INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-202** Course Title: **Mechanical Operations**

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 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.	**Particle Size Analysis:** Sieve analysis, size distribution, size averaging and equivalence, size estimation in sub-sieve range,	5
2.	**Size Reduction:** Theory of crushing and grinding, crushing and grinding equipment and their selection.	4
3.	**Storage of Solids:** Bins, silos, hoppers, Jansen's equation.	2
4.	**Particle Mechanics :** Motion of particles in fluid, effect of particle shape, Stoke's law, hindered settling, jigging and classification	5
5.	**Sedimentation and Floatation:** Centrifugal sedimentation, design of gravity sedimentation tanks, design of continuous thickeners based on settling test data, floatation agents and floatation equipment.	5
6.	**Flow Through Packed Beds:** Characteristics of packings, flow of a single fluid through a packed bed, problems of channeling and wetting, counter-current gas-liquid flow through packed beds, loading and flooding characteristics.	6
7.	**Fluidization :** Fluidization characteristics, aggregative and particulate fluidization, liquid-solid fluidization, minimum fluidization, voidage and minimum fluidization velocity, voidage	6

	correlation, gas-solid fluidization characteristics	
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.	**6**
9.	**Fluid-Solid Conveying :**Pneumatic and hydraulic transport of solids, general characteristics and flow relations	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books /Publishers	Year of Publication
1.	Coulson J. H. and Richardson J.F., "Chemical Engineering, Vol. II", 5th Ed., Butterworth-Heinemann.	2002
2.	Brown G. G., "Unit Operations", CBS publishers.	1995
3.	Narayanan C.M. and Bhattacharya B.C., "Mechanical Operations for Chemical Engineers", Khanna publishers.	1992

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-203** 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**: Autumn** 7. Subject Area**: DCC**

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

9. Objective: To introduce the concept of material and energy balance as applied to chemical engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Units and dimensions in chemical engineering**,** stoichiometric and composition relations, concept of degrees of freedom and linear dependence of a set of equations.	**4**
2.	**Material Balance:** Selection of a basis, conservation of mass/atom, material balance for systems with and without chemical reactions, material balance involving gases, vapors, liquids and solids and uses of real gas relationships, vapor-liquid equilibrium and concept of humidity and saturation; Analysis of systems with bypass, recycle and purge; Analysis of processes involving condensation, crystallization and vaporization.	**14**
3.	**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, calculations of heat of change of phase (solid – liquid and liquid – vapor), heat of reaction, heat of combustion, heat of solutions and mixing, determination of temperatures for adiabatic and non-adiabatic reactions, use of psychrometric and enthalpy-concentration diagrams.	**14**

4.	**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.	**6**
5.	**Unsteady State Material and Energy Balances:** Transient material and energy balances with and without chemical reactions.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books /Publishers	Year of Publication
1.	Himmelblau D.M., "Basic Principles and Calculations in Chemical Engineering", 6th Ed., Prentice Hall of India.	**1996**
2.	Narayanan K.V. and Lakshmikutty B., "Stoichiometry and Process Calculations", Prentice Hall of India.	**2006**
3.	Bhatt B.I. and Vora S.M., "Stoichiometry", 4th Ed., Tata McGraw-Hill	**2004**
4.	Felder R.M. and Rousseau R.W., "Elementary Principles of Chemical Processes", 3rd Ed., John Wiley.	**2005**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

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

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**:** **MI-101**

9. Objective: To impart knowledge on the application 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:** First and second laws of thermodynamics, PVT behavior of fluids – Gibb's phase rule, cubic equations of state and generalized correlations.	**3**
2.	**Thermodynamic Properties of Homogeneous Fluids:** Fundamental property relations, Maxwell's relations, thermodynamic web, introduction to residual properties, residual properties from equations of state, two phase systems, thermodynamic diagrams and tables, generalized property correlations 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 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	**7**

	coefficients from experimental data – Margules, Van-Laar, and Wilson equations, property changes of mixing, heat effects in mixing processes.	
5.	**Phase Equilibria:** Importance of phase equilibria in process industries, equilibrium and stability, vapour-liquid equilibria (VLE) for miscible, partially miscible and immiscible systems, 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 free energy change and equilibrium constant, effect of temperature on equilibrium constant, evaluation of equilibrium constants and compositions, calculation of equilibrium compositions for single reactions, phase rule and Duhem's theorem for reacting systems, introduction to multi-reaction equilibria.	**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
1.	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
2.	Koretsky M.D., "Engineering and Chemical Thermodynamics", John Wiley & sons.	2004
3.	Sandler S.I. "Chemical, Biochemical and Engineering Thermodynamics", 4th Ed., John Wiley & sons.	2006
4.	Kyle B.G., "Chemical and Process Thermodynamics", 3rd ed., Prentice Hall.	1999
5.	Narayanan, K.V., "Chemical Engineering Thermodynamics", Prentice Hall.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-205** 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**: Autumn** 7. Subject Area**: DCC**

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

9. Objective: To provide knowledge of fluids, fluid statics and multi-dimensional fluid dynamics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Fluids and properties of fluids.	**2**
2.	**Fluid Statics:** The basic equation of fluid statics, pressure-depth relationship, pressure forces on surfaces, buoyancy, pressure measurements and pressure in accelerated rigid body motions.	**4**
3.	**One Dimensional Flow of Fluids:** Bernoulli's equation, steady state fluid flow with friction, momentum balance and one-dimensional high velocity gas flow.	**9**
4.	**Models, Dimensional Analysis and Dimensionless Numbers :** Methods of finding dimensionless numbers – method of governing equations, method of force ratios and Buckingham's π method, physical significance of dimensionless numbers.	**6**
5.	**Two- and Three- Dimensional Fluid Dynamics:** Momentum balances for multidimensional flows, Navier-Stokes equation, concept of potential flow.	**5**
6.	**Measurements in Fluid Transport:** Constant area and constant head meters, nozzles, Pitot tubes, weirs and notches.	**4**
7.	**Fluid Handling Machinery:** Positive-displacement pumps and compressors, centrifugal pumps and compressors, Axial flow pumps and	**5**

	compressors, compressor efficiency.	
8.	**Agitation and Mixing:** Agitated vessels, blending and mixing, suspension of solid particles, dispersion operations, selection of agitators and scale-up.	**4**
9.	**Computational Fluid Dynamics:** Introduction to CFD equations and their applications.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books /Publishers	Year of Publication
1.	Nevers N.D., "Fluid Mechanics For Chemical Engineers", 3rd Ed., McGraw Hill Higher Education.	2005
2.	McCabe W.L., Smith J.C. and Harriott P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw Hill.	2001
3.	Denn M., "Process Fluid Mechanics", Prentice Hall.	1998
4.	Darby R., "Chemical Engineering Fluid Mechanics", 2nd Ed., Marcel Dekker Inc.	2001
5.	Streeter V.L., Wylie E.B.,"Fluid mechanics", 9th Ed.,McGraw Hill.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-206** Course Title: **Transfer Processes-I**

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**:** **CH-207**

9. Objective: To provide the basic knowledge of heat transfer processes used in Chemical industries

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review of convective heat transfer correlations**	**2**
2.	**Heat Exchangers:** Importance of heat exchangers in process industries, various types of heat exchange devices and their selection. Double pipe, shell and tube heat exchangers; Design and rating, baffles and their types, F_T-correction factor, liquid-liquid, gas-liquid and gas-gas systems. Extended surfaces for heat transfer, concept of effectiveness and NTU of a heat exchanger.	**8**
3.	**Boiling:** Boiling characteristics. Nucleate pool boiling and forced convection boiling, boiling mechanism, boiling curve and heat transfer correlations, heat pipes.	**3**
4.	**Condensation:** Mechanism and types of condensation of vapour, Nusselt equation for film wise condensation on vertical surface and its extension to inclined and horizontal surfaces, condensation number, film condensation inside horizontal tubes.	**4**
5.	**Evaporator:** Classification and use of evaporators in process industries, effect of boiling point elevation and hydrostatic head on evaporator performance, estimation of surface area in multiple effect evaporator, evaporator calculations in process industries, fouling in	**6**

	evaporators	
6.	**Radiation:** Mechanism and properties, grey body behavior, radiation shape factors – derivations and use of charts, relations between shape factors, heat exchange between non-black bodies, concept of surface resistance and space resistance and assumptions of insulated surfaces and surfaces with large areas, infinite parallel planes and radiation shields, radiation through absorbing and transmitting gases, use of Hottel's charts, heat exchange between gas volume and black / grey enclosures, radiation net work for absorbing and transmitting medium.	**8**
7.	**Crystallization:** Mechanism, crystallization from mixed solutes, crystallizer seed and particle size distribution, classification of crystallizers, enthalpy-concentration diagram, crystallizer-material and energy balance.	**5**
8.	**Thermal Insulation:** Insulation materials, cold and hot insulation materials, thickness calculation for insulating materials.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books /Publishers	Year of Publication
1.	Holman J.P., "Heat Transfer", 9th Ed., McGraw Hill.	2001
2.	Kreith F. and Bohn M., "Principles of Heat Transfer", 6th Ed., Brooks Cole.	2000
3.	Hewitt G.F., Shires G.L. and Bott T.R., "Process Heat Transfer", Begell House.	1994
4.	Incropera F.P. and Dewitt D.P., "Fundamentals of Heat and Mass Transfer", 5th Ed., John Wiley.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

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

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**: DCC**

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

9. Objective: To impart knowledge on momentum, heat and mass transfer in Chemical engineering systems and their analogous behavior.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Molecular Transport Phenomena:** Molecular transport of momentum, heat and mass, laws 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 and their analogous behavior. Estimation of transport coefficients and temperature/pressure dependence.	**9**
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	**6**

	turbulence, velocity profile in circular conduits.	
5.	**Diffusion Phenomena:** Diffusion of gases and liquids in porous solids, Knudsen diffusion, multicomponent diffusion and effective diffusivity.	**4**
6.	**Methods of Analysis of Transport Problems:** General integral balance using macroscopic concepts, integral balance for mass, momentum, energy.	**5**
7.	**Convective Transport:** Free and forced convective heat transfer and mass transfer, interphase mass transport, mass transfer coefficients-individual and overall, mass transfer theories-film, penetration and surface renewal.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books /Publishers	Year of Publication
1.	Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena",2nd Ed., John Wiley and Sons.	2002
2.	Geankoplis C.J., "Transport Processes and Separation Process Principles", 4th Ed., Prentice-Hall of India.	2004
3.	Brodkey, R.S., Hershey H.C., "Basic concepts in transport phenomena, a unified approach". Vol 1, Brodkey Publishing	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

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

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**: DCC**

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

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

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Separation Processes and Modes of Operation:** Classification of separation processes based on different driving mechanisms (separating agents) and different modes of operation, membrane separation processes-basic features and transport mechanisms.	**5**
2.	**Staged Contact Operation:** Ideal stage concept; Single and multi-staged operations in co-, cross- and counter current modes with and without reflux; Systems under different reflux and operating conditions, multiple stream systems, minimum ratio of absorbent to stripping gas, or, solvent to feed (liquid/solid).	**10**
3.	**Special Cases in Staged Operation:** Simplified calculation methods for extraction, absorption and distillation, q-line location, analytical calculation of stages for simple counter current flow; Kremser-Brown-Souder equation; Analytical and graphical calculation of minimum stages at total reflux.	**10**
4.	**Continuous Contact Operation:** Concept of NTU and HTU, application of diffusional phenomena in distillation, absorption and extraction, evaluation of NTU for dilute and concentrated systems, approximate expressions for NTU; Typical procedure for solution of	**8**

	absorption, extraction and distillation in packed columns.	
5.	**Simultaneous Heat and Mass Transfer:** Design of cooling towers and dehumidification systems, determination of NTU; Drying - batch and continuous, mechanism of batch drying, calculation for batch and continuous dryers.	**9**
	Total	**42**

11. Suggested Books:

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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-302** Course Title: **Process Dynamics and 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**: DCC**

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

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

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.	**7**
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.	**7**
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 :** Multi loop control, inverse response control, feed forward and ratio control, adaptive and inferential control, control using digital computers, multivariable control.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	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 and Control", 2nd Ed., John Wiley and Sons.	2004
4.	Ogunnaike B. A. and Ray W. H., "Process Dynamics Modeling and Control", Oxford University Press.	1994
5.	Bequette B. W., "Process Control – Modeling, Design and Simulation", Prentice-Hall of India.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-303** Course Title: **Reaction 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**: DCC**

8. Pre-requisite**:** **CH-203**

9. Objective: To introduce the basic concepts of reaction kinetics and chemical reactors.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Kinetics of Homogeneous Reactions:** Determination of kinetic parameters using batch and continuous reactors; Interpretation of data using differential and integral techniques, batch reactor data for constant volume and varying volume systems using integral and differential methods for, effect of temperature on rate constant.	**5**
2.	**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**
3.	**Design for Multiple Reactions:** Parallel and series reactions, analysis of product distribution and determination of reactor size for different types of ideal reactors, selectivity and yield factors, Denbigh reactions, reactor choice for multiple reactions.	**7**
4.	**Non-Isothermal Operation and Stability of Reactors:** Non-isothermal design of ideal reactors, hot spot in tubular reactor, autothermal process, steady state multiplicity and effect of operating variables on the stability of CSTR, optimal temperature progression for first order reversible reaction, discussion of optimal policy for the operation of reactors with inter stage coolers.	**8**

5.	**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.	**7**
6.	**Fluid Particle Reactions:** Unreacted core model for spherical particles of unchanging size, rate of reaction for shrinking spherical particles, determination of the rate-controlling step.	**4**
7.	**Solid Catalyzed Reactions:** Concept of rate controlling steps, intra- and inter- particle mass transfer. Thiele modulus and effectiveness factor, performance equations for catalytic reactors, product distribution in multiple reactions.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Fogler H. S., "Elements of Chemical Reaction Engineering", 4th Ed., Pearson-Prentice Hall.	2006
2.	Levenspiel O., "Chemical Reaction Enginering", 3rd Ed., John Wiley and Sons.	2000
3.	Schmidt L. D., "The Engineering of Chemical Reactions", 2nd Ed., Oxford University Press.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-304** Course Title: **Chemical Technology**

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** 0

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

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

9. Objective: To study process technologies, availability of raw materials, production trends, preparation of flow sheets, engineering and environmental problems of various chemical industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Pulp and Paper:** Raw materials, pulping processes, recovery of chemicals, stock preparation and paper making.	**4**
2.	**Coal Chemicals:** Various processes for obtaining coal chemicals, coal tar distillation, F-T and Bergious processes for hydrocarbon production.	**4**
3.	**Petrochemicals:** Manufacturing processes of formaldehyde, acetaldehyde, acetic acid, acetic anhydride, maleic anhydride, nitrobenzene, ethylene oxide, ethylene glycol.	**6**
4.	**Pesticides:** Processes for manufacturing of insecticides, fungicides and herbicides.	**3**
5.	**Fuel and Industrial Gases:** Technology options of producing producer gas, syn gas, pyro gas, nitrogen, oxygen and carbon dioxide.	**4**
6.	**Sulphur Industries:** Origin and extraction of sulphur, production routes of suphuric acid and oleum.	**3**
7.	**Phosphorous Industries :** Manufacturing of phosphorus, phosphoric acid and phosphatic fertilizers.	**3**

8.	**Chlor-Alkali Industries :** Production of common salt, caustic soda, chlorine, hydrochloric acid and soda ash.	**4**
9.	**Nitrogen Industries :** Manufacturing of ammonia, nitric acid and nitrogenous and mixed fertilizers	**4**
10.	**Petroleum Industry :** Origin, occurrence and characteristics of crude oil, crude oil distillation and secondary processing.	**3**
11.	**Polymer and Synthetic Fibre :** Introduction to polymerization, commodity polymers, rayon, polyester, polyamide, acrylic fibre and nylons.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Gopala Rao M. and Marshall S., "Dryden's Outlines of Chemical Technology- for the 21st Century", Affiliated East-West Press.	2002
2.	Moulijn J. K., Makkee M. and van Diepen A., "Chemical Process Technology", John Wiley and Sons.	2001
3.	Basta N., "Shreve's Chemical Process Industries Handbook", 5th Ed., McGraw Hill.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-305** Course Title: **Transport Phenomena-II**

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**: DCC**

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

9. Objective: To provide comprehensive knowledge of advanced topics in transport phenomena.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Transport Past Immersed Bodies:** Laminar and turbulent boundary layers, heat and mass transfer during boundary layer flow past a flat plate, flow over cylinders and spheres, drag coefficient correlations. Flow phenomena with gas-liquid and liquid-liquid mixtures.	**10**
2.	**Mass Transfer with Chemical Reaction:** Enhancement of mass transfer due to chemical reaction, gas-liquid reactions in agitated vessel, wetted wall columns and packed beds. Determination of interfacial area and mass transfer coefficient. Application of mass transfer theories to gas-liquid mass transfer with chemical reaction.	**10**
3.	**Phase Equilibria:** Solid-liquid, gas-solid, liquid-solid, vapour-liquid equilibria, effect of temperature, pressure and third component on the equilibrium.	**7**
4.	**Fluid-Solid Mass Transfer:** Adsorption and ion exchange, fixed bed adsorption, break-through curve and bed utilization, design of ion exchangers.	**7**
5.	**Heat Transfer in Turbulent and Non-isothermal Systems**: Temperature distribution in turbulent flow and interphase–transport in non-isothermal systems.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Bird R.B., Stewart W. E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., Wiley-India.	2006
2.	Geankoplis C. J., "Transport Processes and Separation Process Principles", 4th Ed., Prentice-Hall of India.	2004
3.	Treybal R. E., "Mass Transfer Operations", 3rd Ed., McGraw Hill.	1980
4.	Deen W. M., "Analysis of Transport Phenomena", Oxford University Press.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-306** Course Title: **Process Equipment Design***

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

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

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

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

8. Pre-requisite**: CH-206, CH-207, CH-305**

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

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Heat Exchangers:** 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, general design considerations, tube- and shell-side heat transfer coefficient and pressure drop, CAD of shell and tube heat exchangers, mechanical and fabricational aspects; Mechanical drawing of heat exchangers.	**8**
2.	**Condensers:** Design of condensers for single vapor, correlations of heat transfer coefficient 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.	**5**
3.	**Evaporators:** Reboilers, vaporizers and evaporators – Pool boiling, convective boiling, selection of reboilers, and vaporizers, design of reboilers, vaporizers and evaporators, drawing of evaporators.	**5**
4.	**Crystallizers:** Design of crystallizers, agitated vessels and selection	**4**

	of agitators, design of gas-liquid separators and mixing equipment.	
5.	**Distillation Columns:** Design 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.	**12**
6.	**Packed Columns:** type of packing, packed bed height, column diameter, column internals, design methods, design of liquid-liquid extractors and gas-liquid absorbers.	**8**
		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 teacher concerned

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann.	2008
2.	Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India.	2006
3.	I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers", Bureau of Indian Standards.	2007
4.	Hewitt G. F., Shires G. L. and Bott T. R., "Process Heat Transfer", CRC Press.	1994
5.	Serth R.W., "Process Heat Transfer: Principles and Applications", Academic Press.	2007
6.	Coker A. K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol. 1, 4th Ed., Gulf Publishers.	2007
7.	Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2, 3rd Ed., Gulf Publishers.	1997
8.	Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 3, 3rd Ed., Gulf Publishers.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-307** Course Title: **Equipment Design***

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

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

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

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

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge about the mechanical design of chemical engineering equipment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Mechanics of Materials:** Stress, strain, biaxial stress; Stress-strain relationship for elastic bodies; Membrane stresses in various types of thin pressure vessels.	8
2.	**Pressure Vessels:** Selection of type of vessels, 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, selection and design of closures and heads; Introduction to compensation for opening; Design of jacketed portion of vessels; Design of high pressure monoblock and multilayer vessels.	10
3.	**Flanges:** Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Inspection and testing of vessels using heads and flanges as per code specifications.	4
4.	**Piping:** Pipe thickness calculation under internal and external pressure, introduction to flexibility analysis of piping systems.	4
5.	**Tall Tower Design :** Design of shell, skirt, bearing plate and anchor bolts for tall tower used at high wind and seismic conditions.	6

6.	**Supports :** Design of lug support and saddle support including bearing plates and anchor bolts.	**3**
7.	**Storage Tanks :** Introduction to Indian standards**,** filling and breathing losses; classification of storage tanks; Design of liquid and gas storage tanks with and without floating roof.	**7**
	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 teacher concerned

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Brownell L. E. and Young H. E., "Process Equipment Design", John Wiley and Sons.	2004
2.	Bhattacharya B. C., "Introduction of Chemical Equipment Design", CBS Publisher.	2003
3.	I.S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards.	1969
4.	I.S.:803-1962, "Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks", Bureau of Indian Standards.	1962
5.	Moss D. R., "Pressure Vessel Design Manual", 3rd Ed., Gulf Publishers.	2004
6.	Annartone D., "Pressure Vessel Design", Springer-Verlag	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-308** Course Title: **Industrial Instrumentation**

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

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

4. Relative Weightage**:** **CWS** 15 **PRS** 0 **MTE** 35 **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.

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.	**3**
2.	**Static Characteristics of Instruments:** Error, accuracy, repeatability, drift, threshold, backlash, hysteresis, zero-stability, static, coulomb and viscous friction, live zero, suppressed zero, working bind.	**5**
3.	**Sensor and Transducers:** Classification, principles and applications, interpretation of performance specification of transducers.	**4**
4.	**Building Blocks of an Instrument :** Transducer, amplifier, signal conditioner, signal isolation, signal transmitter, display, data acquisition modules, I/O devices, interfaces.	**4**
5.	**Process Instrumentation:** Working principles of transducers/instruments employed for the measurement of flow, level, pressure, temperature, density, viscosity, etc. and their merits and demerits.	**9**
6.	**Miscellaneous Instruments:** Indicating, transmitting and recording type instruments, preparation of instrumentation diagrams,	**3**

	instrumentation of important equipment like distillation column, heat exchanger, etc.	
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors / Book Title / Publisher	Year of Publication
1.	Nakra B. C. and Chaudhry K. K., "Instrumentation, Measurement and Analysis", 2nd Ed., Tata-McGraw Hill.	2004
2.	Andrew W. G., "Applied Instrumentation in the Process Industries", Vol. I, II and III 3rd Ed., Gulf Publication.	1993
3.	Johnson C., "Process Control Instrumentation Technology", 8th Ed., Prentice-Hall.	2005

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-309** Course Title: **Chemical Engineering Lab. - I**

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

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

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

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

8. Pre-requisite**: CH-204 and CH-206**

9. Objective: To provide hands-on experience of experiments on heat transfer and thermodynamics.

10. Details of Course:

Contents	Contact Hours
1 Study of the open pan evaporator with/without stirrer and determination of overall heat transfer coefficient during heating and boiling. **2a.** Study the double pipe hair-pin heat exchanger and to determine experimentally the overall heat transfer coefficient at various liquid Reynolds number and estimate the film heat transfer coefficient on the steam side. **b.** Compute film heat transfer coefficient using standard equation and compare with those experimentally obtained. **3a.** Study the floating head 1-2 shell and tube heat exchanger available in heat transfer laboratory and prepare a detailed dimensioned sketch. **b.** Determine experimentally the overall heat transfer coefficients at various cold-water flow rates and estimate the film heat transfer coefficient on the shell side. **c.** Compute the shell side heat transfer coefficient using standard equations and compare these values with those experimentally obtained. **4a.** Study the fixed head 1-4 shell and tube heat exchanger installed in heat transfer laboratory prepare a detailed dimensioned sketch. **b.** Determine experimentally the overall heat transfer coefficients at various cold-water flow rates and estimate the film heat transfer coefficient on the shell side (steam side).	3 x 14

c. Compute the shell side heat transfer coefficient using standard equations and compare these values with those experimentally obtained. **5.** Study the temperature distribution along metallic rods **6** Study of temperature/ distributing in parallel flow and counter flow heat exchanger, overall heat transfer coefficient in parallel and counter flow runs; and the effectiveness of the given heat exchanger. **7** Determine the surface heat transfer coefficient for a vertical tube losing heat by natural convection. **8** Verify the Clausius- Clapeyron equation. **9.** Determine the activity coefficients for a binary system. **10 a.** Determine the partial molar volumes of water and of ethyl alcohol as a function of concentration at fixed temperature and pressure. **b.** Determine the partial molar volume of water and ethyl alcohol respectively, at their infinite dilutions. **c**. Verify the Gibbs-Duhem equation applied to partial molar volumes of a binary solution **11** Study heat transfer in forced convection **12**. Study drop-wise and film-wise condensation **13.** Study single effect evaporator	
Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Holman J.P., "Heat Transfer", 9th Ed., McGraw Hill.	2001
2.	Perry R.H. and Green D.W., "Perry's Chemical Engineers' Handbook", 8th Ed., McGraw Hill.	2007
3.	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-310** Course Title: **Chemical Engineering Lab. - II**

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

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

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

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

8. Pre-requisite**: CH-301**

9. Objective: To provide hands-on experience of experiments on mass transfer operations.

10. Details of Course:

Contents	Contact Hours
1 Extraction of sodium carbonate from a solid mixture of sand and sodium carbonate with water as a solvent, using simple single contact and simple multiple contact. **2** Calculation of height equivalent to a theoretical plate, number of transfer units and height of transfer units for a packed distillation column operating under total reflux conditions. (System: Acetone -Toluene). **3** To carryout steam distillation of an impure organic liquid (crude aniline) and to compare the experimental results with those theoretically predicted. **4** Measurement of diffusivity of the vapor of a volatile liquid (Acetone) in air. Comparison of the experimentally obtained value of diffusivity with that obtained from theoretical equation. **5** To follow the rate of drying of solid material in a batch drier under constant drying conditions and draw Drying Curve. To determine the critical moisture content in the material. To determine the fraction of total drying time required during constant and falling rate periods. **6** Determine in a Rotary Drier: (a) Holdup, (b) Time of retention of solids, (c) Air requirement and heat losses to the surrounding.	3 x 14

7 Operation of Cooling Tower and determination of the overall volumetric mass transfer coefficient for different flow rates. **8** Verify the Rayleigh equation by conducting differential distillation of binary liquid mixture (alcohol-water). **9** Determination of liquid liquid equilibria for a system of three liquids, toluene(A), water (B) and acetic acid (C), with one pair only partially soluble. **10** Study wetted-wall column **11** Study distillation in sieve plate column **12** Study absorption in sieve plate column **13** Study vapour-liquid equilibria **14** Study fluidized bed drier	
Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Treybal R. E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
2.	Brown G. G., "Unit operations", CBS Publishers.	1995
3.	Perry R. H. and Green D. W., "Perry's Chemical Engineers' Handbook", 8th Ed., McGraw Hill.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-401** Course Title: **Process Modeling and Simulation**

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** 0

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

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

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	**3**
2.	**Models:** Models, need of models and their classification, models based on transport phenomena principles, alternate classification of models, population balance, stochastic, and empirical models.	**10**
3.	**Models of Heat Transfer Equipment:** Development of detailed mathematical models of evaporators, use of Newton-Raphson method for solving evaporator problems.	**4**
4.	**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.	**11**
5.	**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**
6.	**Process Simulation:** Simulation of chemical process equipment,	**6**

	program development and numerical solution.	
7.	**Flow Sheeting:** Introduction to chemical process flow sheeting and Industrial simulators.	**2**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
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 DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-403** 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 Weightage**:** **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

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

8. Pre-requisite**: CH-206 and CH-301**

9. Objective: To provide the fundamentals of economics, scale up methods and design strategies of chemical 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-digit, Sinking-fund, Accelerated cost recovery system, Modified accelerated cost recovery system.	**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.	**7**
5.	**Optimum Design and Design Strategy:** Procedure with one, two	**10**

	and more variables, Optimum production rates in Plant Operation, Case Studies, Linear Programming-Simplex algorithm, Dynamic Programming for optimization, application of Lagrange multipliers, Methods of Steepest Ascent or Descent.	
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, Differential equations, Regime concept, Static Regime, Dynamic Regime-Fluid system, Thermal regime, Chemical regime, Similarity criteria and Scale-equations for important equipment.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Peters M. S. and Timmerhaus K. D., "Plant Design And Economics For Chemical Engineers", 5th Ed., McGraw Hill, International Ed..	2004
2.	Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann.	2008
3.	Couper J., "Process Engineering Economics", CRC Publisher.	2003
4.	Zlokarnik M., "Scale-up in Chemical Engineering" 2nd Ed., Wiley – VCH.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-405** Course Title: **Chemical Engineering Lab. - III**

2. Contact Hours: **L: 0** **T: 0** **P: 4**

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

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

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

8. Pre-requisite**: CH-302 and CH-303**

9. Objective: To provide hands-on experience of experiments on Reaction Engineering and Process Dynamics and Control

10. Details of Course:

Contents	Contact Hours
REACTION ENGINEERING **1** Study the decomposition of calcium carbonate in a muffle furnace and to interpret decomposition time data in terms of a suitable reaction model **2** Study of the residence time distribution (RTD) of a stirred tank vessel using stimulus-response technique and to comment on the nature of actual flow pattern in the vessel. **3** Study of non-catalytic homogeneous saponification reaction in a cascade (or battery) of CSTRs (continuous stirred tank reactors) and to interpret the kinetic data of the given reaction in the form of a rate equation. **4** Study of non-catalytic homogeneous saponification reaction in a tubular flow reactor and to interpret the kinetic data of the given reaction in the form of a rate equation. **5** Study of non-catalytic homogeneous saponification reaction in a semi-batch reactor and to interpret the kinetic data of the given reaction in the form of a rate equation that is to determine the order of reaction and the values of rate	4 x 14

constants. **6** Study of non-catalytic homogeneous saponification reaction in a batch reactor and to interpret the kinetic data of the given reaction in the form of a rate equation that is to determine the order of reaction and the values of rate constants. **PROCESS DYNAMIC AND CONTROL** **7** To study the Macleod gauge and dynamics of vacuum in a vessel being evacuated. **8** To study the dynamics of a stirred tank system fitted with electric heating assembly to step input from the heating system. Also to study the response of an ON/OFF temperature controller thermostat fitted to the tank and to estimate temperature band within which it controls the temperature of the tank. **9** To study the dynamics of pneumatic system and Dead Weight Tester. **10** To study the Equal Percentage, Quick Opening and Linear control valve characteristics and to calculate the gain at various conditions and to study the I/P and P/I converter. **11** Dynamic Study of Thermometer with and without well. **12** Non Interacting and Interacting Systems	
Total	**56**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Fogler H.S., "Elements of Chemical Reaction Engg.", 3rd Ed., Prentice Hall of India.	1999
2.	Levenspiel O., "Chemical Reaction Enginering", 3rd Ed., John Wiley.	2000
3.	Coughanowr D.R. and LeBlanc S. "Process System Analysis and Control", 3rd Ed., McGraw Hill.	2008
4.	Stephanopoulos G. "Chemical Process Control – An Introduction to Theory and Practice", Prentice-Hall of India.	1990
5.	Perry R.H. and Green D.W., "Perry's Chemical Engineers' Handbook", 8th Ed., McGraw Hill.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-411** Course Title: **Petroleum Refining**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**: Nil**

9. Objective: To provide knowledge of refining operations of crude oil and subsequent refining processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Origin of Petroleum:** Origin and occurrence of petroleum crude, status of petroleum refining in India, composition classification and physical properties of petroleum, evaluation of crude oil and petroleum products, future refining trends.	**8**
2.	**Indian and Global Petroleum Industries**: An overview.	**2**
3.	**Crude Oil Distillation Processes**: Pretreatment of crude, atmospheric and vacuum distillation process.	**5**
4.	**Secondary Conversion Processes**: Catalytic reforming, catalytic cracking, deep catalytic cracking, alkylation, isomerisation and polymerization, reformulated gasoline and oxygenates.	**11**
5.	**Heavy Residue Up-gradation Technologies**: Hydro-treating, hydrocracking, hydro-visbreaking, visbreaking and delayed coking.	**6**
6.	**Lubricating Oil, Wax and Bitumen:** Dewaxing, deasphalting, lube hydro-finishing, bitumen air blowing.	**4**
7.	**Sweetening:** Desulfurization and hydro-desulfurisation of petroleum products.	**3**
8.	**Hydrogen**: Production and management.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Wauquier J. P., "Petroleum Refining: Separation Processes", Vol:1-5, IFP, Technip Ed.	1998
2.	Meyers R. A., "Hand book of Petroleum Refining Processes", 3rd Ed., The McGraw-Hill Publication Data.	2004
3.	Dawe R. A., "Modern Petroleum Technology- Part I", by Institute of Petroleum (IP), John Wiley.	2002
4.	Lucas A. G., "Modern Petroleum Technology- Part II", by Institute of Petroleum (IP), John Wiley.	2002
5.	Sarkar G. N., "Advanced Petroleum Refining" Khanna Publishers.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-412** Course Title: **Petrochemicals**

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** 0

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

8. Pre-requisite**: Nil**

9. Objective: To study process technologies, availability of raw materials, production trends and engineering problems of various petrochemicals.

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.	**7**
2.	**Raw Materials:** Raw materials for organic chemicals-coal, biomass, petroleum and natural gas, Evaluation of crude oil, Petrochemical feed stocks- Natural gas, NGL, Naphtha, Kerosene, and Pyrolysis gasoline.	**7**
3.	**Methane and Synthesis Gas Derivatives:** Steam reforming, methanol, formaldehyde, chlorinated methane.	**4**
4.	**Production of Olefins:** Steam cracking of naphtha and natural gas.	**3**
5.	**Treatment and Up-gradation of C_4 and C_5 Cuts:** Up gradation of C_4 and C_5 streams from crackers, MTBE, TAME.	**4**
6.	**Aromatics Production:** Catalytic reforming, aromatic separation, aromatic conversion processes, Cyclar process.	**4**
7.	**C_2, C_3, C_4, C_5 Derivatives:** Ethylene, ethylene oxide, ethylene glycol, propylene oxide, glycol and isopropyl alcohol, butadiene, maleic anhydride, isoprene	**5**
8.	**BTX Derivatives:** Nitrobenzene, aniline, phthalic anhydride, caprolactum, terephthalic acid, DMT, maleic anhydride, linear alkyl benzene	**4**
9.	**Polymers:** Polymer, elastomers and synthetic fiber: polyolefins, PVC,	**4**

	nylon, polyester.	
	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 Ed.	1986
2.	Chaval A. and Lefebvre G., "Petrochemical Processes" Part-II, 2nd Ed., Technip Ed.	1986
3.	Mall I. D., "Petrochemical Process Technology" 1st Ed., Macmillan India Ltd.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-413** Course Title: **Bio-Chemical Engineering**

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** 0

5. Credits**:** 3 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 bio-reactors.

10. Details 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 micro organisms. Chemical composition of the cell, liquids, carbohydrates, proteins and enzymes.	**9**
2.	**Metabolism and Energetics:** Assimilatory and dissimilatory processes, metabolism of the cells.	**4**
3.	**Enzyme and Microbial Kinetics:** Simple enzyme kinetics with one or two substrates, modulation and regulation of enzymatic activity, enzyme reactions in heterogeneous systems. Cell-growth-cycle phase for batch cultivation, modeling of batch growth, product synthesis kinetics, overall kinetics and thermal death kinetics of cells and spores, kinetics with and without inhibition.	**10**
4.	**Unit Operations in Biochemical Processes:** Agitation and aeration, gas liquid mass transfer, determination of oxygen rates, 'a' and K_La', scaling of mass transfer equipment. Heat balance and heat transfer correlations for biotechnical systems, sterilization, filtration and drying. Immobilization of cell and and enzymes.	**8**
5.	**Analysis and Design Bioreactors:** Classification and	**11**

	characterization of different bioreactors, batch and continuous reactors, tubular, CSTR and tower reactors. Aerobic and anaerobic fermentation, process design and operation of typical aerobic and anaerobic fermentation processes, manufacture of 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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-414** Course Title: **Polymer Science and Engineering**

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** 0

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

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

9. Objective: To present in-depth knowledge of mechanism of polymerization 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 Books / Authors	Year of Publication
1.	Kumar A. and Gupta R., "Fundamentals of Polymer Engineering", CRC.	2003
2.	Billmayer Jr., F. W., "Textbook of Polymer Science", 3rd Ed., John Wiley .	1984
3.	Fried J., "Fundamentals of Polymer Science", Prentice Hall.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-415** Course Title: **Fluidization Engineering**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

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

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

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Importance of fluidization in process industry, comparison of fluidized beds with other modes of contacting, advantages and disadvantages, industrial applications.	**5**
2.	**Fluidization and Mapping of Regimes:** Fixed bed of particles of one and mixed sizes, fluidization with and without carryover of particles, minimum fluidization, terminal velocity of particles, pneumatic transport of solids, mapping of regimes Distributors for dense beds, types and design, power consumption for fluidized beds.	**8**
3.	**Bubble Behavior and Bed Properties:** Single rising bubble models, wake region and solids within bubbles, interaction and coalescence of bubbles, bubble formation, slug flow.	**6**
4.	**Bubbling Fluidized Beds:** Emulsion phase, gas flow, bubble properties, physical and flow models.	**4**
5.	**Entrainment and Elutriation From Fluidized Beds:** Free boards behavior, gas outlet location, entertainment from tall and short vessels.	**4**
6.	**High Velocity Fluidization:** Turbulent fluidized beds, fast fluidization, pressure drop in turbulent and fast fluidization.	**4**
7.	**Spouted Beds:** Hydrodynamics and processing in spouted beds.	**2**
8.	**Circulation Systems:** Circuits for the circulation of solids, pressure	**5**

	balance, flow of gas-solid mixtures in down-comers, flow in pneumatic transport lines.	
9.	**Design for Physical Operations:** Design of single stage and multistage systems, heat and mass transfer, fluid bed drier.	**4**
	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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-416** Course Title: **Fertilizer Technology**

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** **0**

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

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

9. Objective: To impart in-depth knowledge of production technology of nitrogenous, phosphatic, potash and mixed fertilizers.

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. Fuel stock availability and energy consumption pattern in fertilizer industry.	**6**
2.	**Nitrogenous Fertilizers:** Various feed stocks, merits/demerits, synthesis gas production by steam reforming and partial oxidation, purification methods; design considerations and developments in primary reformer, shift converters, CO_2 removal and final gas purification.	**6**
3.	**Ammonia Synthesis:** Different types of reactors, their design consideration, operation and comparison of various processes.	**5**
4.	**Urea and other Nitrogenous Fertilisers:** Physico-chemical considerations, various processes and plant practices for industries: urea, calcium ammonium nitrate, ammonium sulphate.	**5**
5.	**Phosphatic Fertilizers:** Raw material and limitation in their use, uncertainties in their availability and their impact on the existing plants and future planning, normal and triple super-phosphates, phosphoric acid, processes of manufacture and their limitations,	**8**

	design considerations and developments.	
6.	**Potash Fertilizers:** Availability, methods of production of potassium chloride and potassium sulphate.	**4**
7.	**Complex N-P-K Fertilizers:** Mono- and di-ammonium phosphates, urea ammonium phosphate, mixed fertilizers, granulation techniques.	**4**
8.	**Engineering Problems:** Fertilizers storage and handling, fertilizer plant effluents and standards laid down for them.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Mortvedt J. J., "Fertilizer Technology and Applications", Meister publication company.	1999
2.	United Nations and Industrial Development Organization, "Fertilizer Manual", University Press of Pacific.	2007
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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-417** Course Title: **Industrial Pollution Control**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 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-product from industrial emission 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	**6**

	biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying.	
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.	"Pollution Control Acts, Rules, Notifications issued there under" CPCB, Ministry of Env. and Forest, G.O.I., 3rd Ed.	2006
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
6.	Tchobanoglous G., Burton F. L. and Stensel H.D., "Waste Water Engineering: Treatment and Reuse", 4th Ed., Tata McGraw Hill	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-418** Course Title: **Process Utilities and Safety**

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** 0

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

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

9. Objective: To provide knowledge of generation, characterization and use of various process utilities, such as, air, water and steam along with their safety aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Utilities in process industries, primary and secondary and their importance.	**2**
2.	**Heat Transfer Media:** Classification, characteristic properties, selection criteria for their industrial applications.	**3**
3.	**Steam Generation and Utilization:** Steam generation, modern boilers, steam handling, condensate removal, steam traps-classification, characteristics and selection, condensate utilization and flash steam.	**5**
4.	**Water:** Raw water and its characteristics, treatment and conditioning of water for use in various process industries, 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 and piping networks for water, steam, condensate and air.	**3**
7.	**Process Safety:** Process safety, accident and loss statistics, nature of the accident/hazardous process, hazardous substance classification and hazardous substance rules; Factories Act. .	**5**
8.	**Toxicology:** Toxic material, dose-response relationships and	**5**

	predictive models for response, threshold dose and its definition, material safety data sheet, industrial hygiene evaluation.	
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 system, prevention of static electricity hazards.	**6**
11.	**Prevention and Control for Safety: C**lassification, selection and design of various reliefs for vapour/gas, liquid and run-away reactions.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
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", II Ed., Prentice Hall.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-419** Course Title: **Industrial and Municipal Solid Waste Management**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

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

9. Objective: To provide a comprehensive coverage of treatment, utilization and management of non-hazardous industrial and municipal solid wastes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Classification of industrial wastes, Characterization of industrial and municipal solid wastes (MSW). Rules and guidelines for waste handling, storage, treatment and management. Minimization of waste generation and recycle and reuse option.	**12**
2.	**Municipal Solid Wastes (MSW):** Handling, storage and management of MSW. Value extraction from MSW. Landfill, biocomposting, mechanical and biological treatment (MBT), thermo-mechanical and thermal processing. Landfill gas and leachate management. Design of typical landfill, biocompost and thermal processing units.	**15**
3.	**Industrial Solid Wastes (ISW):** Hazardous and non-hazardous waste; Handling, storage and management of non-hazardous ISW. Bio-chemical, chemical and thermal treatment of ISW. Energy and material extraction from ISW. Case studies of a few industries for solid wastes handling, storage and management.	**15**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Title/ Publisher	Year of Publication
1.	Tchobangolous G., Theisen H. and Vigil S.A., "Integrated Solid Waste Management: Engineering Principles and Management Issues", McGraw Hill.	1993
2.	Tedder D.W. and Pohland F.G., "Emerging Technologies in Hazardous Waste Management", ACS.	1990
3.	Pichtel J., "Waste Management Practices: Municipal, Hazardous and Industrial", CRC.	2005
4.	Conway R.A. and Ross R.D., "Handbook of Industrial Waste Disposal", Van-Nostrand Reinhold.	1980
5.	"Pollution Control Acts, Rules, Notifications issued there under" CPCB, Ministry of Env. and Forest, G.O.I., 3rd Ed.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-420** Course Title: **Industrial Safety and Hazards Management**

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** 0

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

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

9. Objective: To provide comprehensive coverage of safety aspects in chemical 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 and the factory act, and environment protection act and rules.	**9**
2.	**Toxicology:** Hazards identification-toxicity, fire, static electricity, 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, vapour cloud and boiling liquid expanding vapours explosion (VCE and BLEVE), mechanical and chemical explosion, multiphase reactions, transport effects and global rates.	**7**
5.	**Relief Systems:** Preventive and protective management from fires and	**7**

	explosion-inerting, static electricity passivation, ventilation, and sprinkling, proofing, relief systems – relief valves, flares, scrubbers.	
6.	**Case 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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-421** Course Title: **Clean Technology in Process Industries**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

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

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

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Environmental impact of chemicals and chemical production.	4
2.	**Evaluation of Technology:** Evaluation of present process technologies of ammonia, sulphuric acid, caustic soda, rayon, pulp and paper, leather plastics and polymers. Analysis of raw materials, intermediates, final products, bye-products and wastes.	12
3.	**Modification:** Process modification, waste utilization, water recycling and reuse technologies in relation to above industries.	6
4.	**Alternative Technology:** 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.	12
5.	**Advanced Technology:** Development of biodegradable end-products of polymers and plastics.	8
	Total	42

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Mukhopadhyay P. K. and Roy T. K., "Ecofriendly and Clean Technologies" Indian National Academy of Engineering.	1997
2.	Johansson A., "Clean Technology", CRC.	1992
2.	Kafarov V. V., "Wasteless Chemical Processes", Mir.	1985

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-422** Course Title: **Design of Experiments and Parameter Estimation**

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** 0

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

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

9. Objective: To impart the 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	**8**

	new response observations, regression model diagnostics, testing for lack of fit.	
6.	**Response Surface Methods and Other Approaches:** Response surface methodology, method of steepest ascent, analysis of a second-order response surface, experimental designs for fitting response surfaces, mixture experiments, evolutionary operation, robust design.	**8**
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.	Name of Books / Authors	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", 5^{th} Ed., Wiley.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-423** Course Title: **Advanced Process Control**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

8. Pre-requisite**:** **CH-302**

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**
5.	**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, 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. and Ray W. H., "Process Dynamics Modeling and Control", Oxford University Press	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-424** Course Title: **Novel Separation Techniques**

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** 0

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

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

9. Objective: To provide knowledge of advance separation processes used in chemical and biochemical industries.

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, pervaporation and permeation, nanoseparation.	**12**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	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-India.	2006
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 DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-425** Course Title: **Process Integration**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 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:** Basic concept, comparison with energy auditing, role of thermodynamic laws, problem addressed by pinch technology.	7
3.	**Key Steps of Pinch Technology:** Data extraction, targeting, designing, optimization and supertargeting.	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 DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-426** Course Title: **Process Analysis and Optimization**

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** 0

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

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

9. Objective: To provide knowledge of optimization methods used in process analysis.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Importance of the process design and its relationship with process development and plant design, synthesis of plausible process alternatives and their techno-economic evaluation.	**8**
2.	**Process Analysis:** Creation of alternative and structure analysis of systems and sub-systems. Economic design criteria and general methods of cost estimation.	**7**
3.	**Optimization:** Introduction to optimization and search for optimum conditions, analysis of objective function and its relationship with design variables, direct search techniques for single and multi design variables, introduction of dynamic programming for linear systems, principle of dynamic programming and sub-optimization of systems with acyclic structure, approach to optimization of complex systems. Sensitivity analysis, importance of decomposition, stage combination and cut-state strategies in macro system optimization.	**18**
4.	**Uncertainty Analysis:** Design of optimization of systems with partial knowledge of some variables, future developments, uncertainty in data, failure tolerances.	**9**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Henderson S. M., Perry R. L., and Young J. H., "Principles of Process Engineering", 4th Ed., Asae.	1997
2.	Peters, M. S. and Timmerhaus, K. D., "Plant Design And Economics For Chemical Engineers", 5th Ed., McGraw Hill.	2004
3.	Edgar T. F., Himmelblau D. M. and Lasdon L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-427** Course Title: **Modeling of Dynamic Systems**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 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	**11**

	dimensional fixed bed reactor, fluidized bed reactor and bioreactor.	
6.	**Modeling of Heat Transfer Systems:** Dynamics of the metal jacket wall, heat exchanger dynamics.	**4**
	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.	Bequette B. W., "Process Dynamics: Modeling, Analysis and Simulation", Prentice Hall.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-428** Course Title: **Design of Piping Systems**

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** 0

5. Credits**:** 3 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,	**8**

	branch connections and bolted flange connections.	
7.	**Simplified Methods for Flexibility Analysis:** Thermal expansion loops, code rules, approximate solutions and flexibility analysis by model tests. Approaches to reducing expansion effects, expansions joints.	**7**
	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", 7th 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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-429** Course Title: **Heterogeneous Catalysis and Reactor Design**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

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

9. Objective: To introduce reaction kinetics of heterogeneous catalysis, and analysis and design of catalytic reactors

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Solid Catalyst:** Role of catalyst components and other constituents, characterization of catalyst and its support.	4
2.	**Heterogeneous Catalysis:** Mechanism and kinetic models of surface reactions, determination of kinetics parameters through experiments, analysis of complex reactions, synthesis of kinetic structure.	5
3.	**External and Internal Transport Processes:** Effect of heat and mass transfer, internal effectiveness factor, generalized effectiveness factor, point effectiveness, multiple reactions, transport criteria.	8
4.	**Deactivation of Catalyst:** Physical deactivation, surface diffusion. Sintering-mechanism and kinetics, chemical deactivation-types and kinetics, regeneration of catalyst.	6
5.	**Selectivity and Stability:** Effect of transport processes and deactivation on selectivity and stability of a single pellet.	4
6.	**Multiphase Reactions:** Mass transfer coefficients, effect of transport and global rates.	4
7.	**Design of Catalytic Reactors:** Design and analysis of fixed bed reactors, autothermic operation and stability, fluidized bed reactors,	11

	two phase and multiphase models. Introduction to slurry reactors and trickle-bed reactors.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Lee H. H., "Heterogeneous Reactor Design", Buterworth Heinman.	1985
2.	Carberry J. J. and Verma A., "Chemical Reaction and Reactor Engineering", CRC.	1987
3.	Doraiswamy L. K. and Sharma M.M., "Heterogeneous Reactions", Vol. 1 and 2, Wiley.	1984
4.	Ramchandran P. A. and Chaudhari R. V., "Three – Phase Catalytic Reactors", Gordon and Breach.	1983
5.	Froment G. F. and Bischoff K. V., "Chemical Reactor Analysis and Design", 2nd Ed., Wiley.	1990
6.	Jakobsen H. A., "Chemical Reactor modeling: Multiphase Reactive Flows", Springer.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-430** Course Title: **Advanced Numerical methods**

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** 0

5. Credits**:** 3 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.	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.	Numerical differentiation and numerical integration methods, quadratures and their applications to numerical integration.	**4**
4.	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	**10**

	engineering systems, concept of finite element.	
6.	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.	Cutlip M. B. and Shacham M.., "Problem Solving in Chemical and Biochemical Engineering with POLYMATH, EXCELL and MATLAB", 2nd Ed., Prentice Hall.	2008
6.	Constantinides A. and Mostoufi N., "Numerical Methods for Chemical Engineers with MATLAB Applications", Prentice Hall.	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-431** Course Title: **Hazardous Wastes Management**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: DEC**

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

9. Objective: To provide a comprehensive coverage of treatment, utilization and management of non-hazardous industrial and municipal solid wastes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Hazardous Waste Classification and Characterization:** Fluid and solid wastes, Characterization of hazardous waste-physico-chemical, thermal and bio-characteristics. Examples of wastes from a few industries. Rules and regulation for handling, storage, treatment and management of hazardous waste.	**12**
2.	**Waste Minimization:** Minimization of waste generation, value extraction, recycle and reuse, raw material change in processes.	**06**
3.	**HSW Treatment and Management:** Treatment and management strategies, property and state modification, transformation and blending; physico-chemical, chemical, biological and thermal treatment; membrane treatment. Advanced treatment method like concentration-incineration; wet oxidation, adsorption etc.	**10**
4.	**Case Studies:** characteristics and treatment strategies for hazardous wastes from petroleum refineries, petrochemicals, chemical and associated industries like organic and inorganic industries, pulp and paper mills, metallurgical and metal finishing units, steel plants, mines etc.	**14**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Title/ Publisher	Year of Publication
1.	Tchobangolous G., Theisen H. and Vigil S.A., "Integrated Solid Waste Management: Engineering Principles and Management Issues", McGraw Hill.	1993
2.	Tedder D.W. and Pohland F.G., "Emerging Technologies in Hazardous Waste Management", ACS.	1990
3.	Pichtel J., "Waste Management Practices: Municipal, Hazardous and Industrial", CRC.	2005
5.	"Pollution Control Acts, Rules and Notifications issued there under" CPCB, Ministry of Environment and Forests G.O.I., 3rd Ed.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-432** Course Title: **Process Simulators**

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** **0**

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

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

9. Objective: To provide knowledge of process simulators and their applications in process plant simulation.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Process Simulation:** Steps in a simulation approach, architecture of flowsheeting software, integration of simulation tools, selection of simulation software.	**10**
2.	**Process Flow sheeting:** Approaches to flowsheeting, collection and estimation of thermo-physical properties for the chemical species of the system, computerized thermo-physical properties systems, degrees of freedom in a flow sheet. Flow sheet presentation, manual flow sheet calculations, computer aided flow-sheeting, steady state simulation, manual calculations with recycle streams.	**17**
3.	**Process Synthesis:** Process synthesis by thermodynamic and hierarchical approach, synthesis of reaction systems and synthesis of azeotropic separation systems.	**10**
4.	**Case Studies:** Design and simulation of process industries.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Dimian A. C., "Integrated Design and Simulation of Chemical Processes", Elsevier.	2003
2.	Westerberg, A. W., Hutchison, H. P., Motard, R. L. and Winter, P., "Process Flowsheeting", Cambridge University Press.	1979
3.	Kumar, A., "Chemical Process Synthesis and Engineering Design", Tata McGraw Hill.	1981

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-434** Course Title: **Advanced Control Strategies in Hydrocarbon Industry**

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** 0

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

8. Pre-requisite**:** **CH-302**

9. Objective: To provide the knowledge about analysis and design of advanced control systems for hydrocarbon industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Review of dynamic modeling and response of linear open-loop and closed loop system. stability analysis, frequency response and its use in control system design.	**6**
2.	**Analysis and Design of Control System:** compensatory control for process with large dead time, multi-loop control (cascade, selective, split range), feed forward and ratio control, adaptive and inferential control.	**12**
3.	**Multivariable Control Systems:** alternative control configurations, interaction and decoupling of control loops, relative gain-array method	**5**
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:** Digital control systems-transforms, computer control loop, sampling and reconstruction of signals,	**10**

	conversion of continuous to discrete – time models, discreet time response and stability, design of controllers and control algorithms. On-line process identification and self tuning regulator.	
5.	**Control Systems for Hydrocarbon Industries:** Design, and case studies.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Stephanopoulos G., "Chemical Process Control-An introduction to Theory and practice", Prentice-Hall Of India.	1990
2.	Coughanowr D. R. and LeBlanc S., "Process System Analysis and Control", 3rd Ed., McGraw-Hill.	2008
3.	Seborg D. E., Edgar T. F. and Mellichamp D. A., "Process Dynamics and Control", II ed., John Wiley and sons.	2004
4.	Ogunnaike B. A. and Ray W. H., "Process Dynamics Modeling and Control", Oxford University Press.	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-436** Course Title: **Process Intensification in Hydrocarbon Industry**

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** 0

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

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

9. Objective: To provide knowledge about methods and equipment used for process intensification.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to process intensification and its components, history, type, ways of process intensification, equipment and methods.	**4**
2.	**Reactors and Separators**: Multifunctional reactors, Hybrid separation, Alternative energy sources and other methods.- basic concept, principles, design and application	**8**
3.	**Mixers and Reactors**: Static mixers and reactors, structured and monolithic catalyst and reactors, spinning disc reactors-basic concept, principles, design and application	**8**
4.	**Process Intensification for safety:** Inherent safety, layer of protection, safety strategies, applications, metrics of inherent safety	**5**
5.	**Process Synthesis/Integration:** Conceptual design, role of reaction engineering, design, optimization	**5**
6.	**Process Iintensification in Industrial Practice:** Methodology and application	**6**

7.	**Case Studies related to Hydrocarbon Industries.**	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Green A., "Process Intensification for Chemical Industry – Smaller, Cheaper and Safer", Professional Engg. Publishing.	2007
2.	Galip A., "Process Intensification and Miniaturisation: Principles and Applications in Biological, Chemical and Environmental Technologies", Elsevier Technology Books	2007
3.	Stankiewicz A., "Re-Engineering the Chemical Processing Plant: Process Intensification", Dekker incorporated Marcel.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-438** Course Title: **Refinery Optimization**

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** 0

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

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

9. Objective: To introduce relevant optimization techniques and their specific application to petroleum refinery operations and management.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Refining:** A technical overview of refining operations.	**2**
2.	**Linear Programming:** Introduction to optimization, classical optimization and linear programming as used in refining industry and its application to transportation, blending, product scheduling.	**18**
3.	**Non-Linear Programming:** Introduction to direct search, non-linear programming techniques and dynamics programming and its application to refinery design, operation and control.	**16**
4.	**Applications:** Application of optimization in organizational analysis and managerial decision making.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Taha H. A., "Operation Research an Introduction", 7th Ed., Prentice Hall.	2002
2.	Edgar T. F., Himmelblau D. M. and Lasdon L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill.	2001
3.	Rao S. S., "Engineering Optimization : Theory and Practice", 3rd Ed., New Age International.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-551** Course Title: **Hydrocarbon Processing and Engineering-I**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: MSC**

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

9. Objective: To impart knowledge about down-stream hydrocarbon processing and engineering, catalyst development and design considerations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Major challenges and future strategies in petroleum refining industry, petroleum and petrochemical integration for value addition, future fuel quality and refinery economics.	**5**
2.	**Separation Processes in Petroleum and Gas Processing:** Distillation, extraction, adsorption, absorption and membrane processes.	**8**
3.	**Advanced Distillation:** Advances in crude oil distillation and processing of gases, major equipment, design criteria, tower packing, operation control and troubleshooting.	**4**
4.	**Advances in Catalyst:** Advances in catalyst in petroleum industry.	**4**
5.	**Fluid Catalytic Cracking:** Development in technology, equipment, FCC catalyst and additives, reaction kinetics, FCC reactor and regenerator design criteria, recent developments in FCC hardware.	**5**
6.	**Catalytic Reforming:** Catalytic reforming process, reaction kinetics, reforming reactor design,, catalyst preparation characterization, development and optimization, catalyst deactivation and regeneration, recent trends-global and Indian scenario.	**5**
7.	**Hydrocracking:** Technology and design aspects, recent trends in	**4**

	hydrocracking technology, hydrocracker catalyst development.	
8.	**Lube Base Stock:** Advances in lube base stock refining.	**3**
9.	**Future Fuels:** National fuel policy, fuel options, bio-augmentation of fuel stock, hydrogen production and management in refinery.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books	Year of Publication
1.	Dawe R. A., "Modern Petroleum Technology Part I", by Institute of Petroleum (IP), John Wiley.	2002
2.	Lueas A. G., "Modern Petroleum Technology Part II", by Institute of Petroleum (IP), John Wiley.	2002
3.	George J. A., Abdullha M. A. and Parera J., "Catalytic Naptha Reforming: Science and Technology", Marcel Dekker.	1994
4.	Sadeghbeigi R., "Fluid Catalytic Cracking Handbook", 2nd Ed., Gulf Professional.	2000
5.	Seader, J. D. and Henley, E. J "Separation Process Principles", 2nd Ed., Wiley.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-552** Course Title: **Hydrocarbon Processing and Engineering-II**

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

8. Pre-requisite**:** **CH-551**

9. Objective: To provide down stream processing of hydrocarbons and their engineering aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Clean fuel and petrochemical synergies, introduction to down stream processing for the production of petrochemicals, feed stock for petrochemicals, overview of hydrocarbon processing for petrochemicals.	3
2.	**Separation Processes in Gas Purification and Down Stream Processing:** Distillation, solvent extraction, adsorption, absorption, crystallization, membrane processes.	8
3.	**Petrochemical Conversion Processes:** Cracking, oligmerisation, etherification, steam reforming, partial oxidation, oxidative coupling paraffin dehydrogenation, oxidation, disproportionation, hydroalkylation, isomerisation, aromatization and transalkylation.	8
4.	**Natural Gas Processing:** Natural gas processing and value addition.	4
5.	**Steam Cracking:** Steam cracking of naphtha and natural gas, operating variables, furnace design criteria, advances in decoking, technological development in steam cracking, and olefin production technologies.	5
6.	**Products from FCC and Steam Cracker Gases:** Down stream processing of FCC and steam cracker gases, oxygenates, and other value added products.	3
7.	**Aromatic Production:** Aromatic production and aromatic conversion	4

	processes, advances in reformer design and catalyst development, future trend in aromatic production, separation processes in aromatic production, linear alkyl benzene technology and separation processes and design criteria.	
8.	**Processing of C_1-C_5 Stream:** Processing of C_1-C_5 stream for value addition.	**5**
9.	**Polymers and Monomers:** Down stream processing of hydrocarbons for production of monomers for synthetic fibre and polymers, polymerization reaction engineering.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books	Year of Publication
1.	George J. A., Abdullha M. A. and Parera J., "Catalytic Naptha Reforming: Science and Technology", Marcel Dekker.	1994
2.	Seader, J. D. and Henley, E. J "Separation Process Principles", 2nd Ed., Wiley.	2006
3.	Chauval, A. and Lefebvre, G., "Petrochemical Processes" Part-I and II, 2nd Ed., Technip.	1986
4.	Mall I. D., "Petrochemical Process Technology", Macmillan India Ltd.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-553** Course Title: **Reservoir Engineering**

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** 0

5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: MSC**

8. Pre-requisite**:** **CH-205**

9. Objective: To provide knowledge of storage of hydrocarbons storage and exploitation of oil and gas fields.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic concepts of reservoir engineering.	3
2.	**PVT Analysis for Oil, Gas and Water:** Definitions, fluid sampling, laboratory testing and field condition conversion.	5
3.	**Material balance Applied to Oil Reservoirs:** General equation, reservoir drive mechanisms, solution gas drive, gas cap drive, natural water drive, aquifer model in conjunction with material balance, combination drive – reservoirs and ultimate recovery.	5
4.	**Flow through Porous media:** Darcy's law, flow regimes, flow geometry and pressure distribution, radial flow equation, multiphase flow, effective and relative permeabilities, solution of radial flow equation; transient flow analysis, stabilized deliverability, calculation of water influx.	8
5.	**Oil Well Testing:** The constant terminal rate solution for transient and steady state flow, superposition theories, pressure build-up theory and analysis, well-completion.	6
6.	**Gas Well Testing:** Radial flow of a real gas, solution techniques of radial flow equation, theory of gas well testing, pressure build-up and analysis techniques.	6

7.	**Natural Water Influx and Immiscible Displacement:** Water influx theory and prediction of water influx, oil recovery calculations, displacement under different conditions.	**5**
8.	**Reservoir Simulation:** Classical reservoir engineering and reservoir simulation, effects of variable properties, capillary pressure and flow.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books	Year of Publication
1.	Dake L. P., "Fundamental of Reservoir Engineering", Elsevier.	1978
2.	Smith H. C., Tracy G. W. and Farrar R. L., "Applied Reservoir Engineering:, Vol. I and II, OGCI.	1999
3.	Salter A., Baldwin J. and Jespersen R., "Computer-Aided Reservoir Management", Pennwell.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-554** Course Title: **Oil and Gas Transport**

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** 0

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

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

9. Objective: To provide knowledge about the design and engineering problems of transportation of crude oil, natural gas and petroleum products.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** An overview, rheology of crude oil and petroleum products, API and ASTM codes for petroleum, petroleum products and natural gas transport pipelines.	6
2.	**Type of pipes:** Fundamentals, design of pipelines for petroleum and petroleum products, design consideration for buried pipeline and pipeline from tankers to filling stations, design of gas pipelines, steel pipe design formula, working pressure of pipe, pipe specifications, complex pipeline systems, storage capacity, two phase flow and heat tracing, flexibility anaylsis.	12
3.	**Prime Movers, Pumps and Compressors:** Types, selection, characteristics and design.	6
4.	**Corrosion and Aging:** Aging and replacement of piping, control of internal and external pipeline corrosion – detection and prevention, use of coating, additives, anodic and cathodic protection of pipelines.	7
5.	**Control and Automation:** Pipeline automation, automatic control schemes, alarms, safety trips and interlocks of pipelines	4
6.	**Submarine Pipeline:** Engineering problems, design and construction of submarine pipelines.	4
7.	**Tankers and Rail Transport:** Transportation by tankers and rail.	3

	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books	Year of Publication
1.	Kennedy J. L., "Oil and Gas Pipeline Fundamentals", 2nd Ed., Pennwell Publication.	1993
2.	Boyd O. B., "Petroleum Fluid Flow Systems", OWB Corporation, John M. Campbell and Co.	1983
3.	Molhatab S., Poe W. A. and Speight J. G., "Handbook of Natural Gas Processing and Tranmission", Gulf Publishing Company.	2006
4.	Nolte C. B., "Optimum Pipe Size Selection", Trans. Tech. Publication.	1978

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-556** Course Title: **Natural Gas Engineering**

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** 0

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

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 gas, 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, membrane separation.	**4**
6.	**Gas Processing:** Absorption, refrigeration, fractionation and design consideration, design procedures for absorbtion, adsorption and membrane separation .	**8**
7.	**Gas Hydrates:** Determination of hydrate formation temperature/ pressure, condensation of water vapor, temperature drop due to gas expansion, thermodynamic inhibitors, kinetic inhibitors and anti agglomerates.	**5**
8.	**Gas Engineering:** Steady state flow of gas through pipes,	**5**

	multiphase gas liquid flow, gas compression, gas flow measurement, gas gathering and transport.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books	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 DEPARTMENT: **Chemical Engineering**

1. Subject Code: **CH-558** Course Title: **Distillation Processes**

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** 0

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

8. Pre-requisite**:** **CH-301**

9. Objective: To provide in-depth knowledge of different distillation processes used in hydrocarbon industries and their engineering aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts:** Review of distillation processes, phase equilibria in multicomponent mixtures.	**5**
2.	**Batch Distillation:** Shortcut method for multicomponent batch rectification with constant reflux; stage-by-stage methods for multicomponent batch distillation.	**5**
3.	**Multicomponent multistage Distillation:** Short-cut methods, equilibrium based methods for multicomponent distillation.	**6**
4.	**Atmospheric Distillation Unit (ADU):** Basic principles, design and engineering aspects.	**4**
5.	**Vacuum Distillation. Unit (VDU)**: Design and Engineering aspects.	**4**
5.	**Enhanced Distillation:** Azeotropic and extractive distillation, salt distillation, pressure swing distillation, reactive distillation, catalytic distillation.	**9**
6.	**Column Sequencing**: Sequence of single column, synthesis for complex columns.	**5**
7.	**Heat Integrated Columns**: Heat integration of distillation columns and their sequences.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books	Year of Publication
1.	Seader, J. D., and Henley, E. J., "Separation Process Principles", John Wiley and Sons, Inc., Singapore.	1998
2.	Watkins, Robert N., "Petroleum Refinery Distillation", II Ed., Gulf	1979
3.	Stichlmair J. and Fair J. R., "Distillation: Principles and Practice", Wiley.	1998
4.	Wankat P. C., "Equilibrium Stage Separations", Prentice Hall.	1988
5.	Doherty M. F. and Malone M. F., "Conceptual Design of Distillation Systems", McGraw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Chemical Engineering**

1. Subject Code: **ICH-01** 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**: Both** 7. Subject Area**: ESEC**

8. Pre-requisite**: CH-205 or its equivalent**

9. Objective: To impart knowledge about the applications of computation fluid dynamics (CFD) to various engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts of Fluid Flow:** Philosophy of computational fluid dynamics, conservation principles of mass, energy, and momentum, simplified flow models such as incompressible, inviscid, potential and creeping flows, classification of flows.	6
2.	**Grid Generation:** Structured and unstructured grids, choice of grid, general transformation of equations, some modern developments in grid generation in solving engineering problems.	4
3.	**Finite Difference Method:** Discretization of ordinary and partial differential equations, approximation of first, second and mixed derivatives, implementation of boundary conditions, discretization errors, applications to engineering problems.	10
4.	**Finite Volume Method:** Discretization methods, approximations of surface integrals and volume integrals, interpolation and differentiation practices, implementation of boundary conditions, applications to engineering problems.	12
5.	**Special Topics:** Flow in a sudden pipe contraction / expansion, flow and heat transfer in a complex tubes and channels, reactive flow, multiphase flow. Turbulent flow processes.	10
	Total	42

11. Suggested Books:

S. No.	Name of Authors/Books	Year of Publication
1.	Anderson Jr J. D., "Computational Fluid Dynamics: The Basics with Applications", McGraw Hill.	1995
2.	Muralidhar K. and Sundararajan T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House.	2003
3.	Versteeg H. K. and Malaksekara V., "An Introduction to computational Fluid Dynamics: The Finite Volume Method", Longman Scientific and Technical.	1995
4.	Ferziger J. H. and Peric M., "Computational Methods for Fluid Dynamics", 3rd Ed., Springer.	2002
5.	Ranade V. V, "Computation Flow Modeling for Chemical Reactor Engineering", Academic Press.	2002