.	**Pinch Technology:** Basic concepts, role of thermodynamics. Data extraction, targeting, designing, optimization-supertargteing. Grid diagram, composite curve, problem table algorithm, grand composite curve.	**12**
3.	**Targeting of Heat Exchanger Network (HEN):** Energy targeting, area targeting, number of units targeting, shell targeting, cost targeting.	**5**
4.	**Design of HEN:** Pinch design methods, heuristic rules, stream splitting, design for maximum energy recovery (MER), multiple utilities and pinches, threshold problem, loops and paths.	**6**
5.	**Heat and Mass Integration in Process Systems:** Heat engine, heat pump, distillation column, reactor, evaporator, drier, refrigeration system, water recycle and reuse systems.	**10**
6.	**Heat and Power Integration:** Co-generation, steam turbine, gas turbine.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	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.	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-564** 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 Weightage**: CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

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

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-565** Course Title: **Optimization of Chemical Processes**

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**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce various techniques of optimization and their application to chemical processes.

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 method, 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.	Authors / Name of Book / Publisher	Year of Publication
1.	Edgar T.F., Himmelblau D.M. and Lasdon L.S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill.	2001
2.	Beveridge G.S.G. and Schechter R.S., "Optimization: Theory and Practice", McGraw Hill.	1970
3.	Rao S.S., "Engineering Optimization Theory and Practice", 4th Ed., Wiley.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-566** 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 Weightage**: CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

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

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.	**Pipes and Fittings:** Standards, codes and practices; Wall thickness, tolerances, design of flanges and fittings.	**2**
2.	**Flow of Fluids:** Frictional loss in pipe and ducts, equivalent resistance of fittings, valves and bends, carrying capacity of pipes and piping networks; Pressure drop and diameter calculations of pipe carrying steam, water, oil and gases; Optimum pipe diameter and optimum pipe network design.	**9**
3.	**Gas Liquid Piping:** Flow regimes and piping design for two-phase flow; design of piping for reboiler and condenser systems.	**4**
4.	**Transport of Solids:** Design of homogenous and heterogeneous slurry transport systems; Correlations for various flow regimes. 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 pneumatic systems.	**12**
5.	**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**
6.	**Simplified Methods for Flexibility Analysis:** Thermal expansion loops, approximate solutions and flexibility analysis by model tests; Expansion	**7**

	joints and approaches for reducing expansion effects.	
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Smith P., "The Fundamentals of Piping Design: Drafting and Design Methods for Process Applications", Gulf Publishing.	2007
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", 7th Ed., McGraw Hill.	2000
4.	Boterman R. and Smith P., "Advanced Piping Design", Gulf Publishing.	2008
5.	Deutsch D.J., "Process Piping Systems", McGraw Hill.	1980

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-568** Course Title: **Advanced Process Control**

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**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge about the dynamics and control strategies for linear and non-linear process systems in continuous and discrete domains.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review of Dynamic Process Models:** Linear and non-linear, lumped and distributed parameter systems.	**6**
2.	**Control of Linear Systems**: Laplace transform, review of single-loop feedback control systems, stability and controller tuning, Smith compensator for systems with large dead-time and inverse response, multi-loop control-cascade, selective and split-range control, feed-forward control, ratio-control, adaptive control, inferential control, internal model control, model predictive control.	**16**
3.	**Multiloop and Multivariable Control**: Process interactions and control loop interaction, pairing of controlled and manipulated variables, tuning of multiloop control systems, decoupling and multivariable control strategies, strategies for reducing control loop interactions.	**8**
4.	**Digital Control**: Z transform, sampling and reconstruction, continuous and discrete-time systems, signal processing and data filtering, tuning of digital PID controllers, direct synthesis for design of digital controllers, stability of discrete-time systems, distributed digital control systems.	**8**
5.	**Case Studies:** Control of a distillation column and a heat exchanger.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Stephanopoulos G., "Chemical Process Control", Prentice Hall.	1984
2.	Coughanowr D.R. and LeBlanc S., "Process Systems Analysis and Control", 3rd Ed., McGraw Hill.	2008
3.	Seborg D.E., Edgar T.F. and Mellichamp D.A., "Process Dynamics and Control", 3rd Ed., Wiley.	2010
4.	Bequette B.W., "Process Control – Modeling, Design and Simulation", Prentice Hall.	2003
5.	Roffel B. and Betlem B., "Process Dynamics and Control-Modeling for Control and Prediction", Wiley.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CHN-570** Course Title: **Natural Gas Engineering**

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**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To provide necessary inputs towards natural gas production and its engineering aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Estimation of gas reserves and non-associated gas reserves.	**5**
2.	**Properties:** Phase behaviour fundamentals, properties of natural gases, gas and liquid separation.	**4**
3.	**Natural Gas Hydrates:** Natural gas hydrates, hydrate thermodynamics and formation kinetics, hydrate exploitation.	**7**
4.	**Gas Dehydration:** Gas-water system, water content determination, glycol dehydration, solid bed dehydration.	**4**
5.	**Acid Gas Treating:** Gas sweetening processes, solid bed adsorption, chemical and physical solvent processes, desulphurization, sulphide distillation, gas permeation.	**4**
6.	**Gas Processing:** Absorption, refrigeration, fractionation and design consideration, design procedures for iron sponge units and amine systems.	**8**
7.	**Gas Hydrates:** Determination of hydrate formation temperature/ pressure, condensation of water vapour, temperature drop due to gas expansion, thermodynamic inhibitors, kinetic inhibitors and anti agglomerates.	**5**
8.	**Gas Engineering:** Steady state flow of gas through pipes, multiphase gas liquid flow, gas compression, gas flow measurement, gas gathering and transport.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	William C. L., "Standard Handbook of Petroleum and Natural Gas Engineering", Vol. 2, 6th Ed., Gulf Publishing Company.	2001
2.	Arnold K. and Steward M., "Surface Production Operations: Design of Gas Handling Systems and Functions", Butter Worth Heinemann.	1999
3.	Molhatab S., Poe W. A. and Speight J. G., "Handbook of Natural Gas Processing and Transmission", Gulf Publishing Company.	2006
4.	Kidney A. J. and Prvish W. R., "Fundamentals of Natural Gas Possessing", CRC.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-571** Course Title: **Data Acquisition and Monitoring Techniques**

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**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide a comprehensive coverage of monitoring and analysis of environmental samples, data collection and analysis.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Importance of data in predicting future demands, role of ecological and pollution data in environmental impact assessment and environmental management plan, national and international sources for ecological and environmental data, their collection, monitoring and processing. Real time data analysis.	6
2.	Strategy for setting up of sampling stations and their numbers, collection, preservation and analysis of samples. Field sampling, site selection and location of sampling point, sampling of water and air, preservation and transport of sample and monitoring of various components of environment-water, air, biological and soil parameters.	**6**
3.	Measurement of conductivity, COD, TOC, DO, BOD, AOX, refractory organics, radioactive substances and heavy metals, etc. Monitoring of particulate matter, SOx, NOx, CO, hydrocarbon, ambient air quality and stack monitoring, shop floor air quality.	**12**
4.	Collection, monitoring, storing and analysis of meteorological data like wind speed and direction, lapse rate, solar radiation and rain fall.	**6**
5.	Introduction to spectroscopic, chromatographic and electrochemical methods of instrumental analysis. Introduction to sophisticated instruments like X-ray diffraction, pore area distribution analyzer, elemental analyzer	**12**

	and coupled instrumental techniques like GC-MS, ICP-MS, TGA-GC, etc.	
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Cleceri L.S., Greenberg A.E. and Eaton A.D., "Standard Methods for the Examination of Water and Wastewater", 20th Ed., American Public Health Association.	1998
2.	Skoog A.A., Holler J.F. and Crouch S.R., "Principles of Instrumental Analysis", 6th Ed., Brooks Cole.	2006
3.	Rouessac F. and Rouessac A., "Chemical Analysis: Modern Instrumentation Methods and Techniques", 2nd Ed., Wiley.	2007
4.	Jahnke J.A., "Continuous Emissions Monitoring" Van Nostrand Reinhold, NewYork	1993
5.	Warner, A. C., "Analysis of Air Pollutants", Wiley	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-572** Course Title: **Waste to Energy**

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**: PEC**

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.	4
2.	**Waste to energy through thermal routes:** Incineration, pyrolysis and gasification of various types of solid wastes. Process fundamentals, reactors, co-processing of various types of wastes, downstream applications of products, hydrogen production, storage and utilization, gas cleanup. Oil from waste plastics.	9
3.	**Waste to energy through biochemical routes:** Municipal and industrial wastewater and their energy potential, anaerobic reactor configuration for fuel gas production from wastewater and sludge. Separation of methane and compression. Concept of microbial fuel cells, gas generation and collection in landfills, bio-hydrogen production through fermentation, composting of solid wastes.	8
4.	**Waste to energy through chemical routes:** Production of bio diesel from discarded oils through trans esterification, characterization of biodiesel, usage in CI engines with and without retrofitting, algal biodiesel.	6
5.	**Densification:** Densification of agro and forest wastes, technological options, combustion characteristics of densified fuels, usage in boilers, brick kilns and lime kilns.	6
6.	**Efficiency improvement in power generation:** Steam and gas turbine based power generation, cogeneration, IC engines, IGCC and IPCC concepts, supercritical boilers and efficiency improvement.	6
7.	**Case studies:** Two industrial case studies where waste materials are used to	3

	supplement energy needs.	
	Total	**42**

11. Suggested Books:

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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-573** Course Title: **Design of Experiments and Parameter Estimation**

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**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge about various techniques of model parameter estimation, analysis and statistical design of experiments.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Strategy of experimentation, basic principles, guidelines for designing experiments;	**2**
2.	**Simple Comparative Experiments**: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means, randomized and paired comparison design.	**4**
3.	**Experiments with Single Factor**: Analysis of variance, analysis of fixed effects model, model adequacy checking, nonparametric methods in analysis of variance.	**3**
4.	**Design of Experiments:** Randomized blocks, latin squares and related design, factorial design, two-factor factorial design, blocking in a factorial design, the 2^2 and 2^3 factorial design, the general 2^k factorial design, blocking and compounding in the 2^k factorial design, two-level, three level and mixed level factorial and fractional factorial designs.	**8**
5.	**Parameter Estimation:** Linear regression models, estimation of the parameters in linear regression models, hypothesis testing in multiple regression, confidence intervals in multiple regression, prediction of new response observations, regression model diagnostics, testing for lack of fit.	**8**
6.	**Response Surface Methods and Other Approaches:** Response surface methodology, method of steepest ascent, analysis of a second-order	**8**

	response surface, experimental designs for fitting response surfaces, mixture experiments, evolutionary operation, robust design; Taguchi's method for optimization of experiments.	
7.	**Experiments with Random Factors**: Random effect model, two factor factorial with random factors, two-factor mixed model, sample size determination with random effects, approximate F tests.	**5**
8.	**Design and Analysis:** Nested and split-plot design, non-normal responses and transformations, unbalanced data in a factorial design.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Lazic Z.R., "Design of Experiments in Chemical Engineering: A Practical Guide", Wiley.	2005
2.	Antony J., "Design of Experiments for Engineers and Scientists", Butterworth-Heinemann.	2004
3.	Montgomery D.C., "Design and Analysis of Experiments", 5th Ed., Wiley.	2004
4.	Roy R.K., "A Primer on the Taguchi method", Society of Manufacturing Engineers.	1990
5.	Roy R.K., "Design of Experiments using the Taguchi Approach: 16 Steps to Product and Process Improvement", Wiley.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-574** Course Title: **Novel Separation Techniques**

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**: PEC**

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

9. Objective: To impart knowledge about various novel separation techniques.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Introduction:** Separation processes in chemical and biochemical industries, categorization of separation processes, equilibrium and rate governed processes.	**4**
2.	**Bubble and Foam Fractionation:** Nature of bubbles and foams, stability of foams, foam fractionation techniques, batch, continuous, single stage and multistage columns.	**4**
3.	**Membrane Separation:** Characteristics of organic and inorganic membranes, basis of membrane selection, osmotic pressure, partition coefficient and permeability, concentration polarization, electrolyte diffusion and facilitated transport, macro-filtration, ultra-filtration, reverse osmosis, electro-dialysis. Industrial applications.	**16**
4.	**Special Processes:** Liquid membrane separation, super-critical extraction, adsorptive separation-pressure, vacuum and thermal swing, pervaporation and permeation, nano-separation.	**12**
5.	**Chromatographic Methods of Separation:** Gel, solvent, ion and high performance liquid chromatography.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	King C.J., "Separation Processes", Tata McGraw Hill.	1982
2.	Seader J.D. and Henley E.J., "Separation Process Principles", 2nd Ed., Wiley.	2006
3.	Basmadjian D., "Mass Transfer and Separation Processes: Principles and Applications", 2nd Ed., CRC Press.	2007
4.	Khoury F.M., "Multistage Separation Processes", 3rd Ed., CRC Press.	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-582** Course Title: **Environmental Impact Assessment**

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**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide comprehensive knowledge of environmental impact assessment due to industrial and other developmental activities.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Historical perspective and evolution of guidelines for environmental impact assessment (EIA); Developmental and economic activities and their impact on environmental quality; Carrying capacity and sustainable development.	**4**
2.	**Environmental Impact Policy**: Guidelines for EIA for various developmental activities, environmental indices and indicators; Operational framework, rapid and comprehensive EIA. Environmental review and screening of projects, public hearing, scoping and baseline studies; Projects requiring EIA.	**6**
3.	**Monitoring and Analysis of Environmental Quality**: Monitoring and analysis of wastewater, surface water, ground water, ambient air and emissions; Micro-meteorology, atmospheric dispersion; Noise level monitoring and modeling;	**8**
4.	**Environmental Impacts**: Impact of developmental activities on environmental components and their analysis, quality of air, water and land and their impact on biodiversity, socioeconomic and cultural/ethical aspects and their interconnectivity.	**8**
5.	**Environmental Impact Assessment Methodologies**: Modeling and prediction, impact valuation and composite impact analysis and assessment.	**6**
6.	**Environmental Management Plan**: Protective and preventive planning, cost-benefit analysis, environmental management plan (EMP) and disaster management plan (DMP), on-site and off-site management plan, forest management plan and green-belt design. Post project monitoring.	**5**

7.	**Case Studies**: EIA of fertilizer, petroleum and petrochemical units, power plants and hydro-projects.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Canter L.W., "Environmental Impact Assessment", McGraw Hill.	1996
2.	Rau J.G. and David C., "Environmental Impact Analysis Handbook", McGraw Hill.	1980
3.	"Guidelines for EIA of Industrial and other Projects" Ministry of Environment and Forests, Government of India.	2009
4.	Cheremisinoff P.N. and Morresi A.C., "Environmental Assessment and Impact Statement Handbook", Ann Arbor.	1977
5.	Pollution Control Law Series: Pollution Control Acts, Rules and Notification Issued There under, Central Pollution Control Board, Ministry of Environment and Forest, Government of India.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-584** 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 Weightage**: CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

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

8. Pre-requisite: **Nil**

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

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Industrial processes and hazards potential, mechanical electrical, thermal and process hazards. Safety and hazards regulations, Industrial hygiene. Factories Act, 1948 and Environment (Protection) Act, 1986 and rules thereof.	**9**
2.	**Fire and Explosion:** Shock wave propagation, vapour cloud and boiling liquid expanding vapours explosion (VCE and BLEVE), mechanical and chemical explosion, multiphase reactions, transport effects and global rates.	**7**
3.	**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**
4.	**Toxicology:** Hazards identification-toxicity, fire, static electricity, noise and dust concentration; Material safety data sheet, hazards indices- Dow and Mond indices, hazard operability (HAZOP) and hazard analysis (HAZAN).	**6**
5.	**Leaks and Leakages:** Spill and leakage of liquids, vapors, gases and their mixture from storage tanks and equipment; Estimation of leakage/spill rate through hole, pipes and vessel burst; Isothermal and adiabatic flows of gases, spillage and leakage of flashing liquids, pool evaporation and boiling; Release of toxics and dispersion. Naturally buoyant and dense gas dispersion models; Effects of momentum and buoyancy; Mitigation	**9**

	measures for leaks and releases.	
6.	**Case Studies:** Flixborough, Bhopal, Texas, ONGC offshore, HPCL Vizag and Jaipur IOC oil-storage depot incident; Oil, natural gas, chlorine and ammonia storage and transportation hazards.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	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, 3rd Ed., Butterworth-Heinemann.	2004
3.	Mannan S., "Lee's Loss Prevention in the Process Industries", Vol. II, 3rd Ed., Butterworth-Heinemann.	2005
4.	Mannan S., "Lee's Loss Prevention in the Process Industries", Vol. III, 3rd Ed., Butterworth-Heinemann.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-586** Course Title: **Design of Pollution Control Systems**

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**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide comprehensive knowledge of design of pollution control systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Preventive and end-of-pipe (EOP) design, design for value addition from pollution and prevention control systems, concepts of reduce, recycle and reuse (3R) for economic design.	**4**
2.	**Wastewater Treatment Plant Design**: Design of systems for the removal of organic and inorganic pollutants using the best available technology (BAT); Design, operation, maintenance and control of aerobic and anaerobic systems for the treatment of domestic and municipal sewage, and industrial wastes.	**12**
3.	**Membrane Systems**: Membranes for pollution treatment, filtration and removal – macro, micro and ultrafiltration, reverse osmosis; Use of different types of membranes and their configurations; Membrane bioreactors, hollow fibres and fouling, design of membrane filters and membrane bioreactors.	**9**
4.	**Landfill Design**: Site selection, leachate and gas generation, containment landfills, design of landfill elements, landfill operation and monitoring.	**5**
5.	**Air Pollution Control System Design**: Design of air pollution abatement systems, hoods, ducts and fans; Design of stacks with single and multiple entries and drought balance; Effect of moisture, vapour, particulates and gaseous pollutants on the integrity of stacks; Design for maximum effects for dispersion; Design of multiple equipment in series and their cost optimization; Design for particulate and gaseous pollutants abatement systems.	**12**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Henze M., van-Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D., "Biological Wastewater Treatment. Principles, Modelling and Design", IWA publishing.	2008
2.	Bagchi A., "Design, Construction, and Monitoring of Sanitary Landfill", Wiley.	1990
3.	Theodore L. And Buonicore A.J., "Industrial Air Pollution Control Equipment for Particulates", CRC Press.	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-588** Course Title: **Clean Technology**

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**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To expose to newer eco-friendly and clean technologies for chemical processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Chemical technology and environmental concerns, environmental impact of chemicals, half-life and fate of chemicals, life-cycle assessment of chemicals, concept of clean technology.	**5**
2.	**Evaluation of Technology:** Evaluation of existing process technologies of ammonia, sulphuric acid, caustic soda, rayon, pulp and paper, leather, plastics, polymers and organic chemicals. Analysis of raw materials, intermediates, final products, bye-products and waste generation; Emissions and effluents from the process plants and their ultimate fate.	**12**
3.	**Technology Modification**: Modification in processes, use of new catalysts, waste to wealth approach, recycling and reuse technologies in chemical process industries (petroleum, petrochemical, pulp and paper, chlor-alkali, sugar and distillery).	**6**
4.	**Alternative Technology:** Alternative raw materials; Low temperature, low pressure and energy-efficient routes for the manufacture of caustic soda, leather, plastics, pulp and paper and rayon; Use of CO_2 for valuable chemicals.	**11**
5.	**Advanced Technology:** Development of biodegradable end-products of polymers and plastics, eco-friendly technologies for oil extraction and chemical manufacturing.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Schaltegger S., Bennett M., Burritt R.L. and Jasch C.M., "Environmental management Accounting for Cleaner Production", Springer.	2008
2.	Freeman H.M., Puskas Z. and Olbina R., "Cleaner Technologies and Cleaner Products for Sustainable Development", Springer.	1995
3.	Mukhopadhyay P.K. and Roy T.K., "Ecofriendly and Clean Technologies" Indian National Academy of Engineering.	1997
4.	Johansson A., "Clean Technology", CRC Press.	1992
5.	Kafarov V.V., "Wasteless Chemical Processes", Mir.	1985
6.	Guisnet M. and Gilson J.P., "Zeolites for Cleaner Production", World Scientific.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **CHN-590** Course Title: **Environmental Chemistry**

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**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide an understanding of the chemical and physical processes that occur in the environment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Evolution and structure of the atmosphere; ozone spectroscopy; Vertical transport, troposphere versus stratosphere, along latitude lines, within a hemisphere, across the equator.	**5**
2.	Stratospheric chemistry, UV spectra and photolysis pathways in stratosphere; ozone chemistry sources and sinks for the radical families; diurnal (daily), seasonal, altitudinal, and latitudinal variations in the abundance of ozone and other species; heterogeneous chemistry and kinetics in the perturbed and unperturbed stratosphere; interaction of season (temperature and sunlight), meteorology; Antarctic and Arctic ozone holes. Biogeochemical cycles, Abiotic versus biotic, carbon, nitrogen, sulfur, oxygen, water and 'other' cycles.	**9**
3.	Photochemistry in atmosphere, Photolysis rate, solar zenith angle; spectra, photolysis pathways, photolysis lifetimes, and significance for O_3, NO_2, NO_3, carbonyls, alkyl nitrates, PAN; major degradation pathways for alkanes, alkenes, carbonyls, isoprene and aromatics; Tropospheric aerosols, equilibrium between gas and aqueous aerosol phase;	**5**
4.	Global climate change, Instantaneous radiative forcing, Global warming potential; Role of aerosol and clouds in global climate change; CO_2 emissions; Energy issues.	**5**
5.	Introduction to aquatic chemistry; Speciation of dissolved species; Acid-base chemistry, dissociation of Bronsted-Lowry acids (mono-/di-/tri-protic) and calculation of constants. pE/pH diagrams (Pourbaix system), Nernst equation and principles, Carbonate System, alkalinity. Solubility-precipitation/dissolution; Oxidation-reduction chemistry Organic matter in	**10**

	water, fulvic and humic acids, chelation theory, source and sinks of metals.	
6.	Metal hydration (aquo complexes), iron speciation, mercury and arsenic methylation, man introduced ligands and influence on natural metal cycling. Colloids, clays, interfacial exchange (Langmuir relation, Freundlich relation, octanol/water partition and applicability to bioaccumulation).	**8**
	Total	**42**

11. Suggested Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Holloway, A.M.; Wayne, R.P. "Atmospheric Chemistry", RSC Publishing	2010
2.	Seinfeld, J. H.; Pandis, S. N. "Atmospheric Chemistry and Physics: From Air Pollution to Climate Change", 2nd Ed.	1990
3.	Howard, A.G. "Aquatic Environmental Chemistry", Oxford Science, Oxford.	2006
4.	Sawyer, C.; Mccarty, P.; Parkin G., "Chemistry for Environmental Engineering and Science", 5th Ed., McGraw Hill	2002