M Tech – Green Technology - Revised syllabus - 2015

Semester I

No.		Subjects/Course with code No.	Hours/ week (L + T)	Credits
1	Core I	GTT 2001 Fundamentals of Green Chemistry and Technology	2+1	**3**
2	Core II	GTT 2002 Catalysis I	2+1	**3**
3	Core III	GTT 2003 Chemical Reaction Engineering	2+1	**3**
4	Elective I	GTT 210X	2+1	**3**
5	Elective II	GTT 210X	2+1	**3**
6	Project I	GTP 2001 Critical Review - Research Publication	2+1	**3**
7	Project II	GTP 2002 Seminar	2+1	**3**
		TOTAL	14 + 7	**21**

Semester II

No.		Subjects	Hours/week (L + T)	Credits
1	Core IV	GTT 2004 Advances in Separation Processes	2+1	**3**
2	Core V	GTT 2005 Catalysis II	2+1	**3**
3	Core VI	GTT2006Environmental Engineering	2+1	**3**
4	Core VII	GTT 2007 Safety and hazard analysis	2+1	**3**
5	Elective III	GTT 210X	2+1	**3**
6	Elective IV	GTT 210X	2+1	**3**
7	Project III	GTP 2003 Literature review on the proposed research topic	2+1	**3**
		TOTAL	14 + 7	**21**

Additional electives

1.Fuel Engineering

2. Bio degradable materials for biomedical applications

3.Fuel Cell Technology and Sustainability

4. Membrane Technology for pollution abatement

5. Sonochemistry for sustainable development

6. Colloid and interfacial phenomena

7. Renewable Energy Sources

8. Organic Chemistry

10. Bio chemistry

11. Laboratory course

II. **Inter conversion of elective/ core course**

A. (i) Environmental Engineering (ii) Industrial Safety and Hazard Analysis – are changed to core courses

B. (i) Green Biotechnology and (ii) Nano technology are changed to elective courses

	Course Code: **GTT2001**	**Course Title:** **Fundamentals of Green Chemistry and Technology**	**Credits = 3**		
			L	**T**	**P**
		Total contact hours: 45	**30**	**15**	
List of Prerequisite Courses					

	Bachelors in Engineering, Technology or Pharmacy, MSc (with 2 years industrial experience)	
List of Courses where this course will be prerequisite		
This is the fundamental course for the entire programme		
Description of relevance of this course in M Tech (GT) programme		
To bring in the importance and the underlying principles of green and sustainable technology		
	Course Contents (Topics and subtopics)	**hours**
1	The twelve Principles of Green Chemistry and green engineering with examples	3
2	Green chemistry metrics- atom economy, E factor, reaction mass efficiency and other green chemistry metrics, application of green metrics analysis to synthetic plans	3
3	Waste – sources of waste, different types of waste, chemical, physical and biochemical methods of waste minimization and recyling	3
	Pollution – types, causes, effects and abatement	4
4	Environmentally benign processes- alternate solvents- supercritical solvents, ionic liquids, water as a reaction medium, energy efficient design of processes- photo, electro and sono chmemical methods, microwave assisted reactions	4
5	Green reagents and catalysis in green synthesis	3
6	Designing green processes- safe design, process intensification , in process monitoring	3
7	Safe product and process design – Design for degradation, Real-time Analysis for pollution prevention, inherently safer chemistry for accident prevention	4
8	Industrial case studies	3
List of Text Books/ Reference Books		
1	Green Chemistry – An introductory text - M. Lancaster, RSC	
2	Green chemistry metrics - Alexi Lapkin and david Constable (Eds) , Wiley publications	
3	Environmental chemistry _ Stanley E Manahan, Lewis Publishers	

Course Outcomes

CO1 – To understand the principles of green chemistry and engineering

CO2- To design processes that are benign and environmentally viable

CO3- To design processes and products that are safe and hazard free

CO4 - To learn to modify processes and products to make them green safe and economically acceptable.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	S	M	S	S	S	S	S	N	S	N	S	S
CO2	S	S	S	M	S	S	S	S	S	N	S	M	S	S
CO3	S	S	S	S	S	S	S	S	S	N	S	M	S	S
CO4	M	M	S	S	S	S	S	S	S	N	S	M	S	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code: GTT2002	Catalysis – I Heterogeneous catalysis and photocatalysis	Credits = 3		
			L	T	P
		Total contact hours: 45	30	15	60

List of Prerequisite Courses

Bachelors in Engineering, Technology or Pharmacy, MSc (with 2 years industrial experience)

List of Courses where this course will be prerequisite

Description of relevance of this course in the M Tech (Green Technology) programme

Catalysis plays a major role in green technology and green chemistry. This course will give an understanding about the synthesis , characterization and application of surface and photo catalysis
In making processes green and energy efficient.

	Course Contents (Topics and subtopics)	Hours
1	Types of catalysis: Heterogeneous and Homogeneous catalysis. catalytic cycles. TON, TOF, energetic of catalysis	2
2	Synthesis of sold catalysts: synthesis of bulk and supported catalysts-, skeletal metal catalysts , undoped and doped semiconductor photocatalysts	3
3	Characterization of catalysts: Bulk and surface characterization of catalysts – chemical composition, phase analysis, surface area, surface acidity and basicity, XPS, UPS, AES, EXAFS, XANES, XRD TPD techniques, band gap measurements with case studies	6
4	Adsorption and catalysis – adsorption isotherms of various types, kinetics of catalytic reactions, Langmuir and Rideal Eley mechanisms of surface catalysed reactions, heterogenous catalysis in industrial reactors , promoter effects in catalysis, mass and heat transfer in heterogeneous catalysis	5
5	Catalysis using solid acids and bases: Zeolites, mesoporous materials and clays as catalysts, shape selectivity. catalysis by metals, metal oxides. application in bulk and fine chemical synthesis chemicals, environmental applications	5
6	Catalyst deactivation and reuse – modes of catalyst deactivation and reactivation, catalyst recovery and reuse	3
	Heterogeneous catalysis – examples and case studies	3
7	Photo catalysis - principles , synthesis and applications in water splitting and environmental clean up	3

List of Text Books/ Reference Books

	Concepts of modern catalysis and kinetics - I. Chorkendorff, J.W. Niemantsverdriet- wiley VCH
	Industrial catalysis – optimizing catalysts and processes – R J Wijngarden Wiley - VCH
	Heterogeneous Catalysis - Fundamentals and Applications Julian R.H. Ross - Elsevier
	Principles of catalyst development – James T Richardson – Springer
	Principles of hetrogenous catalysis – J M Thomas and W J Thomas - VCH

Course Outcomes

CO1 – To understand the concepts of homogenous and heterogeneous catalysis, catalytic activity and selectivity and the relevance to green chemistry and technology

CO2 - To understand the kinetics of homogenous and heterogeneous catalytic reactions and catalytic cycles

CO3- To familiarise with the synthesis and characterization of catalysts

CO4- To understand the application and mechanisms of several types of catalysts.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	S	S	W	S	S	S	S	W	S	W	S	S
CO2	S	S	S	S	S	M	S	W	M	M	M	M	S	M
CO3	S	M	M	S	S	M	W	M	S	S	M	S	S	S
CO4	S	M	S	S	S	S	S	M	M	S	S	S	S	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code: GTT2003	Course Title: Chemical Reaction Engineering	Credits = 3		
			L	T	P
		Total contact hours: 45	30	15	-

List of Prerequisite Courses		
	NA	

List of Courses where this course will be prerequisite		
	N/A	

Description of relevance of this course in the M Tech (Green Technology) programme

Understanding the types and operation of reactors

	Course Contents	Reqd. hours
1	Principles of chemical reactor design, kinetics of homogeneous reactions, rate laws and stoichiometry, collection and analysis of rate data.	3
2	Introduction to reactor design - reactors for single reactions – multiple reactors, recycle reactors, reactors for autocatalytic reactions	3
3	Design for multiple reactions- maximizing rate and selectivity , Reactor design, Reactor safety, hydrodynamic characteristics of different phases in particulate and aggregative fluidized beds, bubble columns, slurry reactors spray columns, loop reactors and mechanically agitated contactors.	8
4	Estimation of design parameters such as pressure drop, fractional phase hold-up, mass and heat transfer coefficient, extent of mixing	4
5	Experimental methods on multiphase reaction engineering, mathematical modeling	4
6	Non elementary reactions – active intermediates and reaction pathways	2
7	Reactors for non elementary process – energy balance, non isothermal continuous flow reactors, non adiabatic reactors – operation and design	2
8	Non isothermal reactor design	2
10	. Choosing the right kind of reactor- objectives and variation of process parameters	2

List of Text Books/ Reference Books		
1	Elements of chemical reaction engineering – H. Scott Fogler, PHI	
2	Chemical reaction engineering – Octave Levenspiel- John Wiley and sons	
3	Chemical engineering kinetics – J M Smith	

Course outcome

CO1 – To understand the principles of designing reactors

CO2- To evaluate reaction rates in different types of reactors

CO3- To understand the design and operation of catalytic reactors

CO4 - To design and modify rectors to make processes safe and efficient

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	M	W	M	W	W	S	W	N	S	N	W	N	S	S
CO2	S	M	S	S	S	M	W	N	M	N	M	N	S	M
CO3	M	M	S	S	S	M	M	N	S	N	S	N	M	M
CO4	W	S	S	S	S	S	S	N	S	N	S	N	W	S

S : Strong

M : Medium

W : Weak

N : No correlation

	Course Code: GTT2005	Course Title: Catalysis II	Credits = 3		
			L	T	P
	Semester:	Total contact hours:	30	15	45

List of Prerequisite Courses		
Bachelors in Engineering, Technology or Pharmacy, MSc (with 2 years industrial experience)		
List of Courses where this course will be prerequisite		
	N/A	
	Course Contents (Topics and subtopics)	**Hours**
1	Homogeneous Catalysis**:** Basic concepts of organometallic complexes – oxidation state, electron count and coordination unsaturation, important reaction types – oxidative addition, reductive elimination , insertion and β elimination type reactions	4
	Specific homogeneous catalytic reactions – carbonylation, hydroformylation, polymerization reactions	3
	Coupling reactions - Suzuki coupling, Heck coupling and related cross coupling reactions	4
	Alkene oligomerization and metathesis. Ziegler-Natta catalysts, alkene hydrosilation and hydroboration, catalytic oxidations and reductions, epoxidation, dihydroxylations, decarbonylation, olefin isomerization, arylation, asymmetric synthesis	4
	Metal ligand multiple bonds – carbenes and N heterocyclic carbenes	2
	Asymmetric catalysis – chiral ligands and complexes, asymmetric hydrogenation and epoxidation	
	Organometallic complexes – carbonyls – synthesis , binding mode and reactions, dioxygen and phosphane lignads , metallacenes and sandwich complexes, organometallic complexes in organic synthesis	3
	Hetregenised homogeneous catalysts- synthesis, characterization and applications	2
	Phase Transfer catalysis – basic concepts in phase transfer catalysis- basic steps in PTC, tructural factors affecting the distribution of ions, phase transfer catalysts- quarternary salts, macrocyclic ligands, PEG and other soluble polymers, insoluble PTC	4
	Biocatalysis – enzymes as catalysts – kinetics and mechanism of enzyme catalysis, inhibitor effects, immobilized enzymes as catalysts	3
List of Text Books/ Reference Books		
1	Phase transfer catalysis – fundamentals, applications and industrial perspectives -Charles M Starks , Charles L Liotta, Mark Halern-Springer	
2	Homogeenous catalysis- mechanisms and industrial applications – Sumit Bahduri, Doble Mukesh- Wiley interscience	
3	Organometallic chemistry of transition metals – Robert H Crabtree-wiley interscience	
4	Catalysis- concepts and green applications- Gadi Rothenberg-Wiley VCH	

Course outcome

CO1 – To understand the concepts of homogenous and heterogeneous catalysis, with specific examples to show relevance to green chemistry and technology

CO2 - To study reaction mechanisms and kinetics of homogenous and heterogeneous catalytic reactions.

CO3- To familiarise with the synthesis and characterization of heterogenised homogenous catalysts

CO4- To understand the application and mechanisms of several types of catalysts.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	S	S	W	S	S	S	S	W	S	W	S	S
CO2	S	S	S	S	S	M	S	W	M	M	M	M	S	M
CO3	S	M	M	S	M	M	W	S	S	S	M	S	S	S
CO4	S	M	S	S	S	S	S	M	M	M	S	S	M	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code: GTT2006	Title- Environmental Engineering and pollution prevention	Credits = 3		
			L	T	
		Total contact hours: 45	30	15	

List of Prerequisite Courses	
Bachelors in Engineering, Technology or Pharmacy	
List of Courses where this course will be prerequisite	
NA	
Description of relevance of this course in the M Tech (Green Technology) programme	
NA	

	Course Contents (Topics and subtopics)	Hours
1	Basic concepts- biotic and abiotic environment, environmental acts and regulations, environment and public health, air quality standards, Environmental impact analysis	4
3	Water pollution – nature and types of water pollutants,-- organic and inorganic water pollutants	4
4	Water treatment- municipal sewage and industrial water treatment, Preliminary primary, secondary and tertiary treatment methods water reuse and recycling	4
5	Air pollution: Definition of pollutants, standards and limits of pollutants. Sources and sinks of pollutants. meteorology. Problems associated with dispersion. Sampling techniques. Control techniques for removal of particulate and gaseous pollutants applications	5
6	Global atmosphere- green house gases, global warming, acid rain, ozone depletion and photochemical smog	4
	Solid waste management- sources, characteristic, waste reduction and material recovery, hazardous waste management	4
7	Environmentally compatible materials, Design of unit operations for pollution prevention, Economics of pollution prevention, Process flow-sheet for pollution prevention, sustainable process design, life cycle analysis of plastics and paper	5
	List of Text Books/ Reference Books	
	Introduction to environmental engineering - P. Aarne Veslind- Cenage learning	
	Environmental engineering - Joseph A. Salvato - wiley	
	Unit operations and processes in environmental engineering- Tom D Reynolds – PWS Publishing	
	Course outcome CO-1. To know the sources of environmental pollution and their causes. CO-2 Measure and evaluate levels of various pollutants using sophisticated techniques. CO-3 To know advanced treatment methods and pollution abatement techniqu CO-4 . Analyse and evaluate factors and parameters that affect the environmental and economic scenario CO-5 . Identification, design and evaluation of environmental issues pertaining to industry and society	

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PO 13	PO 14
CO1	S	S	S	M	M	S	S	N	S	N	S	N	M	S
CO2	S	S	S	S	S	M	S	N	M	N	S	N	M	S
CO3	W	S	S	S	M	S	S	N	M	N	S	N	M	S
CO4	M	S	S	S	S	S	S	N	S	N	S	N	M	S
CO5	W	M	S	M	M	S	S	N	S	N	S	N	M	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code: GTT2007	Course Title: -Industrial safety and hazard analysis	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	NA			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		**Hours**	
1	Introduction ISO standards with reference to chemical industry		4	
2	Safety aspects pertaining to the design of chemical plants. Industrial		4	

	hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiations	
3	Hazard identification, assessment and safety audit, HAZOP, HAZAN and consequence analysis.	4
4	Safety aspects related to (i) transport handling and storage of flammable liquids and gases and toxic materials (ii) Process equipment including piping (fire, static electricity, pressure, temperature, etc.)	5
5	Safety aspects at process development and design stage. Reliability engineering. Hazard mitigation systems Emergency planning. Case studies.	3
6	Fire hazards – classification of fires, fire protection and fire fighting.	
7	Origin of hazards and accidents- spillage, leakage and operational failure	3
8	Case study of accidents, risk analysis, personal protective equipment	3
9	Loss prevention in industrial systems – Quality management , development and compliance of standards	3
10	Life cycle analysis- Life-cycle inventory- general issues in Inventory analysis: Issues Applicable to specific life cycle stages: Introduction, Raw Material acquisition stage, Manufacturing stage, Use/Reuse/Maintenance stage, Recycle/Waste Management stage	1
List of Text Books/ Reference Books		
1	Safety and Reliability of Industrial Products, Systems and Structures C. Guedes Soares (Eds), CRC Press	
2	Elements of Industrial Hazards Ratan Raj Tatiya, CRC Press	
3	Ciambrone , D.F., Environmental Life Cycle Analysis, CRC Press	
4	Handbook on Life Cycle Assessment : Operational guide to the ISO standards, Kluwer Academic Publishers	

Course Outcomes:

Students would be able to

1. Life cycle analysis and its scope and relevance at different stages and aspects of safe laboratory practices.
2. Find out inherent hazards of the chemical substance from MSDS(GHS complient) and use it for safe handling of chemicals.
3. Use of different hazard analysis methods for evaluation under different circumstances (batch, continuous processes, incident investigation etc.) also to generate relevant data required for the safe manufacturing process.
4. Understand safety aspects of occupational hygiene and control.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PO 13	PO 14
CO1	S	S	S	S	S	S	S	N	S	N	S	N	S	S
CO2	S	S	S	S	S	S	S	N	M	N	S	N	S	S
CO3	S	S	S	S	S	S	M	N	M	N	S	N	S	S
CO4	S	M	S	M	M	S	M	N	M	N	S	N	S	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code: GTT2004	Course Title: - Advances in separation processes	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	NA			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		**Hours**	
1	General methods of separation , thermodynamics of separation		2	
2	Mass transfer and diffusion		2	
3	Adsorption – adsorption equlibria, batch adsorption, kinetics of adsorption, adsorption in fixed beds, scale up of adsorption		3	
4	Distillation- Vapour-liquid equilibria. Normal and fractional distillation, batch and continuous distillation, heat transfer in distillation. aAzeotropes and separation of azeotropes. steam distillation, reactive distillation		5	
5	Liquid liquid extraction with ternary systems- theory, design and scale up		3	
5	Chemical, physical and biochemical aspects of isolation and purification of biomolecules, product release from biological cells.		3	
6	Design of downstream processing equipment, downstream process economics,super critical extraction		2	
7	Principle of separations through membranes- micro filtration, ultrafiltration. reverse osmosis, selection of membranes, pre evaporation, mechanism of fouling design and scale-up of membrane equipments, electrophoresis and electro dialysis		3	
8	Precipitation, coagulation, and flocculation, sedimentation and crystallization		3	
9	Crystallization, sublimation, drying		4	
List of Text Books/ Reference Books				
1	Separation process- Principles – J.D.Seader, Ernest.J. Henley, John Wiely &Sons			
2	Green separation processes- C. A. M. Afonso, J. G. Crespo (Ed)- Wiley VCH			
3	Transport processes and unit operations – Christie J. Geankoplis- Prentice Hall International			
4	Principles of mass transfer and separation processes- B.K.Dutta- PHI Learning			
5	Separation processes- C.J.King –Mc Graw Hill			

Course Outcomes:

Students would be able to

CO1 – To understand the separation principles of biphasic and triphasic systems

CO2 - To design a process based on separation principles

CO3 – Appropriate application of separation steps in industrial processes

CO4- To compute the kinetics of various types of separation processes

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	M	W	S	W	W	S	M	N	S	N	S	N	S	S
CO2	M	M	S	S	S	M	M	N	M	N	M	N	S	S
CO3	W	M	S	M	S	M	W	N	M	N	S	N	S	S
CO4	M	M	M	S	S	M	S	N	W	N	W	N	M	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	**Course Title: - Nano materials– fundamentals and applications**	**Credits = 3**	
			L	**T**
	Semester:	**Total contact hours:**	**30**	**15**
	List of Prerequisite Courses			
	NA			
	List of Courses where this course will be prerequisite			
	N/A			
	Course Contents (Topics and subtopics)		**Hours**	
1	Introduction to the nano scale – historical development and scope,		2	
	Unique properties of nano scale materials- micro structures, defects and dislocations, nano devices		4	
	Synthesis of nano materials – bottom up and top down approaches – vapour deposistion methods, wet chemical methods – sol gel processes, mechanical methods.		4	
	Metal and metal oxide nano particles- synthesis and stabilization- chemical methods, green synthesis of metal nano particles, metal nnao particles stabilised by framework materials		5	
	Nanao structured materials with applications - quantum dots, nano tubes, nano wires, nano crystals		3	
	Nano materials in catalysis and electrocatalysis		2	
	Nano composites- polymer and protein based nano composites		3	
	Characetrization of nano materials- Structural, microstructural and microchemical analysis of nanomaterials using X-ray diffraction and electron microscopy surface topography using atomic force microscopy and field ion microscopy		3	
	Nano strucrured materials with special applications		2	
	Toxicology and safety of nano materials- Environmental, ecological and health hazards of nanoparticles, nanotoxicology and its impact on environment		2	
	List of Text Books/ Reference Books			
1	Textbook of nano science and nano technology- Baldev Raj, B S Murty, B B Rath, James Murday – Springer University Press			
2	Nanoscale materials in chemistry - Kenneth J. Klabunde, Wiley and Sons			
3	Nanomaterials Chemistry - Recent Developments and New Directions- C.N.R. Rao, A. Muller and A.K. Cheetham (Eds)- Wiley VCH			
	Course Outcomes: **Students would be able to** CO1 – To understand the application of nano science in catalysis and green chemistry CO2- Synthesis of nano materials CO3 - Characterization of nano materials CO4- Physico chemical aspects of different types of nano structures.			

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	M	S	S	S	M	S	S	N	S	N	S	N	M	S
CO2	S	S	S	M	S	M	S	N	M	N	W	N	W	S
CO3	S	M	M	S	S	W	W	N	M	N	W	N	W	S
CO4	S	M	M	S	S	M	W	N	S	N	W	N	W	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	Course Title: - Fuel Engineering	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		**Hours**	
1	Classification of fuels and renewable fuels and energy		2	
2	Gaseous Fuels: Biogas, landfill gas, hydrogen, and comparison with natural gas, LNG, coal-bed methane and shale gas		5	
3	Liquid fuels: Bio-fuels, bioethanol, biodiesel, green diesel and gasoline, methanol, and comparison with petroleum-derived fuels .		5	
4	Solid fuels: Biomass, plastic waste, municipal domestic waste, and comparison with coal		5	
5	Biorefineries and comparison with petroleum refineries Biomass gasification and pyrolysis		5	
6	Renewable power generation from solar, wind, geothermal and hydrothermal sources etc. Combined cycleCogeneration (or combined heat and power) Carbon dioxide capture and its chemical recycling to fuels		5	
7	Integrated gasification combined cycle (IGCC)		3	
List of Text Books/ Reference Books				
1	Biomass and alternate fuel systems – Thomas F. McGowan, Michael L. Brown, William S. Bulpitt, James L. Walsh Jr.. Wiley AICHE			
2	Fuels and combustion – Sameer Sarkar- University press			
3	Alternative fuels- S.S. Thipse – Jaico publishing			

Course Outcomes:

Students would be able to

1. Appreciate and realize the importance of alternative and renewable energy sources (K1)
2. Gain sufficient knowledge about the various fuels and energy sources with applications in industrial processes. (K2)
3. Quantify energy requirements and make useful comparison amongst various energy resources and technologies. (K3)

4. Discuss/Provide solutions to the environmental challenges associated with fossil fuels and other energy resources. (K4)
5. Identify, design and develop systems and processes using suitable fuels in an economic and energy efficient manner (K5)

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	W	M	W	N	M	W	N	M	N	M	N	W	S
CO2	M	N	W	N	S	N	W	M	M	N	M	M	M	S
CO3	M	M	S	M	S	M	W	M	M	S	W	M	S	S
CO4	M	M	W	M	S	N	W	W	S	M	N	W	M	M
CO5	S	S	S	M	S	M	M	M	S	M	M	S	S	M

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	Course Title: - : Sonochemistry for Sustainable Development	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Application of ultrasound in green and energy efficient processes				
	Course Contents (Topics and subtopics)		**Hours**	
1	Introduction to sonochemistry- Historical background, The power of sound		3	
2	The physical basis for sonochemistry -generation of ultrasound , effects of frequency, Power and irradiation intensity, effect of dissolved gas and solvents		5	
3.	Cavitation in different systems - homogeneous liquid-phase systems, cavitation near a surface, heterogeneous solid -liquid biphasic systems		6	
4.	Synthetic applications of sonochemistry in organic chemistry, inorganic and materials chemistry		6	
5.	Reactor design and scale up- Batch treatment, flow systems		5	
6.	Industrial applications of sonochemistry -Process Intensification using sonochemistry, degradation of hazardous chemicals, microbial cell disruption, hybrid process for greener synthesis, wastewater treatment		5	
List of Text Books/ Reference Books				
1	Applied sonochemistry- T.J.Mason, J.P.Lorimer, Wiley VCH			
2	Handbook on applications of ultra sound- sonochemistry for sustainability- Dong Chen, Sanjay K Sharma, Ackmez Mudhoo, CRC Press			
3	Practical sonochemistry- T.J.Mason and D Peters. Elsvier			

Course Outcome

Students would be able to

1. Understand the importance of mechanism and application of sonochemistry in green technology.
2. Gain sufficient knowledge about the basics of sonochemical based systems.
3. Design reactors and systems for waste water applications using sonochemistry.
4. Provide solutions to the environmental challenges associated with water treatment employing cavitation in different scenarios.
5. Identify, design and develop systems and processes for multi-field applications employing sonochemistry to develop solutions in an economic and energy efficient manner.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	M	W	N	M	M	N	M	N	M	N	W	S
CO2	M	W	W	N	S	N	W	M	M	N	M	M	M	S
CO3	S	M	S	M	S	M	W	S	W	S	W	M	S	S
CO4	S	S	S	M	M	N	M	W	S	M	N	W	M	M

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	Course Title: - : Renewable Energy Resources	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Introduction to various renewable energy resources				
	Course Contents (Topics and subtopics)		**Hours**	
1	Introduction to nexus between energy, environment and sustainable development; Energy sources, sun as the source of energy; photosynthesis; classification of energy sources, fossil fuel reserves and resources - overview of global/ India's energy scenario.		6	
2	Energy Ecology and Environment: concept and theories of ecosystems, - energy flow in major manmade ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and environment - environmental laws on pollution control – innovation and sustainability: - eco-restoration/ phyto-remediation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies		6	
3.	Solar Energy: Solar radiation: measurements and prediction. Indian's solar energy potential and challenges, Solar thermal energy conversions systems: flat plate collectors, solar concentrators and other applications. Solar Photovoltaic: Principle of photovoltaic conversion of solar energy, types of solar cells and fabrication.		6	
4.	Wind Energy: Wind Resource: Meteorology of wind, Indian's wind energy potential and challenges, distribution across the world, Eolian features, Biological indicators. Wind measurement systems: anemometers, wind velocity distributions, wind shear, turbulence, Betz limit and energy potentials. Wind Energy Conversion Systems: Classifications and applications		6	
5.	Bioenergy: Biomass as energy resources; bio energy potential and challenges- Classification and estimation of biomass; Source and characteristics of biofuels: Biodiesel, Bioethanol, Biogas. Types of biomass energy conversion systems waste to energy conversions		6	
List of Text Books/ Reference Books				
1	D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis			
2	C. S. Solanki,- Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall			

Course Outcome

Students would be able to

1. Understand and realize the importance of renewable sources of energy and their applications in green technology.
2. Gain sufficient knowledge about the various energy sources such as wind, solar, bioenergy etc.
3. Design reactors and systems for energy based applications.
4. Provide solutions to the environmental challenges associated with energy employing renewable sources in different scenarios.
5. Identify, design and develop systems and processes for multi-field applications to develop solutions in an economic and energy efficient manner.

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	M	W	N	M	M	N	M	N	M	M	M	S
CO2	S	S	W	N	S	N	W	M	M	N	M	M	M	S
CO3	S	M	S	M	S	W	W	S	W	S	W	M	S	S
CO4	S	S	S	S	M	S	M	M	S	M	N	W	M	M

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	Course Title: - : Development of Green Industrial processes	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the importance of analytical techniques in monitoring processes, application of various instrumental techniques in quantitative analysis				
	Course Contents (Topics and subtopics)		**Hours**	
1	Pollution statistics from various industries		3	
2	General Characteristics of Industrial Effluents, Effects on Environment - ISI tolerance limits for discharging industrial effluents into surface water, into public sewers and onto land for irrigation - Toxic chemicals from industry.		5	
3.	Pretreatment of Industrial effluents Necessity of pretreatment - Equalization - Segregation - Process Changes Salvaging - By product Recovery. Removal by Reverse Osmosis, Ion Exchange, Electrodialysis, Solvent Extraction, Floatation.- Removal of Refractory Organics - Removal of Nitrogen and Phosphorus, DeNox, DeSOx technologies		6	
4.	Major Industrial Effluents: Sources, Characteristics and Treatment. Food Industries: Sugar, Dairy, Distilleries, Chemical Industries*:* Paper and Pulp, Tanneries, Textiles, Fertilizers, PharmaceuticalsmCement and Steel industry		6	
5.	Refinery industry -FCC, reforming, platforming, hydroforming, polymerisation, alkylation, isomerisation; hydrodesulfurisation, hydronitrogenation		5	
6	Pharmaceutical and fine chemical industry, Dyestuff and intermediate industries, Perfume and flavour industry		5	
7	Paint industry, Edible oil industry, Food industry, Waste water			
List of Text Books/ Reference Books				
1	Numersorn, N.L., Liquid Waste from Industry – Theories, Practice and Treatment, Addison-Wesley,			
2	Patwardhan, A.D., Industrial Waste Water Treatment, PHI Learning, 2009 Rao, M.N., and Dutta, A.K., Wastewater Treatment, IBH Publications			

Course Outcomes:

Students would be able to

CO1: Ability to understand principles of green chemistry and assess technical importance of green chemistry and green engineering

CO2: Ability to design synthetic routes and modification in existing industrial processes of different disciplines

CO3: Ability to implement theoretical concepts for industrial problems to arrive at suitable solutions.

CO4 Application of green principles to specific industrial processes

CO – PO Correlation

Correlation of Course Outcomes with POs of the programme

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PO 13**	**PO 14**
CO1	S	S	S	S	S	S	S	N	S	N	S	N	S	S
CO2	S	S	S	S	S	S	S	N	M	N	S	N	S	S
CO3	S	S	S	S	S	S	M	N	M	N	S	N	S	S
CO4	S	M	S	M	M	S	M	N	M	N	S	N	S	S

S : Strong
M : Medium
W : Weak
N : No correlation

	Course Code:	Course Title: Green Chemistry Experiments	Credits = 3		
			L	T	P
	Semester:	Total contact hours:			60
List of Prerequisite Courses					
	N/A				
List of Courses where this course will be prerequisite					
	N/A				

Description of relevance of this course in the M Tech (Green technology) programme

To introduce the concepts of Green Technology through experiments
Hands on experience that will be relevant for the forthcoming research project component

	Course Contents (Topics and subtopics)	Reqd. hours
1	Laboratory experiments relevant to Green chemistry programme and research (i) Synthesis and characterization of catalysts and nano materials (ii) Product analysis by instrumental techniques (iii) Reaction sin liquid/ vapor phase at amibient and high pressure conditions (iv) Waste water analysis (v) Methods of water treatment	4 h per session

List of Text Books/ Reference Books		
	Green Chemistry experiments – Manual (DST)	
Course Outcomes		
1	Practical skills relevant for carrying out research programmes	

	Course Code:	Course Title: - : Green Product Design	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the importance of analytical techniques in monitoring processes, application of various instrumental techniques in quantitative analysis				
	Course Contents (Topics and subtopics)		**Hours**	
1	Green product design definition, Product strategy, Life cycle of product, ISO 14000, Environmental load of product, Material selection, resource use, production requirements and planning for the final disposition (recycling, reuse, or disposal) of a product		7	
2	Integration with existing product design approaches such as quality, producibility, and functionality. Upgradability		7	
3.	Greening" Supplier Inputs, Improving Whole Systems, International laws on take-back laws, extended responsibility		8	
4.	Eco-labeling, Examples from Pharmaceuticals, Foods, Cosmetics, Packaging, Computers, Polymers, Automobiles, Electronics Industry.		8	
List of Text Books/ Reference Books				
1	Fiksel, Joseph, ed. Design for Environment: creating eco-efficient products and processes. New York: McGraw- Hill			
2	Green Technology and Design for the Environment Billatos, Samir B. and Nadia A. Basaly.			

	Course Code:	Course Title: - : Biochemistry- A basic course	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the importance of analytical techniques in monitoring processes, application of various instrumental techniques in quantitative analysis				
	Course Contents (Topics and subtopics)		Hours	
1	**The Foundations of Biochemistry** Cellular, Foundations Chemical , ohysical and generic foundations		3	
2	**Proteins:** Purification and characterization. Amino acid sequence, method of determining the sequence - Use of MALDI. Peptide synthesis. Biologically active peptides. Protein conformation and biological functions		5	
3.	**Enzymes:** Nomenclature, classification, isolation, concept of active site, affinity labeling and enzyme modification, Microbial reactions, enzymes in organic solvent, Enzyme inhibitors. Enzyme specificity (region-, stereo-, functional)		6	
4.	**Bioenergetics**: Standard free energy change in biological systems, hydrolysis of ATP, ADP□ ATP, Glucose storage, metal complexes in transmission of energy; chlorophylls, Photosystem I and photosystem II in cleavage of water.		6	
5.	**DNA-Based Information Technologies** DNA Cloning: The Basics- From Genes to Genomes, From Genomes to Proteomes, Genome Alterations and New Products of Biotechnology		5	
6	**Biological Membranes and Transport** The Composition and Architecture of Membranes- Membrane Dynamics Solute Transport across Membranes			
	Lipids: Structure, classification, characterization, metabolism			
List of Text Books/ Reference Books				
1	.Principles of Biochemistry, Lehninger, 4th Edition			
2	Bioorganic Chemistry, Dugas, H, Springer			

	Course Code:	Course Title: - : Organic Chemistry	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the importance of analytical techniques in monitoring processes, application of various instrumental techniques in quantitative analysis				
	Course Contents (Topics and subtopics)		**Hours**	
1	**Mechanisms of organic reactions:** Types of Organic Reaction, Reactive intermediates; their generation, structure, stability and general reactions. Acidity and basicity. Mechanisms of simple organic transformations		3	
2	**Stereochemistry:** Stereodescriptors, Elements of symmetry, stereochemistry of compounds containing one and two carbon atoms. Racemates and their resolution, conformation of cyclic and acyclic systems, Idea of asymmetric synthesis		5	
3.	**Aromaticity:** Huckel's theory of Aromaticity. Aromaticity of simple benzenoid and non benzenoid species. **Aromatic compounds:** Sources. BTX, Aromatic hydrocarbons. General mechanisms of aromatic electrophilic and nucleophilic substitution reactions. Orientation of electrophile in arenes.		6	
4.	**Chemistry of alkanes, alkenes and alkynes:** Acyclic and cyclic compounds. General reactions. Functionalization of alkanes – alkanes to alkenes and haloalkanes. Alkanes as fuels – environmental issues, carbon footprint. Oligomerization and polymerization of olefins. Acidity of terminal alkynes		4	
5.	**Sources of organic compounds:** Coal, petroleum, biomass. Petrochemical processes. C1 sources, natural gas hydrates.		5	
6	**Heterocyclic chemistry:** Comparison with carbocyclic compounds. Aromaticity, simple methods of preparation, electrophilic orientation, and simple reactions of - Pyrrole, Furan, Thiophene, Pyridine			
List of Text Books/ Reference Books				
1	. Organic Chemistry, J. McMurry, Brooks/Cole			
2	Organic Chemistry, T.W.G. Solomons, C.B. Fryhle, John Wiley and Sons Inc			
3	Organic Chemistry, L.G. Wade Jr, Pearson Education			
4	Organic Chemistry, Paula Y. Bruice, Pearson Education			

	Course Code:	Course Title: - : Chiral Engineering	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		Hours	
1	Chirality and green chemistry, Preparation and Importance of Chiral Molecules		3	
2	chirality in pharmaceuticals, agrochemicals and specilities, Wehland - Meischer Dione, Chiral Synthesis		5	
3.	Crown Ether Technology, Nazarov's Reagent Production, Michael Addition, Chiral Analysis, Engineering of enantiomeric excess, , Computer Modeling		6	
4.	chiral auxiliaries, chromatographic techniques, enantiomers-specific reactions, and resolution		6	
5.	Chiral catalysts and chiral polymer- design and synthesis		5	
6	Supramolecular chemistry and molecular recognition			
List of Text Books/ Reference Books				
1	Handbook of chiral chemicals- David Ager (Eds)- CRC Press			
2	Supramolecular Chemistry- Jonathan W Steed and Jerry L Atwood- John Wiley and Sons			

	Course Code:	Course Title: - : Instrumental methods of analysis	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the importance of analytical techniques in monitoring processes, application of various instrumental techniques in quantitative analysis				
	Course Contents (Topics and subtopics)		Hours	
1	Analytical procedures- hazards and handling, treatment of waste, good laboratory practices		3	
2	Aspects of analysis- errors – systematic and random errors, statistical treatment of experimental results, least square method, correlation coefficients Sampling – basics and procedures, preparation of laboratory samples, T- F- and C tests, Regression analysis, Instrument calibration and validation, certified reference materials.		5	
3.	Applied analysis – analytical procedures in environmental monitoring, water, soil and air quality, BOD and COD determinations		6	
4.	Instrumental methods – Criteria for selecting instrumental methods - precision, sensitivity, selectivity, and detection limit, transducers, sensors and detectors,signals and noise		6	
5.	Chromatographic methods of analysis –GC and HPLC- Principles, columns including chiral columns, detectors. Ion exchange chromatography, exclusion chromatography, gel permeation chromatography, HP-TLC		5	
6	Atomic and molecular Spectroscopic methods – AES, ICP-AES, flame photometry UV-Vis,, FT-IR and NMR techniques in quantitative and qualitative analysis			

	Course Code:	**Course Title: - :** **Biodegradable materials for biomedical applications**	**Credits = 3**	
			L	**T**
	Semester:	**Total contact hours:**	**30**	**15**
List of Prerequisite Courses				
	NA			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		**Hours**	
1	Introduction of Biomaterials		2	
2	Biomaterials Surfaces: Structure and Properties, Surface Energy Adsorption and Reconstruction at Surfaces,		4	
3.	Protein-Surface Interactions Proteins: Structure, Properties, Functions, Protein Adsorption: Complex Phenomena, Measurement		4	
4.	Cell-Surface Interactions: Host Response to Biomaterials: Cell adhesion mechanism, coagulation cascade, immune response		4	
5.	Surface characterization: AES, XPS, AFM, contact angle measurements			
6.	Quantifying cell behavior: cell culture, cellular assays		2	
7.	Biosensors and Diagnostic devices		2	
8.	Drug Delivery: Controlled Release, Diffusion Controlled and Membrane based devices, Mechanical Pumps		3	
9.	Biomaterial for Organ Replacement Mechanical Properties, Bone Substitutes		3	
10.	Introduction of Tissue Engineering: Cell, Scaffold design, Artificial liver, pancreas, cartilage		2	
11.	Regulatory overview		2	
List of Text Books/ Reference Books				
1	Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine. 2nd ed. Burlington, MA: Academic Press			

	Course Code:	Course Title: - : Fuel Cell Technology and Sustainability	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
	Course Contents (Topics and subtopics)		Hours	
1	Introduction and overview of fuel cell – requirement, history, principle, overview and basic electrochemistry of the fuel cell		2	
2	Thermodynamics of Fuel Cell- Gibb's free energy, reversible and irreversible lossess, fuel cell efficiency, Nernst equation: Effect of temperature, pressure and concentration on Nernst potential, Concept of Electrochemical Potential		4	
3.	Components of Fuel cell: Electrolyte, catalyst, bipolar plate/current collector		3	
4.	Activation Polarization-electrochemical kinetics, reaction rate, surface coverage, Activation polarization for charge transfer reaction, Butler-Volmer equation, Tafel equation.		5	
5.	Concentration Polarization: Diffusion transport in electrodes, transport through flow channel, concentration polarization		3	
6.	Ohmic polarization: Ionic conductivity and Electronic Conductivity		3	
7.	Fuel Cell Characterization: Possible ways of Characterization, IV characteristics and electrochemical impedance spectroscopy, cyclic voltametry		3	
8.	Comparison of High temperature and low temperature fuel cell, Different types of fuel cell		3	
9.	Hydrogen production and storage, safety issues and Cost issues		2	
10.	Advances in sold oxide fuel cells		2	
List of Text Books/ Reference Books				
1	O 'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, N.Y			
2	Bard, A. J. , L. R., Faulkner, Electrochemical Methods, Wiley, N.Y			
3	Basu, S. (Ed) Fuel Cell Science and Technology, Springer, N.Y.			
4	Liu, H., Principles of fuel cells, Taylor & Francis, N.Y			
5	Electrochemistry of cleaner environments, J OM Bockris , Springer, US			

	Course Code:	Course Title: - : Green Biotechnology	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding the impact of biotechnology on environment and application of biotechnology to achieve green technology goals				
	Course Contents (Topics and subtopics)		**Hours**	
1	Biotechnology, Applications of green concepts in biotechnology		6	
2	Genetics and Genetic engineering, DNA recombinant technology, hybrid technology, single cell proteins, gene manufacturing		6	
3.	Fermentation and design of fermenters with modified organisms Bioprocess simulations, molecular modelling for protein synthesis and drug design, protein engineering, Applications in fermentation industry, pharmaceutical industry, medical field such as gene therapy, Biomedical engineering, from case studies		6	
4.	Bioreactor design, Scale up of bioreactions/reactors, Downstream processing in biochemical industry		6	
5.	Organic synthesis using supported microbes and enzymes. Biopharmaceuticals, biorefinery and biotechnology, bio-inorganics		6	
List of Text Books/ Reference Books				
1	Industrial biotechnology- sustainable growth and economic success- Wilm Soetaert Reic J Wandamme- Wiley VCH			
2	Concepts in Biotechnology – History Science and Business- Klaus Buckholz, John Collins – Wiley VCH			

	Course Code:	Course Title: - : Colloid and interfacial phenomena	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	N/A			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Understanding interfacial phenomena as an all prevailing aspect of surfaces and interfaces				
	Course Contents (Topics and subtopics)		**Hours**	
1	Capillarity: Definition, Existence of surface tension/surface free energy, Laplace equation, Young Equation, Capillarity rise phenomena, Measurement of surface tension, Contact angle Wetting characteristics		3	
2	Surface Thermodynamics: Surface thermodynamic properties, Kelvin equation, Gibbs adsorption isotherm and Surface excess quantities, insoluble monolayers		5	
3.	Adsorption: Localised vs. Mobile adsorption, Adsorption isotherms [Langmuir Freundlich, BETetc., (Adsorption from solution, ,electrical double layer-models, adsorption at s/l and l/l interfaces		6	
4.	Surfactants and surfactant aggregates - classification and synthesis of surfactants, bio surfactants, surfactant biodegradability, surfactant aggregats- CMC – determination and factors affecting shape and size of aggregates, determination of HLB, models for micelle formation, Swollen micelles, Hydrotropy, Solubilisation in micelles: Location of solubilizate in micelles, Measurement of solubilization,		6	
5.	Detergency and selective solubilization		5	
6.	Disperse systems – colloids and emulsions, stability of colloids, emulsions: Micro and macro emulsions, Stability ofemulsions (Mechanical vs.thermodynamic), Bancroftrule, deemulsification, HLB for emulsion, multiple emulsions, applications, Foams: Gibbs triangle, Film elasticity, drainage of films, Foam, defoaming, applications of foam		5	
List of Text Books/ Reference Books				
1	Foundations of colloid science- Robert J Hunter – Oxford University Press			
2	Surfactants and interfacial phenomena- Milton J Rosen, Wiley Interscience			
3	Surfaces , interfaces and colloids- Drew Myers- John Wiley and Sons			

	Course Code:	Course Title: - : Membrane Technology for pollution abatement	Credits = 3	
			L	T
	Semester:	Total contact hours:	30	15
List of Prerequisite Courses				
	NA			
List of Courses where this course will be prerequisite				
	N/A			
Description of relevance of this course in the M Tech (Green Technology) programme				
Application of membrane separation as a green method for pollution abatement				
	Course Contents (Topics and subtopics)		**Hours**	
1	Membrane technology past, present and future		2	
2	Preparation of polymeric and ceramic membranes		3	
3.	Membrane Reactors- Fundamentals of membrane reactors and biochemical membrane reactors (MBR)		4	
4.	CO_2 capture with membrane systems- Basics, membrane materials for CO_2 capture, challenges and future outlook		5	
5.	Desalination- Filtration theory, Fouling potential of feed water , Membrane fouling quantification, pre-treatment and cleaning of membranes, membrane modules and plant configuration		4	
6.	Membrane technologies for oil-water separations- sources of oil-water mixtures, fundamentals of oil-water mixtures,technologies for oil-water separations advances in membrane technologies		4	
7.	Membrane processes for reclamation of municipal water- fundamentals of municipal waste water treatment , use of membranes for municipal water treatment, process design using membranes , UF and RO for tertiary treatment, and TOC removal, reclamation of mixed sewage waters - MBRs		4	
8.	Industrial water treatment with examples- dairy water treatment, landfill leachates, membrane applications in cosmetics industry		4	
List of Text Books/ Reference Books				
1	R.Baker, Membrane Technology and applications – John wiley and Sons			
2	M.Mulder, Basic Principles of Membrane Technology, Springer			
3	K.Wang and J.P.Chen, Membrane and desalination technologies- Humana Press			
4	M.C.Porter – Handbook of industrial membrane technology – Noyes Publications			