MS(R) in Chemical Engineering

Department of Chemical Engineering

The overall probable credit structure for MS(R)

Category	PC	PE	OC	Total
Credits	5+34	6	9	54

Program Core (PC)

CLL701	MODELLING OF TRANSPORT PROCESSES	(2-0-0) 2
CLL702	PRINCIPLES OF THERMODYNAMICS, REACTION KINETICS & REACTORS	(2-0-0) 2
CLP704	TECHNICAL COMMUNICATION FOR CHEMICAL ENGINEERS	(0-0-2) 1
CLD895	MSR PROJECT	(0-0-68)34

PROGRAM ELECTIVE (PE)

CLL 705	Petroleum Reservoir Engineering	(3-0-0) 3
CLL 706	Petroleum Production Engineering	(3-0-0) 3
CLL 707	Population Balance Modeling	(3-0-0) 3
CLL 720	Principles of Electrochemical Engineering	(3-0-0) 3
CLL 721	Electrochemical Methods	(3-0-0) 3
CLL 722	Electrochemical Conversion and Storage Devices	(3-0-0) 3
CLL 723	Hydrogen Energy and Fuel Cell Technology	(3-0-0) 3
CLL 724	Environmental Engineering and Waste Management	(3-0-0) 3
CLL 725	Air Pollution Control Engineering	(3-0-0) 3
CLL 726	Molecular Modeling of Catalytic Reactions	(3-0-0) 3
CLL 727	Heterogeneous Catalysis and Catalytic Reactors	(3-0-0) 3
CLL 728	Biomass Conversion and Utilization	(3-0-0) 3
CLL 730	Structure, Transport and Reactions in BioNano Systems	(3-0-0) 3
CLL 732	Advanced Chemical Engineering Thermodynamics	(3-0-0) 3
CLL 734	Process Intensification and Novel Reactors	(3-0-0) 3
CLL 735	Design of Multicomponent Separation Processes	(3-0-0) 3
CLL 742	Experimental Characterization of BioMacromolecules	(3-0-0) 3
CLL 743	Petrochemicals Technology	(3-0-0) 3
CLL 786	Fine Chemicals Technology	(3-0-0) 3

CLL 761	Chemical Engineering Mathematics	(3-0-0) 3
CLL 762	Advanced Computational Techniques in Chemical Engineering	(2-0-2) 3
CLL 766	Interfacial Engineering	(3-0-0) 3
CLL 767	Structures and Properties of Polymers	(3-0-0) 3
CLL 768	Fundamentals of Computational Fluid Dynamics	(2-0-2) 3
CLL 769	Applications of Computational Fluid Dynamics	(2-0-2) 3
CLL 771	Introduction to Complex Fluids	(3-0-0) 3
CLL 772	Transport Phenomena in Complex Fluids	(3-0-0) 3
CLL 773	Thermodynamics of Complex Fluids	(3-0-0) 3
CLL 774	Simulation Techniques for Complex Fluids	(3-0-0) 3
CLL 775	Polymerization Process Modeling	(3-0-0) 3
CLL 776	Granular Materials	(3-0-0) 3
CLL 777	Complex Fluids Technology	(3-0-0) 3
CLL 778	Interfacial Behaviour and Transport of Biomolecules	(3-0-0) 3
CLL 779	Molecular Biotechnology and in-vitro Diagnostics	(3-0-0) 3
CLL 780	Bioprocessing and Bioseparations	(3-0-0) 3
CLL 781	Process Operations Scheduling	(3-0-0) 3
CLL 782	Process Optimization	(3-0-0) 3
CLL 783	Advanced Process Control	(3-0-0) 3
CLL 784	Process Modeling and Simulation	(3-0-0) 3
CLL 785	Evolutionary Optimization	(3-0-0) 3
CLL 791	Chemical Product and Process Integration	(3-0-0) 3
CLL 792	Chemical Product Development and Commercialization	(3-0-0) 3
CLL 793	Membrane Science and Engineering	(3-0-0) 3
CLL 794	Petroleum Refinery Engineering	(3-0-0) 3
CLL 798	Selected Topics in Chemical Engineering - I	(3-0-0) 3
CLL 799	Selected Topics in Chemical Engineering - II	(3-0-0) 3
CLL 833	Experimental Characterization of Multiphase Reactors	(3-0-0) 3
CLV 796	Current Topics in Chemical Engineering	(1-0-0) 1
CLV 797	Recent Advances in Chemical Engineering	(2-0-0) 2

SEM	Courses (number, abbreviated Title, L-T-P, Credits)					Lecture	Contact H/Week				Credits
							L	T	P	Total	
I	CLL701 MOD. TRANS. PROC. (2-0-0)2	CLL702 PRIN. THERMO. REACTION KINETICS & REACTORS (2-0-0)2	PE1 (3-0-0)3	CLD895 MSR PROJECT	PE2 (3-0-0)3	4	10			10	10
II	OE1 (3-0-0)3	OE2 (3-0-0)3	CLD895 MSR PROJECT	CLP704 TECH. COMMC HEM. ENG. (0-0-2)1	OE3 (3-0-0)3	3	9			18	9
Summer			CLD895 MSR PROJECT								
III											
IV			CLD895 MSR PROJECT								34

Master of Technology in Chemical Engineering

Department of Chemical Engineering

The overall credits structure for M.Tech.

Category	PC	PE	OC	Total
Credits	37	12	3	52

Program Core (PC)

CLL701	MODELLING OF TRANSPORT PROCESSES	(2-0-0) 2
CLL702	PRINCIPLES OF THERMODYNAMICS, REACTION KINETICS & REACTORS	(2-0-0) 2
CLL703	PROCESS ENGINEERING	(3-0-0) 3
CLP704	TECHNICAL COMMUNICATION FOR CHEMICAL ENGINEERS	(0-0-2) 1
CLL731	ADVANCED TRANSPORT PHENOMENA	(3-0-0) 3
CLL733	INDUSTRIAL MULTIPHASE REACTORS	(3-0-0) 3
CLD771	MINOR PROJECT	(0-0-6) 3
CLD781	MAJOR PROJECT PART-1	(0-0-16)8
CLD782	MAJOR PROJECT PART-2	(0-0-24)12

PROGRAM ELECTIVE (PE)

CLL 705	Petroleum Reservoir Engineering	(3-0-0) 3
CLL 706	Petroleum Production Engineering	(3-0-0) 3
CLL 707	Population Balance Modeling	(3-0-0) 3
CLL 720	Principles of Electrochemical Engineering	(3-0-0) 3
CLL 721	Electrochemical Methods	(3-0-0) 3
CLL 722	Electrochemical Conversion and Storage Devices	(3-0-0) 3
CLL 723	Hydrogen Energy and Fuel Cell Technology	(3-0-0) 3
CLL 724	Environmental Engineering and Waste Management	(3-0-0) 3
CLL 725	Air Pollution Control Engineering	(3-0-0) 3
CLL 726	Molecular Modeling of Catalytic Reactions	(3-0-0) 3
CLL 727	Heterogeneous Catalysis and Catalytic Reactors	(3-0-0) 3
CLL 728	Biomass Conversion and Utilization	(3-0-0) 3
CLL 730	Structure, Transport and Reactions in BioNano Systems	(3-0-0) 3
CLL 732	Advanced Chemical Engineering Thermodynamics	(3-0-0) 3
CLL 734	Process Intensification and Novel Reactors	(3-0-0) 3

CLL 735	Design of Multicomponent Separation Processes	(3-0-0) 3
CLL 742	Experimental Characterization of BioMacromolecules	(3-0-0) 3
CLL 743	Petrochemicals Technology	(3-0-0) 3
CLL 786	Fine Chemicals Technology	(3-0-0) 3
CLL 761	Chemical Engineering Mathematics	(3-0-0) 3
CLL 762	Advanced Computational Techniques in Chemical Engineering	(2-0-2) 3
CLL 766	Interfacial Engineering	(3-0-0) 3
CLL 767	Structures and Properties of Polymers	(3-0-0) 3
CLL 768	Fundamentals of Computational Fluid Dynamics	(2-0-2) 3
CLL 769	Applications of Computational Fluid Dynamics	(2-0-2) 3
CLL 771	Introduction to Complex Fluids	(3-0-0) 3
CLL 772	Transport Phenomena in Complex Fluids	(3-0-0) 3
CLL 773	Thermodynamics of Complex Fluids	(3-0-0) 3
CLL 774	Simulation Techniques for Complex Fluids	(3-0-0) 3
CLL 775	Polymerization Process Modeling	(3-0-0) 3
CLL 776	Granular Materials	(3-0-0) 3
CLL 777	Complex Fluids Technology	(3-0-0) 3
CLL 778	Interfacial Behaviour and Transport of Biomolecules	(3-0-0) 3
CLL 779	Molecular Biotechnology and in-vitro Diagnostics	(3-0-0) 3
CLL 780	Bioprocessing and Bioseparations	(3-0-0) 3
CLL 781	Process Operations Scheduling	(3-0-0) 3
CLL 782	Process Optimization	(3-0-0) 3
CLL 783	Advanced Process Control	(3-0-0) 3
CLL 784	Process Modeling and Simulation	(3-0-0) 3
CLL 785	Evolutionary Optimization	(3-0-0) 3
CLL 791	Chemical Product and Process Integration	(3-0-0) 3
CLL 792	Chemical Product Development and Commercialization	(3-0-0) 3
CLL 793	Membrane Science and Engineering	(3-0-0) 3
CLL 794	Petroleum Refinery Engineering	(3-0-0) 3
CLL 798	Selected Topics in Chemical Engineering - I	(3-0-0) 3
CLL 799	Selected Topics in Chemical Engineering - II	(3-0-0) 3
CLL 833	Experimental Characterization of Multiphase Reactors	(3-0-0) 3
CLV 796	Current Topics in Chemical Engineering	(1-0-0) 1
CLV 797	Recent Advances in Chemical Engineering	(2-0-0) 2

SEM	Courses (number, abbreviated Title, L-T-P, Credits)					Lecture	Contact H/Week				Credits
							L	T	P	Total	
I	CLL701 MODL. TRANS. PROC. (2-0-0)2	CLL702 PRIN. THERMO. REACTION KINETICS & REACTORS (2-0-0)2	CLL703 PROC. ENGG. (3-0-0)3	PE1 (3-0-0)3	PE2 (3-0-0)3	5	13		0	13	13
II	CLL731 ADV. TRANSP. PHEN. (3-0-0)3	CLL733 INDUS. MULTIPHASE REACT. (3-0-0)3	CLD771 MINOR PROJECT (0-0-6)3	PE3 (3-0-0)3	CLP704 TECH. COMMU CHEM. ENG. (0-0-2)1	3	9		8	17	13
Summer			CLD781 MAJ. PROJ. PART-1 (0-0-16)8								
III				PE4 (3-0-0)3	OE1 (3-0-0)3	2	6		16	26	14
IV			CLD782 MAJ. PROJ. PART-2 (0-0-24)12						24	24	12

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	MODELLING OF TRANSPORT PROCESSES
3.	**L-T-P structure**	2-0-0
4.	**Credits**	2
5.	**Course number**	CLL701
6.	**Status** (*category* for *program*)	All PG program except Dual degree

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL110,CLL113
8.2	Overlap with any UG/PG course of other Dept./Centre	MTL107,MTP290,MTL445,CVL734,COL726
8.3	Supercedes any existing course	CHL603

9.	**Not allowed for** (indicate program names)	B.Tech and Dual for all departments

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All Chemical Engineering faculty	
12.	**Will the course require any visiting faculty?**	NO

13. Course objective *(about 50 words)*:

This course will provide an overview of the Transport processes and numerical methods required for analysis of the chemical processes.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Fundamentals of momentum transport, Mass and momentum conservation equations and their applications to solve 1-D problems, Fundamentals of heat transport, Equation of energy/temperature and its application to solve problems involving conduction, Fundamentals of mass transport, Equation of mass conservation and its application to solve problems involving binary diffusion.

Introduction to methods for solution of algebraic equations, Methods for solution of ODEs, Functions, approximations and regression analysis, Introduction to Design of Experiments

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Fundamentals of momentum transport	1
2	Mass and momentum conservation equations and their applications to solve 1-D problems	4
3	Fundamentals of heat transport	1
4	Equation of energy/temperature and its application to solve problems involving conduction	4
5	Fundamentals of mass transport	2
6	Equation of mass conservation and its application to solve problems involving binary diffusion	4
7	Methods for solution of algebraic equations	4
8	Methods for solution of ODEs	4
9	Function approximations and regression analysis	2
10	Introduction to Design of Experiments	2
11		
12		
COURSE TOTAL *(14 times 'L')*		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Bird R.B., Steward W.E. and Lightfoot E.N., "Transport Phenomena", 2nd edition, John Wiley & Sons, 2007.

Welty J. , Wicks C. E., Wilson R. E and Rorrer G. L., "Fundamentals of Momentum, Heat and Mass Transfer " , 5th edition, John Wiley & Sons, Inc, 2007.

Chapra S.C. and Canale R.P., "Numerical Methods for Engineers with Personal Computer Applications", McGraw Hill Book Co., 1985.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PRINCIPLES OF THERMODYNAMICS, REACTION KINETICS & REACTORS
3.	**L-T-P structure**	2-0-0
4.	**Credits**	2
5.	**Course number**	CLL702
6.	**Status** (*category* for *program*)	All PG program except Dual degree

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 121 CLL 122 CLL 222
8.2	Overlap with any UG/PG course of other Dept./Centre	MCL140: 50% MCL141: 50% MCL142: 50%
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	UG & DD students of all programs

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All Chemical Engineering faculty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** The intent of this course is to provide an overview of the principles of chemical engineering thermodynamics, chemical reaction kinetics and chemical reactor engineering.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to thermodynamics; Notion of equilibrium, states and reversibility; First and Second Laws of Thermodynamics; Equations of state; Equilibrium behaviour of mixtures of fluids; Phase equilibria and VLE; Reaction thermodynamics. Reaction equilibria and chemical kinetics; Ideal reactors; Isothermal reactor

	design; Temperature and pressure effects in ideal reactors; Heterogeneous catalysis and effectiveness factors; Fluid-solid non-catalytic reactions.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	First Law for open and closed systems, reversible & irreversible processes	2
2	Phases, phase transitions, PVT behavior; description of materials – Ideal gas, Equations of states, Correlations in description of material properties and behavior	2
3	Second law and entropy, reversible and irreversible processes, losses	2
4	Solution Thermodynamics, fundamental property relationships, free energy, chemical potential, Thermodynamic properties of typical solutions	3
5	Ideal solution, VLE at low to moderate pressures, Bubble and Dew point	3
6	Introduction to reaction equilibria	2
7	Reaction rates, rate forms, notion of order	1
8	Batch reactors: kinetics data interpretation, series and parallel reactions	2
9	Ideal flow reactors: sizing and analysis of well-mixed (CSTR), plug flow and recycle reactors: solving design equations for constant and variable density systems, reactors in series and parallel	4
10	Temperature and pressure effects: isothermal reactors, adiabatic reactors, simultaneous material and energy balance	2
11	Introduction to heterogeneous catalyis: Kinetics, rate forms and mechanism; Basic reactor design; Diffusion-reaction interactions and notion of catalyst effectiveness	3
12	Non-catalytic gas-solid reactions: shrinking core model	2
COURSE TOTAL *(14 times 'L')*		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Smith, J. M., Van Ness, H. C., Abbott, M. M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill, 2005.

Fogler H. S., 'Elements of Chemical Reaction Engineering', Prentice Hall.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL703
6.	**Status** (*category* for *program*)	Compulsory for all 2 year M.Tech. and Dual Degree Program in Chemical Engineering

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	CHL701

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Ratan Mohan,Shalini Gupta, Shantanu Roy, Anupam Shukla, Munawar Shaik	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)*: To learn the issues and techniques involved in designing of large scale chemical processes with multiple unit operations

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Process synthesis, material balances and decision making in reactors with recycle streams, input-output structure of flowsheet for batch vs. continuous reactors, hierarchal approach for process engineering design, reactor and separation system selection guidelines, distillation column sequencing, heat exchanger network design, pinch technology, utility selection, grand composite curve, steam and cooling water circuits, integration of heat pumps and heat engines Process economics: Cost estimation, annuities, perpetuities and present value, tax and depreciation, profitability measures, comparison of equipments and projects, NPV, IRR, risk management. Process modeling tools: AspenPlus® or Promax that are used in industry for

	large scale problem solving to undertake problems of current interest.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to process engineering design and heirarchical approach to flowsheet synthesis	1
2	Input output flowsheet and concept of economic potential of batch, continuous and recycle reactors	3
3	Guidelines for selection of reactors and separation systems	3
4	Heat and energy integration by calculating demands and targets using pinch analysis	8
5	Distillation column sequencing	3
6	Heat exchanger network design	8
7	Grand composite curve and utility targeting	4
8	Integration of heat pumps and heat engines	4
9	Process economics and profitability analysis	5
10	Problem solving using process modeling tools such as AspenPlus® or Promax	3
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text: Conceptual Design of Chemical Processes by James M. Douglas, New York, NY: McGraw-Hill, 1988

Chemical Process: Design and Integration by Robin Smith, 1st ed. West Sussex, UK: Wiley, 2005

References: Seider, W. D., J. D. Seader, and D. R. Lewin. Product and Process Design Principles: Synthesis, Analysis, and Evaluation. 2nd ed. New York, NY: Wiley, 2003

Optimization of Chemical Processes by Edgar and Himmelblau, New York, NY: McGraw Hill, 1988

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Process simulation software
19.2	Hardware	PC
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	PSL
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ADVANCED TRANSPORT PHENOMENA
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL731
6.	**Status** (*category* for *program*)	DE for B. Tech. PC for DD/ M. Tech.

7.	**Pre-requisites** (course no./title)	CLL110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	AML360: 20% AML711: 15%
8.3	Supercedes any existing course	CHL603

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Vivek Buwa, Gaurav Goel, Jayati Sarkar, Paresh Chokshi, Vikram Singh, Shantanu Roy	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The courses intents to provide an in-depth understanding of processes involving mass, energy, and momentum transport. The course has been designed to cover broad array of topics and introduce analytical tools relevant to graduate research in this area
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Review of fluid kinematics, conservation laws and constitutive equations. Solutions methods for equations of change (e.g., unsteady fluid flow in bounded/unbounded geometries). Creeping flow and lubrication approximation. Surface tension driven flows and multiphase flows. Boundary layer theory. Unsteady heat and mass transport. Coupled transport processes-- forced convection heat and mass transport in confined/unconfined flows.

	Multicomponent energy and mass transport. Turbulence modeling.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Reynolds transport theorem, Conservation laws and constitutive equations, Phase interface conditions	6
2	Solution methods for steady and unsteady fluid flow, pulsatile/oscillatory flow problems -- Similarity, Finite Fourier Transforms in Cartesian and polar coordinate	5
3	Creeping flow: Properties of creeping flows, stream function formulation, drag forces on immersed bodies.	3
4	Lubrication approximation: Porous channel, thin films, lubrication force, Flow through porous media	4
5	Boundary layer theory: Boundary layers over rigid bodies. Blasius solution, Similarity solution	3
6	Unsteady heat conduction and mass diffusion	2
7	Coupled transport: Forced convection heat and mass transport in confined/unconfined laminar flows, low Peclet and high Peclet approximations, buoyancy driven flows	5
8	Introduction to Multicomponent energy and mass transport: Stefan-Maxwell equations, simultaneous energy and mass transport	2
9	Turbulence modeling: Characteristics of turbulent flows, length and time scales, energy cascade, Reynolds averaged transport equations, Introduction to turbulence modeling: Phenomonological models, Kolmogorov hypotheses, universality and turbulence spectra	5
10	Transport phenomena in large-scale systems/chemical reactors	5
11	Transport phenomena in small-scale systems: micro-fluidic devices	2
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text book:

1. Deen W. M., Analysis of Transport Phenomena, Oxford University Press, New York, 1998.

Reference Books:

1. Slattery J. C., Advanced Transport Phenomena, Cambridge University Press, 1999.
2. Leal L. G., Advanced Transport Phenomena: Fluid mechanics and convective transport processes, Cambrige University Press, 2010.
3. Pope S. B., Turbulent Flows, Cambridge University Press, 2000.
4. Bird. R. B., Stewart, W. E. and Lightfoot, E. N., Transport Phenomena, 2nd edition, John Wiley & Sons, 2006
5. Belfore, L. A., Transport Phenomena for Chemical Reactor Design, John Wiley & Sons, 2003.
6. Ramachandran, P. A. "Advanced Transport Phenomena", Cambridge University Press, 2014.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	INDUSTRIAL MULTIPHASE REACTORS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL733
6.	**Status** (*category* for *program*)	DE for B. Tech. / PC for DD, M. Tech. PE for Adv Stand for Energy & Env/Proc. Eng., Mod.

7.	**Pre-requisites** (course no./title)	CLL122, CLL 222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 727: 20% CLL 734: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL723

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Shantanu Roy, Vivek Buwa, Divesh Bhatia, K. K. Pant, M. Ali Haider, U. Sreedevi, A. K. Saroha, Ratan Mohan	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To understand hydrodynamics and transport effects in multiphase reactors, to learn lower order model for prediction of their performance, to introduce industrial multiphase reactors, and to apply the model to design multiphase reactors for a few specific applications.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to advanced reactor analysis tools: RTD theory, RTD based models, axial dispersion, tank-in-series, multizonal models. Hydrodynamics and flow regimes. Transport effects in multiphase reactors, interplay of length and time scales. Process parameters of interest. Effectiveness factors in G/S and L/S systems, including non-isothermal effects. Enhancement factor in G/L

	systems. Models for non-catalytic heterogeneous reactions. Introduction to multiphase reactors and their applications, classification of multiphase reactors, performance/operating characteristics. Mechanically agitated reactors, bubble column/slurry bubble column reactors, fluidized bed, packed bed, trickle bed reactor reactors. Limitations of models, applications to design of multiphase reactors for specific applications.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of reaction kinetics and ideal reactors	3
2	Review of fluid-solid reactions: catalytic and non-catalytic reactions	3
3	Principles of non-ideal flow, central volume principle and RTD theorems, data analysis and interpretation	4
4	Models for non-ideal flow patterns: tanks-in-series, axial dispersion, multi-zonal models	6
5	Gas-Solid and Liquid-Solid Catalytic Reactions: Effectiveness factor and Thiele modulus, Non-isothermal reactions, Falsification of kinetics, external mass transfer effects in two-phase and three-phase reactions	6
6	Gas-Liquid Reactors: Enhancement factor and Hatta number, Various regimes of gas-absorption and reaction	3
7	Introduction and classification of multipahse reactors: Issues related to flow patterns and micro-, meso- and reactor scale hydrodynamic phenoemena	2
8	Two- and three- phase packed bed reactors	4
9	Fluidized reactors	4
10	Bubble columns and slurry bubble columns	3
11	Two- and three- phase stirred tanks	2
12	Novel reactors and process intensification: Introduction	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

Some sessions may be used to discuss selected problems in the above topics. No separate tutorial hours are envisioned.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Froment, G. F. and K. B. Bischoff, Chemical Reactor Analysis and Design, John Wiley (1990).

Doraiswamy, L. K. and D. Uner, Chemical Reaction Engineering: Beyond the Fundamentals, CRC Press (2013).

Carberry, J. J. and A. Varma, Chemical Reaction and Reactor Engineering, Marcell-Dekker (1986).

Nauman, E. B. and B. A. Buffam, Mixing in Continuous Flow Systems, Wiley (1983).
Rosner, D. E. Transport Processes in Chemically Reacting Systems, Dover (2000).

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	MINOR PROJECT
3.	**L-T-P structure**	0-0-6
4.	**Credits**	3
5.	**Course number**	CLD771
6.	**Status** (*category* for *program*)	Core for M.Tech.

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	Replaces CHD771

9.	**Not allowed for** (indicate program names)	All, Except two year M.Tech. Chemical Engg

10.	**Frequency of offering**	☒Every sem ☐1st sem ☐2nd sem ☐Either sem

11.	**Faculty who will teach the course** All Chemical faculty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** In this course students will do literature survey on an alloted topic. They will do a critical review of the collected literature and write a technical report identifying the problem for their research work. Students are expected to do research work on the identified problem.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Literature survey, Writing technical report, Planning and execution of the project work within the stipulated time frame.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Should involve at least 6 hours of work commitment per week.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	MAJOR PROJECT PART-1
3.	**L-T-P structure**	0-0-16
4.	**Credits**	8
5.	**Course number**	CLD781
6.	**Status** (*category* for *program*)	Core for M.Tech.

7.	**Pre-requisites** (course no./title)	CLD771

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	Replaces CHD781

9.	**Not allowed for** (indicate program names)	All, Except two year M.Tech. Chemical Engg

10.	**Frequency of offering**	☒Every sem ☐1st sem ☐2nd sem ☐Either sem

11.	**Faculty who will teach the course** All Chemical faculty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** In this course students will implement the knowledge gained in their academics/professional work to do theoretical/experimental research.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Literature survey, Writing technical report, Planning and execution of the project work within the stipulated time frame.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Activity to be decided by supervisor. Should involve at least 16 hours of work commitment per week.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	

19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	MAJOR PROJECT PART-2
3.	**L-T-P structure**	0-0-24
4.	**Credits**	12
5.	**Course number**	CLD782
6.	**Status** (*category* for *program*)	Core for M.Tech.

7.	**Pre-requisites** (course no./title)	CLD781

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	Replaces CHD782

9.	**Not allowed for** (indicate program names)	All, Except two year M.Tech. Chemical Engg

10.	**Frequency of offering**	☒Every sem ☐1st sem ☐2nd sem ☐Either sem

11.	**Faculty who will teach the course** All Chemical faculty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** In this course students will implement the knowledge gained in their academics/professional work to do theoretical/experimental research. It is the continuation of CLD781
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Literature survey, Writing technical report, Planning and execution of the project work within the stipulated time frame. Analysis and interpretation of the obtained data.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	TECHNICAL COMMUNICATION FOR CHEMICAL ENGINEERS
3.	**L-T-P structure**	0-0-2
4.	**Credits**	1
5.	**Course number**	CLP704
6.	**Status** (*category* for *program*)	Compulsory for all 2 year M.Tech. program and PhD students of Chemical Engineering

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All Chemical Engineering faculty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)*: To provide aspects of - (i) scientific writing and communication (ii) paper critiquing and referencing, (iii) research methodology and ethics, and (iv) utilization of web resources in the Chemical Engineering discipline
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Technical paper and report writing, Knowledge of leading Chemical Engineering journals and confernces, carrying out literature search, research methodology, paper referencing and critiquing, ethics and plagiarism, improving presentation and communication skills

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to the course and leading areas of research, conferences and journals in Chemical Engineering	2
2	Technical paper and report writing taking specific examples from the Chemical Engineering discipline	8
3	Paper critiquing	4
4	Utilization of web resources, referencing and Chemical Engineering related search engines	4
5	Improvement of presentation skills	3
6	Improvement of communication skills	2
7	Basic guidelines of working in a lab, research ethics and plagiarism	2
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		28

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Strunk W. and White, E.B. The Elements of Style, 4th edition, Pearson Education Company, MA, USA, 2000

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	

19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS PLANT DESIGN
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL402
6.	**Status** (*category* for *program*)	DE for UG (B. Tech. & DD) PE for Adv Stand for Process Eng., Mod. & Optimizaton

7.	**Pre-requisites** (course no./title)	CLL 371

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 701: 20%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL702

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** K. K. Pant, B. Pitchumani, Shantanu Roy, Divesh Bhatia	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** This course is intended to provide a holistic view of chemical engineering from a design perspective as relevant in the conceptualization, design and commisioning of the chemical plant. The course builds on the covers basics of unit operations and process technology, and incorporates various aspects of plant design, namely, process flowsheeting, equipment selection and design, plant and operating economics, safety and loss prevention, and design and optimization of utilities. The instruction would be done with the help of real case studies.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Plant layout and flowsheeting. Issues related to materials handling, equipment selection and design (pumps, blowers and compressions, mixers, conveyors, seperation columns, reactors), utilities and auxiliaries, offsite facilities. Cost estimation. Selection and detailed design of equipment. Steam handling. Valves, piping and instrumentation. Environmental footprint assessment,

	pollution reduction, and life cycle analysis of process plant.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Plant layout and flowsheeting.	4
2	Plant cost estimation	3
3	Materials handing, off-site facilities, utilities and auxilliaries	3
4	Selection and design of pumps, compressors, pipe fittings, piping and valves	4
5	Design of reactors and separators	8
6	Heat exchanger design and networks	4
7	Water handling, treatment and storage	3
8	Steam handling: generation, conveying, traps and ejectors	3
9	Transporation of materials: handling, belt conveying, pneumatic and hydraulic conveying	3
10	Pipeline design and networks	2
11	Environmental footprint and pollution abatement	2
12	Life cycle analysis	3
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Towler, G. P., & Sinnott, R. K. (2013). Chemical Engineering Design: Principles, Practice, and Economics of Plant and Process Design. Elsevier.

Smith, R. M. (2005). Chemical Process: Design and Integration. John Wiley & Sons.

Ludwig, E. E. (1997). Applied Process Design for Chemical and Petrochemical Plants: Volume 2 (Vol. 2). Gulf Professional Publishing.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	

19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHE
2.	**Course Title** *(< 45 characters)*	PETROLEUM RESERVOIR ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL705
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	CLL110, CLL121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL706: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	Either semester (once a year)

11.	**Faculty who will teach the course:** Jyoti Phirani, Sanat Mohanty, A. K. Saroha	
12.	**Will the course require any visiting faculty?**	None

13.	**Course objective** *(about 50 words)***:** Basic understanding of reservoir engineering concepts from making a static model to production forecast. Introduction to secondary and tertiary recovery mechanisms of oil recovery.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:**

	Introduction of static model including porosity, permeability, compressibility and saturations. Crude oil phase behaviour and their measurement techniques for reservoir and laboratory settings. Meaning and calculation of ‘oil in place’ numbers with respect to different recovery mechanisms. Material balance for hydrocarbon reservoirs. Pressure transient analysis. Primary, secondary and tertiary recovery mechanisms, Buckley- Leverett theory (fractional flow curves) for immiscible and miscible displacement. Production forecasting and introduction to reservoir simulation.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to oil reservoirs(static model and dynamic model)	2
2	Rock properties: porosity, permeability, compressibility, wettability, capillary pressure, relative permeability, building a reservoir description	6
3	Fluid properties: formation volume factor, gas oil ratio, viscosity, tests for oil characterization	6
4	Oil in place numbers, definition of reserves, resources, different methods of reserves estimation, material balance for hydrocarbon reservoirs	3
5	Pressure transient analysis	4
6	Recovery mechanisms 1. Primary: solution gas drive, gas cap drive, water drive.	4
7	Recovery mechanisms 2. Secondary: gas injection, water flooding, Buckley-Leverett theory	4
8	Recovery mechanisms 3. Tertiary recovery: chemical methods, thermal methods	4
9	Production forecasts	4
10	Reservoir simulations	5
11		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Fundamentals of reservoir engineering, L. P. Dake, 2010 (Reprint edition), Elsevier.

References:
Waterflooding (SPE textbook series), G. Paul Willhite, 1986
Enhanced Oil Recovery, Larry W. Lake, 1996
Buckley, S. E. and Leverett, M. C.: “Mechanism of fluid displacement in sands”, Trans. AIME, 146, 1942, 107-116

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	C/Fortran/Matlab/some engineering programming language, Spreadsheets, possibly eclipse, CMG or UTCHEM
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Projector
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	-
20.2	Open-ended problems	10%: Finding recovery mechanisms for different reservoirs
20.3	Project-type activity	15% : Simulating / Modeling 1-D Buckley Leverett problems
20.4	Open-ended laboratory work	-
20.5	Others (please specify)	-

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHE
2.	**Course Title** *(< 45 characters)*	PETROLEUM PRODUCTION ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL706
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	CLL 231, CLL 121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 705: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	Nil
8.3	Supercedes any existing course	Nil

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	Once a year

11.	**Faculty who will teach the course:** Jyoti Phirani, Sanat Mohanty, Anil K. Saroha	
12.	**Will the course require any visiting faculty?**	None

13.	**Course objective** *(about 50 words)***:** Basic understanding of oil production engineering concepts, well drilling, well completions, artificial lift mechanism, how to find a non-performing well in a reservoir, finding the remedy using well logging and well stimulation.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Basic concepts: well drilling, well completions, drive mechanisms for different reservoirs, Darcy's law. Movement of fluids in the well, different artificial lift mechanisms, VLP (vertical lift performance curves), IPR (inflow performance relationships). Well analysis tools (different well performance curves, well logging). Problem identification in wells (examples). Well stimulation techniques.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to oil reservoirs	3
2	Basic reservoir engineering concepts (porosity, permeability, darcy's law)	3
3	Different drive mechanisms of reservoir, different artificial lifts used in the wells	4
4	Basic concepts of production engineering (tests run in wells to evaluate performance, parameters defining flow in a well)	5
5	IPR (inflow performance curve), VLP (vertical lift performance), Vogel equation, flow in pipe	5
6	Well analysis tools	4
7	Problem identification and remediation in well	6
8	Logging and well stimulation techniques	6
9	Production well simulation or Sand control and horizontal wells	6
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Michael J. Economides, A. Daniel Hill, and Christine Ehlig-Economides, Petroleum Production System, PTR Prentice Hall, Inc, New Jersey, 1994.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	C/Fortran/Matlab/some engineering programming language, Spreadsheets
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Projector
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	-
20.2	Open-ended problems	10%: Finding recovery mechanisms for different reservoirs
20.3	Project-type activity	15% : Doing work-overs for problem wells
20.4	Open-ended laboratory work	-
20.5	Others (please specify)	-

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	POPULATION BALANCE MODELLING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL707
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for adv stand in Proc Engg, Mod and Opt

7.	**Pre-requisites** (course no./title)	MAL120, CLL331, CLL352

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL807

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Paresh Chokshi, Ashok Bhaskarwar, Rajesh Khanna, Shantanu Roy, Vivek Buwa, Ratan Mohan	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course aims to introduce the framework to model dispersed/particulate systems with evolving distribution of dispersed entities. The governing equation for the dynamics of particle size distribution and its application to multiphase systems will be covered.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Theory of crystallization. Particle size distribution, particle phase space. Population balance equation for convection in state space (pure growth). Solution of PBE using method of characteristics. PBE with breakage and coalescence/aggregation terms. Scaling theory and phenomenological models for rate of breakage and coalescence induced by turbulence. Solution of PBE for pure breakage and pure coalescence. Moment transformation of PBE. Numerical approaches to solve PBE. Integrating PBE with transport equations.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to dispersed phase systems, Modelling approaches for multiphase systems	2
2	Overview of crystallization kinetics: Classical theory of nucleation - homogeneous and heterogeneous, Nucleation rate, Crystal growth models	3
3	Particle size distribution, Representation and properties of distributions	2
4	Particle phase space (particle state vector), Framework to derive population balance equation (PBE) with pure convection (growth)	4
5	Solution of PBE for crystallzation (nucleation and growth) - Continuous crystallizer: Steady-state MSMPR crystallizer, Batch crytallizer: Dynamic population balance, Method of characterisitcs	6
6	Birth and death terms in PBE: breakage and coalescence (aggregation)	3
7	Pure breakage: breakage functions, Modeling of breakage rate using scaling theory of turbulence (Kolmogorov hypotheses)	5
8	Exact solution of PBE for pure breakage (binary with uniform daughter size distribution)	4
9	Pure coalescence: Coalescence kernel, Modeling of droplet (bubble) coalescence using hydrodynamics; Coalescence induced by turbulence, laminar shear, Brownian motion and gravity	5
10	Exact solution for pure coalescence using simplified kernels	3
11	Moment transformation of the population balance equation and analytical solution for general PBE	3
12	Numerical approaches to solve PBE and moment equations; Brief introduction to integrating population balance model with transport equations (CFD)	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:

Randolph, A. D. and Larson, M. A., Theory of Particulate Processes: Analysis and Techniques of Continuous Crystallization, 1st Edition, Academic Press, 1971.

Ramkirishna, D., Population Balances: Theory and Applications to Particulate Systems in Engineering, 1st Edition, Academic Press, 2000.

Reference materials:

Yeoh, G. H., Cheung, C. P. and Tu, J., Multiphase Flow Analysis Using Population Balance Modeling: Bubble, Drops and Particles, 1st Edition, Butterworth-Heinemann, 2014

Journal articles

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PRINCIPLES OF ELECTROCHEMICAL ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL720
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 721: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	Nil
8.3	Supercedes any existing course	Nil

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Anupam Shukla, M. Ali Haider, Suddhasatwa Basu	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** Aim of the course isto present basic principles of electrochemistry, thermodynamics of ionic/charges surface systems, electrokinetic phenomena required for modeling anddesign of electrochemical processes and electrochemical devices.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Volta and Galvani potentials, electrochemical potential, electrochemical equilibrium, Nernst equation. Born-Haber cycle for enthalpy and Gibbs free energy calculation, conventions for ionic species, solvation energy, ionic equilibrium. Electrochemical cell, standard electrode potential, Pourbaix diagram, Donnan potential, reversible electrode. Born model for ion-solvation energy. Ion-ion interactions: Debye-Huckel theory, activity coefficient of ionic solution, ion pair, Bjerrum theory and Fuoss theory. Ionic transport: migration, extended Nernst-Planck equation, electrochemical mobility and its relation with

	diffusivity, Stokes-Einstein equation, ionic conductivity, transport number, Kohlrausch law. Charged interface: surface excess quantity, Lippmann equation, Gouy-Chapman model, Stern layer, internal and external Helmholtz layer, zeta potential, energy of double layer. Electrokinetic phenomena: Non-equilibrium formulation, diffusion potential, junction potential, Planck-Henderson equation, pH electrode, electrosmosis, electrophoresis, streaming potential, sedimentation potential. Introduction to electrode kinetics: Butler-Volmer formulation, Tafel equation

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction: Volta and Galvani potentials, electrochemical potential, electrochemical equilibrium, Nernstequation, ionic equilibrium, dissociation constant	3
2	Born-Haber cycle for enthalpy and Gibbs free energy calculation andconventions for ionic species, solvation energy, ionic equilibrium, electrochemical cell,standardelectrode potential,reversibleelectrode, Pourbaix diagram, Donnan potential, Born model for ion-solvation energy	6
3	Ion-ion interaction:Debye-Huckel theory, activity coefficient of ionic solution, ion pair, Bjerrum model and Fuoss theory	6
4	Ionic transport: migration, extendedNernst-Planck equation, electrochemical mobility and its relation withdiffusivity, ionic conductivity, transport number, Kohlrausch law	6
5	Chargedinterface:surface excess quantity, Lippmann equation, Gouy-Chapman model, Stern layer, inner &outer Helmholtz planes, zeta potential, energy of double layer, capacitance of double layer	8
6	Electrokinetic phenomena:Non-equilibriumformulation, diffusion potential, junction potential - Planck Hendersonequation, pH electrode, electrosmosis, electrophoresis, streaming potential,sedimentation potential	9
7	Introduction to electrode kinetics: Butler-Volmer formulation, Tafel equation	4
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		

6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text: Hubert H. Girault, Analytical and Physical Electrochemistry, EPFL Press, 1st Edition (2004) ISBN 2-940222-03-7

Ref: Thomas Z. Fahidy, Principles of Electrochemical Reactor Analysis, Elsevier Science Ltd., 1st Edition (1985) ISBN-13: 978-0444424518

Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd Edition edition (5 January 2001), ISBN-13: 978-0471043720

Chritopher M A Brett and Ana M O Brett, Electrochemistry: Principles, Methods, and Applications, Oxford University Press, 1st Edition (1994), ISBN: 019-8553897

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	LCD projector
19.7	Site visits	No

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	N/A
20.2	Open-ended problems	N/A
20.3	Project-type activity	N/A
20.4	Open-ended laboratory work	N/A
20.5	Others (please specify)	N/A

Date: 15/01/2014 (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ELECTROCHEMICAL METHODS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL721
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 720: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	Nil
8.3	Supercedes any existing course	Nil

9.	**Not allowed for** (indicate program names)	N/A
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem
11.	**Faculty who will teach the course** M. Ali Haider, Suddhasatwa Basu, Anupam Shukla	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

The course work introduces a comprehensive coverage on fundamentals for electrochemical methods. An overview of the electrode processes, electrochemical thermodynamics and potential is provided leading to a detail discussion on electrode kinetics and mass transfer by diffusion and migration. Utilizing the basic concepts several electrochemical methods and experimental techniques such as impedance spectroscopy and voltammetry are discussed.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Galvani Potential, Butler-Volmer Equation, Tafel Equation. Potential Step voltammetry, pulse voltammetry, cyclic voltammetry. Controlled current methods, current-interrupt measurements. Conductivity relaxation, impedance spectroscopy. Coulometric methods, scanning probe techniques, spectro-electrochemistry.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Electrochemical Fundamentals (Faradaic and Non-Faradaic Processes, Electrical Double Layer, Electrochemical Thermodynamics and Potential, Nernst Equation)	3
2	Electrode Kinetics (Arrhenius Equation, Transition State Theory, Butler-Volmer Model, Electrode Polarisation, Transfer Coefficient, Tafel Equation)	6
3	Mass and Charge Transfer (Mass Transfer Effect, Mass Transfer by Migration and Diffusion, Charge Transfer and Marcus Theory, ionic and electronic conductivity)	4
4	Cyclic Voltammetry, Electrochemically Active Surface Area	9
5	Potential and Current Methods (Pulse Voltammetry, Controlled Current Methods, Current-Interrupt Measurements, Conductivity Relaxation, Coulometric Methods, Diffusion Control)	6
6	Electrochemical Impedance Spectroscopy (Equivalent Circuit, Nyquist Plot, Bode plot, Kinetics Parameters from Impedance Measurement)	9
7	Scanning Probe Techniques, Spectroelectrochemistry	5
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Hubert H. Girault, Analytical and Physical Electrochemistry, EFPL Press, 25 October 2004

Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd edition, 5 January 2001

John O'M. Bockris, Amulya K.N. Reddy, Maria E. Gamboa-Aldeco, Modern Electrochemistry 2A: Fundamentals of Electrodics, Springer; 2nd edition, 31 January 2001

Mark E. Orazem, Bernard Tribollet, Electrochemical Impedance Spectroscopy, Wiley-Blackwell, 26 September 2008

Evgenij Barsoukov, J. Ross Macdonald, Impedance Spectroscopy: Theory, Experiment, and Applications, Wiley-Blackwell, 2nd Edition, 8 April 2005

Andrzej Lasia, Electrochemical Impedance Spectroscopy and its Applications, Springer, 2014 edition, 31 January 2014

Vladimir S. Bagotsky Fundamentals of Electrochemistry, Wiley-Blackwell; 2nd Edition, 16 December 2005

Alan Bond, Broadening Electrochemical Horizons: Principles and Illustration of Voltammetric and Related Techniques, OUP Oxford, 5 December 2002

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	LCD projector
19.7	Site visits	No

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	N/A
20.2	Open-ended problems	N/A
20.3	Project-type activity	N/A
20.4	Open-ended laboratory work	N/A
20.5	Others (please specify)	N/A

Date: 15/01/2014 (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ELECTROCHEMICAL CONVERSION AND STORAGE DEVICES
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL722
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL723 (20 %)
8.2	Overlap with any UG/PG course of other Dept./Centre	Nil
8.3	Supercedes any existing course	Nil

9.	**Not allowed for** (indicate program names)	NA

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Suddhasatwa Basu, M. Ali Haider, Anupam Shukla	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)*: The course work introduces direct applications of electrochemical engineering. Working principle, materials and characterization of electrochemical conversion and storage devices are discussed in detail which include Fuel Cells, Solar Cells, Batteries, Supercapacitors and Electrolysis/Dialysis.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Electrochemical cell, fuel cells, proton exchange membrane fuel cells, solid oxide fuel cells. Batteries, lead acid battery, Nickel-metal hydride (Ni-MH) rechargeable batteries, lithium-ion rechargeable batteries, liquid-redox rechargeable batteries. Electrochemical supercapacitors. Solar cells. Electrodialysis and reverse electrodialysis. Electrochemical hydrogen production and storage.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Electrochemical Conversions and Storage Introduction (Devices and Principles)	2
2	Fuel Cells (Types of Fuel Cells, Proton Exchange Membrane Fuel Cells, Solid Oxide Fuel Cells)	6
3	Batteries (primary and secondary batteries, limitations of battery performance, Lead Acid Battery, Nickel-Metal Hydride (Ni-MH) Rechargeable Batteries, Lithium-Ion Rechargeable Batteries, Liquid-Redox Rechargeable Batteries)	10
4	Electrochemical Supercapacitors (Materials for Electrodes and Electrolyte, Transport Properties)	6
5	Solar Cell (Working Principle, Materials for Electrodes and Electrolyte, Transport Properties)	8
6.	Electrodialysis and Reversed Electrodialysis	4
7.	Electrochemical Hydrogen Production and Storage	6
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, Electrochemical Technologies for Energy Storage and Conversion, Wiley-VCH, 1st edition, 12 December 2011

Hubert H. Girault, Analytical and Physical Electrochemistry, EFPL Press, 25 October 2004

Ryan O'Hayre (Author), Suk-Won Cha (Author), Whitney Colella (Author), Fritz B. Prinz (Author) Fuel Cell Fundamentals, Wiley, 2nd edition, 9 January 2009

Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd edition, 5 January 2001

John O'M. Bockris, Amulya K.N. Reddy, Maria E. Gamboa-Aldeco, Modern Electrochemistry 2A: Fundamentals of Electrodics, Springer; 2nd edition, 31 January 2001

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	LCD Projector
19.7	Site visits	No

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	N/A
20.2	Open-ended problems	N/A
20.3	Project-type activity	N/A
20.4	Open-ended laboratory work	N/A
20.5	Others (please specify)	N/A

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	HYDROGEN ENERGY AND FUEL CELL TECHNOLOGY
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL723
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for advanced standing in Energy and Env Tech

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL722 (20 %)
8.2	Overlap with any UG/PG course of other Dept./Centre	nil
8.3	Supercedes any existing course	CHL 722

9.	**Not allowed for** (indicate program names)	nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Suddhasatwa Basu, M. Ali Haider, Anupam Shukla	
12.	**Will the course require any visiting faculty?**	no

13. Course objective *(about 50 words)*:

To teach students fundamentals required in the development of hydrogen and fuel cell technology. Thermodynamics, chemical reaction engineering, transport processes and electrochemical engineering will be covered in the perspective of fuel cell technology. Source of hydrogen and hydrogen generation processes including storage and transportation will be covered. Students will be given hands-on experience on hydrogen energy and fuel cell technology in fuel cell lab.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Overview of fuel cells: low and high temperature fuel cells. Fuel cell thermodynamics – heat and work potentials, prediction of reversible voltage, fuel cell efficiency. Fuel cell reaction kinetics – electrode kinetics, overvoltages, exchange currents. Electrocatalysis - design, activation kinetics. Fuel cell charge and mass transport - transport in flow field, electrode and electrolyte. Fuel cell characterization- in-situ and ex-situ characterization techniques, i-V

	curve, application of voltammetry and frequency response analyses. Fuel cell modeling and system integration. Fuel cell diagnostics. Balance of plant. Different routes of hydrogen generation: electrolysis versus reforming for hydrogen production, solar hydrogen. Hydrogen storage and transportation, safety issues. Cost expectation and life cycle analysis.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction and overview of hydrogen and fuel cells technology: low and high temperature fuel cells	4
2	Different types of fuel cells and standard potentials and effect of pressure, temperature and concentration, Fuel cell efficiency	4
3	Fuel cell reaction kinetics: Electrode kinetics for different types of fuel cell	4
4	Exchange current and electrocatalysis, activation polarization, Catalyst-electrode design;	4
5	Fuel cell charge transport - ohmic over potentials, different types high, low and intermediate temperature electrolyte; Mass transport - concentration overpotential	4
6	Fuel cell characterization: ex-situ and in-situ diagnostics	6
7	Fuel cell modeling and system integration: Balance of plant;	4
8	Different routes of hydrogen production and storage and transportation;	8
9	Safety issues and cost expectation and life cycle analysis of fuel cells.	4
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Components of fuel cells and electrolyser- demonstration; Running a proton exchange fuel cell: measurement and analyses of fuel cell performance. (No additional laboratory hours required)	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

Text book: 1., O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, NY (2010)
2. Basu, S. (Ed) Fuel Cell Science and Technology, Springer, N.Y. (2007)

3. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y. (2006)
4. Matthew M. Mench, Fuel Cell Engines, Wiley NJ (2008)
5. Rand, David A., Dell, R. M., Hydrogen Energy: Challenges and Prospects, RSC Energy 2008

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	No
19.2	Hardware	PEM fuel cell with e-load
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	fuel cell lab in the dept of chem eng will be used
19.5	Equipment	potentiostat-galvanostat
19.6	Classroom infrastructure	LCD projector
19.7	Site visits	Nil

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	Design of flow systems in Fuel cell, electrode and electrode-electrolyte assembly design – 10%
20.2	Open-ended problems	N/A
20.3	Project-type activity	Conceptual design of new type of fuel cell – 10%
20.4	Open-ended laboratory work	N/A
20.5	Others (please specify)	N/A

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ENVIRONMENTAL ENGINEERING AND WASTE MANAGEMENT
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL724
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./Dual Degree/M. Tech. PE for Adv Standing in Energy & Env

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	20% with CLL725
8.2	Overlap with any UG/PG course of other Dept./Centre	ESL 710, Energy, Ecology and Environment (10%) ESL 735, Hazardous Waste Management (15%) BEL 715, Biological Waste Treatment (15%) CEL 793, Air Pollution and Control (10%) CEL 794, Solid and Hazardous Waste Management (5%) CEL 795, Wastewater Treatment Process (10%) ASL 705, Boundary Layer Metrology and Air Pollution (10%) ASL 724, Atmospheric Diffusion and Air Pollution (10%)
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	

11.	**Faculty who will teach the course:** A. K. Saroha, Jyoti Phirani, Divesh Bhatia, S. Basu, K. K. Pant	
12.	**Will the course require any visiting faculty?**	None

13.	**Course objective** *(about 50 words)*: The course is aimed at the basic concepts of environment, its composition, ecological balances, and different aspects of environmental degradation and its effects. Air, water quality models and pollutant dispersion models for the impact of release of pollutants. Various control techniques including physical, biological and chemical systems.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: The course covers the concept of ecological balance and the contribution of industrial and human activities in the changes of the environmental quality. Ecological cycles. Concept of pollutants and regulatory measures for the maintenance of environmental quality. Air pollution sources and its dependence on the atmospheric factors, atmospheric stability and dispersion of pollutants. Control of emission of pollutants using multi-cyclone systems, electrostatic precipitators, bag filters, wet scrubbers for gas cleaning, adsorption by activated carbon etc. Water pollution, its causes and effects. Pollutants and its dispersion in water bodies to predict water quality through modeling. Concept of inorganic and organic wastes and definition of BOD and COD. Control of water pollution by primary treatment and biological treatment systems. Solid waste management systems. Hazardous waste treatment, disposal and storage in engineered landfill.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction, Ecological cycles, environmental pollution its definition and relationship with human activities	2
2	Definition of pollutants in air and water. Regulations and standards, concept of primary and secondary pollutants.	2
3	Temperature Profile in Atmosphere. Atmospheric Stability and Inversion. Air Quality Modelling and Dispersion of Pollutants in Atmosphere.	4
4	Control of Air Pollution: Dry and Wet Systems	2
5	Design and Analysis of Cyclone, Bag Filters and ESPs	5
6	Types of Wet Scrubber and their Design and Analysis for Gaseous Pollutants.	3
7	Water Quality Model, Effluent Characterization and Oxygen Sag Curve.	3
8	Design Concept of Effluent Treatment Plant: Primary, Secondary and Tertiary Treatment.	3
9	Design of Physical and Chemical Treatment Systems	2
10	Biological Reactions and Treatment Systems	3
11	Design and Analysis of Aerobic Biological Treatment Systems: Activated Sludge Processes, Fixed Media Systems like Trickling Filters, Anaerobic Treatment of Organic Pollutants	5
13	Design of Tertiary Treatment Systems like Sand Filter, Activated Carbon etc.	2
14	Advanced Effluent Treatment & Water Recycle Systems	2
15	Solid Waste Management and Energy Recovery Systems	2
16	Hazardous Waste Management : Its Disposal & Treatment	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		

10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Metcalfe and Eddy; "Biological Treatment of Waste Water : Reuse and"; 5th edition, McGraw Hill Book Company, New Delhi (1995)

Rao,C.S.; "Environmental Pollution Control Engineering", Willey Eastern Ltd. (1991), New Delhi

B.G.Liptak & David H.F.Liu; " Environmental Engineers' Handbook", 2nd Edition, Lewis Publishers, (1996), NewYork

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	AIR POLLUTION CONTROL ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL725
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Energy & Env

7.	**Pre-requisites** (course no./title)	CLL 222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL724: 20%
8.2	Overlap with any UG/PG course of other Dept./Centre	CEL793: 10%
8.3	Supercedes any existing course	nil

9.	**Not allowed for** (indicate program names)	NA

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Divesh Bhatia, Shantanu Roy, Jyoti Phirani	
12.	**Will the course require any visiting faculty?**	no

13.	**Course objective** *(about 50 words)***:** Objective of the course is to familiarize students with various catalytic and non-catalytic technologies for control of different air pollutants. The course will first introduce students to fundamental concepts of environmental catalysis, filtration and particle capture. Technologies for mobile sources (automotive) and stationary sources (like power plants) will be discussed, along with engineering aspects. Finally, some of the upcoming technological inventions of air quality management will be discussed.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Overview of air pollution from mobile and stationary sources. Modeling of emission profile from IC engine. Effect of fuel type and quality and engine performance on air quality. Automotive catalysts and monoliths. Diesel particulate filters and their operation. Selective catalytic reduction. Stationary sources of air pollutants. Household pollutants and control of indoor air quality. Control of pollutants from power plants.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of air pollution from mobile and stationary sources: Link between fossil fuel type and quality, engine and combustor performance,nature and classification of pollutants, current and future regulations, methods for measurement and quantification	5
2	Fundamentals of environmental catalysis, preparation of catalytic materials and substrates, monolithic reactors, other configurations	4
3	Automotive catalysts and substrates, first generation catalytic convertors, three-way catalysts, engineered catalyst design, durability of substrates	9
4	Particulate and NOx control in diesel engines: design of diesel particulate filters, filter regenaration, durablity, coupling with selective catalytic reduction catalyst and diesel oxidation catalyst, exhaust gas recirculation	8
5	Stationary sources and volatile organic compounds (VOCs), indoor air quality management	4
6	NOx reduction in power plants	4
7	Emission control in small engines, generators and turbines	4
8	Issues related to ambient air clean-up	2
9	Active and future research - Lean NOx traps, continuously regenerating traps	2
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Heck, R. M., Farrauto, R. J., & Gulati, S. T. (2012). Catalytic air pollution control: commercial technology. John Wiley & Sons.

Licht, W. (1988). Air pollution control engineering: Basic calculations for particulate collection

(Vol. 10). CRC Press.
De Nevers, N. (2010). Air pollution control engineering. Waveland Press.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Nil
19.2	Hardware	Nil
19.3	Teaching aides (videos, etc.)	Nil
19.4	Laboratory	Nil
19.5	Equipment	Nil
19.6	Classroom infrastructure	Regular classroom infrastructure such as projector
19.7	Site visits	Nil

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	65%
20.2	Open-ended problems	10%
20.3	Project-type activity	25%
20.4	Open-ended laboratory work	Nil
20.5	Others (please specify)	NA

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	MOLECULAR MODELING OF CATALYTIC REACTIONS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL726
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Energy & Env

7.	**Pre-requisites** (course no./title)	CLL 222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 727: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** M. Ali Haider, Kamal K.Pant, Sreedevi Upadhyayula	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

The course work deals with experimental and theoretical aspects of heterogeneous catalytic reactions, with primary emphasis on understanding of reaction mechanisms. Subject treatment will follow a reductionist approach, wherein the chemistry of the reaction is elucidated by elementary steps occuring on the catalyst surface. Ab-intio quantum simulations will be employed to gain insight into the reaction energetics.

The objective is to introduce interesting recent trends in research and development of a heterogeneous catalyst, in which experimental results are directly inferred by quantum mechanical simulations, so as to develop a molecular level understanding of the catalytic reactions.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

	Sabatier principle. Catalytic cycle, transition state theory. Ensemble effect, defect sites, cluster size effects, metal-support interactions, structural effects, quantum size effects, electron transfer effects. BrØnsted-Evans-Polanyi relations. Reactivity of transition-metal surfaces, quantum chemistry of chemical bond, bonding to transition metals, chemisorption. Kinetics of elementary steps (adsorption, desorption and surface reactions). Reaction on uniform and non-uniform surfaces. Structure-sensitive and non-sensitive reactions on metals. Electronic structure methods, potential energy surface, Born–Oppenheimer approximation, Hartree-Fock theory, self-consistent field, Kohn-Sham Density Functional Theory, Bloch's theorem and plane wave basis set, exchange-correlation functionals, pseudo-potential. Search for transition state, dimer method, nudged elastic band method, density of states. Catalysis by metals, oxides, sulfides and zeolites. Aqueous phase heterogeneous catalysis and electrocatalysis.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Principles of Molecular Heterogeneous Catalysis (Sabatier principle, Catalytic Cycle, Transition State Theory, Ensemble Effect, Defect Sites, Cluster-Size Effects, Metal-support Interactions, Structural Effects, Quantum Size Effects, Electron Transfer Effects, BrØnsted-Evans-Polanyi Relations, Reactivity of Transition-Metal Surfaces)	8
2	Quantum Chemistry of Chemical Bond, Bonding to Transition Metals, Chemisorption	8
3	Kinetics of Catalytic Reactions (Adsorption, Desorption and Surface Reactions, Reaction on Uniform and Non-Uniform Surfaces, Structure Sensitive and Non-Sensitive Reactions on Metals)	4
4	Introduction to Density Functional Theory (Born–Oppenheimer approximation, Hartree-Fock Theory, Self-Consistent Field, Kohn-Sham Density Functional Theory, Bloch's Theorem and Plane Wave Basis Set)	6
5	Computational Methods (Electronic Structure Methods, Potential Energy Surface, Exchange-Correlation Functional, Pseudo-Potential, Search for Transition State, Dimer Method, Nudged Elastic Band Method, Density of States)	8
6	Literature Readings on Molecular Modeling of Catalytic Reactions (Catalysis by Metals, Oxides, Sulfides and Zeolites. Aqueous Phase Heterogeneous Catalysis and Electrocatalysis)	8
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text: Rutger A. van Santen, Matthew Neurock, Molecular Heterogeneous Catalysis: A Conceptual and Computational Approach, 1st edition (March 10, 2006), Wiley-VCH, ISBN: 978-3-527-29662-0

Ref: I. Chorkendorff, J. W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics Wiley VCH, 2nd edition (22 August 2007), ISBN: 978-3527316724

David Sholl (Author), Janice A Steckel (Author) Density Functional Theory: A Practical Introduction, Wiley-Interscience; 1 edition (April 13, 2009), ISBN: 978-0470373170

M. Albert Vannice, Kinetics of Catalytic Reactions, Springer; 2005 edition (August 24, 2005)

Wolfram Koch, Max C. Holthausen, A Chemist's Guide to Density Functional Theory, Wiley-VCH; 2 edition (July 11, 2001), ISBN: 978-3527303724

Michel Boudart, Kinetics of Heterogeneous Catalytic Reactions, Princeton University Press 198 (1984), ISBN: 978-0691083476

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Accelrys Materials Studio 7.0 (Accelrys, Inc. San Diego, CA 92121, USA)
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	HETEROGENEOUS CATALYSIS AND CATALYTIC REACTORS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL727
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./Dual Degree/M. Tech. PE for adv standing Energy & Env

7.	**Pre-requisites** (course no./title)	CLL222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	10% with CLL 726 20% with CLL 733
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	CHL727

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	Either sem, once a year

11.	**Faculty who will teach the course:** K. K. Pant, Divesh Bhatia, M. Ali Haider, U. Sreedevi, S. Roy, Vivek Buwa	
12.	**Will the course require any visiting faculty?**	Some invited lectures from industry may be useful (2-3 lectures of one hour duration)

13.	**Course objective** *(about 50 words)***:** This course examines the detailed structures, preparation methods and reactivities of solid catalysts like zeolites, solid state inorganics, supported metals and metal-support interactions, carbon catalysts, anchored catalysts and others. Several important catalyst properties and their determination

	techniques such as surface area and pore size measurements, temperature Programmed desorption (TPD), acidity and various spectroscopic techniques used in surface science such as X-ray photoelectron spectroscopy (ESCA), electron microprobe, scanning electron microscopy, Fourier-transform infrared, enhanced laser Raman spectroscopy will be described for characterization of the catalytic surfaces. The relationship between the structures and reactivities of important catalysts used in hydrocarbon oxidation and functionalization and syngas reactions will be examined to rationalize how they accomplish specific catalytic transformations

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Basic concepts in heterogeneous catalysis, catalyst preparation and characterization, poisoning and regeneration. Industrially important catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, synthesis gas and related processes. Commercial reactors: adiabatic and multi-tubular packed beds, fluidized bed, trickle-bed, slurry reactors. Heat and mass transfer and its role in heterogeneous catalysis. Calculations of effective diffusivity and thermal conductivity of porous catalysts. Reactor modeling. Chemistry and engineering aspects of catalytic processes along with problems arising in industry. Catalyst deactivation kinetics and modeling.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to basic concepts	2
2	Acid-base catalysis	2
3	Application of catalyst functionality concepts for control of reaction selectivity and kinetic models	2
4	Steps in catalytic reaction (Adsorption, Kinetic models, interparticle and intraparticle transport process	4
5	Selection and design of catalysts	2
6	Preparation and characterization of catalysts	3
7	Properties of catalysts	3
8	Catalyst deactivation, various deactivation models	3
9	Optimal distribution of catalyst in a pellet	2
10	Application of functionality concepts for control of reaction selectivity and kinetic models	3
11	Zeolites their Application	2
12	Preparation and characterization of various Zeolite catalysts	2
13	Commercial Reactors (Adiabatic, fluidized bed, trickle bed, slurry etc.)	4
14	Industrially important catalysts and processes such oxidation, processing of petroleum and hydrocarbons, synthesis gas and related processes,	4
15	Environmental catalysis	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Experiments on catalyst preparation and characterization (no additional laboratory hours required)	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Catalytic Chemistry : Bruce Gates
2. Optimal distribution of catalyst in a pellet: Morbidelli and Verma
3. Catalysis of Organic reactions: editor M.E.Ford, Marcel Dekker Inc.
4. Heterogeneous Reactions Vol 1 and Vol II : M. M. Sharma and Doraiswamy
5. Principles and practice of heterogeneous Catalysis: Thomas, J.M., Thomas W.J.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	Classroom hardware
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Projector
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	30%
20.2	Open-ended problems	40%
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	10%
20.5	Others (please specify)	Nil

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHEMICAL ENGINERING
2.	**Course Title** *(< 45 characters)*	BIOMASS CONVERSION AND UTILISATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL728
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	CLL122

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	No

9.	**Not allowed for** (indicate program names)	N/A

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** K K Pant, M. Ali Haider	
12.	**Will the course require any visiting faculty?**	

13.	**Course objective** *(about 50 words)***:** Objective of the course is to provide knowledge of fuel and chemical production from biomass, and enable the student to perform technical, economic and environmental comparisons of various bio-energy systems.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Critical analysis of issues associated with implementing large scale biofuel and biomass energy production. Processes for converting feedstocks to biofuels by thermochemical methods. Biomass conversion catalysis, kinetics and reaction mechanisms, reactor design and scale up issues. .

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Biomass, compostion and energy density of biomass, energy crops for the production of fuels and chemicals, waste biomass resources, algae biomass, land resources, issues related to food versus fuel, available technologies for the conversion of biomass to fuels and chemicals, comparision of thermochemical and biological processes, physical and chmeical properties of lignin and its utilization	7
2	Development of a biorefinery, top 10 products, feedstock choices, thermochemical production of building blocks, biomass pretreatment and dehydration.	4
3	Biomass gasification, gasification chemistry, reaction stages, conversion of biomass to liquid fuels and chemicals via the Fischer–Tropsch synthesis route, biomass to liquids (BTL), syngas derived from biomass, conversion of syngas to alcohols, thermodynamic limitations, product distribution, reaction kinetics and mechanisms.	6
4	Biomass pyrolysis, reactor and process technologies, hydrothermal processing of biomass, hydrothermal liquefaction, nitrogen partitioning and hydrothermal gasification, properties of biooil and its upgrading, catalytic upgrading, hydrotreating	8
5	Aqueous phase processing of biomass derivatives, aqueous phase reforming, catalytic conversion of biomass derivatives such as glycerol, levulinic acid, gamma-valerolactone, furfural into fuels and chemicals	6
6	Opportunities for heterogeneous catalysis in biomass conversion, catalyst materials, bimetallic catalyts, role of support and promoter, catayst activity and selectivity, stability of a catalyst and its deactivation, integrated bio and chemo catalytic conversion of biomass	8
7	Life cycle analysis of various biomass conversion processes, estimation of green house gas emissions, issues related to sustainability and development of a sustainability criterion.	3
8		
9		
10		
11		

12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1`. Thermochemical Conversion of Biomass to Liquid Fuels and Chemicals
RSC Energy and Environment Series
Editor-in-Chief: Professor Laurence Peter, University of Bath, UK

2. Catalysis for the Conversion of Biomass and Its Derivatives
Malte Behrens and Abhaya K. Datye Published under Creative Commons by- nc-sa Germany Licence
http://creativecommons.org/licenses/by-nc-sa/3.0/de/

3. Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power
Robert C. Brown (Editor), Christian Stevens (Series Editor)
ISBN: 978-0-470-72111-7, March 2011
4. Articles from Journals

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	No
19.5	Equipment	No

19.6	Classroom infrastructure	LCD projector
19.7	Site visits	No

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	N/A
20.2	Open-ended problems	N/A
20.3	Project-type activity	N/A
20.4	Open-ended laboratory work	N/A
20.5	Others (please specify)	N/A

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	STRUCTURE, TRANSPORT AND REACTIONS IN BIONANO SYSTEMS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL730
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for adv standing in Biopharma & Fine Chem

7.	**Pre-requisites** (course no./title)	CLL110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL778: 15%
8.2	Overlap with any UG/PG course of other Dept./Centre	SBV882: 10% MEL3XX Thermofluid Analysis of Biosystems (50%) (new course)
8.3	Supercedes any existing course	CHL730

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Shalini Gupta, Gaurav Goel, Anurag Rathore, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

This course will focus on developing mathematical models for coupled transport in bionano systems. It will also discuss how molecular interactions in these systems lead to evolution of structure for optimum transport and reactions. Current trends in this topic will be discussed through in-depth case studies from recent research in bionano systems.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Introduction to biology: protein structure, composition, pKa and isoelectric point. Governing equations applied to biological systems: conservation laws, flux equations, mathematical functions and solutions, scaling and order,

	laminar flow. Electromechanical transport: biomolecular migration through blood capillaries, Poisson-Boltzmann equation in heterogeneous media, electrical-shear stress balance in electrical double layers. Transport across membranes: structure and self-assembly of lipid bilayers, ligand-receptor interactions, membrane permeability, Nernst potential, adsorption isotherms and transport across membrane. Estimation of transport coefficients based on biomolecular interactions. Research-specific case studies incorporating coupled migration through reactive, electrical and heterogeneity considerations.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to basic biology: Composition, structure and properties of proteins	2
2	Conservation laws, mathematical functions and solutions	3
3	Scaling and order, low Reynolds flow	2
4	Migration of biomolecules through capillaries	3
5	Poisson-Boltzmann equation revisited for heterogeneous media	4
6	Balance of electrical and shear stresses in double layers	4
7	Self-assembly of lipid bilayers and ligand-receptor interactions	3
8	Membrane dynamics and Nernst potential	3
9	Coupled migration across membranes through reactive, electrical and heterogeneity considerations	5
10	Rheological properties of biological systems	5
11	Research-specific case studies: drug delivery, cellular response in changing environment etc.	8
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		0

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Philip Nelson, Biological Physics: Energy, Information, Life, W. H. Freeman and Company, New York, 2004.
2. William M. Deen, Analysis of Transport Phenomena, Oxford University Press, New York, 1998.
3. Ronald G. Larson, The Structure and Rheology of Complex Fluids, Oxford University Press, USA, 1998.
4. Alan J. Grodzinsky, Fields, Forces, and Flows in Biological Systems, First edition, Garland Science (Taylor and Francis group), 2011
5. J. N. Israelachvili, Intermolecular and Surface Forces, third edition, Elsevier, Inc. 2011

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Air-conditioning
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	0
20.2	Open-ended problems	0
20.3	Project-type activity	0
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	HWs and class projects

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL732
6.	**Status** (*category* for *program*)	DE for B. Tech. PE for DD/ M. Tech.

7.	**Pre-requisites** (course no./title)	CLL121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL773: 15%
8.2	Overlap with any UG/PG course of other Dept./Centre	MEL703: 25%
8.3	Supercedes any existing course	CHL721

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sanat Mohanty, Gaurav Goel, Anupam Shukla, M. Ali Haider	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

Analysis and estimation/description of material properties (for pure materials and mixtures), macroscopic perspective of changes in material properties and analysis of processes and equipment using materials with changing conditions under equilibrium. Understanding of equilibrium, nature of equilibrium, reversible and irreversible processes. Molecular perspective of equilibrium and states of materials, axioms of statistical thermodynamics and applications to simple gas systems, lattice structures and structure – property analysis of such systems.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

First and second law of thermodynamics. Application in analysis of energy and efficiency of equipment, flow through equipment. State and behavior of materials, degree of freedom analysis. Material properties as a function of conditions. Relationships between material properties, and changes in material properties. Equilibrium properties of materials: pure materials, and mixtures. A-

	priori probability postulate, ergodic hypothesis, introduction to microcanonical, canonical and grand canonical ensembles, derivation of physical properties for pure components and mixtures, ideal gas and lattice gas, virial coefficient calculations. Crystal structures, solutions, modeling and analysis of adsorption phenomena, relating them to macroscopic thermodynamics.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Thermodynamics, Structure-Property relationships of Matter, Degree of freedom, Equilibrium, Review of Classical thermodynamics - Energy, conservation & First Law, Open and closed systems, reversible & irreversible processes	2
2	Phases, phase transitions, PVT behavior; description of materials – Ideal gas description, van der Waals and cubic EOS, Virial EOS, Reduced conditions & corresponding states theories, correlations in description of material properties and behavior	2
3	Efficiency of heat engines, Carnot cycles, temperature scales, entropy as a state property, reversible and irreversible processes, entropy of an ideal gas, Second Law, Losses, Third Law	2
4	Thermodynamic property of fluids, Maxwell relations, 2-phase systems, graphs and tables of thermodynamic properties, steam tables, Thermodynamics of flows in ducts, pipes, piping fixtures, nozzles, compressors, pumps, of steam power plants, & combustion engines, Refrigeration & Liquefaction - A review	5
5	Solution Thermodynamics, fundamental property relationships, free energy and chemical potential, partial properties, definition of fugacity and fugacity coefficient of pure species and species in solution, the ideal solution and excess properties, thermodynamic properties of typical solutions and relationship to molecular interactions	3
6	Liquid phase properties from VLE, Gibbs energy, heat effects and property change on mixing	3
7	VLE at low to moderate pressures, equilibrium, phase rule & Duhem's theorem, graphical understanding of phase behavior of mixtures, activity coefficient and its use in VLE analysis, Raoult's and Henry's Law approximations, Flash calculations, Bubble and Dew point calculations, Properties of fluids from equations of state, Stability Analysis of solutions, Metastable States and Spinodal Decomposition	4
8	Adsorption Thermodynamics	2
9	Chemical Reaction Thermodynamics	3
10	Postulates of Statistical Thermodynamics (a-priori probability postulate, Ergodic hypothesis), Probability analysis and relating statistical properties to macroscopic properties. Microcanonical, Canonical and Grand Canonical Ensembles, Molecular interactions and force fields	7
11	Modeling of ideal gases (monatomic, diatomic, polyatomic), degrees of freedom and internal energy, specific heat capacity, entropy and free energy. Modeling of lattice gas. Modeling of gas mixtures.	4
12	Modeling of crystals – perfect crystals, defects. Internal energy and heat capacity. Modeling of Adsorption. Introduction to perturbation analysis.	5
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:

Smith & Van Ness: Introduction to Chemical Engineering Thermodynamics, McGraw Hill, any edition from 4th – 7th.

Richard Elliot, Introductory Chemical Engineering Thermodynamics, Pearson Education, 2nd Edition, 2014

Terrel L Hill, Introduction to Statistical Thermodynamics, 1st Edition, Dover Publications,1988

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS INTENSIFICATION AND NOVEL REACTORS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL734
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Energy & Env

7.	**Pre-requisites** (course no./title)	CLL 122, CLL 222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 733: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Vivek Buwa, Shantanu Roy, Divesh Bhatia, Ratan Mohan	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To learn the importance of process intensification, ways of process intensification, and to learn process intensification through multifunctional and miniaturized reactors and other novel reactors
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to process intensification, possible ways of process intensification and their examples. Introduction to multifunctional reactors/process equipment: reactive distillation, reactor-heat-exchangers. membrane reactors, micro-reactors, structured/monolithic reactors. Intensification of conventional reactors/process equipments, analysis of fluid dynamics and transport effects of intensified reactors. Order of magnitude analysis of reaction rates, heat/mass transfer rates. Flow patterns in intensified reactors. Design and scale of intensified reactors, fabrication issues. Examples of process intensification.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Concept of process intensification: Background, history and principles; concept of multi-functionality; expected benefits	4
2	Intensification through design modifications: Examples in conventional reactors	4
3	Process intensification through microreactor technology	6
4	Structured catalysts and reactors	6
5	In-line and high intensity mixers	2
6	Reactive separations	6
7	Compact multi-functional heat exchangers	2
8	Cavitation, sonochemical and photochemical reactors	4
9	Microwave assisted synthesis	2
10	Intensification in high-gravity fields (rotating packed beds, spinning disk reactors)	2
11	Process intensification in Industrial Practice	2
12	Process intensification as a tool for green chemistry and sustainable development	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Stankiewicz, A. and J. A. Moulijn, "Re-Engineering the Chemical Processing Plant: Process Intensification", Marcel-Dekker (2003).

Cybulski, A. and J. A. Moulijn, "Structured Catalysts and Reactors", 2nd Ed., Marcel-Dekker (2005).

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	DESIGN OF MULTICOMPONENT SEPARATION PROCESSES
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL735
6.	**Status** (*category* for *program*)	DE/PE for B.Tech/Dual Degree/M.Tech PE for adv standing Energy & Env, Proc Eng, Mod & Opt

7.	**Pre-requisites** (course no./title)	CLL352

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	10% with CLL352
8.2	Overlap with any UG/PG course of other Dept./Centre	nil
8.3	Supercedes any existing course	CHL735, CHL751

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Suddhasatwa Basu, Rajesh Khanna, Munawar Shaik	
12.	**Will the course require any visiting faculty?**	no

13. Course objective *(about 50 words)*:

To teach student basics of multi-component mass transfer, properties of non-ideal mixtures and design of multicomponent stage separation processes - distillation, extraction, adsorption and ion-exchange, membrane separtion and other new separation processes

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Overview of multi-component separation. Non-ideal solution and properties, equation of state, vapour liquid equilibrium. Multi component separation: Short cut method, rigorous calculations - sum rate, boiling point and Newton's methods, inside-out method for designing of multi-component distillation, absorption and extraction column / contacting devices. Choice of column: tray, random packing and structured packing. Design of adsorption and ion exchange column. Crystallization. Affinity separation and chromatographic separation. Optimal reflux ratio (recycle stream) - operating expenditure versus

	capital expenditure for all types of columns and contacting devices.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of multi-component separation: challenges;	2
2	Non-ideal solution and properties, Equation of state, vapour-liquid equilibrium,	6
3	Multi component distillation design- short cut method - Fenske-Underwood-Gilliland Method	4
4	Rigorous calculation - sum rate, boiling point and Newton's method, Inside-out method, Design of distilation, absorption and extraction column / contacting devices for multi component systems	10
5	Choice of column - tray, random packing and structured packing, column internal design, Height and diameter of tray, packed column calculation	6
6	Design of adsorption and ion exchange column for multi-component system	4
7	Crystallization, affinity separation and chromatographic separation	6
8	Optimization of reflux ratio (recycle stream) and no of stages against operating cost and capital cost for all columns / contacting devices	4
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Kister, H. Z. Distillation Design McGraw-Hill 1992
2. Seader and Henley, Separation Process Principles, Wiley 2005
3. Humphrey, J. L. and Keller, G. E. Separation Process Technology, McGraw- Hill, NY 1997

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	50
20.2	Open-ended problems	
20.3	Project-type activity	50
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHEMICAL ENGINEERING
2.	**Course Title** *(< 45 characters)*	EXPERIMENTAL CHARACTERIZATION OF BIOMACROMOLECULES
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL742
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Biopharma & Fine Chemicals

7.	**Pre-requisites** (course no./title)	CLL141, CLL271

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL779: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	CYL713: 10% PHL654: 10% TTL712: 10% PTL705: 10%
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sudip Pattanayek, Anurag Singh Rathore, Shalini Gupta, Sanat Mohanty, Gaurav Goel	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

This course intends to familiarize students to various analytical techniques that are used to characterize biomolecules. These tools will include both the traditional ones that are widely used for characterization as well as those that are emerging as the tools of choice for high resolution analysis. The bulk of the course will focus on explaining the mechanism behind the working of these tools and the attributes that they can measure. Case studies will be presented to illustrate applications of these tools. Hands-on experience will be provided for some of these tools as well.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

	Theory and working principles of analytical instruments including high performance liquid chromatography (HPLC), ultra-high performance liquid chromatography (UPLC), capillary electrophoresis (CE), capillary isoelectric focusing (cIEF), gel electrophoresis, circular dichroism (CD) spectroscopy, Fourier transform infrared spectroscopy (FTIR), mass spectroscopy (MS), atomic force microscopy (AFM), scanning electron microscope (SEM), differential scanning calorimetry (DSC), ultraviolet (UV) spectroscopy, surface plasmon resonance (SPR), 2D gel electrophoresis, fluorescence spectroscopy, Zeta-meter, contact angle goniometer, oscillatory drop module (ODM) of goniometer, and quartz crystal microbalance (QCM). Hands-on experience on characterization of proteins. Case studies in biotech industry.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Structure of biomolecules and their attributes	6
2	Principles behind workings of high performance liquid chromatography (HPLC), ultra-high performance liquid chromatography (UPLC), capillary electrophoresis (CE), capillary isoelectric focusing (cIEF), gel electrophoresis, circular dichroism (CD) spectroscopy, Fourier transform infrared spectroscopy (FTIR), mass spectroscopy (MS), atomic force microscopy (AFM), scanning electron microscope (SEM), differential scanning calorimetry (DSC), ultraviolet (UV) spectroscopy, surface plasmon resonance (SPR), 2D gel Electrophoresis, Fluorescence spectroscopy, Zeta-meter, contact angle goniometer, Oscillatory drop module (ODM) of Goniometer, and Quartz crystal microbalance (QCM).	14
3	Case studies involving use of the above mentioned instruments	8
4	Hands on experience on characterization of proteins will be given on HPLC, 2D gel Electrophoresis, UV, Fluorescence spectroscopy, Zeta-meter, contact angle goniometer, and surface elasticity using ODM.	14
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

B. Stuart,Infrared Spectroscopy: Fundamentals and Applications, 2004 John Wiley & Sons, Ltd

Guangming Liu, Guangzhao Zhang, QCM-D Studies on Polymer Behavior at Interfaces, 2013, Springer Berlin Heidelberg.
Analytical Techniques for Biopharmaceutical Development, Roberto Rodriguez-Diaz (Editor), Tim Wehr (Editor), Stephen Tuck (Editor) , 20005, CRC Press.
Methods For Protein Analysis: A Practical Guide for Laboratory Protocols, Robert A. Copeland (Editor), 19994, Springer.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Laptop projection
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	Nil
20.2	Open-ended problems	Nil
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	Nil
20.5	Others (please specify)	Nil

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	Petrochemicals Technology
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL743
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for Energy & Env

7.	**Pre-requisites** (course no./title)	CLL222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	10%: CLL794
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	CHL743

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** K. K. Pant, U. Sreedevi, Divesh Bhatia, M. Ali Haider, S. Roy, Vivek Buwa	
12.	**Will the course require any visiting faculty?**	Some special lectures may be given by the experts form petrochemical companies

13. Course objective *(about 50 words)*:
The main objective of this course is to provide students a thorough understanding in the area of petroleum and petrochemicals and new trends in petrochemical industries. The course will focus on the conventional processes in downstream petroleum and petrochemical industries, particularly oil derivatives, polymers, materials, detergents and synthesis gas derivatives. New innovations in the petrochemicals sector will be highlighted.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:
Composition of petroleum: laboratory tests, refinery products, characterization of crude oil. Review of petrochemicals sector and Indian petrochemical industries in particular. Feed stocks for petrochemical industries and their sources. Overview of refining processes: catalytic cracking, reforming, delayed coking, Hydrogenation and Hydrocracking, Isomerization, Alkylation and

	polymerization, purification of gases, separation of aromatics by various techniques. Petrochemicals from methane, ethane, ethylene, acetylene, C3/C4 and higher hydrocarbons. Synthesis gas chemicals. Polymers from Olefins. Synthetic fibers, rubber, plastics and synthetic detergents. Energy conservation in petrochemical Industries. Pollution control in petrochemical industries. New trends in petrochemical industry. Planning and commissioning of a petrochemicals complex.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction: Composition of petroleum, laboratory tests, refinery products	5
2	Petrochemical industries: Indian Scenario	1
3	Feed stocks for petrochemical Industries	2
4	Introduction to Catalytic cracking, Catalytic reforming, Delayed coking, Hydrogenation and Hydrocracking, Isomerization, Alkylation and Polymerization	4
5	Purification of gases Separation of aromatics by various Techniques	4
6.	Petrochemicals from Methane	2
7.	Petrochemicals from Ethane – Ethylenes – Acetylene	3
8.	Petrochemicals from C3, C4 and higher Hydrocarbons	3
9.	Synthetic Gas Chemicals	1
10.	Polymers from Olefins	5
11.	Petroleum Aromatics	3
12.	Synthetic Fibers, Rubber , Plastics and Synthetic Detergents	3
13.	Energy conservation in petrochemical Industries	1
14.	Pollution control in Petrochemical Industries	2
15.	New Trends in petrochemical Industry	1
16.	Planning and commissioning of a petrochemicals complex	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

Not required

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Hatch, Lewis Frederic, and Sami Matar. *From hydrocarbons to petrochemicals*. Gulf Publishing Company, Book Division, 1981.

Meyers, Robert, and Robert Allen Meyers, eds. *Handbook of petrochemicals production processes*. McGraw-Hill Prof Med/Tech, 2005.

Spitz, Peter H. *Petrochemicals: the rise of an industry*. New York: Wiley, 1988.

Articles related to new trends in Petrochemical Industries published in various

Chemical Engineering journals

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Application of Petroplan for optimizing process
19.2	Hardware	NA
19.3	Teaching aides (videos, etc.)	NA
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Regular classroom infrastructure such as projector
19.7	Site visits	NA

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	60%
20.2	Open-ended problems	20%
20.3	Project-type activity	15%
20.4	Open-ended laboratory work	5%
20.5	Others (please specify)	-

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	CHEMICAL ENGINEERING MATHEMATICS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL761
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for adv stand in Proc Engg, Mod and Opt

7.	**Pre-requisites** (course no./title)	MAL110, CLL110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL761

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Gaurav Goel, Shantanu Roy, Rajesh Khanna, Divesh Bhatia, Paresh Chokshi, Jayati Sarkar, Vivek Buwa	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

After successfully completing the course the student should be able to

a. Present data in appropriate form.

b. Estimate the error component in data.

c. Analyze data by statistical methods

d. Solve linear algebraic, ordinary differential and partial differential equations by analytical methods

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Classification, estimation and propagation of errors. Presentation of data. Statistical methods: sample and population distributions, testing of hypothesis, analysis of variance.

Vector spaces, basis, matrices and differential operators. Eigen values, vectors and functions. Solvability conditions for linear equations. Frobenius

	method for ordinary differential equations. Sturm-Louiville Theorom: Separation of variables and Fourier transform. Green's function and its applications.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Error analysis and propagation	2
2	Presentation of data	1
3	Population distributions	4
4	Sample distributions	3
5	Analysis of variance	2
6	Vector spaces	2
7	Matrices and operators	3
8	Solution of linear algebraic equations	3
9	Solution of ordinary differential equations	4
10	Frobenius method for solving ordinary differential equations	6
11	Solution of partial differential equations	12
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

(a) Mathematical Methods in Chemical Engineering by S. Pushpvanam, Prentice Hall India
(b) Applied Mathematics and Modeling for Chemical Engineers by Rice and Do, John Wiley and Sons, Inc
(c) Applied Mathematics in Chemical Engineering by Mickley, Sherwood and Reed, Tata-McGraw-Hill
(d) Advanced Engineering Mathematics by Erwin Kreyszig, John Wiley and Sons

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	

19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector, Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	5%, problems will be given in assignments and exams.
20.2	Open-ended problems	5%, problems will be given in assignments and exams.
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHEMICAL ENGINEERING
2.	**Course Title** *(< 45 characters)*	ADVANCED COMPUTATIONAL TECHNIQUES IN CHEMICAL ENGG.
3.	**L-T-P structure**	(2-0-2)
4.	**Credits**	3
5.	**Course number**	CLL762
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Proc Engg, Modeling & Opt

7.	**Pre-requisites** (course no./title)	CLL113

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL768 (20%)
8.2	Overlap with any UG/PG course of other Dept./Centre	AML430 (15%)
8.3	Supercedes any existing course	CHL830

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Jayati Sarkar, Rajesh Khanna, Gaurav Goel, Paresh Chokshi, Vivek Buwa, Ratan Mohan, Shantanu Roy, Divesh Bhatia	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

To introduce students to advanced numerical techniques like FEM, OC, MC methods to solve problems that arise in different areas in chemical engineering like in chemical reaction engineering, heat, mass and momentum transfer. To write their own programs in languages like C/Fortran to solve the problems. To get used to different plotting tools to visualize the results and symbolic tools to validate their results with analytical results.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Introduction to models in Chemical Engineering. Formulation of problems leading to ODEs of initial value types. Stability and stiffness of matrices. Solution of stiff problems like Rober's problem in autocatalytic reactions by Gear's algorithm. Formulation of problems leading to steady state ODEs of boundary value types. Different weighted residual methods to solve BVPs. Orthogonal collocation and Galerkin finite element method. Application to

	reaction diffusion in porous catalysts pellets under non-isothermal conditions, calculation of effectiveness factor. Moving boundary problems. Transient problems leading to PDEs. Examples in heat and mass transfer and their numerical solution: orthogonal collocation. Monte Carlo method and its applications. Introduction to LBM method to solve fluid flow problems.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to models in Chemical Engineering leading to linear and nonlinear equations of algebraic, oridnary and partial differential equations	2
2	Ordinary differential equations of initial value types. Stability and stiffness of matrices.Gears algorithm	7
3	Ordinary differential equations - boundary value problem: Introduction to weighted residual methods - Collocation, Subdomain method, Least Square method, Moment method, Galerkin method.	2
4	Orthogonal Collocation Method - Problem solving	4
5	Galerkin finite element methods	4
6	Partial Differential Equations and solving them by orthogonal collocation method	2
7	Moving boundary problems.	1
8	Monte Carlo method and its applications	3
9	Introduction to LBM method to solve fluid problems.	3
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Solution of matrices through Gauss Elimination, Gauss Jordon and Jacobi method	2
2	Solving ODE-IVP problems by varoius implicit, explicit, PC and RK methods to get an understanding of stability	4
3	Solution of stiff problems like Robers problem in autocatalytic reactions by GEARs algorithm	2
4	Learning plotting tools	2
5	Learning analyis of results	2
6	Learning symbolic calculation tool	2
7	Solving reaction diffusion problem of porous catalysts pellets using Orthogonal collocation using Jacobi polynomial.	4
8	Understanding how to deal with linear bcs like Dirichlet, Robin bcs and nonlinear bcs.	2
9	Solving elliptic, parabolic PDE with OC and OC in finite elements	4
10	Solving FE problems with the help of shape factors	4
COURSE TOTAL *(14 times 'P')*		28

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text books:

Rice, R. R. and Do, D. D., Applied Mathematics and Modeling for Chemical Engineers, 2nd

Edition, Wiley, 2012

Gupta, S. K., Numerical Methods for Engineers, 1st Edition, New Age International, 1995

Pushpavanam, S., Mathematical Methods in Chemical Engineering, 1st Edition, PHL Learning Pvt. Ltd, 1998

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Fortran and C compilers
19.2	Hardware	30 PCs
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	Computational Lab with 30 PCs
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	INTERFACIAL ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL766
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL110, CLL121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL771 (10%)
8.2	Overlap with any UG/PG course of other Dept./Centre	CYL210 (10%) PHL702 (10%)
8.3	Supercedes any existing course	CHL766

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Ashok Bhaskarwar, Rajesh Khanna, S. Basu, Gaurav Goel, Shalini Gupta, Sudip Pattanayek, Jayati Sarkar, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To introduce the chemical engineering students to the fundamental concepts of interfacial science and to the applications of these concepts to the design and manufacture of chemical products. The students are also expected to be exposed to various interfacial processes, besides the fundamental principles.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Concept and definition of interface. Physical surfaces. Surface chemistry and physics of colloids, thin films, dispersions, emulsions, foams, polyaphrons. Interfacial processes such as crystallization, epitaxy, froth flotation, adsorption, adsorptive bubble separation, catalysis, reaction-injection moulding, microencapsulation. Industrial aspects of interfacial engineering.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Concept and definition of interface	3
2	Physical surfaces, Surface energy, Surface tension, Wettability, Contact angle	8
3	Surface chemistry, Physics of colloids, Intermolecular forces, dispersion forces	8
4	Physics of thin films, emulsions, foams and polyaphrons	8
5	Interfacial processes such as crystallization, epitaxy, froth flotation,adsorption, adsorptive bubble separation	8
6	Catalysis, reaction-injection moulding, microencapsulation	4
7	Industrial aspects of interfacial engineering	3
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:

J. N. Israelachvili, Interfacial and Surface Forces, Academic Press, 2nd Ed., 1991.

Ghosh, P., Colloid and Interface Science, PHI Learning, 2009

Journal articles and class notes

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	20%
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	STRUCTURE AND PROPERTIES OF POLYMERS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL767
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Complex Fluids

7.	**Pre-requisites** (course no./title)	CLL141

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	10% with PTL703, 15% with PTL701, 10% with TTL712
8.3	Supercedes any existing course	CHL792

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sudip K. Pattanayek, Paresh Chokshi, Sanat Mohanty, Manojkumar C Ramteke, Gaurav Goel	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** This course will provide thermodynamics perspective to polymer physics. In addition this will focus on dynamics to understand the behaviour of polymers in solution and melt.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Overview of polymer science and engineering with reference to polymer-solution. Chain dimension: variation of chain dimension with concentration, solvency etc., scaling theory. Molecular weight distribution and its effect on properties of polymer solution. Polymer solution thermodynamics: Flory-Huggins equation and its development, phase separation. Polymer in good, theta and poor solution. Colligative properties of polymer solution. Flow

	phenomena in polymeric liquids. Material functions for polymeric liquids. General linear viscoelastic fluid: Rouse dynamics, Zimm dynamics. Hyper branched polymer and its physical properties in various solutions. Dynamics of entangled polymers - polymer melt, chain reptation, tube model, chain length fluctuations. Convective constraint release.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of polymer science & engineering	4
2	Chain dimension; variation of chain dimension with concentration, solvency etc., Scaling theory.	8
3	Molecular weight distribution and its effect on properties of polymer solution.	2
4	Polymer solution thermodynamics, Flory-Huggins eqn. and its development	8
5	Phase separation, polymer in good, theta and poor solution, colligative properties of polymer solution	4
6	Flow phenomena of polymeric liquids, material functions for polymeric liquids, general linear viscoelastic fluid, Rouse dynamics, Zimm dynamics	8
7	Hyper branched polymer and its physical properties in various solution.	2
8	Dynamics of entangled polymers - polymer melt, Chain reptation, Tube model, Chain length fluctuations, Convective constraint release	6
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text books:

P.C. Hiemenz, T.P. Lodge, Polymer Chemistry, 2nd Edition, CRC Press, 2007.

A. Kumar, R. Gupta, Fundamentals of Polymer Engineering, second edition, Marcel Dekker, Inc, NY, 2003.

I. Teraoka Polymer Solutions: An Introduction to Physical Properties, John Wiley & Sons, Inc., 2002

G. R. Strobl, The Physics of Polymers: Concepts for Understanding Their Structures and Behavior, Springer, 1997.

Reference texts:
A. R. Khokhlov, Statistical physics of macromolecules, Springer,1994.

M. Doi, S. F. Edwards The theory of polymer dynamics, Oxford University Press, 1988.

R.B. Bird, R.C. Armstrong, O Hassager, Dynamics of polymeric liquids, Vol-1, second edition, 1987, John, Wiley & Sons, NY, 1987.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	FUNDAMENTALS OF COMPUTATIONAL FLUID DYNAMICS
3.	**L-T-P structure**	2-0-2
4.	**Credits**	3
5.	**Course number**	CLL768
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env/ Proc Modeling

7.	**Pre-requisites** (course no./title)	CLL113, CLL231

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	AML410 (20%) MEL807 (10%)
8.3	Supercedes any existing course	CHL768

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Vivek Buwa, Jayati Sarkar, Ratan Mohan, Shantanu Roy	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)***:**

To introduce the fundamentals of Computational Fluid Dynamics, i.e. the numerical solution of the governing equations of fluid flow; in particular, learning the finite volume method.

14. Course contents *(about 100 words) (Include laboratory/design activities)***:**

Review of basic fluid mechanics and the governing (Navier-Stokes) equations. Techniques for solution of PDEs – finite difference method, finite element method and finite volume method. Finite volume (FV) method in one-dimension. Differencing schemes. Steady and unsteady calculations. Boundary conditions. FV discretization in two and three dimensions. SIMPLE algorithm and flow field calculations, variants of SIMPLE. Turbulence and turbulence modeling: illustrative flow computations. Commercial software - grid generation, flow prediction and post-processing.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of fluid mechanics basics	2
2	Finite difference metohds, Finite element method and intorductory finite volume method	2
3	Finite volume method in 1-dimension	2
4	Differencing schemes	2
5	Unsteady calculations	3
6	Finite volume in 2- and 3-dimensions	2
7	SIMPLE algorithm, flow field calculations and variants of SIMPLE algorithm, Boundary conditions	5
8	Turbulence modeling	3
9	Illustrative computations	4
10	Commercial softwares - case studies	3
11		
12		
COURSE TOTAL *(14 times 'L')*		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to numerical schemes and programming	4
2	Use of commerical softwares - grid generation, boundary conditions, writing of user defined functions	6
3	Solution of 1-d problems	4
4	Solution of 2-d (planar) problems	6
5	Solution of 3-d problems	8
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		28

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:

Patankar, S. V., Numerical Heat Transfer and Fluid Flow, 1st Edition, CRC Press, 1980.

Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2nd Edition, Pearson Education Ltd. 2007

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	FLUENT and CFX (Commercial)
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	Computational Lab with 30 PCs
19.5	Equipment	
19.6	Classroom infrastructure	Projector
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	20%
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	APPLICATIONS OF COMPUTATIONAL FLUID DYNAMICS
3.	**L-T-P structure**	2-0-2
4.	**Credits**	3
5.	**Course number**	CLL769
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env / Proc Modeling

7.	**Pre-requisites** (course no./title)	CLL113, CLL331

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	AML811 (15%) MEL818 (15%) MEL807 (10%)
8.3	Supercedes any existing course	CHL869

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Vivek Buwa, Jayati Sarkar, Ratan Mohan, Shantanu Roy	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** Application of CFD to single and multiphase flows of interest in Chemical processes.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Brief review of CFD for single phase flows. Solution of scalar equations – heat and mass transfer. Application to heat exchanger and stirred tank flows. CFD for multiphase systems – Lagrange-Euler and Euler – Euler approaches. Multiphase models – granular kinetic theory. Reaction modeling. Volume of Fluid (VOF) method for two-phase flow with interfaces. Current status of multiphase flow simulation in various chemical process equipment--bubble column, phase separator, packed bed, fluidized bed, polymerization reactor, cyclones etc.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of single phase CFD	1
2	Heat & Mass transfer calculations and applications	3
3	Lagrange –Euler method	3
4	Euler –Euler method	3
5	Granular kinetic theory and other multiphase models	4
6	Reaction modeling	4
7	VOF method	3
8	Current status w.r.t. CFD for chemical process equipments	7
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Discussion on lecture topics	8
2	CFD modeling of multiphase flows	6
3	Use of commerical softwares and modules for multiphase modeling	4
4	Solution of case studies problems	10
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		28

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:

Ranade, V. V., Computational Flow Modeling for Chemical Reactor Engineering, 1st Edition, Academic Press, 2001.

Ferziger, J. H. and Peric, M., Computational Methods for Fluid Dynamics, 3rd Edition, Springer, 2013

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	FLUENT and CFX (Commercial)
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	Computational Lab with 30 PCs
19.5	Equipment	
19.6	Classroom infrastructure	Projector
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	20%
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	INTRODUCTION TO COMPLEX FLUIDS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL771
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 296: 10% CLL 766: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL731

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Shalini Gupta, Gaurav Goel, Rajesh Khanna, Paresh Chokshi, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

The introductory course aims to provide exposure to various materials that do not obey the behavior of simple fluids. The understanding of the underlying microstructure and the intermolecular interactions in these complex fluids and its relation to the material properties in both static and flow situations will be highlighted. The basic principles for major experimental techniques used in soft matter research will also be discussed.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Overview of complex fluids: forces, energies, responses and timescales in complex fluids. Types of complex fluids: colloidal dispersions, polymers, gels, liquid crystals, polymer crystals, granular materials, biomolecules. Characterization of structure-property relationships in complex fluids.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to types of complex fluids (colloidal and non-colloidal suspensions, liquid crystals, polymers, etc.)	2
2	Microstructures – simple vs complex fluids	2
3	Overview of intra-molecular and inter-molecular forces and energies	4
4	Forces in colloidal system and stability – DLVO theory	5
5	Non-DLVO forces – hydrophobic interaction, Depletion and solvation forces	4
6	Linear response to external stimuli and time scales in complex fluids; relating time scales to microstructures	5
7	Thermodynamic principles of self-assembly in complex fluids	4
8	Experimental techniques in complex fluids – force and structure characterizing techniques	5
9	Polymers and gelation	3
10	Liquid crystals – smectics, nematics, cholesterics	3
11	Surfactants and micelles	3
12	Bio-molecules and bio-fluids	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Books:
Isaraelachvili, J.,Intermolecular and Surface Forces, 3rd Edition, Academic Press, 2011

Jones, R. A. L., Soft Condensed Matter, 1st Edition, Oxford University Press, 2002

Reference Books:
D. F. Evans and H. Wennerstrom, The Colloidal Domain – Where Physics, Chemistry, Biology and Technology meet, 2nd Edition, Wiley-VCH, 1999
Witten, T. A. and Pincus, P. A., Structured Fluids – Polymers, Colloids, Surfactants, Oxford University Press, 2004

R. G. Larson, The Structure & Rheology of Complex Fluids, 1st Edition, Oxford University Press, 1999
Chaikin, P. M. and Lubensky, T. C., Principles of Condensed Matter Physics, Cambridge University Press, 1998

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector, Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	TRANSPORT PHENOMENA IN COMPLEX FLUIDS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL772
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	PTL707 (20%) AML704 (25%) AML814(10%)
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Jayati Sarkar, Paresh Chokshi, Rajesh Khanna, Sudip Pattanayek, Gaurav Goel	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)*: The course presents a multi-scale framework for transport phenomena in complex fluids enabling students to understand macroscopic behavior of complex fluids resulting from a particle level response to external stimuli. The students will also develop understanding of the rheology and interpretation of rheological data on complex fluids. They will have a thorough understanding of momentum, heat and to some extent mass transfer in complex fluids.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Classification of fluids under time dependent, time independent and viscoelastic behaviors. Particle level responses: microstructural origins of deformation. Linear and non-linear viscoelasticity. Transport processes in a

	variety of self-assembling fluids, including surfactant micelles, nano-emulsions, gels, liquid crystalline polymers. Dynamics of rod-like polymers. Static and viscoelastic properties of interfaces. Rheometry and constitutive modeling. Heat transfer in complex fluids: boundary layers. Mixing equipment and its selection.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of conservation laws	2
2	Stresses in complex fluids, Classification of materials based on mechanical response - time independent and time dependent; Understanding viscoelasticity	4
3	Linear and non-linear viscoelasticity	2
4	Rheological chracterization of complex fluids; Influence of microstructure on rheology	3
5	Rheometry; Linear and non-linear rheology	4
6	Constitutive modelling for suspensions, polymers, liquid crystals, gels	7
7	Static and viscoelastic properties of interfaces; Rheological modeling of foams	3
8	Transport properties and flow behavior of multiphase and self-assembling fluids - micellar solutions, suspension of rods, emulsions, liquid crystalline polymers	6
9	Hear transfer in complex fluids	3
10	Boundary layers (heat, mass and momentum)	4
11	Storage, mixing and transportation equipments for complex fluids	4
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Book:

Chhabra, R. P. and Richardson, J. F., Non-Newtonian Flow and Applied Rheology: Engineering Applications, 2nd Edition, Butterworth- Heinemann, 2008

Reference Books:

R. G. Larson, The Structure & Rheology of Complex Fluids, 1st Edition, Oxford University Press, 1999

Findley W. N., Lai, J. S. and Onaran, K., Creep and Relaxation of Non-linear Viscoelastic

Materials Bird, R. B., Armstrong, R. C., Hassager, O.,Dynamics of Polymeric Liquids Volume-1: Fluid Mechanics, 1st Edition, John Wiley and Sons, 1987

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector, Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	THERMODYNAMICS OF COMPLEX FLUIDS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL773
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL121

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL732 - 15% CLL296 - 15%
8.2	Overlap with any UG/PG course of other Dept./Centre	PHL556/Stat. Mech (10%)
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem
11.	**Faculty who will teach the course** Gaurav Goel, Rajesh Khanna, Paresh Chokshi, Sanat Mohanty, Jayati Sarkar, Sudip Pattanayek	
12.	**Will the course require any visiting faculty?**	No
13.	**Course objective** *(about 50 words)*: To provide a thermodynamic framework to understand various phenomena in complex fluids. The equilibrium structure and the origin of various physical behavior of soft matter will be explained with the help of statistical mechanics. The course mainly focuses on phase separation and phase transition in soft matter.	
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)*: Intermolecular forces. Statistical mechanical approach to thermodynamic potentials. Characterization of free energy curves. Entropically driven phase separation, nucleation and spontaneous phase separations in complex fluids. Characterization of structures: Minkowski functionals. Phase separation in	

	confinement. Mean field theories for phase transition, their break-down, introduction to field theory. Thermodynamics of colloidal systems and polymers.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of interaction potentials	2
2	Basic thermodynamics and statistical mechanics – thermodynamic of homogenous fluids, phase space and ensembles, Boltzmann law	5
3	Phases and phase diagram, Binary phase separation – nucleation-growth and spinodal decomposition	5
4	Chracterization of structures - Correlation length, structure factor and Minkowski functionals	4
5	Phase transition – first order and higher order	3
6	Symmetric breaking and Order parameter	2
7	Landau's mean-field theory for phase transition – Ising model, Nematic-isotropic phase transition, Scaling laws for phase separation kinetics, Break-down of mean field theory, introduction to field theory	7
8	Colloidal systems - stability and kinetics of coarsening (Oswald ripening)	4
9	Phase separation under external field and confinement	2
10	Polymers – entropic origin of elasticity, distribution of chain conformation, polymer chains under confinement and at interface	4
11	Thermodynamics of amphilic molecules	4
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Book:

Barrat J. L. & Hansen, J. P., Basic Concepts for Simple and Complex Liquids, Cambrige Univerisity Press, 2003

Reference Books:

Chaikin, P. M. and Lubensky, T. C., Principles of condensed matter physics, Cambridge University Press, 1998

McQuarrie, D. A., Statistical Thermodynamics, Ist Edition, University Science Books, 2000

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector, Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	SIMULATION TECHNIQUES FOR COMPLEX FLUIDS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL774
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL113

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	CYL668 (15%) (based on old curriculum) MEXXX Nanomechanics (10%) (new course)
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem
11.	**Faculty who will teach the course** Gaurav Goel, Rajesh Khanna, Paresh Chokshi, Sanat Mohanty, Jayati Sarkar, Sudip Pattanayek	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

The course is aimed at introducing the advanced simulation methods to describe the behavior of complex fluids under both equilibrium and non-equilibrium conditions. The simulation tools will be applied to improve the understanding of the structure-property relationships in colloidal suspensions, polymers, granular materials, and other classes of complex fluids.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Simulation techniques: Molecular Dynamics, Brownian Dynamics, Monte-

	Carlo, Discrete Element Method and Lattice Boltzmann Simulations. Force fields and interactions. Statistical measures and trajectory analysis to determine structure (e.g., radial distribution function) and properties (e.g., self-diffusivity, shear-dependent viscosity) of complex fluids.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of types of complex fluids – colloids, polymers, surfactants	2
2	Length scales and time scales to describe complex fluids	2
3	Classical mechanics, equations of motion, phase space, Interaction potentials and force fields	5
4	Ensembles, time and ensemble averaging, Error determination	3
5	Equilibrium molecular dynamics simulation, Velocity Verlet integration algorithm	4
6	Correlation functions, Calculation of transport coefficients using MD simulation	5
7	Systematic Coarse-graining of macromolecules	3
8	Monte-Carlo method – Importance sampling, Metropolis algorithm	5
9	Generalized ensemble algorithms- enhanced sampling for MD & MC	2
10	Brownian dynamics method – Brownian motion, Fluctuation-dissipation theorem, Langevin equation, application to colloids and polymers	6
11	Lattice Boltzmann method	5
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text Book:
Allen, M. P. and Tildesley, D. J., Computer Simulation of Liquids, Oxford University Press, 1989
Reference Books:
Frenkel, D. and Smit, B., Understanding Molecular Simulation, 2nd Edition, Academic Press, 2002
D. Succi. The Lattice Boltzmann Equation for Fluid Dynamics and Beyond, Oxford Science Publications, 2001.
M. C. Sukop and D. T. Thorne Jr. Lattice Boltzmann Modelling: An Introduction for

Geoscientists and Engineers. Springer, 2006.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector, Screen
19.4	Laboratory	Computer Lab for in-lecture tutorial
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	POLYMERIZATION PROCESS MODELLING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL775
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL122

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	15% with PTL701, 10% with TTL711, 30% with CYL230
8.3	Supercedes any existing course	CHL392

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Manojkumar Ramteke, Sudip K. Pattanayek, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	NO

13.	**Course objective** *(about 50 words)***:** This course will provide detatiled knowledge of modelling of polymerization reactions, reactor designing and control and polymer processing.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Modeling of step-growth, chain-growth and non-linear polymerization in homogeneous and heterogeneous conditions. Design of CSTR, plug flow, batch and multistep reactors for different polymerization reactions. Control and optimization of polymer reactors, Mathematical modeling and analysis of polymer processing units.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Distinct features of polymers and polymerization reactors, polymer charecterization, classification of mechanism	2
2	Step growth polymerization: equal and unequal reactivity analysis, Concepts of moments, polymerization kinetics and molecular weight distribution (MWD), generating function method	5
3	Chain growth polymerization: kinetics of free radical polymerization and its MWD, gel effect, equilibrium polymerization, copolymerization and its MWD	6
4	Non linear polymerization: branching, pre and postgel regime, gelation theory, long chain branching	4
5	Reactor configuration: homogeneous continuous stirred tank reactors, segregated continious stirred tank reactors, tubular reactors, reactive extrusion, semibatch or multistep reactors, microfluidic reactors	6
6	Heterogeneous polymerization: suspension polymerization, emulsion polymerization, heterogeneous coordination (Ziegler Natta) polymerization	6
7	Reactor operation and control: reactor residence time distribution, Denbigh rules, effect of RTD on MW and composition	5
8	Reactor dynamics and stability, Control of semibatch and continuous polymerization; Statistical process control; Optimization of reactors	4
9	Processing operations:mathematical analysis of extrusion, injection molding and mold designing, polymer nano composite and mathematical analysis of their properties	4
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. N. A. Dotson, R. Galvan, R. L. Laurence, M. Tirrell, Polymerization process modeling, VCH, NY,1996.
2. A. Kumar, R. Gupta, Fundamentals of polymer engineering, second edition,Marcel Dekker, Inc, NY,2003.
3. C McGreavy, Polymer reactor engineering, VCH, NY,1994.
4. S. K. Gupta, A. Kumar, Reaction engineering of step growth polymerization, Plennum, 1987.
5. J. A. Beisenberger, D. H. Sebastian, principles of polymerization engineering, John Wiley & Sons, 1983.
6 G. Odian, Principles of polymerization, John Wiley & Sons, 2002.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	GRANULAR MATERIALS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CHL776
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL331

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL133 (20%)
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Jayati Sarkar, B Pitchumani, Sudip Pattanayek, Vikram Singh	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course aims to provide a framework to model the granular material systems. Various approaches to develop constitutive model based on particle dynamics will be presented. The course also enable students to design granular particles handling devices in chemical and pharmaceutical industries.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Continuum mechanics, statistical physics and rigid body dynamics approaches to understand microscopic and macroscopic behavior of granular materials. Constitutive modeling and rheology of granular materials. Advanced simulation techniques for particle dynamics. Design of flow and handling systems for granular materials.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to granular materials and applications	3
2	Flow properties of granular materials, angle of internal friction, wall friction, flow factor	3
3	Continuum and discrete models	3
4	Forces and conservation laws for continuum models	6
5	Developing constitutive relations for slow and fast flows	5
6	Rheology and plasticity of granular materials, Experimental techniques	6
7	Analysis of simple problems – statics (storage) and granular flows	6
8	Powder flow through silos and hoppers	3
9	Discrete modeling – Event driven simulation	5
10	Flow induced segregation and pattern formation in granular media	2
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text books:

1. Nedderman, R., Statics and Kinematics of Granular Materials, Cambridge, 1992.

2. Rao, K. K. and Nott, P. R., An Introduction to Granular Flow, Cambridge, 2008.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	

19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	COMPLEX FLUIDS TECHNOLOGY
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL777
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Complex Fluids & Materials

7.	**Pre-requisites** (course no./title)	CLL141

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Shalini Gupta, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	Yes

13.	**Course objective** *(about 50 words)***:** To introduce the students to the unique properties of complex fluids and their evolution into various technological applications such as in the fields of consumer goods, chemical industry, medical science, electronics and photovoltaics. Illustrate strategies for large-scale fabrication and surface modification. Expose students to the existing entrepreneurial activities in the complex fluids area and give perspective on the future opportunities.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** An overview of various technologies based on complex fluids and relate them to fundamental principles of thermodynamics and transport phenomena in complex fluids, e.g., how to manipulate micro-structures and their environment to achieve new products with desired properties. Case studies involving assembly, stability and applications of colloids, emulsions, suspensions, polymer melts and granular materials.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction and historical perspectives of technological applications in complex fluids	3
2	Surface modification strategies: thin film deposition, layer-by-layer, molecular self assembly, biofunctionalization	6
3	Fabrication of bioMEMS devices: etching, micromachining, lithographic techniques	6
4	Complex fluids in the consumer goods' space: engineered amphiphiles, emulsions and foams	5
5	Evolution of photovoltaics: Silicon solar cells, polymer-nanocomposite-based devices, ionic gel networks	5
6	Soft matter in medical applications: drug delivery, bio-integrated systems, bioimplants etc.	5
7	Electronic devices: liquid crystal displays	4
8	Challenges faced in granular material industry	4
9	Entrepreneurial activities and future opportunities in the complex fluids area	4
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

No prescribed textbook.
Published journal articles and case studies
Jones, R. A. L., Soft Machines: nanotchnology and life, Oxford University Press, 2004
Steven Vogel, Life's devices: The Physical World of Animal and Plants, Princeton University Press, 1988
Badilescu, S. and Packirisamy, M., BioMEMS: Science and Engineering Perspectives, CRC Press, 2011

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHEMICAL ENGINEERING
2.	**Course Title** *(< 45 characters)*	INTERFACIAL BEHAVIOUR AND TRANSPORT OF BIOMOLECULES
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CHL778
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Biopharma & Fine Chemicals

7.	**Pre-requisites** (course no./title)	CLL110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL730: 15%
8.2	Overlap with any UG/PG course of other Dept./Centre	CYL669: 15% SBL705: 10% SBV885: 5%
8.3	Supercedes any existing course	

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sudip Pattanayek, Gaurav Goel, Shalini Gupta, Sanat Mohanty, Anurag Rathore, Rajesh Khanna	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** This course will focus on the role of interfacial phenomena towards behaviour of biomolecules, interactions of biomolecules with other surfaces and transport of biomolecules and other bionano systems. Fundamentals of these phenomena will be presented along with current trends and in-depth case studies.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Structure of biomacromolecules. Attributes of biomacromolecules: size, charge, hydrophobicity. Characteristics of surface and interfaces: roughness, charge, hydrophobicity. Interactions between biomacromolecules and interfaces: adsorption, specific binding. Aggregation of proteins, modeling of

	the underlying phenomena. Elasticity of adsorbed macro-molecules at interfaces. Equilibrium and transient description of transport of biomolecules through intra- and extracellular space. Governing equations applied to biological systems: conservation laws, flux equations, Fickian and non-Fickian diffusion, diffusion with reaction/ binding, electrochemical transport. Constitutive laws and solution methods applied to biological systems. Adsorption isotherms and transport across membrane.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to biomacromolecules and their utilization	1
2	Various forces of interactions in protein in various state; Protein's structure and characteristics with change in environment such salts, pH and acids.	5
3	Surfaces, Interfaces and their characterization. Change in physical and mechanical behavior of proteins due to change of environment at surface such as charge, hydrophobicity etc	6
4	Adsorption of proteins and polymers at interfaces Effect of diffusion and surface morphology on adsorption.	4
5	Aggregation of proteins: thermodynamics of protein solution	4
6	Interfacial Rheology: Diffusion of proteins towards the interface and elasticity of the interface.	4
7	Mass conservation and constitutive laws: Fick's law and beyond. Steady state and transient diffusion (Separation of variables). Example problems: concentration profile of chemoattracnt in tissue,	5
8	Diffusion with reaction/binding: scaling analysis and solution methods	5
9	Electrochemical Transport: Electroquasistatics constitutive laws and solution methods.	2
10	Electrochemical Transport: Electrical double layers at bio-interfaces, Donnan Equilibrium (partiotioning of charged molecules into charged tissues/gels), Non-equilibirum transport through charged media ((Charged macromolecule moving through charged tissues to charged cell surface; ion trasnport across membrane/tissues)	6
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Philip Nelson, Biological Physics: Energy, Information, Life, W. H. Freeman and

Company, New York, 2004.
2. William M. Deen, Analysis of Transport Phenomena, Oxford University Press, New York, 1998.
3. J. N. Israelachvili, Intermolecular and Surface Forces, third edition, Elsevier, Inc. 2011
4. David L. Nelson, Michael M. Cox, Lehninger PRINCIPLES OF BIOCHEMISTRY, W. H. Freeman; 5th edition, 2008.
5. Arthur W. Adamson , Alice P. Gast, Physical Chemistry of Surfaces, Wiley-Interscience; 6th edition, 1997.
6. Reinhard Miller, Libero Liggieri (Editors) Interfacial Rheology, CRC Press, 2009.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Air-conditioning
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	0
20.2	Open-ended problems	0
20.3	Project-type activity	0
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	HWs and class projects

Date: 28th January 2014 (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHEMICAL ENGINEERING
2.	**Course Title** *(< 45 characters)*	MOLECULAR BIOTECHNOLOGY AND IN VITRO DIAGNOSTICS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL779
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Biopharma & Fine Chemicals

7.	**Pre-requisites** (course no./title)	Nil

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 742: 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sudip Pattanayek, Sanat Mohanty, Shalini Gupta, Anurag Rathore	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

The course will aim to provide a deeper understanding in diagnostic technologies, principles and applications as they are found in modern state-of-art diagnostic systems. A successfully completed course should enable the student to extract the latest findings from the scientific literature relating to the various fields of analytical biotechnology and design a functional diagnostic platform for a particular disease.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Introduction to the cellular structure and function of biomolecules, theory and experimental characterization of commonly-used laboratory techniques in molecular diagnostic protocols. Identification of the important parameters such as sensitivity, specificity, LOD etc. in the design of a quality system for molecular analyses. Highly sensitive reporter technologies and applications, technologies providing highly dense and bioactive solid phases, novel bioaffinity binders, heterogeneous and homogenous assay concepts, and

	multiplexed bioassays.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Structure and function of biomolecules	3
2	Selecting the right target: protein vs. nucleic acids vs. pathogens	3
3	Choice of detection strategy: target and signal amplification	3
4	Existing biomolecular diagnostic technique platforms (optical, electrical, spectroscopy etc.)	12
5		
6	Design parameters for fabricating an efficient biosensor	3
7	Novel bioaffinity binders and bioactive scaffolds	3
8	Highly sensitive reporter technologies and multiplexed bioassays	3
9	Market survey of existing molecular diagnostic devices	3
10	From conceptualization to product development: steps and challenges	5
11	Specific case studies	4
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Text:

Chemical Sensors and Biosensors: Fundamentals and applications by F.-G. Banica, 1st ed. (2012) Wiley

Ref:

Bioconjugate Techniques by G. T. Hermanson, 2nd ed. (2008) Elsevier

Principles of Biochemistry by M.M. Cox and D.L. Nelson, 5th ed. (2011) W.H. Freeman and Company

Published research journal articles

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	None
20.2	Open-ended problems	None
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	None
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	BIOPROCESSING AND BIOSEPARATIONS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL780
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Biopharma and Fine Chem

7.	**Pre-requisites** (course no./title)	CLL271

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	nil
8.2	Overlap with any UG/PG course of other Dept./Centre	BEL703 (15%), BEL820 (10%)
8.3	Supercedes any existing course	CHL777

9.	**Not allowed for** (indicate program names)	None

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Anurag Singh Rathore, Anupam Shukla, Sudip Pattanayek, Shalini Gupta	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

This course is intended for UG and PG students who may be interested in pursuing a career in the pharmaceutical/ biotech industry. The course will present fundamenal concepts and practical applications involving the various bioprocessing steps, in particular separation techniques that are employed in the industry. The focus will be on aspects that are critical for successful manufacturing including but not limited to scale-up, process optimization, Good Manufacturing Practices (GMP) and process validation. Industrial case studies that elucidate the above concepts will be presented.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Introduction to the different unit operations utilized in production of biotech drugs in the areas of upstream processing, harvest, and downstream processing. Introduction to analytical methods used for characterization of biotech products and processes (high performance liquid chromatography,

	mass spectrophotometry, capillary electrophoresis, near infrared spectroscopy,UV spectroscopy). Optimization of biotech processes - unit operation specific optimizaion vs. process optimization, process intensification, statistical data analysis. Scale-up of different unit operations utilized in bioprocessing: procedures, issues that frequently occur and possible solutions. Good Manufacuring Practices (GMP): need, principles and key practical issues. Process validation: basics, planning and implementation. Industrial case studies in bioprocessing. Current topics in bioprocessing and bioseparations: Quality by Design and Process Analyical Technology.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to bioprocessing unit operations	10
2	Analytical methods for process and product characterization	3
3	Optimization of biotech processes	6
4	Scale-up of bioprocessing unit operations	6
5	Good Manufacturing Practices (GMP)	3
6	Process Validation	4
7	Industrial case studies in bioprocessing unit operations	4
8	Current topics in bioprocessing and bioseparations	6
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

Not applicable

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Not applicable	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. P. A. Belter, E. L. Cussler, W. –S. Hu. Bioseparations: Downstream Processing in Biotechnology, Wiley Interscience, 1988.
2. A. A. Shukla, M. R. Etzel and S. Gadam. Process Scale Bioseparations for the Biopharmaceutical Industry, Taylor and Francis, Boca Raton,FL, 2007.
3. M. R. Ladisch, Bioseparations Engineering, Wiley Interscience, New York, 2001.
4. A.S. Rathore, Elements of Biopharmaceutical Production, Advanstar Communications, New York, 2007.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Microsoft office
19.2	Hardware	None

19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Laptop projection system
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	10%
20.2	Open-ended problems	No
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	No
20.5	Others (please specify)	None

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS OPERATIONS SCHEDULING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL781
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Process Eng, Mod & Opt

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	SML745 (15%), MEL421(10%), MEL425(10%), CSL854(10%)
8.3	Supercedes any existing course	CHL771

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Munawar Shaik, Manojkumar Ramteke	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course covers different mathematical programming approaches for modeling and solution of process scheduling problems for chemical process operations
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to enterprise-wide supply-chain optimization. Decision making for planning and scheduling. Classification of scheduling formulations: various storage policies, network representations, time representations. Short-term scheduling of batch processes: discrete-time and continuous-time based models. Cyclic and short-term scheduling of continuous processes. Solution of resulting models with industrial applications using GAMS modeling language.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to enterprise-wide & supply chain optimization	2
2	Hierarchy of decision making: planning & scheduling of process operations	2
3	Classification of scheduling problems: network representation (STN vs. RTN), time representation (discrete & continuous time), storage policies, different objectives.	3
4	Introduction to GAMS modeling language	3
5	Short-term scheduling of batch processes: Discrete time models based on STN & RTN representation, slot based models, global event based models, unit-specific event based models.	10
6	Short-term scheduling of continuous processes: Discrete time models based on STN & RTN representation, slot based models, global event based models, unit-specific event based models.	10
7	Cyclic scheduling of continuous processes: slot based models	4
8	Different industrial applications	8
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Korovessi, E., Linninger, A. A., Batch Processes, Taylor & Francis, 2006.

Mendez, C. A., Cerda, J., Grossmann, I. E., Harjunkoski, I., and Fahl, M., State-of-the-art Review of Optimization Methods for Short-Term Scheduling of Batch Processes, Comp. Chem. Engg. 30, 2006, pp 913 - 946.

Shaik, M. A., Janak, S. L., and Floudas, C. A., Continuous-time Models for Short-Term Scheduling of Multipurpose Batch Plants, Ind. Eng. Chem. Res., 45, 2006, pp 6190-6209.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	MATLAB/GAMS
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD projector, bio-metric device for attendance
19.4	Laboratory	Process Simulation Lab (PSL) with access to desktop PCs and MATLAB/GAMS
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	10 % (in terms of Assignments)
20.3	Project-type activity	20 % (solving industrial examples using GAMS)
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS OPTIMIZATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL782
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Proc Eng, Mod & Opt

7.	**Pre-requisites** (course no./title)	CLL222, CLL352

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	MAL210 (60%), AML872(60%) MAL704(60%), MAL726(60%), MEL875(20%), SML740(50%) CEL737(60%), CEL886(30%)
8.3	Supercedes any existing course	CHL774

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem
11.	**Faculty who will teach the course** Munawar Shaik, Ramteke MK, Ratan Mohan, Anupam Shukla, AS Rathore	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course provides basic knowledge of analytical and numerical techniques in solving chemical engineering optimization problems using traditional or deterministic optimization techniques including gradient based and direct search based methods.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to optimization and applications; classification (LP, NLP, MILP,

	MINLP), convexity, unimodal vs multimodal. Single variable and multivariable unconstrained optimization methods. Linear programming, branch and bound method for MILP. Constrained optimization: nonlinear programming. Necessary and sufficient conditions of optimality. Quadratic programming. Case studies from chemical industry.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to optimization & applications in process industry; Classification of different optimization models (LP, NLP, MILP, MINLP); Problem formulation; Convexity, Unimodal vs Multimodal analysis; Introduction to professional software (such as GAMS)	5
2	Single variable optimization: analytical & numerical methods	4
3	Unconstrained multivariable optimization: direct search and gradient based methods	8
4	Linear Programming, Duality theory, Sensitivity analysis	7
5	Branch and bound method for MILP & applications	4
6	Transportation algorithm	2
7	Constrained optimization: NLP, necessary and sufficient conditions	5
8	Quadratic programming	2
9	Different case studies from chemical industry	5
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Edgar, T.F., Himmelblau, D.M., Lasdon, L.S. Optimization of Chemical Processes, 2nd ed., McGraw-Hill, 2001

Rao, S.S. Engineering Optimization: Theory and Practice, John-Wiley, 2009

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	MATLAB/GAMS
19.2	Hardware	

19.3	Teaching aides (videos, etc.)	LCD projector, bio-metric device for attendance
19.4	Laboratory	Process Simulation Lab (PSL) with access to desktop PCs and MATLAB/GAMS
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	10 % (in terms of assignments)
20.3	Project-type activity	20 % (solving industrial examples)
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	Membrane Science and Engineering
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL793
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. Adv standing for E & E/PEMO/BPFC

7.	**Pre-requisites** (course no./title)	CLL110, CLL252

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	CHL793

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** S. K. Gupta, Anupam Shukla, Sanat Mohanty	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To introduce the field of Membrane Science and Engineering to chemical engineering students
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to membrane separation processes, their classification, and applications. General transport theories including theory of irreversible thermodynamics for multicomponent systems. Membrane preparation techniques. Design and analysis and industrial application of various membrane processes such as reverse osmosis, ultra filtration, electrodialysis, dialysis, liquid membrane separation, gas permeation and pervaporation.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Membrane separation processes and their classification	3
2	Membrane structure and membrane preparation techniques	6
3	Membrane mass transport theories	6
4	Reverse osmosis (RO): RO membranes, transport models, design and analysis	6
5	Ultrafitration and microfiltration	4
6.	Gas separation using membranes	6
7.	Separation using liquid membranes	5
8.	Electrodialysis and dialysis	3
9.	Pervaporation	3
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Ho, WS Winston, and Kamalesh K. Sirkar, eds. *Membrane handbook*. Springer, 1992.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	NA
19.2	Hardware	NA
19.3	Teaching aides (videos, etc.)	NA
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Regular classroom infrastructure such as projector
19.7	Site visits	NA

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	70%
20.2	Open-ended problems	10%
20.3	Project-type activity	20%
20.4	Open-ended laboratory work	-
20.5	Others (please specify)	-

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	CHE
2.	**Course Title** *(< 45 characters)*	PETROLEUM REFINERY ENGINEERING
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL794
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Energy & Env

7.	**Pre-requisites** (course no./title)	CLL222, CLL352

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	10% - CLL 727 10% - CLL 743 10% - CLL 371 10% - CLL 735
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	CHL 794

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	Either semester, once a year

11.	**Faculty who will teach the course:** K. K. Pant, U. Sreedevi, S. Roy	
12.	**Will the course require any visiting faculty?**	Some special lectures (2-3) may be given by the experts form petroleum refineries

13.	**Course objective** *(about 50 words)***:** The main objective of this course is to provide students a thorough understanding in the area of petroleum oil processing and new trends in refinery operations. The course will cover topics relevant to the oil refining

	sector, such as characterization of crudes, their geographical distribution, and processes like catalytic cracking, catalytic reforming, delayed coking, hydrogenation and hydrocracking. Process like isomerization, alkylation and fuel up-gradation would be discussed. New trends in petroleum refinery operations will be discussed.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Composition of petroleum, laboratory tests, refinery products, characterization of crude oil. Design of crude oil distillation column. Catalytic cracking, catalytic reforming, delayed coking, furnace design, hydrogenation and hydrocracking, isomerization, alkylation and polymerization. Lube oil manufacturing. Energy conservation in petroleum refineries. New trends in petroleum refinery operations. Pyrolysis of naphtha and light hydrocarbons.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction: Composition of petroleum, laboratory tests, refinery products	5
2	Design of crude oil distillation column	8
3	Catalytic cracking	4
4	Catalytic reforming	4
5	Delayed coking	2
6	Furnace design	4
7	Hydrogenation and Hydrocracking	3
8	Isomerization, Alkylation and Polymerization	2
9	Lube oil manufacturing	3
10	Energy conservation in petroleum refineries	3
11	New Trends in petroleum refinery operations	2
12	Pyrolysis of Naphtha and light hydrocarbons	2
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

Not required if two hour lab work allotted

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Students may be asked to devote two hours in a week in the analysis and testing of petroleum products, Application of refinery layout and analysis software etc. (No additional laboratory hours required)	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Nelson, Wilbur L. "Petroleum refining engineering." *McGraw-Hill, New York* (1958): 111.

Watkins, Robert N. *Petroleum refinery distillation*. Houston, TX,: Gulf Publishing Company, Book Division, 1979.

Sarkar, G. N. "Advanced Petroleum Refining.", Khanna Publishers (2000).

Meyers, Robert Allen, and Robert Allen Meyers. *Handbook of petroleum refining processes*. New York: McGraw-Hill, 2004.

Speight, James G., and Baki Ozum, eds. *Petroleum refining processes*. CRC Press, 2001.

Edmister, Wc, and B. I. Lee. "Applied Hydrocarbon Thermodynamics, Gulf Pub." *Co., Houston* (1961).

Daubert, T. E., and R. P. Danner. "API technical data book-petroleum refining." *American Petroleum Institute (API), Washington DC* (1997).

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Application of Petroplan for optimizing process
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	Projector
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	60%
20.2	Open-ended problems	15%
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	15%
20.5	Others (please specify)	-

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	FINE CHEMICALS TECHNOLOGY
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL786
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing Biopharm. and Fine Chemicals

7.	**Pre-requisites** (course no./title)	CLL 222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	nil
8.3	Supercedes any existing course	nil

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Anurag Rathore, H. M. Chawla (Chemistry), Shantanu Roy, M. Ali Haider, Rajesh Khanna, Other faculty from Chemical Engineering and Chemistry	
12.	**Will the course require any visiting faculty?**	no

13.	**Course objective** *(about 50 words)***:** Objective of the course is to familiarize students with the fine chemicals, high value chemicals and pharmaceutical industry. The course will cover aspects of synthesis, reactor technology and scale-up, specialized separation techniques and novel interventions in the fine chemicals industry.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to fine and high value chemicals. Historical perspectives. Synthesis methods from chemical (petrochemicals and natural products) and biotechnology routes (enzymatic methods, fermentation and cell culture technology). Extraction of fine chemicals from microorganisms, plant sources and animal sources. Chromatographic separations. Reactor technology for fine chemicals. Scale-up and scale-out of reactors. Microreactor technology and process intensification. Novel high value chemicals for adhesives, electronic materials, food additives, specialty polymers, flavours and fragrances.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of fine chemicals technology, distinguishing features, historical perspectives, examples	2
2	Classification of fine chemical industry: based on sources: chemical (petrochemicals and natural products), and biotechnology routes (enzymatic methods, fermentation and cell culture technology); Extraction of fine chemicals from natural sources	4
3	Catalysis in fine chemicals: homogeneous and heterogeneous catalysis, phase transfer catalysis; Improvement of selectivity using micromixing, emulsions, zeolites, photochemistry, sonication etc.	8
4	Basic reactor modeling, microreactors and process intensification	8
5	Enrichment and separation methods: extraction, phase separation, centrifugation, filtration, crystallization, chromatography,	4
6	Scale up of unit operations: scaling principles for key unit operations, scale related issues	4
7	Process design and optimization - integration of different unit operations, continuous processing, process targets and creation of an optimized process that achieves those targets	4
8	Manufacturing aspects - utilities, safety, good manufacturing practices, raw material handling, equipment and facility related issues	4
9	Case studies - Illustration of process creation and optimization for two fine chemical products	4
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Cybulski, A., Sharma, M. M., Sheldon, R. A., & Moulijn, J. A. (2001). Fine Chemicals Manufacture: Technology and Engineering. Gulf Professional Publishing.

Sheldon, R. A., & van Bekkum, H. (Eds.). (2008). Fine chemicals through heterogeneous catalysis. John Wiley & Sons.
Bioseparations Engineering, Michael R. Ladisch, (2001), John Wiley.
Biotechnology, Eds. H. -J. Rehm and G. Reed, (1993) VCH (Wiley).

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	CHEMICAL PRODUCT DEVELOPMENT AND COMMERCIALIZATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL792
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M. Tech. PE for adv standing in Biopharma & Fine Chem

7.	**Pre-requisites** (course no./title)	CLL 110

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 791: 20%
8.2	Overlap with any UG/PG course of other Dept./Centre	10% with MAL727, 10% with MAL 719, 10% with SML802
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	
10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem
11.	**Faculty who will teach the course** Anurag S. Rathore, Sanat Mohanty, Shantanu Roy, Divesh Bhatia	
12.	**Will the course require any visiting faculty?**	No

13. Course objective *(about 50 words)*:

This course is intended to present some key topics for UG and PG students that are related to how product development and commercialization occur in the chemical industry. The course will present fundamenal concepts as well as practical applications that have been selected to further elucidate these concepts. Industrial case studies that illustrate application of these concepts will also be presented. Lectures from appropriate industrial experts will be arranged to present "real life" applications and examples.

14. Course contents *(about 100 words) (Include laboratory/design activities)*:

Design of experiments - factors, responses, main effects, interactions, different kinds of designs - screening vs. high resolution. Statistical data analysis - applied probability, sampling, estimation, hypothesis testing, linear regression, analysis of variance, types of data plots. Technology transfer of processes -

	need of technology transfer, key attributes, key challenges, solutions to various issues. Intellectual property management - intellectual property rights, IPR laws, patents, trademarks, designs, copyrights, licensing, IP management. Commercialization of technologies - invention, product development, technical and market feasibility analysis, intellectual property acquisition.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Design of experiments - introduction	2
2	Different experimental designs - resolution and objective	5
3	DOE case studies	3
4	Statistical data analysis - introduction	2
5	Data sampling and hypothesis generation	4
6	Linear regression and ANOVA	4
7	Data visualizaiton	3
8	Technology transfer - concepts	4
9	Tehnology transfer - case studies	3
10	Intellectual property management	6
11	Commercialization of technologies	6
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

Tutorials, as needed, will be taken as part of class.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Not applicable	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Montgomery, D. C., "Design and Analysis of Experiments", John Wiley & Sons, 2009
Buzzi-Ferraris, G. and Manenti, F., "Interpolation and Regression Models for the Chemical Engineer", Wiley VCH, 2010
Teaching material will be provided for the remaining topics.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Microsoft office
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	None
19.4	Laboratory	None

19.5	Equipment	None
19.6	Classroom infrastructure	Laptop projection system
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	5%
20.2	Open-ended problems	No
20.3	Project-type activity	10%
20.4	Open-ended laboratory work	No
20.5	Others (please specify)	None

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	CHEMICAL PRODUCT AND PROCESS INTEGRATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL791
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Stand for Biopharma / Proc Engg & Mod

7.	**Pre-requisites** (course no./title)	CLL 371

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	CLL 792: 20%
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Sanat Mohanty, Shantanu Roy, Divesh Bhatia	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course will be an opportunity for students to learn about how principles of chemical engineering are used in development of products and processes in the industry.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** The course will be a structured project based course with initial exposure to industrial processes of understanding Voice of Customers, identifying design specifications, scoping the technology and product landscape and deciding on the technology strategy. Technical and economic feasibility analysis as well as scale-up and manufacturing concerns will also be discussed. Each group will identify a specific product or process of interest and work through these considerations as well as integrate thermodynamics, transport principles, fluid mechanics and reactor design understanding to design the product or process chosen.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction and historical perspective of product design, processes vs. products, need for product design, product design procedure	4
2	Innovation cycle, assessment of customer needs, developing product specifciations, prototyping	4
3	Product selection based on thermodynamics, transport principles and kinetics. Feasibility Analysis of Product / Process.	4
4	Processes for manufacture of products, scale-up/scale-down, and economics; (on-web / coatings, vessel based scale-up, integration)	6
5	Commodity products: Process engineering, reactors and separatores	4
6	Devices (electronics, automotive, diagnostics): process engineering	4
7	Microstructures and synthetic materials	3
8	Quality	3
9	Economics and Intellectual property	4
10	Case studies	6
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Cussler, E. L., Moggridge, G. D., & Moggridge, G. D. (2001). Chemical Product Design. Cambridge: Cambridge University Press.

Ulrich, K. T. (2003). Product design and development. Tata McGraw-Hill Education.

Turton, R., Bailie, R. C., Whiting, W. B., & Shaeiwitz, J. A. (2008). Analysis, synthesis and design of chemical processes. Pearson Education.

Seider, W. D., Seader, J. D., & Lewin, D. R. (2009). PRODUCT & PROCESS DESIGN PRINCIPLES: SYNTHESIS, ANALYSIS AND EVALUATION, (With CD). Wiley. com.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	ADVANCED PROCESS CONTROL
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL783
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Proc. Eng., Mod. & Opt.

7.	**Pre-requisites** (course no./title)	CLL261

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	Nil
8.2	Overlap with any UG/PG course of other Dept./Centre	EEL325: 50% EEL723: 30% BEL415: 40%
8.3	Supercedes any existing course	CHL710

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Munawar Shaik, Ramteke MK, Shantanu Roy, Anurag Rathore	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To introduce advanced concepts in process control (beyond the classical PID controllers & transfer function approaches). Enabling multivariable control, system identification, and digital control with emphasis on computer-aided case studies from chemical engineering
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** State-space models. Distributed parameter models. Feedforward control. Ratio control. Dead-time compensation. Relative gain array. Z-transforms and digital control. Internal model control. State estimation and process identification. Adaptive control. Non-linear control. Model-based control structures. Synthesis of control systems with case studies. Intelligent control, model predictive control.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of classical feedback control & transfer function approaches	2
2	State-space models	2
3	Distributed parameter models	2
4	Introduction to advanced process control; feedforward control, ratio control, dead time compensation	4
5	Multivariable control & relative gain array	4
6	Internal model control	3
7	Z-transforms & introduction to digital control	5
8	State estimation & system identification	5
9	Adaptive control; nonlinear control, intelligent control	3
10	Model predictive control	4
11	Synthesis of control structures, case studies & use of MATLAB control system toolbox & SIMULINK	8
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Seborg, D.E., Edgar, T.F., Mellichamp, D.A. "Process Dynamics and Control", 2nd ed., John Wiley (2003).

Stephanopoulos, G. "Chemical Process Control: An Introduction to Theory and Practice", Pearson Education (1984).

Coughanowr, D. R., LeBlanc, S.E. "Process Systems Analysis and Control", 3rd ed., McGrawHill (2008)

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	MATLAB/labview
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD projector, bio-metric device for attendance
19.4	Laboratory	Process Simulation Lab (PSL) with access to desktop PCs and MATLAB
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	10 % (in terms of assignments)
20.3	Project-type activity	20 % (solving industrial examples)
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	PROCESS MODELING & SIMULATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL784
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for adv standing in Proc Eng, Mod & Opt

7.	**Pre-requisites** (course no./title)	CLL222; CLL352

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	Nil
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	CHL712; CHL 762

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All Chemical Engineering faculty	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** To emphasize mathematical modeling of physical systems and introduce flowsheet simulation as a tool for process analysis. Enabling systems approach in modeling of a process with interaction among several unit processes and unit operations and provide insight into development of simulators to do steady-state and dynamic simulation.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to modeling, physical and mathematical models, modeling individual units vs. process. Role of simulation and simulators. Sequential and modular approaches to flowsheet simulation: equation solving approach. Decomposition of networks: tearing algorithms, convergence promotion. Specific purpose simulation. Dynamic simulation. Case studies using commercial or open source simulation packages.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to mathematical modeling: lumped vs distributed parameter systems, process synthesis, design, simulation & analysis	2
2	Modeling of various chemical systems covering heat, mass, momentum transfer, and reactions.	8
3	Sequential and simultaneous modular approaches for flowsheet simulation	4
4	Equation solving approaches: Partitioning, Decomposition, Disjointing, PTM, SWS-, Steward-, and Rudd-Algorithms, Sparcity, Direct Methods, Pivoting, Iterative methods, BTF, BBTF, Block Back Substitution, BTS.	6
5	Decomposition of networks: Tearing algorithms, digraph, MCN, signal flow graph, B&M algorithm, BTA, K&S algorithm, M&H-1 & -2 algorithms, and related problems.	7
6	Convergence Promotion	1
7	Sources and data banks of physical & thermodynamic properties, Modularity & Routing	2
8	Specific purpose simulation: case studies & use of professional simulation packages	6
9	Dynamic simulation: case studies & use of simulation packages	6
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Jana, A.K. Chemical Process Modeling & Computer Simulation, 2nd ed., PHI Learning, 2011
Babu, B.V. Process Plant Simulation, Oxford University Press, India, 2004.
Luyben, W.L. Process Modeling, Simulation & Control for Chemical Engineers, 2nd ed., Mc Graw Hill, 1990

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Aspenplus/Promax
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD projector, bio-metric device for attendance
19.4	Laboratory	Process Simulation Lab (PSL) with access to desktop PCs and simulators
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	10 % (in terms of assignments)
20.3	Project-type activity	20 % (solving industrial examples)
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	EVOLUTIONARY OPTIMIZATION
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL785
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for adv standing in Proc Eng, Mod & Opt

7.	**Pre-requisites** (course no./title)	CLL222

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	Nil
8.2	Overlap with any UG/PG course of other Dept./Centre	EEL487: 20% EEL706: 70% EEL878: 40%
8.3	Supercedes any existing course	Nil

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Manojkumar Ramteke, Munawar Shaik	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course provides basic knowledge of new methods in computational intelligence or soft computing inspired by different phenomena in nature (such as annealing, genetics) leading to non-traditional, evolutionary, and stochastic optimization techniques. The emphasis is on solution of large-scale industrial case studies drawn from different chemical industries.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Traditional vs. nontraditional optimization techniques. Population based search algorithms. Evolutionary strategies. Simulated annealing. Genetic algorithms. Differential evolution. Different strategies of differential evolution. Memetic algorithms. Scatter, Tabu search. Ant-colony optimization. Particle swarm optimization. Self-organizing migrating algorithm. Neural networks.

	Quantum computing. DNA computing. Multi-objective optimization. Industrial applications.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction;Traditional Vs Nontraditional Optimization Techniques; Local Vs Global Optimum; Overview of evolutionary methods	2
2	Simulated Annealing	2
3	Introduction to population based direct search methods	1
4	Genetic Algorithms	2
5	Differential Evolution and its variants	3
6	Memetic Algorithms	3
7	Tabu Search and Scatter Search	4
8	Particle Swarm Optimization; Ant Colony Optimization	4
9	Self-organizing migrating algorithms; Neural Networks	4
10	Quantum & DNA Computing	4
11	Multiobjective optimization	5
12	Industrial case studies	8
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Onwubolu, G. C., Babu, B. V., New Optimization Techniques in Engineering, Springer-Verlag Publication, Germany, 2003.

Kalyanmoy Deb, Multi-Objective Optimization Using Evolutionary Algorithms, John Wiley & Sons, 2001.

David Corne, Marco dorigo, Fred Glover, New Ideas in Optimization, McGraw-Hill, 1999

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	MATLAB
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD projector, bio-metric device for attendance
19.4	Laboratory	Process Simulation Lab (PSL) with access to desktop PCs and MATLAB
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	10 % (in terms of assignments)
20.3	Project-type activity	20 % (solving industrial examples)
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	SELECTED TOPICS IN CHEMICAL ENGINEERING - I
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL798
6.	**Status** (*category* for *program*)	DE/pe for B. Tech./DD/M.Tech.

7.	**Pre-requisites** (course no./title)	To be declared by instructor

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL740

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All faculty of Chemical Engineering Department, including Visiting Faculty.	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course is intended to cover specific topics within the general Chemical Engineering domain, as determined by the instructor(s) and declared to students before or at the time of registration.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** As per declaration of instructor(s).

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	To be declared at time of floating of course.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be declared at time of floating of course.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	SELECTED TOPICS IN CHEMICAL ENGINEERING - II
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL799
6.	**Status** (*category* for *program*)	DE/pe for B. Tech./DD/M.Tech.

7.	**Pre-requisites** (course no./title)	To be declared by instructor

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	CHL740

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All faculty of Chemical Engineering Department, including Visiting Faculty.	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course is intended to cover specific topics within the general Chemical Engineering domain, as determined by the instructor(s) and declared to students before or at the time of registration.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** As per declaration of instructor(s).

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	To be declared at time of floating of course.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be declared at time of floating of course.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	CURRENT TOPICS IN CHEMICAL ENGINEERING
3.	**L-T-P structure**	1-0-0
4.	**Credits**	1
5.	**Course number**	CLV796
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M.Tech.

7.	**Pre-requisites** (course no./title)	To be declared by instructor

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All faculty of Chemical Engineering Department, including Visiting Faculty.	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course is intended to provide very focussed and modular coverage of a topic of current interest in Chemical Engineering. The topic to be covered will depend on the instructor, but will relate to advanced research level material. To be taken by students specifically interested in that area of research.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** As per declaration of instructor(s).

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	To be declared at time of floating of course.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be declared at time of floating of course.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	RECENT ADVANCES IN CHEMICAL ENGINEERING
3.	**L-T-P structure**	2-0-0
4.	**Credits**	1
5.	**Course number**	CLV797
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/M.Tech.

7.	**Pre-requisites** (course no./title)	To be declared by instructor

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	Nil

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** All faculty of Chemical Engineering Department, including Visiting Faculty.	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** The course is intended to provide very focussed and modular coverage on multiple topics of current interest in Chemical Engineering. The topics to be covered will depend on the instructor, but will relate to advanced research level material. To be taken by students specifically interested in the corresponding areas of research.
14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** As per declaration of instructor(s).

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	To be declared at time of floating of course.	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

N/A

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	N/A	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be declared at time of floating of course.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	None
19.2	Hardware	None
19.3	Teaching aides (videos, etc.)	Projector and screen
19.4	Laboratory	None
19.5	Equipment	None
19.6	Classroom infrastructure	None
19.7	Site visits	None

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Chemical Engineering
2.	**Course Title** *(< 45 characters)*	EXPERIMENTAL CHARACTERIZATION OF MULTIPHASE REACTORS
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	CLL833
6.	**Status** (*category* for *program*)	DE/PE for B. Tech./DD/ M. Tech. PE for Adv Standing for Energy & Env.

7.	**Pre-requisites** (course no./title)	CLL733

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supercedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1st sem ☐2nd sem ☒Either sem

11.	**Faculty who will teach the course** Vivek Buwa, Shantanu Roy, K. K. Pant, U. Sreedevi, Divesh Bhatia, Ratan Mohan	
12.	**Will the course require any visiting faculty?**	No

13.	**Course objective** *(about 50 words)***:** This course intends to introduce and expose students to modern characterization techniques that are useful to reaction engineering R&D and plant operation. The course will expose to students to analytical techniques, catalyst characterization techniques, and flow characterization techniques. The course is intended to be 2-0-2, wherein the lectures will explain the theory and context of the techniques, and the laboratory sessions will be for demonstration and hands-on experiments.

14.	**Course contents** *(about 100 words) (Include laboratory/design activities)***:** Analytical techniques: Introduction to various analytical techniques e.g. GC, HPLC, UV Spectroscopy, TGA /DTA, FTIR, MS, GCMS, NMR, TOC, CHONS. Principle of measurement techniques, instruments and procedures. Calibration, data processing, analysis and interpretation. Few working demonstrations.

	Catalysis characterization: Introduction to various catalysis preparations and characterization techniques, e.g. porosity, surface area, pore volume and pore size distribution (using BET), XRD, SEM, TEM, NMR, AFM, ESCA. Mossabauer spectroscopy, chemisorption, TPD/TPR. Flow characterization: Introduction to single/multiphase flows/reactors, role of hydrodynamics. Process parameters of interest, length and time scales, instantaneous vs. time averaged characteristics. Introduction to various advanced intrusive and non-instrusive flow measurement technqiues, e.g. mininaturized pressure probes, gamma-ray tomography, densitometry, PIV, RPT, ECT/ERT, high speed photography, tracers and radiotracers.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Experimental charecterization in Chemical Reaction Engineering: Introduction, Data Analysis and presentation, Data reporting methods	4
2	Basics of catalyst preparation and characterization: determination of surface area and pore volume, pore size distribution of the catalyst	2
3	Understanding the surface morphologies of the catalyst by XRD, SEM AND TEM (+ demo)	4
4	Chemical analysis of catalyst by TPR, TPD, FTIR	3
5	Understanding the principle of catalyst characterisation by NMR, AFM, ESCA, Mossabauer spectroscopy, Chemisorption, TPD/TPR, AFM. Understanding the principle of measurement techniques, measurements.	3
6		
7	Flow characterization in multiphase reactors: Introduction, Intrusive vs. Non-intrusive measurements	2
8	Pressure probes and voidage probes, data analysis (+demo)	4
9	Tomography methods: Introduction, gamma-ray tomography (+demo), electrical capacitance/resistance tomography (+demo)	4
10	Velocity measurement methods: PIV (+demo) and RPT (+demo)	4
11	Tracer measurements (+demo) and Radiotracing	2
12	Measurement of mass and heat transfer coefficients (+demo)	3
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Demonstrations and some hands-on work as part of the course	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL *(14 times 'P')*		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Chaouki, J., Larachi, F., & Dudukovic, M. P. (Eds.). (1997). Non-invasive monitoring of multiphase flows. Elsevier.

Manuals, animations and study materials prepared by the instructors.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Microphone, Projector and Screen
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date: (Signature of the Head of the Department)