National Institute of Technology , Raipur (C.G.)														
Department of Chemical Engineering														
Course of Study				M. Tech.: Chemical Engineering						First Semester				
S.No.	Board of Studies	Sub. Code	Subject Name	Periods/week			Examination Scheme					Total Marks	Credits L+(T+P)/2
				L	T	P	TA	FE	SE	ESE	Pract. ESE		
1	Chemical Engineering	CL41111(CL)	Advanced Separation Processes	3	1	-	20	15	15	100	-	150	4
2	Chemical Engineering	CL41112(CL)	Advanced Transport Phenomena	3	1	-	20	15	15	100	-	150	4
3	Chemical Engineering	CL41113(CL)	Chemical Reactor Analysis & Design	3	1	-	20	15	15	100	-	150	4
4	Chemical Engineering		Elective-I	3	1	-	20	15	15	100	-	150	4
5	Chemical Engineering		Elective-II	3	1	-	20	15	15	100	-	150	4
6	Chemical Engineering	CL41121(CL)	Computational Fluid Dynamics Lab.	-	-	3	75	-	-	-	50	125	2
7	Chemical Engineering	CL41122(CL)	Chemical Reaction Engineering Lab.	-	-	3	75	-	-	-	50	125	2
			Total	**15**	**5**	**6**	**250**	**75**	**75**	**500**	**100**	**1000**	**24**

List of Elective-

1. Experimental & Analytical Methods in Chemical Engineering CL41131(CL)
2. Alternative Energy Sources CL41132(CL)
3. Polymer Technology CL41133(CL)
4. Microelectronics fabrication CL41134(CL)
5. Membrane Technology CL41135(CL)

National Institute of Technology , Raipur (C.G.)

Department of Chemical Engineering

Course of Study				M. Tech.: Chemical Engineering									Second Semester	
S.No.	Board of Studies	Sub. Code	Subject Name	Periods/week			Examination Scheme						Total Marks	Credits L+(T+P)/2
				L	T	P	TA	FE	SE	ESE	Pract. ESE			
1	Chemical Engineering	CL41211 (CL)	Advanced Thermodynamics	3	1	-	20	15	15	100	-		150	4
2	Chemical Engineering	CL41212 (CL)	Advanced Process Control	3	1	-	20	15	15	100	-		150	4
3	Chemical Engineering	CL41213 (CL)	Advanced Heat Transfer	3	1	-	20	15	15	100	-		150	4
4	Chemical Engineering		Elective-III	3	1	-	20	15	15	100	-		150	4
5	Chemical Engineering		Elective-IV	3	1	-	20	15	15	100	-		150	4
6	Chemical Engineering	CL41221 (CL)	Environmental Engineering Lab.	-	-	3	75	-	-	-	50		125	2
7	Chemical Engineering	CL41222 (CL)	Modeling & Simulation Lab.	-	-	3	75	-	-	-	50		125	2
			Total	**15**	**5**	**6**	**250**	**75**	**75**	**500**	**100**		**1000**	**24**

List of Elective-

1. Advanced Process Modeling & Simulation CL41231(CL)
2. Advanced Enviromental Engineering CL41232(CL)
3. Nano Technology CL41233(CL)
4. Operation Research CL41234(CL)
5. Process Intensification CL41235(CL)

National Institute of Technology , Raipur (C.G.)														
Department of Chemical Engineering														
Course of Study				M. Tech.: Chemical Engineering						Third Semester				
S.No.	Board of Studies	Sub. Code	Subject Name	Periods/week			Examination Scheme					Total Marks	Credits L+(T+P)/2
				L	T	P	TA	FE	SE	ESE	Pract. ESE		
1	Chemical Engineering	CL41321(CL)	Preliminary work on Dissertation	-	-	24	100	-	-	-	200	300	12
2	Chemical Engineering	CL41322(CL)	Comprehensive Viva Voce & Seminar	-	-	-	-	-	-	-	200	200	4
			Total	**0**	**0**	**24**	**100**	**0**	**0**	**0**	**400**	**500**	**16**

National Institute of Technology , Raipur (C.G.)													
Department of Chemical Engineering													
Course of Study				M. Tech.: Chemical Engineering						Fourth Semester			
Sr.No.	Board of Studies	Sub. Code	Subject Name	Periods/week			Examination Scheme					Total Marks	Credits L+(T+P)/2
				L	T	P	TA	FE	SE	ESE	Pract. ESE		
1	Chemical Engineering	CL41421(CL)	Dissertation	-	-	32	200	-	-	-	300	500	16
			Total	0	0	32	200	0	0	0	300	500	16

NATIONAL INSTITUTE OF TECHNOLOGY RAIPUR

1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41111 (CL)**	Course Title:	**Advanced Separation Processes**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Details of Course:

Prerequisite:
Concepts of binary distillation and diffusion along with basics in chemical thermodynamics

Course objectives:
To provide advanced knowledge of separation processes. Student will have knowledge of multicomponent distillation and diffusion. Also the student shall be able to discuss about industrial membrane processes.

Unit I
Multi-component Distillation column Design:Selection of two key components, number of plates, minimum number of plates, feed plate locations, minimum reflux ratio, Lewis Sorel's method, Underwood's equation.

Unit II
Multi-component diffusion: Maxwell's law of diffusion, regular and random surface renewal theory, mass transfer and chemical reaction – steady state and unsteady state ,film-penetration theory, interfacial turbulence.

Unit III
Diffusion-Eddy transfer Mixing length and eddy kinematics viscosity, universal velocity profile, the turbulent core, the laminar sub-layer, the buffer layer, velocity profile for all regions, velocity gradients, laminar sub-layer and buffer layer thickness.

Unit IV
Introduction to membrane separation processes: Classification of membrane processes, general membrane equation, membrane materials and membrane modules.

Unit V
Membrane processes: Liquid permeation membrane processes, gas permeation membrane processes, microfiltration, ultra-filtration, reverse osmosis membrane processes, pervaporation, dialysis and electrodialysis.

Name of Text Books and References
1. C.J.Geankoplis, "Transport processes and unit operations", Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
2. J. M. Coulson and J.F. Richardson, "Chemical engineering, Fluid flow, heat transfer and mass transfer", Vol -1, 1998.
3. R.E. Treybal, "Mass-transfer operations", McGraw-Hill, New York, 1980.
4. C.J. King, "Separation processes", Tata McGraw Hill, New Delhi, 1982.
5. J.D. Seader and E J.Henley.,"Separation process principles", John Wiley & Sons, 1998.

NATIONAL INSTITUTE OF TECHNOLOGY RAIPUR

1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41112 (CL)**	Course Title:	**Advanced Transport Phenomena**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Fluid mechanics, heat transfer, mass transfer, numerical methods, mathematics, chemical process calculations, computer languages and codes, modeling and simulation, physics, chemical reactors and chemical reaction engineering, mixers etc.

Course objectives:
The course is an advanced course to transport phenomenon where the students shall be made to solve the various physical problems of both laminar and turbulent flows to be solved by numerical methods. The equations of change shall be transformed in the light of assumptions and solved under the suitable boundary conditions to obtain the differential equation. The solution of differential equation by hand is not practical and hence come the need to discretize these equations to algebraic forms. The algebraic form of equation shall have to be solved on the space using finite difference or finite volume which shall be done through the window of CFD. CFD meshing, design and solution strategy shall be taught to the students to get the problems solved and this shall be called as numerical experiments. Thus the course aims to learn the practical behavior and solutions of problems of Chemical Engineering using solution of equation numerically.

Details of Course:

Unit I
Introduction: Basic principles and equations of change in transport of momentum, heat and mass; Equations of continuity, motion, mechanical energy, angular momentum, energy, and equation of continuity for multicomponent mixture

Unit II
Development of model equations for laminar flows: Flow of Newtonian and non Newtonian fluids, use of equation of change for developing equations for laminar flow in internal and external flows, boundary layer flows, flow in stirred tanks, flow in viscometers, flow in pipe line and over flat plates and other physical situations for both Newtonian and Non-Newtonian fluids

Unit III
CFD: Philosophy of computational fluid dynamics CFD, grid generation, structured and unstructured grids, choice of suitable grid, grid transformation of equations, some modern developments in grid generation for solving engineering problems, CFD essentials.

Unit IV
Numerical fluid flow and heat transfer: Finite difference method (FDM), finite volume method (FVM) and finite element method (FEM): Discretization of ODE and PDE, approximation for first, second and mixed derivatives, approximations of volume integrals, implementation of boundary conditions, discretization errors, applications to engineering problems.

Unit V

Special Topics: Modeling two dimensional flow over a flat plate for laminar and turbulent flow, steady two dimensional incompressible laminar flow between stationary plates, laminar flow past circular cylinder, steady state heat conduction across a infinite long solid slab, flow in stirred tanks, solution of Newtonian and Non-Newtonian fluid flows, heat transfer studies in various systems.

Name of Text Books and References

1. R.B. Bird., W.E. Stewart and E.N.Lightfoot, "Transport phenomena", 2nd Ed., Wiley, 1994
2. J.D. Anderson, "Computational fluid dynamics", McGraw Hill. 1995
3. S.V. Patankar, "Numerical heat transfer and fluid flow", Taylor and Francis, 2004
4. H.K.Versteeg, W.Malalsekera, "Introduction to computational fluid dynamics- the finite volume method", Longman scientific and technical, 1995.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41113 (CL)**	Course Title:	**Chemical Reactor Analysis & Design**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
UG level chemical reaction engineering, Physics, Chemistry, Mathematics, Ordinary differential equations & Integration.

Course objectives:
The intent of this course is to learn the student about several advanced concepts in chemical reaction engineering, notably:
1) advanced reactor design and stability, including consideration of the energy balance;
2) chemical reaction mechanisms and rate theories;
3) transport effects in reactive systems, and;
4) biological applications of chemical kinetics.

Details of Course:

Unit I
Industrial reactors: stirred tank reactors, tubular reactors, kilns and hearth furnaces, fixed and moving bed reactors, fluidized beds, multiphase reactors, special types of reactors. Isothermal reactor design: Design structure; scale up of liquid phase batch reactor to the design of CSTR, tubular reactors, pressure drop in reactors, reversible reactions, unsteady state operation of reactors, simultaneous reaction and separation.

Unit II
Non-isothermal reactor design:
Energy balance, non-isothermal CSTR and PFR at steady state, equilibrium conversion, Unsteady state operation, non-adiabatic reactor operation, multiple steady state.

Unit III
Fluid particle reactions design: Performance equations for uniform gas composition - particles of single size + plug flow of solids, particles of different but unchanging size + plug flow of solids, particles of different but unchanging size + mixed flow of solids, particles of different size + mixed flow of solids, application to fluidized bed with entrainment of solid fines.

Unit IV
Fluid - Fluid reactions design: Towers for fast reactions- mass transfer with and without reaction, Towers for slow reaction, mixer settlers, semi-batch contacting patters, reactive and extractive reactions.

Unit V
Solid catalyzed reaction design: Design of staged adiabatic packed bed reactors, Design of fluidized bed reactors. Scaling up test results: method of scale up and blow up, similitude.

Name of Text Books and References

1. J.B. Rawlings, and J.G. Ekerdt, Chemical Reactor Analysis and Design Fundamentals. Nob Hill Publishing, 2002.
2. H.S. Fogler, Elements of Chemical Reaction Engineering, 4th Ed., Prentice Hall, New Jersey, 2005.
3. S.D. Kirkpatrick, Reaction kinetics for chemical engineers., McGraw Hill series.
4. O. Levenspiel Chemical Reaction Engineering., John willey & Sons.
5. H.S. Fogler, Elements of Chemical Reaction Engineering, 3rd Ed. Prentice Hall, 2004.
6. S.D. Dawande, Principles of Reaction Engineering, Central Techno Publications.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41131 (CL)**	Course Title (Elective):	**Experimental & Analytical Methods in Engineering &Technology**	
4	Contact hours	**L-3**	**T-1**	**P-0 Credits- 4**	
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite: - Nil

Course objectives:
1. To provide a fundamental understanding of the statistical analysis of the various experimental data, planning the experiments
2. To give an in depth knowledge on interpretation of data from various analytical techniques, and understand approaches for the validation of the results.
3. To impart knowledge to the students so that they get an understanding of selection of the proper analytical method for a given system
4. Students will be able to select and apply appropriate separation methods to the analysis of real world problems.

Details of Course:

Unit I
Mathematical statistics: Introduction, random sampling, point estimation of parameters, confidence intervals, acceptance sampling, goodness of fit, χ^2 test, regression, fitting straight lines, correlation.
Unit II
Atomic spectroscopy: An introduction to spectrometric methods, optical atomic spectrometry, atomic absorption and atomic fluorescence spectrometry, atomic emission spectrometry, atomic mass spectrometry, atomic X-ray spectrometry.
Unit III
Molecular spectroscopy: An introduction to ultraviolet / visible molecular absorption spectrometry, molecular luminescence spectrometry, infrared spectrometry, Raman spectroscopy, NMR spectroscopy, molecular mass spectrometry, surface characterization by spectroscopy and microscopy.
Unit IV
Separation Methods: An introduction to chromatographic separations, gas chromatography, high performance liquid chromatography, supercritical fluid chromatography and extraction, capillary electrophoresis, capillary electrochromatography.
Unit V
Electroanalytical chemistry and miscellaneous methods: Introduction to electoanalytical chemistry, potentiometry, coulometry, voltammetry, thermal methods, radiochemical methods, particle size analysis.

Name of Text Books and References
1. E. Kreyszig, “Advanced engineering mathematics” Wiley, 9th Edition, 2014.
2. J. Cazes, “Ewing’s Analytical instrumentation hand book”, Taylor & Francis, 3rd Edition, 2004.
3. D. A. Skoog, F .J. Holler, S. R. Crouch, “Principles of instrumental analysis”, 6th Edition, Cengage Learning, 2014.
4. H. H. Willard, Merritt, Dean, Settle “Instrumental methods of analysis”, CBS Publishers, 7th Edition, 2004.
5. J. Mendham, “Vogel’s Quantitative chemical analysis”, 6th Edition, Pearson India, 2009.

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1	Name of Department	**Chemical Engineering Department**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41132 (CL)**	Course Title**(Elective):**	**Alternate Energy Sources**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Basic knowledge of energy, its types and basics about renewable energy. Applied Physics, Applied Chemistry.

Course objectives:
The major goal of this course is to provide fundamental knowledge that will help students understand and analyze problems with various practices of alternate energy production and use, and to evaluate the feasibility of possible solutions to these problems and also to:
1. Understand the difference between conventional and alternate energy sources and identify and distinguish between different forms of alternate energy.
2. Understand the advantages and limitations of different alternate energy sources and identify a wide variety of applications for alternate energy.
3. Understand the basic as well as advanced scientific and technical principles behind large-scale applications of alternate energy.
4. Identify selected political, social, and economic incentives that would accelerate the implementation of alternate energy.

Details of Course:

Unit I
Energy Scenario and Development: Overview of world and India's energy scenario, energy and development linkage, energy sources: classification of alternate energy sources, future energy systems, cleanenergy technologies, renewable energy sources. Fuel cell: Principle of working, basic thermodynamic and electrochemical principles, classifications, applications of fuel cell for power generations.
Unit II
Bio-energy: Overview of biomass as energy source, biomass conversion routes: biochemical, chemical and thermo chemical, anaerobic digestion, biogas production mechanism, digesters, biogas plants, biogas utilization and storage, liquid biofuel, biodiesel, gassohol, chemical conversion of biomass for energy production, hydrolysis and hydrogenation, synthesis of biofuel, bio-refinery, thermo-chemical conversion of biomass, pyrolysis, carbonization, charcoal (biochar) production ,biomass gasification, energy plantation, waste to energy.
Unit III
Nuclear and Magneto-hydro-dynamic (MHD) Energy: Nuclear fission and nuclear fusion, nuclear power plants, magneto-hydro-dynamic (MHD) energy conversion ,electrochemical energy, batteries, role of carbon nanotubes in electrode, magnetic and electric storage system, super conducting magnetic energy storage (SMES) systems, capacitor and super capacitor.
Unit IV
Other Alternative Energy Sources: Advance and recent developments in other alternative energy sources. Hydrogen energy, basics of hydrogen energy, production methods, storage and transportation and applications, solar energy,wind Energy, geo-thermal energy, ocean energy, wave energy conversion, tidal energy conversion, geothermal Energy.

Unit V

Socio-economical Aspects of Energy Resources: Energy use & climate change, green house gas emission and carbon credit, impacts, mitigation, global warming, sustainability issues of energy use ,rural development, poverty alleviation, employment; security of supply and use, environmental and ethical concerns, international treaties & convention on environmental mitigation, environmental laws on pollution control, energy audit.

Name of Text Books and References

1. R.A. Ristinen, J.J. Kraushaar,“Energy and the environment”, 2nd edition, John Willey & Sons, 2006.
2. A. Pandey,“Hand book of plant¬basedbio¬fuel”, CRC Press, Taylor & Francis, 2008.
3. K.M. Mital,“Biogas systems, principle and applications”, New Age International Ltd., 1996.
4. G.D. Rai,“Non¬conventional energy sources”,Khanna Publication, 2001.
5. R. Narayan, B. Biswanathan,“Chemical and electrochemical energy systems”, University Press (India) Ltd., 1998.
6. V.V.N. Kishore, “Renewable energy engineering and technologies”, TERI, 2009.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41133 (CL)**	Course Title(Elective):	**Polymer Technology**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Basic knowledge on polymerization reactions and structure of long chain molecules. Fundamental idea about chemical bondings and forces. General physical and chemical characteristics/properties of the materials.

Course objectives:

To get the basic concepts of polymers such as types, structure, forces, thermal transition and bonding in polymers.
To develop the deep knowledge on Polymer preparation and various methods of processing.
To give knowledge on properties and characterization techniques of polymers.
To learn about Polymer additives, blends and composite.
To address the developments in polymer processes, management and applications of polymers.

Details of Course:

Unit I
Introduction to polymers: Basic concepts and definitions, classification of polymers, polymer structure, molecular forces and chemical bonding in polymer, molecular weight and its distribution, chemical structure and thermal transition.
Unit II
Polymer preparation and processing methods: Step-reaction (condensation) polymerization, radical chain (addition) polymerization, ionic and coordination chain (addition) polymerization, copolymerization, polymerization conditions and polymer reactions.Various polymeric processing methods.
Unit III
Polymer characterization: Characterization - molecular weight and molecular size determination, thermoanalytical methods of characterization including TGA, DTA, and DSC; spectroscopy (IR, NMR, UV-visible) of polymers. Properties – solution properties, mechanical properties and polymer viscoelasticity.
Unit IV
Polymer additives, blends and composites: Additives – plasticizers, fillers and reinforcements, other important additives. Polymer blends and interpenetrating networks - polymer blends, toughened plastics and phase-separated blends, interpenetrating network. Introduction to polymer composites – Mechanical properties, composite fabrication.
Unit V
Specific topics in polymer technology: Biodegradable polymers, Scale up of polymerization processes, recent developments in polymer processes, applications of the polymers in various fields, management of polymeric products in the environment.

Name of Text Books and References

1. J. O. Fried, "Polymer science and technology", 3rd Edition, Prentice Hall Publisher, 2014
2. R. R. Ebewele, "Polymer science and technology", CRC Press, Boca Raton, New York 2000.
3. F. W. Billmeyer, "Textbook of polymer science", 3rd Edition, A Wiley-lnterscience Publication 1984.
4. T. Meyer and J. Keurentjes, "Handbook of polymer reaction engineering", A Wiley-VCH Publication 2008.
5. S. Palsule, "Polymer composites", New Age International 2008.
6. P. M.Ajayan, L. S Schadler., P. V Braun., "Nanocompositescience &technology", Wiley-VCH 2003

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41134 (CL)**	Course Title(Elective):	**Microelectronics Fabrication**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:

Nil

Course objectives:

1. Gives a basic understanding on operating principles of electronic and optical devices, the process of semiconductor chip fabrication.
2. Give an in-depth knowledge on various steps in integrated chip manufacturing processes.
3. To encourage the students to pursue for a career in semiconductor processing facilities / research works.

Details of Course:

Unit I

Overview and materials: Unit processes and technologies, semiconductor substrates, phase diagrams and solid solubility, crystallography and crystal structure, crystal defects, Czochralski growth, float zone growth, Bridgman growth of GaAs, wafer preparation and specifications.

Unit II

Hot processing and ion implantation: Diffusion, atomistic models of diffusion, analytic solutions of Fick’s law, corrections to simple theory, analysis of diffused profiles, thermal oxidation, the deal-grove model of oxidation, the linear and parabolic rate coefficients, oxide characterization, the effects of dopants during oxidation and polysilicon oxidation, ion implantation, coulomb scattering, shallow junction formation, rapid thermal processing, rapid thermal activation of impurities, rapid thermal processing of dielectrics.

Unit III

Pattern transfer: Optical lithography, lithography overview, diffractions, advanced mask concepts, photoresists, photoresist types, organic materials and polymers, non-optical lithographic techniques, vacuum science and plasmas, etching, wet etching, chemical mechanical polishing, reactive ion etching.

Unit IV

Thin films: Physical deposition – evaporation and drying, sputtering high density plasma sputtering, chemical vapor deposition, metal chemical vapor deposition, epitaxial growth, metal organic chemical vapor deposition.

Unit V

Process integration: Device isolation, contacts, metallization, CMOS technologies, GaAs technologies, silicon bipolar technologies, MEMS, integrated circuit manufacturing, introduction to devices and integrated circuit formation, introduction to integrated circuits, packaging.

Name of Text Books and References

1. S. A. Campbell, “The science and engineering of microelectronic fabrication –, Oxford University Press, 2nd Edition, 2001.
2. R. C. Jaeger, “Introduction to microelectronic fabrication”, Vol. 5 of Modular Series on Solid State Devices -, Prentice Hall, 2nd Edition, 2001.
3. P. V. Zant, “Microchip fabrication”, McGraw Hill, 5th Edition, 2004.
4. S. M. Sze, “VLSI technology”, McGraw Hill, 2nd Edition, 2003.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- First Semester**			
3	Subject Code:	**CL41135(CL)**	Course Title(Elective):	**Membrane Technology**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:

Fundamental principles of mass transfer operations, understanding of various driving forces of mass transfer. Basic knowledge on modelling equations, determination of rate equations, design of batch and continuous reactors.

Course objectives:

To provides a compact, intensive, hands-on introduction with engaging assignments and activities to membrane technology.

To learn the principles of membrane technology and engineering aspects of membrane separation processes, including gas permeation, pervaporation, reverse osmosis, ultrafiltration, microfiltration, and dialysis.

To provide the knowledge on mechanisms of transport in membranes, and design and modelings of membrane processes.

To teach the current trends and future directions of membrane technology.

Details of Course:

Unit I

Fundamentals of the membrane separation: Basic principles, classifications of membranes and its processes, membrane materials and properties, preparation and characterization of membranes.

Unit II

Membrane transport theory: Porous membrane - bulk flow, liquid diffusion in pores, gas diffusion. non-porous membranes – solution diffusion for liquid mixtures and gas mixtures.

Unit III

Membrane reactor function and use: Membrane modules, flow patterns, concentration polarization, fouling and its control, industrial/commercial and environmental applications of membrane separation.

Unit IV

Important membrane separation processes and their modeling for Liquid and Gas streams: Reverse osmosis, nanofiltration, ultrafiltration, microfiltration, dialysis and electro dialysis. pervaporation and gas permeation.

Unit V

Specific Topics: Advancements in polymeric, nano-composite, ceramic, metal and liquid membrane process. future challenges and directions in membrane science and technology.

Name of Text Books and References

1. K. Nath, “Membrane separation processes”, PHI Learning Pvt Ltd, New Delhi, 3rd Edition, 2012.
2. M. Mulder, “Basic principles of membrane technology”, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2nd Edition, 1996.

3. J.D. Seader, E. J. Henley, “Separation process principles”, John Wiley & Sons, Inc, 2nd Edition.
4. R. W. Baker, “Member technology and applications”, John Wiley & Sons Ltd, 2nd Edition.
5. A. K. Pabby., S.S. H. Rizvi., A. M. Sastre, “Hand book of membrane separations: Chemical, Pharmaceutical, Food, and Biotechnological Applications”, CRC press, Taylor & Francis Group, 2009.
6. K. Scott, “Handbook of industrial membranes”, Published by Elsevier Advanced Technology, Ist Edition, 2006.

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<table>
<tr><td>1</td><td>Name of Department</td><td colspan="4">Chemical Engineering</td></tr>
<tr><td>2</td><td>Semester:</td><td colspan="4">M.Tech.- First Semester</td></tr>
<tr><td>3</td><td>Subject Code:</td><td>CL41121(CL)</td><td>Course Title:</td><td colspan="2">Computational Fluid Dynamics Lab.</td></tr>
<tr><td>4</td><td>Contact hours</td><td>L-0</td><td>T-0</td><td colspan="2">P-3 Credits- 2</td></tr>
<tr><td>5</td><td>TA: 75</td><td>FE: 0</td><td>SE: 0</td><td>ESE: 50
(Min. Pass Marks: 25)</td><td>Total: 125</td></tr>
<tr><td>6</td><td>Examination Time</td><td colspan="4">3 hrs</td></tr>
</table>

Details of Course:

Prerequisite:
Fluid mechanics, heat transfer, mass transfer, numerical methods, mathematics, chemical process calculations, computer languages and codes, modeling and simulation, physics, chemical reactors and chemical reaction engineering, mixers etc.

Course objectives:
The lab involved the numerical solution of some common problems of chemical engineering and aim to visualize the effect of various factors on the flow of heat and mass transfer.

List of experiments

1. Study of fluid flow and heat transfer in mixing tee.
2. Study of flow maldistribution in different shapes of headers.
3. Velocity boundary layer analysis of flow of fluid over a flat plate in laminar flow.
4. Study of laminar and turbulent flow in pipe line.
5. Modeling of forced convection in pipe line flows.
6. Study of flow of fluid over air foil and effect of angle of attack.
7. Modeling steady flow past cylinder and other geometries.
8. Study of fluid flow and heat transfer in mixing elbow.
9. Study the effect of roughness in turbulent flow through pipe line.
10. Study of flow of fluid through a nozzle.
11. Study of fluid flow in a rotating disk.
12. Modeling motion of sphere in cylinder falling under gravity.

Software
Ansys Fluent

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<table>
<tr><td>1</td><td>Name of Department</td><td colspan="4">Chemical Engineering</td></tr>
<tr><td>2</td><td>Semester:</td><td colspan="4">M.Tech.- First Semester</td></tr>
<tr><td>3</td><td>Subject Code:</td><td>CL41122(CL)</td><td>Course Title:</td><td colspan="2">Chemical Reaction Engineering Lab.</td></tr>
<tr><td>4</td><td>Contact hours</td><td>L-0</td><td>T-0</td><td colspan="2">P-3 Credits- 2</td></tr>
<tr><td>5</td><td>TA: 75</td><td>FE:0</td><td>SE: 0</td><td>ESE: 50(Min. Pass Marks: 25)</td><td>Total: 125</td></tr>
<tr><td>6</td><td>Examination Time</td><td colspan="4">3 hrs</td></tr>
</table>

Details of Course:

Prerequisite:
A basic course in chemical reaction engineering which is part of a bachelor program in chemical engineering. Principles of chemical reactor analysis and design. Experimental determination of rate equations, design of batch and continuous reactors

Course objectives:
To provide a core foundation for the analysis and design of chemical reactors
To learn about reaction kinetics for single, multiple, isothermal, non-isothermal reactions and reactor design procedures
To analyse the experimental results on the basis of theory taught in the introductory course in chemical reaction engineering

List of experiments

1. Kinetic study of dissolution of benzoic acid in batch reactor
2. Study of a non-catalytic homogeneous reaction in an isothermal batch reactor
3. To study of a non-catalytic homogeneous reaction in a straight type plug flow reactor under ambient conditions
4. To study residence time distribution (RTD) in a CSTR
5. To study a non catalytic homogeneous second order liquid phase reaction in a CSTR
6. To study a non catalytic homogeneous reaction in a packed bed
7. Study a second order saponification reaction in a semi-batch reactor and to determine the reaction rate constant
8. Study of the hydrolysis of acetic anhydride or propylene oxide with water in presence of an acid catalyst (H_2SO_4) and to predict the degree of conversion from time-temperature data
9. To study a photo-catalytic reaction and the mineralization of industrial or synthetic effluents

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41211 (CL)**	Course Title:	**Advanced Thermodynamics**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Details of Course:

Prerequisite:

UG level chemical engineering thermodynamics, ordinary differential equations, UG level applied chemistry.

Course objectives:

The objectives of this course are;

1. To provide students with tools in applying thermodynamics principles.
2. To predict physical phenomena and to solve engineering problems.
3. To teach the students how to use state equations for property calculation.
4. To define the basic activity coefficient models and to apply them and solve phase equilibria problems for vapor-liquid equilibrium (VLE), liquid-liquid equilibrium (LLE), solid liquid equilibrium (SLE), and solid-vapor equilibrium (SVE), as well as chemical reaction equilibrium.
5. To show how to use thermodynamics principles and concepts for the analysis of chemical processes.

Unit I

An Introduction to Vapour-Liquid Equilibria: Qualitative behaviour of the vapour-liquid equilibria (VLE), Simple models for vapour - liquid equilibria: Raoult's and Henry´s laws, Dew point and bubble point calculations, VLE by modified Raoult´s law and K-value correlations. Flash calculations.

Unit II

Fundamental property relation, The chemical potential and phase equilibria, Partial properties. Equations relating molar and partial molar properties, Partial properties in binary solutions, Relations among partial properties, Ideal gas mixtures, Fugacity and fugacity coefficient for pure species, VLE for pure species, Fugacity of a pure liquid, Fugacity and fugacity coefficient for species in solution, The fundamental residual property relation, Fugacity coefficients from the virial equation of state and generalized correlations, The ideal solution: the Lewis/Randall rule, Excess properties, The excess Gibbs energy and the activity coefficient, The nature of excess properties.

Unit III

Solution Thermodynamics: Applications: Liquid phase properties from VLE data, Fugacity, Activity coefficient, Excess Gibbs energy, Data reduction,Thermodynamic consistency, Models for the excess Gibbs energy, Local composition models. Property changes of mixing. Heat effects of mixing processes. Heats of solution. Enthalpy- Concentration diagrams.

Unit IV

Chemical Reaction Equilibria: The reaction coordinate, Multireaction stoichiometry, Application of equilibrium criteria to chemical reactions, The standard Gibbs energy change and equilibrium constant, Effect of temperature on the equilibrium constant, Evaluation of equilibrium constants, Relation of equilibrium constants to composition, Gas-phase and liquid-phase reactions, Equilibrium conversions for single reactions, Single phase reactions, Reactions in heterogeneous systems, Multireaction equilibria.

Unit V

Topics in Phase Equilibria: The gamma/phi formulation of VLE, VLE from cubic equations of state, Equilibrium and stability, Liquid-liquid equilibrium, Vapour-liquid equilibrium, Solid-liquid equilibrium, Osmotic equilibrium and osmotic pressure.

Name of Text Books and References

1. J.R. Elliot and C.T. Lira: Introductory Chemical Engineering Thermodynamics: Prentice-Hall.
2. M. Modell and R.C Reid: Chemical Engineering Thermodynamics, Prentice-Hall.
3. S. I. Sandler: Chemical and Engineering Thermodynamics, Wiley and Sons.
4. B.G. Kyle: Chemical and Process Thermodynamics: B.G Kyle, Prentice-Hall.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- Second Semester**			
3	Subject Code:	**CL41212 (CL)**	Course Title:	**Advanced Process Control**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
A basic knowledge on the control system.

Course objectives:

1. To provide the students an in-depth knowledge on advanced control strategies.
2. To impart knowledge on theoretical analysis of complex processes, controller tuning and process identification.
3. Ability to analyze the sampled data control system and application of the same to some of the physical systems.
4. **Details of Course:** To give an understanding on multivariable control systems.

Unit I
Advanced control strategies, controller tuning and process identification: Cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control, controller tuning, tuning rules, process identification.

Unit II
Control valves and theoretical analysis of complex processes: Control valve construction, valve sizing, valve characteristics, valve positioned, control of a steam-jacketed kettle, dynamic response of a gas absorber, distributed-parameter systems.

Unit III
Z-Transforms and discrete-time response of dynamic system: Z – Transform, inversion of Z-transforms and modified Z – transform, discrete-time analysis of continuous systems, pulse transfer function, discrete-time analysis of closed-loop systems.

Unit IV
State-space methods: State-space representation of physical systems, state variables, transfer function matrix, transition matrix, multivariable control, control of interacting systems, stability of multivariable systems, decoupling, relative gain array.

Unit V
Model predictive control: Predictions for SISO models, predictions for MIMO models, model predictive control calculations, set-point calculations, selection of design and tuning parameters, implementation of MPC.

Name of Text Books and References

1. D. R. Coughanowr, S. E. LeBlanc, “Process systems analysis and control”, McGraw-Hill Education, 3rd Edition, 2008.
2. D. E. Seborg, T. F. Edgar, A. Duncan, “Process dynamics and control”, Mellichamp, Francis J. Doyle III – Wiley Publishers, 3rd Edition, 2011.
3. P. Harriott, “Process control”, Tata McGraw Hill Education, 1st Edition, 2001.
4. G. Stephanopoulos, “Chemical process control: An introduction to theory and practice” Prentice Hall, 2012.
5. W. L. Brogan, “Modern control theory”, Prentice-Hall, 3rd Edition, 1991.
6. B.A.Ogunnaike, W.H.Ray, “Process dynamics, modelling and control”, Oxford Press, 1994.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- Second Semester**			
3	Subject Code:	**CL41213 (CL)**	Course Title:	**Advanced Heat Transfer**	
4	Contact hours	**L-3**	**T-1**	**P-0** **Credits- 4**	
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
A basic knowledge on the three modes of heat transfer.

Course objectives:

1. To give an in-depth understanding of basic heat transfer principles to the students.
2. Ability to model multidimensional heat conduction processes, leading to a governing equation.
3. To provide an understanding of forced convection system principles and equations.
4. To give the students a feel of heat transfer applications in chemical engineering processes.

Details of Course:

Unit I

Conduction: General three dimensional differential equation of heat conduction, steady state systems without and with internal heat generation, systems with variable thermal conductivities, mathematical and graphical analysis of 2-D systems, electrical analog of 2-D systems, numerical relaxation methods for 2-D and 3-D systems.

Unit II

Transient heat conduction: Lumped systems, systems with finite surface and internal resistance, systems with negligible surface resistance; use of charts, numerical procedures and graphical solution of transient heat conduction.

Unit III

Forced convection heat transfer: Analytical and semi-analytical solution, equations for velocity and temperature distribution in vertical and horizontal planes for cylinders and spheres, physical significance of dimensionless groups with respect to momentum and energy equations.

Unit IV

Radiation: Radiation heat transfer concepts; angle factor calculations; network method of analysis of radiation exchange; radiation calculation through gas and vapors.

Unit V

Specific applications: Design of compact heat exchangers, heat transfer due to boiling, liquid metal heat transfer, pinch technology.

Name of Text Books and References

1. J. P. Holman, S. Bhattacharya, “Heat Transfer”, McGraw Hill, 10th Edition, 2011.
2. F. P. Incropera, D. P. Dewitt, T. L. Bergman, A. S. Lavine, “Fundamentals of engineering heat & mass transfer”, Wiley, 2013.
3. D. Q.Kern, “Process heat transfer”, McGraw Hill, 1997.
4. R. B. Bird, W. E. Stewart, E.N. Lightfoot, “Transport phenomena”, Wiley, 2nd Edition, 2013.
5. Y. A. Cengel, A. J. Ghajar, “Heat and Mass Transfer”, McGraw Hill, 4th Edition, 2011.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41231 (CL)**	Course Title(Elective):	**Advanced Process Modeling & Simulation**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Details of Course:

Prerequisite:
Mathematics, chemical reaction engineering, mass transfer, heat transfer, fluid flow, control.

Course objectives:
Apply the knowledge of mathematics in solving engineering problems

Details of Course:

Unit I
Numerical Techniques for Computer simulation: Linear algebraic equations, nonlinear algebraic equations, ordinary differential equations, partial differential equations. transport phenomena based models. modeling and simulation of fluid flow operations, introduction to simulation software.

Unit II
Modeling and simulation of unsteady and steady state chemical reaction processes: Batch reactor, CSTR flow reactor, plug flow reactor. Recycled reactor, slurry reactor, fluidized reactor, Population balance model.

Unit III
Modeling and simulation of unsteady and steady state heat transfer processes: Shell and tube heat exchanger, multiple effect evaporators, condenser.

Unit IV
Modeling and simulation of mass transfer operations I: Modeling and simulation of unsteady and steady state distillation, flashing processes.

Unit V
Modeling and simulation of mass transfer operations II: Modeling and simulation of unsteady and steady state drying, extraction and absorption processes.

Name of Text Books and References

1. W.L. Luyben,"Process modeling, simulation and control for chemical engineers", McGraw-Hill Publishing Co., 1990.
2. C. D. Holland, "Fundamental and modeling of separation process", Prentice Hall, Inc., New Jersey,
3. B. V. Babu, "Process plant simulation", Oxford University Press India, 2006.
4. B.A. Ogunnaike and W.H. Ray, "Process dynamics modeling and control", Oxford University Press, 1994.
5. D. M. Himmemblue, K.B. Bischof, "Process analysis and simulation", Deterministic system, John Willey and Sons, INC, New Delhi, 1968.
6. G.Stephanopoulos "Chemical process control: An introduction to theory and practice", Prentice-Hall INC, 1984.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41232 (CL)**	Course Title(Elective):	**Advanced Environmental Engineering**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Basic knowledge of environmental engineering, chemical engineering unit operations, unit process and chemical kinetics, mathematical knowledge of solving matrices and differential equations.

Course objectives:
To impart in-depth knowledge of environmental engineering calculations and design.
To impart step by step, practical calculation procedures in different areas of environmental engineering.
To integrate regulatory requirements into environmental designs.

Details of Course:
Unit I
Introduction to Air, Water and Noise Pollution and Solid Waste management: H&WM rules 1991, Environmental Impact Assessment; Thermodynamics used in Environmental Engineering; Air Pollution Control: Air Emission Control, Particulate Emission Control, Wet and Dry Scrubbers for Emission Control, Air Toxic Risk Assessment.
Unit II
Physico-chemical waste water treatment: Waste Water Treatment Systems, Screening Devices, Comminutors, Grit Chamber, Flow Equalization, Sedimentation, Primary Sedimentation Tanks, Coagulation, Electrocoagulation
Unit III
Biological and Advanced Waste Water Treatment: Biological (Secondary) Treatment Systems Activated Sludge Process, Trickling Filter, Rotating Biological Contactor, Stabilization Ponds, Secondary Clarifier, Effluent Disinfection, Sludge (Residuals) Treatment and Disposal, Application of Membranes, Pervaporation and Dialysis.
Unit IV
Solid Waste Calculations: Basic Combustion and Incineration-Introduction, Basic Combustion Principles, Basic Mass and Energy Balance Calculations, Basic Incinerator Design, System Calculations.
Practical Design of Waste Incineration: Combustion Process Calculation, Waste Combustion System, Control of Emissions from Combustion, Controlled and Uncontrolled Emission Factors, Conversions and Correction.
Unit V
Calculation for Permitting and Compliance: Calculation of Emissions from the Stack, Regulatory Emission Standards and Guidelines, Calculation to confirm Compliance with Standards, Environmental Impacts of Stack Emissions, Environmental Risk Assessment. Incineration Technologies and Facility Requirements: Incineration Technology, Resource Recovery System, Facility Design Feature.

Name of Text Books and References

1. C.C. Lee, Shun Dar Lin,“Handbook of environmental engineering calculation”, 2nd edition McGraw Hill, 2007.
2. L. K. Wang, Y.-Tse Hung, N. K. Shammas,“Advanced physicochemical treatment Technologies”, Volume-5, Humana Press, 2007
3. A. P. Sincero, G.A.Sincero,“Environmental engineering: A design approach”, Prentice Hall, 2007.
4. Metcalf & Eddy, “Waste water engineering- Treatment disposal and reuse”, Tata-McGraw Hill Publishing Company limited, New Delhi 2003.
5. W. W. Eckenfelder, “Industrial water pollution control”, McGraw Hill, New Delhi 1989.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41233 (CL)**	Course Title(Elective):	**Nano Technology**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Knowledge of basic sciences, application of mass transfer and heat transfer
Course objectives:
To prepare, characterize various nano metarials and its application in various fields.

Unit I
Introduction to nanotechnology: background, definition, basic ideas about atoms and molecules, physics of solid state, review of properties of matter and quantum mechanics.
Unit II
Preparation of nano materials: Preparation of Nanostructured Materials, Lithography, nanoscale lithography, E-beam lithography, dip pen lithography, nanosphere lithography. Sol gel technique Molecular synthesis, Selfassembly, Polymerization,
Unit III
Characterization of nano materials: Characterization of Nano-structured materials. Cross-cutting, nano materials in heat and mass transfer applications, Molecular electronics, Nanophotonics
Unit IV
Areas of Application of Nanotechnology: Energy storage, Production and Conversion. Agriculture productivity enhancement Water treatment and remediation. Disease diagnosis and screening. Drug delivery systems. Food processing and storage.Air pollution and remediation. Construction. Health monitoring. Vector and pest detection, and control. Biomedical applications.
Unit V
Emerging trends in applications of nanotechnology: Industrial applications of Nanotechnology: Development of carbon nanotube based composites. Nanocrystalline silver Antistatic conductive coatings, nanometric powders, sintered ceramics, nanoparticle ZnO and TiO_2 for sun barrier products, quantum dots, sensors, molecular electronics, other significant implications

Name of Text Books and References

1. S.M. Lindsay, “Introduction to Nanoscience”, Oxford University Press, 2009.
2. S. K. Kulkarni, “Nanotechnology: Principles and Practices”, Capital Publishing Company, 2007.
3. R. Kelsall, I. Hamley, M. Geoghegan, “Nanoscale Science and Technology”, John Wiley & Sons, 2005.
4. G. Cao, “Nanostructures and Nanomaterials”, Imperial College Press, London, 2004.
5. M.Ratner, D.Ratner, “A Gentle Introduction to Next Big Thing”, Pearson Education 2005.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41234 (CL)**	Course Title(Elective):	**Operation Research**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Details of Course:

Prerequisite:
Mathematics, basic chemical engineering, basic management

Course objectives:
Application of various optimization techniques in chemical engineering problems.

Unit I
Linear programming problem: Basic concepts in linear programming,mathematical formulation of L.P.P, graphical solution, simplex method, The big-M method, two phase method, degeneracy in simplex method, dual simplex method, integer programming.

Unit II
Non-linear optimization: Introduction to constrained and unconstrained optimization problems – Newton method, secant method, Region elimination method, Lagrange multiplier method.

Unit III
Transportation problem: North – West comer rule and Vogel's approximation method to find optimal basic feasible solution, Modi method.

Unit IV
Assignment problem: Characteristics of $M/M/1/\infty$, $M/M/1/K$ and $M/M/c/\infty$ queuing models in the steady-state. Introduction to the inventory problem: Deterministic and probabilistic models.

Unit V
Introduction to network construction: CPM/PERT techniques, critical path method(CPM),determination of critical path(Labeling Method),the project evaluation and review Technique(PERT), probability considerations in PERT, distinction between PERT and CPM, project cost, time-cost optimization algorithm.

Name of Text Books and References

1. T.F. Edgar and D. M. Himmelblau, “Optimization of Chemical Processes”, 2nd Edition, McGraw Hill, 2001.
2. S. R. Singiresu, “Engineering Optimization: Theory and Practice”, 4th Edition, John Wiley & Sons Ltd., 2009.
3. M. C. Joshi and K. M. Moudgalya, “Optimization: Theory and Practice”, Alpha Science International Limited, 2004.
4. K. Deo, “Optimization Techniques”, Wiley Eastern, 1995.
5. R. Panneerselvam, “Operation Research”, Second edition, PHI Learning private Ltd., New Delhi, India, 2006.
6. P. K. Gupta and D.S. Hira, “Problems in Operations Research (Principles andSolutions)”, S.Chand and company Ltd. New Delhi, India, 2008.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.- Second Semester**			
3	Subject Code:	**CL41235 (CL)**	Course Title(Elective):	**Process Intensification**	
4	Contact hours	**L-3**	**T-1**	**P-0**	**Credits- 4**
5	TA: **20**	FE: **15**	SE: **15**	**ESE: 100** (Min. Pass Marks: 40)	**Total: 150**
6	Examination Time	**3 hrs**			

Prerequisite:
Fluid mechanics, heat transfer, mass transfer, chemical reactors and chemical reaction engineering.

Course objectives:
The course is an advanced course to chemical engineering and do consider as the advancement of the chemical engineering field in the last many decades. Here the history of the chemical systems such as reactors, columns, chambers etc is focused to see what is prevalent in the industry till date and how could once look for the intensification of the existing either through modification or change. The reluctance of change is the major reason of emergence of change in any system and so is in chemical engineering, however there is scope in latest technologies which needs to be highlighted. So learn the birth of process intensification where the advances system of momentum, heat and mass transfer are discussed in the five units of this course. The student shall learn about how could once provided a technology which is cheap, safe and clean compared to the conventional.

Details of Course:

Unit I

History, philosophy and principles of process intensification (PI): Introduction, philosophy and opportunities of PI, Types of PI equipments - Equipments and methods.

Unit II

High gravity in chemical processing: Historical development, fundamentals, mechanical design, applications, scale-up and commercial use, future, rotation packed bed, spinning disc reactor.

Unit III

Multifunctional heat exchanger: Introduction, compact heat exchanger technology, single phase flow, heat transfer and mass transfer, applications.

Micro-reaction technology: Microtechnology, effect of miniaturization, microfabrication, implementation.

Unit IV

Structured catalysis and reactors: Introduction, overview of structured reactors, gas phase reactions, multiphase reactions.

Inline and high intensity mixers: Importance of mixing, motionless mixers, mixing concepts, mixing performance in inline mixers, design guidelines and correlations.

Unit V

Reactive and hybrid separations: Reactive distillation, membrane based reactive separations, reactive extraction, reactive crystallization, reactive absorption, extractive distillation, adsorptive distillation, membrane distillation, membrane chromatography, membrane extraction.

Process intensification industrial practice: Positive results on PI on various aspects, PI methodology, Case studies.

Name of Text Books and References

1. A. Stankiewiez, A. M. Jacob, “Reengineering the chemical processing plant”, Marcel Dekker Inc. New York, Basel, 2004.
2. J.M. Navarro, A. Bailly, “Compact brazed plate heat exchanger”. Elsevier, Paris. 1994.
3. R.K. Shah, “Compact heat exchanger for the process industry”, Begell House, 1997.
4. Ehrfeld W., Hessel V., Lowe, H., Weinheim, “Microreactors”, Willey-VCH, 2000.
5. J.M., Douglas, “Conceptual design of chemical processes”, McGraw-Hill, New York, 1988.
6. S. Suresh, A. Keshav, Separation processes, Studium Press India, 2012.

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1	Name of Department	**Chemical Engineering**			
2	Semester:	**M.Tech.-Second Semester**			
3	Subject Code:	**CL41221(CL)**	Course Title:	**Environmental Engineering Lab.**	
4	Contact hours	**L-0**	**T-0**	**P-3**	**Credits- 2**
5	TA: 75	FE:**0**	SE: **0**	**ESE: 50**(Min. Pass Marks: 25)	**Total: 125**
6	Examination Time	**3 hrs**			

Prerequisite:

Basic knowledge on water, soil, air and noise pollution. International and national standards and acts for water and air quality. Fundamentals of water and wastewater treatment and, water pollutants.

Course objectives:

- To analyse the experimental results on the basis of theory taught in the introductory course of environmental engineering.
- To learn the various wastewater treatment techniques.
- To get knowledge on water, wastewater, soil and air quality standards.
- To know the various analytical methods available for wastewater treatment.
- To learn fundamentals of water chemistry.

List of experiments

1. Determination of the turbidity, electrical conductivity and pH of the given water sample.
2. Determination of optimum coagulant dosage for given water sample using Jar Test Apparatus.
3. Determination of acidity, alkalinity and types of hardness in given water sample.
4. Determination of various types of solids in the given water sample.
5. Determination of sulphate and sulphide in the given water sample.
6. Determination of D.O and B.O.D. in the given water sample.
7. Determination of C.O.D. in the given water sample.
8. Determination of oil and grease in the given water sample.
9. Determination of residual chlorine in the given water sample.
10. Determination of coliforms using MPN Test in the given water sample.
11. Determination of toxic heavy metals concentration in the given water sample using AAS.
12. Determination of alkali and alkaline earth metals in the given water sample using Flame Photo meter
13. Determination of NOx, SOx and COxin the given air sample
14. Determination of noise/Sound level at different places.
15. Determination of particulate matter in air sample.

Reference Books:

APHA, Standard Methods for the Examination of Water and Wastewater, 22nd Edition.

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<table>
<tr><td>1</td><td>Name of Department</td><td colspan="4">Chemical Engineering</td></tr>
<tr><td>2</td><td>Semester:</td><td colspan="4">M.Tech.-Second Semester</td></tr>
<tr><td>3</td><td>Subject Code:</td><td>CL41222(CL)</td><td>Course Title:</td><td colspan="2">Modeling & Simulation Lab.</td></tr>
<tr><td>4</td><td>Contact hours</td><td>L-0</td><td>T-0</td><td colspan="2">P-3 Credits- 2</td></tr>
<tr><td>5</td><td>TA: 75</td><td>FE:0</td><td>SE: 0</td><td>ESE: 50(Min. Pass Marks: 25)</td><td>Total: 125</td></tr>
<tr><td>6</td><td>Examination Time</td><td colspan="4">3 hrs</td></tr>
</table>

Prerequisite:
Mathematics, chemical reaction engineering, mass transfer, heat transfer, fluid flow, control.
Course objectives:
Apply the knowledge of mathematics in solving engineering problems

List of experiments

1. Simulation of CSTR in series
2. Simulation of batch reactor
3. Simulation of non-isothermal reactor
4. Simulation of fluidized bed reactor
5. Simulation of shell and tube heat exchanger
6. Simulation of multiple effect evaporator
7. Simulation of flash drum
8. Simulation of absorber
9. Simulation of distillation tower
10. Simulation of extractor