INSTITUTE OF CHEMICAL TECHNOLOGY

Master of Technology in Green Technology

Syllabus

(2021 – 2022)

PREAMBLE

Vision and Mission of the Department

Vision

To become a globally recognized Green Technology Centre of Excellence through illustrious academic contributions at the national and international level.

Mission

1) To promote the objectives, principles and outcome of green processes and products.
2) To transmit research outcome to industry for making processes and products environmentally benign.
3) Human resource development with awareness of environment and hazard related issues.
4) To undertake sponsored projects of national relevance.
5) To get quality publications in pear reviewed journals, national and international forums for the benefit of scientific community and society.

Program Education Objectives

PEO1	Post-graduate students of this program will learn to understand the issues of the environment and the concepts of Green Chemistry and Technology.
PEO2	They are expected to develop analytical and problem solving skills.
PEO3	They will learn the tools and methodologies that would make processes and products hazard and waste free, environmentally and energetically effective.
PEO4	They will be able to think critically and come up with rational solutions for making industrial processes that are compatible to environment and the society.

Program Outcomes

PO1	An ability to independently carry out research/investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Students should be able to work as professional researchers or entrepreneurs with social and environmental awareness of green technology and cope up with futuristic technologies which will lead the chemical processing towards sustainability

Syllabus Details for the Degree of Master of Technology in Green Technology

No.	Subject	Credit	Hr/Week			Marks			
			L	T	P	Continuous Assessment	Mid-semester Examination	Final Examination	Total
SEMESTER I									
GTT2001	Core I: Fundamentals of Green Chemistry and Technology	3	2	1	0	10	15	25	50
GTTXX	Core II: Chemical Process Development and Engineering	3	2	1	0	10	15	25	50
GTT2003	Core III: Chemical Reaction Engineering	3	2	1	0	10	15	25	50
	Elective I	3	2	1	0	10	15	25	50
CETXX	Chemical Safety and Risk Management	3	2	1	0	10	15	25	50
GTP2100	Seminar	2	0	0	4			30 (Report) 20 (Presentation)	50
GTP2101	Chemical Engineering Practical	3	0	0	6	25		25	50
GTP2102	Research Project I	4	0	0	8			30 (Report) 20 (Presentation)	50
	TOTAL:	24	10	5	18				400
SEMESTER II									
GTT2004	Core IV: Advances in Separation Processes	3	2	1	0	10	15	25	50
GTTXX	Core V: Catalysis	3	2	1	0	10	15	25	50
GTT2006	Core VI: Environmental Engineering and Pollution Control	3	2	1	0	10	15	25	50
	Elective II	3	2	1	0	10	15	25	50
	Elective III	3	2	1	0	10	15	25	50
	Elective IV	3	2	1	0	10	15	25	50
GTP2103	Research Project II	6	0	0	12			60 (Report) 40 (Presentation)	100
	TOTAL:	24	12	6	12				400
SEMESTER III									
GTPXX - Research Project III: 24 Credits									
SEMESTER IV									
GTP2105 – Research, Thesis and Open Defence: 24 Credits									

Semester I

	Course Code: GTT2001	Course Title: Fundamentals of Green Chemistry and Technology	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the relevance and context of green technology	K2
2	Analyze process options using metrics of green chemistry and engineering	K4
3	Evaluate several chemical processes for a product and recommend the best choice	K5

	List of Prerequisite Courses	
	Industrial & Engineering Chemistry; Chemical Processes; Applied Chemistry	

	List of courses where this course will be prerequisite	
	Research Project II, III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will introduce students to the ever-increasing relevance of green chemistry, engineering and technology in chemical and allied industries.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Twelve principles of green chemistry and green engineering with examples	4
2	Green chemistry metrics – atom economy, E-factor, reaction mass efficiency etc.	4
3	Waste – sources of waste, different types of waste, chemical, physical and biochemical methods of waste minimization and recycling Pollution – types, causes, effects and methods for abatement	6 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-chemical methods	8
5	Green reagents and catalysis in green synthesis	4
6	Designing green processes, safe design, process intensification, in-process monitoring	6
7	Safe product and process design – Design for degradation, real-time analysis for pollution prevention, inherently safer chemistry for accident prevention	5
8	Industrial case studies	4

	List of Text Books	
1	Introduction to Green Chemistry – Albert Matlack, CRC Press	
2	New Trends in Green Chemistry – V. K. Ahluwalia, M. Kidwai, Springer	
3	Green Chemistry and Engineering: A Practical Design Approach – Concepción Jiménez-González, David J. C. Constable, Wiley	
4	Green Chemistry – An Introductory Text – M. Lancaster, RSC	
5	Green Chemistry Metrics: Measuring and Monitoring Sustainable Processes – Alexi Lapkin and David Constable (Eds.), Wiley	

	List of Additional Reading Material / Reference Books	
1	Handbook of Green Chemistry, Editor – Paul Anastas, Wiley-VCH	

	Course Code: GTTXX	Course Title: Chemical Process Development and Engineering	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Describe key steps in the development of industrial processes	K1
2	Assess techno-economic parameters of proposed projects	K5
3	Describe procedures for the development and engineering of chemical processes	K1
4	Apply principles of process development and engineering to improve existing processes	K3
5	Assess alternative chemical processes and provide recommendations for the best choice	K5
6	Develop methodology for the launch of novel processes and products	K6

	List of Prerequisite Courses	
	Industrial & Engineering Chemistry; Chemical Processes; Industrial Catalysis; Chemical Technology	

	List of courses where this course will be prerequisite	
	Research Project II, III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will introduce students to several useful concepts such as green-to-sustainable processes, transition from batch-to-continuous, modular production, process intensification, scale-up and retrofit.

	Course Contents (Topics and subtopics)	Reqd. hours
1	From green to sustainable processes, Tools for development of advanced sustainable technologies	4
2	Methods for sustainability assessment; Tools, indicators and framework; Challenges to advance sustainability at process level	4
3	Intensification of chemical processes; Guiding principles and elements of PI; Equipment and methods for PI; Separation process intensification; Examples and case studies	6
4	Small-scale continuous chemical production; Technology gaps and challenges	4
5	Scale-up of chemical processes; Objectives, steps and procedures; Pilot plants; Commercial scale-up of new chemical processes	6
6	Future production concepts in the chemical industry; Modular, small-scale and continuous	4
7	Steps to transform a batch process reaction to a continuous process	4
8	Methodology for techno-economic process evaluation; Examples; Introduction to new approaches for process development	6
9	Process retrofit; Analysis of process bottlenecks; Methods to identify and remove bottlenecks; Procedures for process retrofits	4
10	Product design; Developing and launching new products	3

	List of Text Books	
1	Industrial Chemical Process Design – D. L. Erwine, McGraw-Hill	
2	Unit Processes in Organic Synthesis – P. H. Groggins, McGraw-Hill	
3	Chemical Technology – Andreas Jess, Peter Wasserscheid, Wiley-VCH	
4	Industrial Catalysis – A Practical Approach – Jens Hagen, Wiley-VCH	

	List of Additional Reading Material / Reference Books	
1	Handbook of Chemical Process Development – Wenyi Zhao, CRC Press	

	Course Code: GTT2003	Course Title: Chemical Reaction Engineering	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand various types of chemical reactions	K2
2	Apply reactor design equations for determination of the relevant parameters	K3
3	Classify different reactor types and analyze reactor performance	K4
4	Develop procedures for the design of reactors for a particular application	K6

	List of Prerequisite Courses	
	Physical Chemistry; Applied Mathematics	

	List of courses where this course will be prerequisite	
	Research Project II, III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

In this course, students will be introduced to many useful concepts: types of reactions, categories of reactors, performance analysis, mass transfer considerations, kinetics study, design procedures etc.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Reaction types and examples, kinetics of homogeneous and heterogeneous reactions, rate laws and stoichiometry, collection and analysis of rate data	6
2	Introduction to reactor design, reactor types, multiple reactors, recycle reactors, novel reactor configurations	6
3	Multiple reactions, maximizing rate and selectivity, reactor safety	3
4	Hydrodynamics in fluidized beds, bubble columns, slurry reactors, spray columns, loop reactors and mechanically agitated contactors	6
5	Estimation of design parameters such as pressure drop, fractional phase hold-up, mass and heat transfer coefficients, extent of mixing	6
6	Experimental methods in multiphase reaction engineering, mathematical modeling	6
7	Non-elementary reactions, active intermediates and reaction pathways	3
8	Energy balance, non-isothermal operation of reactors	3
9	Design of non-isothermal reactors	3
10	Choice of reactor-type, factors affecting selection, industrial examples	3

	List of Text Books	
1	Chemical Reaction Engineering – Octave Levenspiel	
2	Elements of Chemical Reaction Engineering – H. Scott Fogler	
3	Heterogeneous Reactions, Vol. I and II – L.K. Doraiswamy, M.M. Sharma	
4	Chemical Engineering Kinetics – J. M. Smith	

	List of Additional Reading Material / Reference Books	
1	Chemical Reaction Engineering Handbook of Solved Problems – Stanley M. Walas	

	Course Code:	Course Title: Elective I	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 45	2	1	0

Candidate will have to choose one of the elective subjects offered for that semester. A consolidated list of all the elective subjects is given at the end.

	Course Code: CETXX	Course Title: Chemical Safety and Risk Management	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	List principles of safety, risk management and material hazards	K1
2	Define safety principles, procedures, standards and regulations	K1
3	Describe safety aspects related to chemicals, fires, electricity, pathogens etc.	K2
4	Apply SHE management principles in the industry	K3
5	Assess the risks and environmental impact of projects and processes	K4
6	Perform tasks such as hazard identification or plant layout etc.	K3

	List of Prerequisite Courses	
	Chemical Processes	

	List of courses where this course will be prerequisite	
	This course will be useful for advanced level course on chemical process safety.	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will provide key information on several safety-related aspects in the chemical industry or research laboratories.

	Course Contents (Topics and subtopics)	Reqd. hours
1	**Introduction to Safety and Risk Management** Major industrial disasters and evolution of safety and risk management	3
2	**Material hazard - GHS MSD - physical hazard, toxic hazard and eco-toxicity** MSDS (Material Safety Data Sheet), 16-point MSDS, uniformity in MSDS, details of MSDS, LD_{50} & LD_{10} dosage values; TLV, STEL, Flash, Vapour pressure; Globally Harmonized System (GHS), R&S phrases	4
3	**PSM elements** Why PSM; Overview of 14 elements	2
4	**Hazard evaluation techniques – What-If, Checklist, HAZOP, FEMA etc.** Overview of each of HAZOP & HAZAN Analysis; Cause and Consequence Analysis; FEMA; LOPA; Fault Tree Analysis; QRA	3
5	**Hazard identification and assessment – 1. Basic** Hazard identification, assessment & measures	2
6	**Flammability and fire safety-extinguishers** Fire types, Types of fire extinguishers, Agents for fire-fighting, Fire hydrant	2
7	**SHE regulations in India- Factories act, water and environment act** Statutory regulations in India; Codes and Standards; Scenario at present and vision for future; Factory Act.	2
8	**Human elements in safety - behaviour safety**	2
9	**Laboratory safety** Basics and Dos & Do nots	2
10	**Basic OSH** Occupational hygiene basics	1
11	**Compliance to statutory safety audits** Overview of safety audits based on ISO standards (14000)	1
12	**Biosafety** Biohazards; Basic microbiology of pathogens; Pathogenic risks; Containment; Biosafety levels; Laboratory facilities for handling pathogens; Personal protective equipment; Disinfection and decontamination; Biohazard waste disposal; Emergency measures	6
13	**Plant layout based on process safety & fire safety-fire hydrant system design** Solvent yard, warehouse and plant layout with design of fire safety system	1
14	**Management Practice in SHE in Plant Operation** Man-management, organization management, policy management; Fundamentals of safety management systems for occupational safety, job hazard analysis (confined space, height safety, hot jobs); Chemical and plant security; Cyber security as applicable to Chemical Projects; Management	3

	of change; Incident reporting and investigation; Human elements in safety, ergonomics and behavioral safety	
15	**Hazard assessment – 2. Process safety, thermal safety, dust explosion etc.** Inherent safety concepts for processes and unit operations; Powder handling hazards - dust explosion	2
16	**Safety in utilities** Safety in electrical power generation units including nuclear, steam boilers, boiler feed water, thermic fluids, transformers	2
17	**Storage, handling and transportation of hazardous substances** Safety provisions during transport of petroleum products including LNG and other hazardous materials by ship, rail, air cargo and roads; transport emergency; isolated storage; warehouses; color coding of pipelines; inventory management; packaging and labelling.	3
18	**Environmental Impact Assessment** Environmental impact and risk assessment (EIRA), risks of projects, process related risks, measurement and monitoring tools	2
19	**Emergency response plan** Hazard identification and elements of emergency response plan; OHC categorization, control banding and precautions while handling substances; GMP principles	2
List of Textbooks		
1	Elements of Industrial Hazards – Ratan Raj Tatiya, CRC Press	
2	Environmental Life Cycle Analysis – Ciambrone, D. F., CRC Press	
List of Additional Reading Material / Reference Books		
1	Handbook on Life Cycle Assessment: Operational Guide to ISO Standards, Kluwer Academic Pub.	

	Course Code: GTP2100	**Course Title: Seminar**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**0**	**0**	**4**

Seminar will be supervised by the seminar supervisor (viz. a faculty member other than the research supervisor). Candidate should perform comprehensive analysis of the literature related to a topic (other than the research topic), which is suggested by the seminar supervisor. Candidate shall submit a report (as per the guidelines provided below) and make a presentation of the work done to the seminar supervisor and an external examiner from the Department/Industry. A suitable combination of the marks for report and presentation will be considered for the final evaluation.

Guidelines

1. Typically, the report should contain the following:

(a) Introduction: 3 pages at the most

(b) Exhaustive review of literature (including figures): 10 – 15 pages

(c) Critical analysis of the literature and comments: critical analysis should also contain quantitative comparison of observations, results and conclusions reported in past works

2. Two typed copies of the report on thesis size bond paper (297 mm × 210 mm) should be submitted to the Coordinator at the **date/time decided by the Coordinator**. **In addition, soft copy of the report should be uploaded on the portal.** The detailed timetable for the presentation should be communicated to the students.

3. The report should be prepared using the Times New Roman font (size 12) with 1 1/2 spacing leaving 1-inch margin on all sides producing approximately 29 lines per page. The report should be typed on one side of the paper and need not be bound in a hard cover binding. Figures and tables should be shown as a part of the running text. Each figure should be drawn inside a rectangular box of 12 cm width and 10 cm height. The figures must be sufficiently clear and hand-drawn figures will be acceptable. Particular care must be taken if a figure is photocopied from source. Each figure must have a sequence number and caption below. Each table must have a sequence number and title at the top.

4. Name of the student, title of the problem and year of the examination must be indicated on the top cover. THE NAME OF THE SEMINAR SUPERVISOR (ONLY INITIALS) MUST APPEAR ON THE BOTTOM RIGHT CORNER OF THE TOP COVER.

5. The report must be precise. All important aspects of the topic should be considered and reported. **The total number of pages, including tables, figures and references should not exceed 30.** Chapters or subsections need not begin on new pages, while getting the report typed.

6. Typographical errors in the report must be corrected by the student. The student will be discredited for any omission in the report. All the symbols used in the text should be arranged in an alphabetical order and given separately after conclusions.

7. The list of references should be arranged in alphabetical order of the names of authors. In the text, the reference should be cited with the author's name and year (author – year style). For example:

a. The flow pattern in gas-liquid-solid fluidized bed has been reported in the published literature (Murooka et al., 1982).

OR

b. Murooka et al. (1982) have measured flow patterns in gas-liquid-solid fluidized beds. The title of the article should also be included. The references must be given in the following standard format.

(a) Format for listing references of articles from periodicals: Murooka S., Uchida K. and Kato Y., "Recirculation turbulent flow of liquid in gas-liquid-solid fluidised bed", J. Chem. Engg. Japan, 15, 29-34 (1982).

(b) Format for listing references of books:
Constant R. F. Crystallization, Academic Press, New York, pp. 89-90, 1968.

(c) Format for listing thesis:
Niranjan K., "Hydrodynamic and Mass Transfer Characteristics of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(d) Format for listing references of Patents in Chemical Abstracts:
Cananaush R.M., U.S. Patent 2,647,141, Cf. C.A. 48, 82636 (1954).

(e) Format for listing Handbooks, Tables, Symposia etc.:
Kumar R and Kuloor N.R., "Formation of Drops and Bubbles", in Advances in Chemical Engineering, Vol.8, T.B. Drew et.al. (Eds.) New York, Academic Press, pp.256-364 (1970).

(f) Format for listing Private Communications and other categories:
Sharma, M.M., Private Communication (1984).

8. Consistency of units should be maintained in the written report. SI systems should be used [For SI system – Ref: Ind. Chem. Engr., 24, 32, 3 (1983)]. Units used in the literature (if not SI) should be correctly converted.

9. The time allotted for the oral presentation is 20 minutes: additional 10 minutes are provided for questions and answers.

10. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED.

11. The last date for submission will NOT be extended.

12. There must not be any acknowledgment about the guidance by the faculty in the report.

13. The report will be evaluated on the basis of (i) rational approach to the problem, ii) correctness and completeness of the written text and iii) performance in the oral presentation.

14. Word-to-word copying from the published article is not permitted. Flowery language is not to be used.

Course Outcomes (students will be able to…..)		
1	Collect literature related to an assigned area	K1
2	Understand the lacunae in the literature	K2
3	Analyze the literature and present suitable guidelines	K4
4	Write a neat report following the guidelines	K2, K4
5	Propose a defined plan for the research	K6
List of Prerequisite Courses		
1	Undergraduate seminar or design project	
List of courses where this course will be prerequisite		
	Research Project II, III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program
This course enables students to gather scientific information on a particular topic, analyze the information, and present a written and oral summary on that topic. This enables the students to function in a professional environment later on in their career.

	Course Code: GTP2101	Course Title: Chemical Engineering Practical	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 90	0	0	6

Course Outcomes (students will be able to…..)		
1	Understand basic chemical engineering principles	K2
2	Analyze laboratory data	K4
3	Develop experimental and analytical skills	K6

List of Prerequisite Courses		
1	Chemical Engineering Operations	

List of courses where this course will be prerequisite		
	Research Project II, III and Research, Thesis & Open Defence; Advances in Separation Processes	

Description of relevance of this course in the M. Tech. (Green Tech.) Program
Students will learn basic principles of chemical engineering. Also, they will be trained at performing experiments, observing experimental phenomena, collecting laboratory-scale data, analyze data, represent the results and make relevant conclusions.

	Course Contents (Topics and subtopics)	Reqd. hours
1	A suitable number of experiments from the below-mentioned list will be performed: Flow through pipes, coils and fittings; Orifice, venturi and rotameter; Flow through packed beds; Compressors, blowers and pumps; Fluidization; Mixing Heat transfer in shell and tube and plate heat exchangers; Evaporators Adsorption isotherms; Adsorption/ion exchange in fixed beds Absorption with chemical reactions in packed, plate and bubble columns and stirred vessels Distillation in packed and/or plate column Spray, packed and mechanically agitated extraction columns Membrane separations Kinetics of solid-catalyzed liquid phase reactions Demonstration experiments related to advanced analytical instruments such as GC, HPLC, GC-MS, LC-MS, SEM, FTIR, UV-Vis Spectrophotometry, TEM, ICP, particle size analyzer etc. The students will work in groups and submit a report on theory, working principle, standard operating procedure and a case study.	

List of Text Books		
	Laboratory manuals on chemical engineering operations	

List of Additional Reading Material / Reference Books		

	Course Code: GTP2102	Course Title: Research Project I	Credits = 4		
			L	T	P
	Semester: I	Total contact hours: 120	0	0	8

Research Project I will be supervised by the research supervisor. Candidate should perform comprehensive analysis of the literature related to the research area, decide scope of work, appropriately plan experimental and analytical procedures and perform few preliminary trials in the laboratory. All these activities will be supervised by the research guide. Candidate shall submit a report (as per the guidelines provided below) and make a presentation on the work done to the research supervisor and an external examiner from the Department/Industry. A suitable combination of the marks for report and presentation will be considered for the final evaluation. Candidate should also submit attendance record and laboratory journal (both signed by the research supervisor).

Guidelines

1. Typically, the report should contain the following:

(a) Introduction: 2 pages at the most

(b) Exhaustive review of literature (including figures): around 10 pages

(c) Critical analysis of the literature and comments: critical analysis should also contain quantitative comparison of observations, results and conclusions reported in past works

(d) Brief discussion on the scope of work, plan of experiments, setup/procedures and results of few preliminary trials

2. Two typed copies of the report on thesis size bond paper (297 mm × 210 mm) should be submitted to the Coordinator at the **date/time decided by the Coordinator**. **In addition, soft copy of the report should be uploaded on the portal.** The detailed timetable for the presentation should be communicated to the students.

3. The report should be prepared using the Times New Roman font (size 12) with 1 1/2 spacing leaving 1-inch margin on all sides producing approximately 29 lines per page. The report should be typed on one side of the paper and need not be bound in a hard cover binding. Figures and tables should be shown as a part of the running text. Each figure should be drawn inside a rectangular box of 12 cm width and 10 cm height. The figures must be sufficiently clear and hand-drawn figures will be acceptable. Particular care must be taken if a figure is photocopied from source. Each figure must have a sequence number and caption below. Each table must have a sequence number and title at the top.

4. Name of the student, title of the problem and year of the examination must be indicated on the top cover. THE NAME OF THE SUPERVISOR (ONLY INITIALS) MUST APPEAR ON THE BOTTOM RIGHT CORNER OF THE TOP COVER.

5. The report must be precise. All important aspects of the topic should be considered and reported. **The total number of pages, including tables, figures and references should not exceed 30.** Chapters or subsections need not begin on new pages, while getting the report typed.

6. Typographical errors in the report must be corrected by the student. The student will be discredited for any omission in the report. All the symbols used in the text should be arranged in an alphabetical order and given separately after conclusions.

7. The list of references should be arranged in alphabetical order of the names of authors. In the text, the reference should be cited with the author's name and year (author – year style). For example:

(i) The flow pattern in gas-liquid-solid fluidized bed has been reported in the published literature (Murooka et al., 1982).

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9. The time allotted for the oral presentation is 20 minutes: additional 10 minutes are provided for questions and answers.

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Course Outcomes (students will be able to…..)

1	Collect literature related to an assigned area	K1
2	Understand the lacunae in the literature	K2
3	Analyze the literature and present suitable guidelines	K4
4	Write a neat report following the guidelines	K2, K4
5	Propose a defined plan for the research	K6

List of Prerequisite Courses

1	Undergraduate seminar or design project	

List of courses where this course will be prerequisite

	Research Project II, III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course enables students to gather scientific information on a particular topic, analyze the information, present a written and oral summary on that topic, identify scope of work and plan experiments. This enables the students to function in a professional environment later on in their career.

Semester II

	Course Code: GTT2004	Course Title: Advances in Separation Processes	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the underlying principles in traditional separation techniques	K2
2	Analyze the performance of a separation technique	K4
3	Compare different separation processes and provide recommendations for the best choice	K5
4	Develop strategies for product separation in a chemical process	K6

	List of Prerequisite Courses	
1	Chemical Processes	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Several useful aspects of traditional separation processes, such distillation, extraction, adsorption, membrane separation and crystallization will be taught. Students will understand the importance of separation processes in a chemical plant.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Types of separation processes	2
2	Mass transfer and diffusion	2
3	Adsorption – adsorption equilibria, batch adsorption, kinetics of adsorption, adsorption in fixed beds, scale up of adsorption	6
4	Distillation – vapor-liquid equilibria, normal and fractional distillation, batch and continuous distillation, heat transfer in distillation, azeotropes and separation of azeotropes, extractive distillation, steam distillation, reactive distillation	9
5	Liquid-liquid extraction with ternary systems – theory, design and scale up	6
6	Chemical, physical and biochemical aspects of isolation and purification of bio-molecules, product release from biological cells	4
7	Design of downstream processing equipment, downstream process economics, super-critical extraction	4
8	Principles of separations through membranes – micro-filtration, ultra-filtration, reverse osmosis, pervaporation, selection of membranes, mechanism of fouling, design and scale-up of membrane equipment, electrophoresis and electro-dialysis	6
9	Precipitation, coagulation and flocculation, sedimentation	2
10	Crystallization, sublimation, drying	4

	List of Text Books	
1	Principles of Mass Transfer and Separation processes – B. K. Dutta	
2	Transport Processes and Unit Operations – Christie J. Geankoplis – Prentice Hall International	

	List of Additional Reading Material / Reference Books	
1	Separation Processes – C. J. King – McGraw Hill	

	Course Code: GTTXX	Course Title: Catalysis	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand different types of catalysts and their features and industrial applications	K2
2	Determine suitability of a catalyst for a given process	K3
3	Analyze catalytic features and characteristics	K4
4	Compare different catalysts and provide recommendations on the best choice	K5

	List of Prerequisite Courses	
	Applied Chemistry; Chemical Processes	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will teach basic concepts of catalysis – homogeneous and heterogeneous – and discuss industrially important catalytic processes.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Heterogeneous and homogeneous catalysis	1
2	Heterogeneous catalysis: Synthesis and characterization of solid catalysts	6
3	Adsorption and catalysis, adsorption isotherms, kinetics of catalytic reactions, Hougen-Watson and Eley Rideal mechanisms, promoter effects, catalyst deactivation and reuse, heterogeneous catalysts in industrial processes	6
4	Catalysis using solid acids and bases, zeolites, mesoporous materials and clay catalysts, shape selectivity, catalysis by metals and metal oxides, applications in bulk and fine chemical synthesis	6
5	Catalysis for environmental applications, photo-catalysis	2
6	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.	6
7	Carbonylation, hydroformylation, polymerization reactions, coupling reactions, alkene oligomerization, decarbonylation, asymmetric catalysis	6
8	Metal ligand multiple bonds	3
9	Organo-metallic complexes	3
10	Heterogenized homogeneous catalysts, phase-transfer catalysts, bio-catalysts	6

	List of Text Books	
1	Heterogeneous Catalysis in Practice – Charles N. Satterfield, McGraw-Hill	
2	Homogeneous Catalysis: Mechanisms and Industrial Applications – Sumit Bhaduri, Doble Mukesh	
3	Industrial Catalysis – A Practical Approach – Jens Hagen, Wiley-VCH	

	List of Additional Reading Material / Reference Books	
1	Catalyst Handbook – Martyn V. Twigg	

	Course Code: GTT2006	Course Title: Environmental Engineering and Pollution Control	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Identify pollutant sources, effects of contaminants and typical treatment levels	K1
2	Understand key features of existing and upcoming pollution control measures	K2
3	Compare treatment strategies and provide recommendations for the best option	K5
4	Formulate strategies for control of pollution and valorization of waste	K6

	List of Prerequisite Courses	
	Chemical Processes, Chemical Process Development and Engineering	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will provide useful information on industrial wastewater treatment, solid waste management, air pollution control, environmental impact assessment, life cycle analysis and relevant rules/regulations.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Environmental acts and regulations, quality standards, EHS management, ISO14000+	4
2	Environmental Impact Assessment, Life-cycle analysis	6
3	Water pollution – nature and types of water pollutants, sources of water pollutants, impact on environment and health	4
4	Industrial wastewater treatment, levels of treatment, classification of treatment processes, examples and case studies, removal of color, odor, NH_4-N and heavy metals, recovery of nutrients, nano-materials for wastewater treatment	6
5	Municipal solid waste management, waste-to-energy techniques, hazardous waste treatment	6
6	Air pollution – types of pollutants, sources and impacts, methods for prevention of air pollution, dispersion and sampling, plume behavior, emergency response to sudden leaks	10
7	Prevention of pollution in the chemical industry, waste valorization	6
8	Major environmental disasters, remedial measures	3

	List of Text Books	
1	Environmental Pollution Control Engineering – C. S. Rao, New Age International Publishers	
2	Environmental and Pollution Science – Mark Brusseau, Ian Pepper, Charles Gerba	

	List of Additional Reading Material / Reference Books	
1	Wastewater Engineering 4th Edition – Metcalf and Eddy Inc.	

	Course Code:	Course Title: Elective II	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0

Candidate will have to choose one elective subject offered for that semester. A consolidated list of all the elective subjects is given at the end.

	Course Code:	Course Title: Elective III	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0
Candidate will have to choose one elective subject offered for that semester. A consolidated list of all the elective subjects is given at the end.					

	Course Code:	Course Title: Elective IV	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 45	2	1	0
Candidate will have to choose one elective subject offered for that semester. A consolidated list of all the elective subjects is given at the end.					

	Course Code: GTP2103	Course Title: Research Project II	Credits = 6		
			L	T	P
	Semester: II	Total contact hours: 180	0	0	12
The research project, which was commenced during the 1st semester as Research Project I, will be continued further. Additional experiments will now be performed. Based on the results obtained thus far, the candidate shall submit a report (as per the guidelines provided in Research Project I) and make a presentation on the work done to the research supervisor and an external examiner from the Department/Industry. A suitable combination of the marks for report and presentation will be considered for the final evaluation. Candidate should also submit attendance record and laboratory journal (both signed by the research supervisor).					

Semester III & IV

	Course Code: GTPXX	Course Title: Research Project III	Credits = 24		
			L	T	P
	Semester: III	Total contact hours: 360	0	0	24
The research project will be continued further. Based on the work done during this semester, the candidate shall submit a report (as per the guidelines provided in Research Project I) and make a presentation on the work done to the research supervisor and an external examiner from the Department/Industry. A suitable combination of the marks for report and presentation will be considered for the final evaluation. Candidate should also submit attendance record and laboratory journal (both signed by the research supervisor).					

	Course Code: GTP2105	Course Title: Research, Thesis and Open Defence	Credits = 24		
			L	T	P
	Semester: IV	Total contact hours: 360	0	0	24
The research project will be continued further. At the end of this semester, the candidate shall write thesis (as per Institutional guidelines) and defend the work done in this thesis (Open Defence) by making a presentation to a Committee comprising the research supervisor, an external examiner from the Academia/Industry and another faculty member from the Department (as per Institutional guidelines). A suitable combination of the marks for thesis and presentation will be considered for the final evaluation. Candidate should also submit attendance record and laboratory journal (both signed by the research supervisor).					

Electives

	Course Code: GTT2101	Course Title: Cavitation for Green Processes	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the process intensification aspects for cavitational reactors	K1, K2
2	Predict cavitational intensities required for specific applications	K4
3	Apply the ultrasound reactors to greener processing	K3, K5
4	Understand the scale-up aspects	K2, K4
5	Design cavitational reactors for specific applications	K6

List of Prerequisite Courses		

List of courses where this course will be prerequisite		

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Application of ultrasound in green and energy efficient processes

	Course Contents (Topics and subtopics)	Reqd. hours
1	Introduction to cavitation, types of cavitation, sonochemistry, mechanisms of intensification	3
2	Theoretical aspects in terms of bubble dynamics, design aspects, prediction of cavitational intensity, reactions inside the bubbles	3
3	Cavitational reactor designs and effects of operating parameters	3
4	Applications of cavitational reactors in chemical processing such as synthesis, wastewater treatment, enzymatic reactions etc.	6
5	Applications of cavitational reactors in physical processing such as crystallization, atomization, emulsification, extraction, distillation	6
6	Applications of cavitational reactors in food processing applications	3
7	Possible combined routes for synergistic effects	3
8	Scale-up aspects	3
9	Case study, short review projects related to the above topics will be given in the tutorial hours	15

List of Text Books		
1	Applied Sonochemistry – T. J. Mason, J. P. Lorimer, Wiley VCH	
2	Handbook on Applications of Ultrasound – Sonochemistry for Sustainability – Dong Chen, Sanjay K Sharma, Ackmez Mudhoo, CRC Press	

List of Additional Reading Material / Reference Books		
1	Practical Sonochemistry – T. J. Mason and D Peters, Elsevier	

	Course Code: GTT2102	Course Title: Fuels Engineering	Credits = 45		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the difference between fossil-derived and alternative fuels	K2
2	Analyze the national and international energy scenario	K4
3	Evaluate various options in the path to clean energy transition	K5
4	Formulate strategies to integrate alternative fuels in the national energy basket	K6

	List of Prerequisite Courses	
1	Chemical Processes	

	List of courses where this course will be prerequisite	
	This course will be useful for advanced courses on clean energy transition in future.	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

A comprehensive discussion on fossil-derived transportation fuels, bio-fuels, other alternative/renewable fuels and fuel additives will be provided. The upcoming hydrogen economy and methanol economy will also be discussed.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Energy sources; classification of fuels; traditional and alternate fuels; properties of fuels	2
2	Gaseous fuels: Biogas, landfill gas, hydrogen, LPG, natural gas, CNG, LNG, gas hydrates, coal-bed methane and shale gas	8
3	Liquid fuels: Biofuels, bioethanol, biobutanol, biodiesel, green diesel, methanol and comparison with petroleum-derived fuels	8
4	Solid fuels: Biomass, plastic waste, municipal solid waste and comparison with coal	8
5	Bio-refineries; types and classification; examples; comparison with petroleum refineries	6
6	Carbon capture and utilization/storage; IGCC; Fisher-Tropsch synthesis; gas-to-liquids and coal-to-liquids etc.	5
7	Hydrogen economy; Methanol economy	2
8	Carbon credit; Cogeneration; Fuel cells	2
9	Combustion of fuels	2
10	Fuels and fuel additives from renewable resources	2

	List of Text Books	
1	Fundamentals of Petroleum Refining – Mohamed A. Fahim, Taher A. Alsahhaf and Amal Elkilani	
2	Biomass for Renewable Energy, Fuels, and Chemicals – Donald L. Klass	
3	Chemistry of Fossil Fuels and Biofuels – Harold H. Schobert	
4	Fuels and Combustion – Sameer Sarkar - University Press	
5	Alternative Fuels - S. S. Thipse – Jaico Publishing	

	List of Additional Reading Material / Reference Books	
1	Biofuels Engineering Process Technology – C. M. Drapcho, N. P. Nhuan, T. H. Walker	

	Course Code: GTT2103	Course Title: Nano-materials: Fundamentals and Applications	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Identify scope of nanotechnology and applications of nanomaterials	K1
2	Understand properties and features of nanomaterials	K2
3	Understand methods for the analysis of nanomaterials	K2
4	Evaluate techniques for the synthesis of nanomaterials	K5

	List of Prerequisite Courses	
1	Fundamentals of Green Chemistry and Technology	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will enable the students realize the importance of nanotechnology and its applications.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Introduction to the nano scale – historical development and scope	3
2	Unique properties of nano scale materials – micro structures, defects and dislocations, nano devices	6
3	Synthesis of nano materials – bottom up and top down approaches – vapor deposition methods, wet chemical methods – sol gel processes, mechanical methods	6
4	Metal and metal oxide nano particles – synthesis and stabilization - chemical methods, green synthesis of metal nano particles, metal nano particles stabilized by framework materials	6
5	Nano structured materials with applications – quantum dots, nano tubes, nano wires, nano crystals	4
6	Nano materials in catalysis and electro-catalysis	4
7	Nano composites- polymer and protein based nano composites	4
8	Characterization of nano materials – Structural, microstructural and micro-chemical analysis of nanomaterials using X-ray diffraction and electron microscopy	4
9	Nano structured materials with special applications	4
10	Toxicology and safety of nano materials – Environmental, ecological and health hazards of nanoparticles, nano-toxicology and its impact on environment	4

	List of Text Books
1	Textbook of Nanoscience and Nanotechnology – B. S. Murty, P. Shankar, Baldev Raj, 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
4	Nanotechnology: Fundamentals and Applications – Manasi Karkare

	List of Additional Reading Material / Reference Books
1	Nanostructures and Nanomaterials: Synthesis, Properties and Applications – G. Cao, Y. Wang
2	Handbook of Nanotechnology – Bharat Bhushan, Springer

	Course Code: GTTXX	Course Title: Intensification of Chemical Processes	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Identify the scope of process intensification in chemical engineering and green chemistry	K1
2	Understand basic PI concepts such as principles, domain, tools etc.	K2
3	Classify equipment and methods for process intensification	K4
4	Choose the best among separation process intensification technologies	K5

	List of Prerequisite Courses	
	Chemical Technology; Separation Processes	

	List of courses where this course will be prerequisite	
1	Process Optimization	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will provide in-depth insight into intensification of chemical processes and separation techniques.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Process Intensification (PI) – Why?	3
2	Principles of PI; Domains of PI; Toolbox for PI	6
3	Equipment for PI – Operations with / without chemical reactions: Static mixers, Rotating packed beds, Heat exchange reactors etc.	12
4	Methods for PI – Multifunctional reactors, Hybrid separations, Alternative energy sources, Other methods Reactive distillation, Reactive extraction, Membrane reactors Fuel cells, Ultrasound and Microwave, Supercritical fluids etc.	12
5	Separation Process Intensification Technologies – Examples and Applications Internally heat-integrated distillation, Dividing wall column, Cyclic distillation	12

	List of Text Books	
1	Process Intensification Technologies For Green Chemistry – Kamelia Boodhoo, Adam Harvey, Wiley	
2	The Fundamentals of Process Intensification - Andrzej Stankiewicz, Tom Van Gerven, Georgios Stefanidis, John Wiley & Sons	

	List of Additional Reading Material / Reference Books	
1	Re-Engineering the Chemical Processing Plant - Andrzej Stankiewicz, Jacob A. Moulijn, CRC Press	

	Course Code: GTT2105	Course Title: Renewable Energy Resources	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the categories of renewable energy resources and their relevance	K2
2	Analyze the advantages and challenges in the renewable energy sector	K4
3	Evaluate various options in the path to clean energy transition	K5
4	Formulate strategies to integrate renewables in the national energy basket	K6

	List of Prerequisite Courses	
1	Industrial & Engineering Chemistry	

	List of courses where this course will be prerequisite	
	This course will be apt for an advanced course on any renewable resources, viz. solar or wind etc.	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Several aspects of renewable energy resources, such as solar, wind, hydro-power, biomass etc. will be introduced to the students. Besides, the challenges ahead along the clean energy transition will be discussed.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Introduction to the link 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 the 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	8
3	Solar Energy: solar radiation - measurements and prediction; India'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	8
4	Wind Energy: Wind Resource; Meteorology of wind; India'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	8
5	Bioenergy: Biomass as energy resource; bio-energy potential and challenges - classification and estimation of biomass; Sources and characteristics of biofuels: Biodiesel, Bio-ethanol, Biogas; Types of biomass energy conversion systems; waste to energy conversions	8
6	Other renewable resources: Hydro-electricity; Geothermal; Tidal energy etc.	7

	List of Text Books	
1	Renewable Energy Sources and Emerging Technologies – D. P. Kothari, K. C. Singal, Rakesh Ranjan	
2	Non-Conventional Energy Sources – G. D. Rai	
3	Textbook of Renewable Energy (Woodhead Publishing India in Energy) – S. C. Bhatia, R. K. Gupta	

	List of Additional Reading Material / Reference Books	
1	Solar Photovoltaics: Fundamental Applications and Technologies – C. S. Solanki, Prentice-Hall	

	Course Code: GTT2106	Course Title: Green Biotechnology	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Identify green concepts in biotechnology	K1
2	Understand the scope of green biotechnology	K2
3	Understand the principles of green biotechnology in fermentation industry	K2
4	Evaluate methods for the design and scale-up of bio-reactors	K5

	List of Prerequisite Courses	
	Biochemical Engineering	

	List of courses where this course will be prerequisite	
	Advanced courses in applications of biotechnology	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Green aspects of biotechnology will be introduced to the students. The vast potential of green biotechnology and the key challenges will be elucidated.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Biotechnology, applications of green concepts in biotechnology	6
2	Genetic engineering, DNA recombinant technology, hybrid technology, single cell proteins, gene manufacturing	9
3	Fermentation, 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, case studies	12
4	Bioreactor design, scale-up of bio-reactors, downstream processing in the biochemical industry	9
5	Organic synthesis using supported microbes and enzymes Biopharmaceuticals; Bio-refineries and biotechnologies; Bio-inorganics	9

	List of Text 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	

	List of Additional Reading Material / Reference Books	

	Course Code: GTTXX	Course Title: Life Cycle Assessment	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the basic concept of life cycle assessment	K2
2	Apply LCA to process selection, design and optimization	K3
3	Analyze environmental systems	K4
4	Develop methodological framework for life cycle process design	K6

	List of Prerequisite Courses	
1	Fundamentals of Green Chemistry and Technology	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Life cycle assessment and its application to process selection, design and optimization will be taught in this course.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Introduction to Life Cycle Assessment (LCA)	4
2	Methodological framework for LCA	4
3	Stages in the life cycle of a product; Interactions between LCA stages	4
4	Environmental system analysis	5
5	Applications of LCA; Uses of LCA by the industry	6
6	LCA for process selection, design and optimization	8
7	Examples and case studies; LCA flow diagrams	8
8	General methodological framework for Life Cycle Process Design	6

	List of Text Books	
1	Life Cycle Sustainability Assessment for Decision-Making Methodologies and Case Studies - Edited by: Jingzheng Ren and Sara Toniolo	
2	New Frontiers on Life Cycle Assessment Theory and Application - Edited by Antonella Petrillo	
3	Life Cycle Assessment Theory and Practice - by Michael Z. Hauschild, Ralph K. Rosenbaum, Stig Irving Olsen	

	List of Additional Reading Material / Reference Books	
1	Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products – Mary Ann Curran	

	Course Code: GTTXX	Course Title: Membrane Technology	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Differentiate between several membrane technologies	K2
2	Apply basic principles to determine membrane performance	K3
3	Assess different membrane techniques and choose the best option for a given application	K5
4	Formulate an appropriate design strategy	K6

	List of Prerequisite Courses	
1	Basic course on separation techniques	

	List of courses where this course will be prerequisite	
1	Advanced course on the applications of membrane separations in the chemical industry	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

Students will learn basics of several membrane technologies, industrial applications and design considerations.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Membrane separation processes, preparation and characterization of membranes	4
2	Principles of reverse osmosis, nanofiltration, ultrafiltration, microfiltration	4
3	Transport through membranes, resistance models, concentration polarization and fouling	4
4	Membrane modules, arrangement of modules in cascades	4
5	Performance criteria and design considerations	6
6	Forward Osmosis, Gas separation, Pervaporation, Dialysis, Electrodialysis	4
7	Membrane reactors	4
8	Emulsion liquid membranes, Supported liquid membranes	4
9	Examples of applications: Desalination, CO_2 separation using membranes, Membranes in wastewater treatment	8
10	Recent advances in membrane technology	3

	List of Text Books	
1	Membrane Technology and Applications – R. W. Baker, John Wiley and Sons	
2	Basic Principles of Membrane Technology – M. Mulder, Springer	
3	Membrane and Desalination Technologies – Lawrence K. Wang, Jiaping Paul Chen, Yung-Tse Hung, Nazih K. Shammas, SpringerLink	

	List of Additional Reading Material / Reference Books	
1	Handbook of Industrial Membrane Technology – M. C. Porter, Noyes Publications	

	Course Code: GTT2109	Course Title: Instrumental Methods of Analysis	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Understand the basic principles of instrumental methods of analysis	K2
2	Determine the error in analytical measurements	K3
3	Assess various options for analysis and choose the best option	K5
4	Apply analytical procedures for specific applications	K3

	List of Prerequisite Courses	
	Any basic course on analytical chemistry	

	List of courses where this course will be prerequisite	
	Research Project III and Research, Thesis & Open Defence	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will ensure that students understand theory and operating principles of analytical instruments.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Analytical procedures; Good laboratory practices	5
2	Errors in analysis - systematic and random errors, statistical treatment of experimental results, least square method, correlation coefficients Sampling – basics and procedures, preparation of laboratory samples, t and F 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 determination	7
4	Instrumental methods – Criteria for selecting instrumental methods - precision, sensitivity, selectivity, and detection limit, transducers, sensors and detectors, signals and noise	8
5	Chromatographic methods of analysis – GC and HPLC – Principles, columns including chiral columns, detectors. Ion exchange chromatography, exclusion chromatography, gel permeation chromatography, HP-TLC	10
6	Atomic and molecular spectroscopic methods – AES, ICP-AES, flame photometry UV-Vis, FT-IR and NMR techniques in quantitative and qualitative analysis	10

	List of Text Books	
	Vogel's Textbook of Quantitative Chemical Analysis – John Wiley and Sons	

	List of Additional Reading Material / Reference Books	

	Course Code: GTT2110	Course Title: Colloid and Interfacial Phenomena	Credits = 3		
			L	T	P
	Semester:	Total contact hours: 45	2	1	0

	Course Outcomes (students will be able to…..)	
1	Describe basics of colloids and interfacial phenomena	K1
2	Discuss the characteristics of surfactants	K2
3	Understand the features of surface thermodynamics	K2
4	Analyze the performance of surfactants and disperse systems	K4

	List of Prerequisite Courses	
1	A basic course on adsorption and surface phenomena	

	List of courses where this course will be prerequisite	
1	Advanced course on interfacial science	

Description of relevance of this course in the M. Tech. (Green Tech.) Program

This course will introduce the students to colloids, interfacial phenomena and surfactants.

	Course Contents (Topics and subtopics)	Reqd. 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	6
2	Surface Thermodynamics: Surface thermodynamic properties, Kelvin equation, Gibbs adsorption isotherm and surface excess quantities, insoluble monolayers	8
3	Adsorption: Localized vs. Mobile adsorption, Adsorption isotherms – Langmuir, Freundlich, BET etc. (Adsorption from solution, electrical double layer models, adsorption at s/l and l/l interfaces)	8
4	Surfactants and surfactant aggregates - classification and synthesis of surfactants, bio-surfactants, surfactant biodegradability, surfactant aggregates – CMC – determination and factors affecting shape and size of aggregates, determination of HLB, models for micelle formation, swollen micelles, hydrotropy, solubilization in micelles: location of solubilizate in micelles, measurement of solubilization	9
5	Detergency and selective solubilization	6
6	Disperse systems – colloids and emulsions, stability of colloids, emulsions: micro and macro emulsions, stability of emulsions (mechanical vs. thermodynamic), Bancroft rule, de-emulsification, HLB for emulsion, multiple emulsions, applications, Foams: Gibbs triangle, film elasticity, drainage of films, foam, defoaming, applications of foam	8

	List of Text Books	
1	Foundations of Colloid Science – Robert J Hunter – Oxford University Press	
2	Surfactants and Interfacial Phenomena – Milton J Rosen, Joy T. Kunjappu, Wiley Interscience	
3	Surfaces, Interfaces and Colloids: Principles and Applications – Drew Myers, John Wiley and Sons	

	List of Additional Reading Material / Reference Books	