INSTITUTE OF CHEMICAL TECHNOLOGY
Ordinances, Regulations and Syllabi relating to the
Degree of Master of Technology in Green Technology (M. Tech. - Green Tech.)

1. Introduction

The Institute is revamping its academic structure especially for the masters courses by way of introducing the compulsory industrial training for a period of six months (to be taken in the third semester of the course). The number of credits in the first two semesters has also been increased and a research component has been included. The total credits in the first two semesters now stand at 27 each instead of earlier 21. All the courses will continue to be credit based and the evaluation will be grade based. The programme outcomes for M. Tech. (Green Technology) courses are as follows:

Programme Outcomes (POs)

Sr. No.	Graduate Attribute	Programme Outcomes (POs)
1	Engineering knowledge	They will attain knowledge in basic sciences engineering and technology to design and quantify processes and products
2	Problem analysis	They should be able to systematically analyze existing environmental and industrial problems pertaining to hazard and environment
3	Design & Development of Solutions	They will be able to design and develop green industrial Technologies
4	Investigation of Problem	They will be able to design and conduct experiments as well as analyze and interpret data.
5	Modern tools usage	The graduate will be able to use modern tools, software, equipment, modern analytical instruments to analyze and interpret data.
6	Engineer and society	They will be able to study the environmental impact of process industry on a global, economical and societal context
7	Environment & sustainability	They will become conscious of sustainability and environmental viability
8	Ethics	The are expected to practice basic ethics in their deliverance and achievement.
9	Individual & team work	They will learn to work with individuals across interdisciplinary areas of science engineering and technology
10	Communication	They will be able to articulate their views in assertive and effective manner.

11	Lifelong learning	They will remain environmental conscious and will also proliferate the importance of green and clean processes and products.
12	Project management & finance	They will be able to assess and budget their requirements for the attainment of a specific task.

Programme Specific Objectives

Sr. No.		Programme Outcomes (POs)
13	----	They will be aware of issues related to Resource management and sustainable development.
14	----	They will have enough knowledge and skill to pursue research in contemporary areas

Credit system is a systematic way of describing an educational programme by attaching credits to its components. The definition of credits may be based on different parameters, such as student workload, learning outcomes and contact hours. It is a student-centric system based on the **student workload** required to achieve the objectives of a programme. It should facilitate academic recognition of the courses and mobility of the students. Credits assignment is based on the principle that Credits can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved. As per the AICTE norms 2L/week of lectures are 2 credits, while 2h/week of practical/ /seminar/literature review/research work are 1 credit. This has been taken as the basis during the working of the proposed syllabus.

Student workload consists of the time required to complete all prescribed learning activities such as attendance at lectures/practical, seminars, projects, etc. Credits are allocated to all the educational components of a study programme and indicate the quantity of work each component requires to achieve its specific objectives.

Evaluation is an important component of any teaching-learning process. The Institute gives emphasis on continuous evaluation with considerable freedom to the teacher in deciding the mode of evaluation of the students. The performance of the student is documented by a **grade** at the end of the semester. The grading scale ranks the students on a statistical basis. Therefore, statistical data on student performance is a prerequisite for applying the grading system.

2. Course Credits

In general a certain quantum of work measured in terms of **credits** is laid down as the requirement for a particular degree. The student acquires credits by passing courses every semester, the amount of credit associated with a course being dependent upon the number of hours of instruction per week in that course.

There are mainly two types of courses in the Institute - lecture courses and laboratory courses. Lecture courses consist of lecture (L) and tutorial (T) hours. Laboratory courses consist of practical (P) hours. The credit (C) for a course is dependent on the number of hours of instruction per week in that course as given below:

1. 1 h/week of lecture (L) or tutorial (T) = 1 credit
2. 2 h/week of Practicals (P) = 1 credit

3. Credit (C) for a theory course = No. of hours of lectures per week + No. of hours of tutorials per week = L + T
4. Credits (C) for a Laboratory course/Seminar/research work = ½ x No. of hours per week

Credits will be assigned to in-plant training, seminar, projects and other mandatory course requirements also and these will be mentioned in the respective syllabi. There may be some non-credit requirements. A student is required to earn credits as mentioned in the syllabus.

3. Evaluation

3.1 The weightage of different modes of assessment shall be as under.

	In-Semester evaluation		End-Semester-Exam	Components of continuous mode
	Continuous mode	Mid Semester-Exam		
Theory	20%	30%	50%	Quizzes, class tests (open or closed book), home assignments, group assignments, *viva-voce* assignments, discussions
Practical	50%	-	50%	Attendance, *viva -voce*, journal, assignments, project, experiments, tests
Seminar/ Research work			100%	Continuous evaluation not applicable, End semester evaluation will be based on written report evaluation and presentation in front of the external examiner within the Department

3.2. In-Semester Evaluation:

(a) It is expected that the teacher would conduct at least two assessments (in any form as quizzes, tests, home work, group work etc) under the continuous mode in a Semester.

(b) The teacher will announce at the beginning of the respective course the method of conducting the tests under the continuous mode and the assignment of marks

(c) In-semester performance of all students should be displayed and sent to the academic office by the teacher at least 15 days before the end-semester examination.

(d) For the theory courses, there will be one mid-semester test for each course to be held as per the schedule fixed in the Academic Calendar.

(e) For mid-semester examinations in theory papers, duration of examination will be 1 hour for 3 credit courses and 2 hours for 4 credit courses

3.3. End-Semester examination:

a) The semester end examination will cover the full syllabus of the course and will be conducted as per the Institutional time table at the end of each semester.

b) For end-semester examinations in theory papers, duration of examination will be 1 hour for 3 credit courses and 2 hours for 4 credit courses
c) For the end semester evaluation of seminar/research work, student will be expected to submit a written report and also make a presentation. The evaluation will be based on the quality of the written report and presentation.

3.4 Passes and Fail

(a) The candidates who obtain 40% and more marks of the total marks of a subject head shall be deemed to have **passed** the respective subject head.

(b) The candidates who obtain marks less than 40% of the total marks of a subject head shall be deemed to have **failed** in the respective subject head **(Grade FF).**

3.5 Grades:

(a) The performance of a student shall be documented by a **Letter grade.** Each letter grade has a **Grade point** associated with it. The Grades and Grade points shall be assigned to each head of passing and both will be indicated in the mark-list of the semester examination.

(b) The total marks (in-semester + end-semester) of a candidate in a subject head are converted into a letter grade, based on the relative (and sometimes the absolute) performance of the student.

Letter Grade	**Grade Point**
AA	10
AB	9
BB	8
BC	7
CC	6.5
CD	6
DD	5.5
EE	5

(d) For granting class, a grade point of 6.0 and above will be considered equivalent to First class.

(c) The grades to be allotted in the case of students who fail or do not appear at the end-semester examination shall be as under:

Letter Grade	**Grade Point**	**Explanation**
FF	0	The candidate fails in subject head. The candidate will be allowed to take end-semester repeat or subsequent examinations as per rule.
XX		The candidate has not kept term for the subject head due to attendance less than requisite. Further see 3.5(g) below. In the above cases, the candidate has to repeat the respective course by paying the fees.
I	0	The candidate has kept term for the subject head, has taken all the internal examinations with satisfactory performance, but has failed to take the end-semester examination or repeat examination due to

		genuine reasons. The candidate will be allowed to take end-semester repeat or subsequent examinations as per rule.
FR	0	The candidate has exhausted all the permissible chances to clear the end-semester examinations. The candidate has to register for the respective semester again for all the subject heads or will be out of the respective degree course as per the rules.
DR	0	(i) The candidate hasn't participated in academic programme. (ii) The candidate has taken a drop for the subject head; - provided he/she intimates the same (i or ii) at least 7 days in advance of the commencement of the end-semester examination for the respective year.

(d) Grades **FF** and **I** are place-holders only and do not enter into CPI/SPI calculations directly. These grades get converted to one of the regular grades after the end-semester examination.

(e) A candidate with an **FR** grade is not eligible for any repeat examination in that course and has to re-register for that semester by paying the appropriate fees.

(f) **I** grade will not be continued beyond the permissible number of end-semester/repeat examinations.

(g) **'XX' Grade:** The grade **XX** in a course is awarded if – (i) candidate does not maintain the minimum 75% attendance in the Lecture/Tutorial/Practical classes, (ii) candidate receives less than 20% of the combined marks assigned for continuous assessment and mid-semester examination, and (iii) candidate indulges in a misconduct/uses unfair means in the examination, assignments, etc., of a nature serious enough to invite disciplinary action in the opinion of the teacher.

(**Note:** Award of the **XX** grade in the case of g(iii) above shall be done by Disciplinary Action Committee (DAC)).

(h) The names/roll numbers of students to be awarded the **XX** grade should be communicated by the teacher to the Academic office as per academic calendar before the last date of submission of the application for end-semester examination.

3.6. Awarding the grades

The grading scale ranks the students on a statistical basis on the basis of the overall performance of the students of a given class in the given subject head. Therefore, statistical data on students' performance is a prerequisite for applying the grading system. While assigning grades in a given subject head, it is essential to know the **average marks (AM)** obtained by the students *who have passed the subject head* and the **highest marks (HM)** obtained in the *same subject head*.

3.6.1. If the **average marks (AM)** obtained by the students *who have passed the subject head* is <60%, the interval AM shall be awarded grade CC and the other grades shall be decided as follows:

(i) AA, AB, BB, and BC grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

3.6.2. If the **average marks (AM)** obtained by the students *who have passed the subject head* is such that **60% ≤ AM < 70%,** the interval AM shall be awarded grade BC and the other grades shall be decided as follows:

(i) AA, AB, BB grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) CC, CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

3.6.3. If the **average marks (AM)** obtained by the students *who have passed the subject head* is **≥ 70%,** the interval AM shall be awarded grade BB and the other grades shall be decided as follows:

(i) AA and AB grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) BC CC, CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

4. SPI and CPI

(a) **Semester Performance Index (SPI):** The performance of a student in a semester is indicated by **Semester Performance Index (SPI),** which is a weighted average of the grade points obtained in all the courses taken by the student in the semester and scaled to a maximum of 10. (SPI is to be calculated upto two decimal places.)

A Semester Grade Point Average (SGPA) will be computed for each semester as follows:

$$\text{SGPA} = \frac{\left(\sum_{i=1}^{n} c_i g_i\right)}{\left(\sum_{i=1}^{n} c_i\right)}$$

where

'n' is the number of subjects for the semester,

'c_i' is the number of credits allotted to a particular subject, and

'g_i' is the grade-points awarded to the student for the subject based on his performance as per the above table.

SGPA will be rounded off to the second place of decimal and recorded as such.

(b) **Cumulative Performance Index (CPI):** An up to date assessment of the overall performance of a student from the time he entered the Institute is obtained by calculating **Cumulative Performance Index (CPI)** of a student. The CPI is weighted average of the grade points obtained in all the courses registered by the student since he entered the Institute. CPI is also calculated at the end of every semester (up to two decimal places). .

Starting from the first semester at the end of each semester (S), a Cumulative Grade Point Average (CGPA) will be computed as follows:

$$CGPA = \frac{\left(\sum_{i=1}^{m} c_i g_i\right)}{\left(\sum_{i=1}^{m} c_i\right)}$$

where

'm' is the total number of subjects from the first semester onwards up to and including the semester S,

'c_i' is the number of credits allotted to a particular subject, and

'g_i' is the grade-points awarded to the student for the subject based on his performance as per the above table.

CGPA will be rounded off to the second place of decimal and recorded as such.

(c) The CGPA, SGPA and the grades obtained in all the subjects in a semester will be communicated to every student at the end of every semester / beginning of the next semester.

(d) **When** a student gets the grade 'FF', or I' in any subject head during a semester, the SGPA and CGPA from that semester onwards will be tentatively calculated, taking only 'zero' grade point for each such 'FF' or 'I' grade. When the 'FF' grade(s) has / have been substituted by better grades after the repeat examination or subsequent semester examination, the SGPA and CGPA will be recomputed and recorded.

5. Repeat End-Semester Examination

5.1. For those candidates who fail in a subject head or are eligible for appearing at the repeat examination, **Repeat End-Semester Examination** will be conducted within one month from the declaration of the results of regular end-semester examination, as per **Regulation R.14**.

5.2. The marks obtained by candidates in the in-semester examinations (continuous assessment and periodic test) will be carried forward in such cases.

5.3. Grading the performance in the Repeat Examination: The grades will be assigned as per 3.5 and 3.6 above. However, for a candidate taking any repeat examination or subsequent regular semester examination or performance improvement examination shall be awarded **one grade lower** than that decided on the basis of the actual marks obtained; provided 'EE' grade obtained in such an examination shall remain 'EE'. For reference see the table below.

Grade obtained in repeat or subsequent end-semester examination	**Grade to be assigned**	**Grade point**
AA	AB	9.0
AB	BB	8.0
BB	BC	7.0
BC	CC	6.5
CC	CD	6.0
CD	DD	5.5
DD	EE	5.0
EE	EE	5.0

5.4. Revaluation of end-semester and repeat examination: Candidate's performance in these examinations will be displayed on proper notice board and after 3 days of such display the marks will be sent to the Academic Office. No revaluation of these examinations will be allowed.

6. Passing of a Semester examination

A candidate shall be declared as **'PASSED'** any semester examination if he/she has

(a) Cleared all heads of passing by securing grades EE or higher in all the heads;
(b) Passed all the heads of passing such as project, seminar, training, etc as per the rules;
(c) Satisfactorily completed all the mandatory requirements of the course;
(d) paid all the Institute dues;
(e) No case of indiscipline pending against him/her.

7. Eligibility for the Award of a Degree

A candidate shall be declared eligible for the award of a degree, if he/she has cleared all the semester examinations as given in (6) above.

8. Allowed to keep terms (ATKT)

8.1 A candidate who has I grade in one or more heads of passing of an odd semester of an academic year shall be allowed to keep terms for the respective even semester.

8.2. A candidate shall be allowed to keep terms for the subsequent academic year if he/she has FF or I grades in not more than two heads of passing from all the heads of passing of the two terms of the previous academic year taken together. Such a candidate shall be declared as **FAILED, ATKT**.

9. Repeating a course

9.1 A student is required to repeat the course of a subject head under the following situations:

(a) A student who gets an **XX, FR, or DR** grade in a course; or
(b) A student has exhausted all permissible chances to clear the subject head.

9.2 A candidate from first year who remains absent for the regular end-semester examination of a semester and the corresponding repeat examination for **ALL SUBJECTS** shall have to take fresh admission for the corresponding year; unless the candidate has dropped out / terminated from the course.

9.3 If a candidate at the Second, fails to pass any semester examination in not more than 4 consecutive examinations, including the repeat examinations, from the date of registering for the respective year, the candidate shall have to take readmission for the corresponding year again in which the failure has occurred, provided the course is not changed.

10. Improvement of performance

A candidate will be allowed to appear at the **entire examination** after the regular end-semester examination as per the respective rules to improve the performance. In such a case if the result of the examination repeated –

1. Is better than the previous one, the previous result shall be declared null and void; and

2. Is worse than the previous one, the result of the subsequent examination shall not be declared.
3. However, awarding of final grade will be made under the provision of sub clause 5.3 above.

11. Exit rules for poorly performing students

A candidate shall be excluded from a course under the following conditions:

(a) If he/she fails to pass any semester examination of the any year of the course in not more than four consecutive attempts (Examination conducted by Institute) from the date of joining the course.

(b) If he/she does not keep two consecutive terms without giving any reasonable justification (as prescribed by the institute) for doing so.

(c) If a candidate fails to fulfil all the requirements of his/her respective degree within the prescribed period from the date of taking admission to the course, the candidate shall be excluded from the course.

12. Miscellaneous

(a) Although CPI will be given in the Semester grade report, the final degree certificate will not mention any **Class** whatsoever.

(b) Not withstanding anything said above if a course is revised /restructured then transient provisions applicable at the time of revision /restructuring shall be applicable.

Syllabus Details for M. Tech. (Green Technology)

Semester I

No.	Contents	Course Code	Subjects	Hours/Week (L+T)	Marks	Credits
1.	Core I	GTT2001	Fundamentals of Green Chemistry and Technology	**(2+1)**	**50**	**3**
2.	Core II	GTT2002	Catalysis I	**(2+1)**	**50**	**3**
3.	Core III	GTT2003	Chemical Reaction Engineering	**(2+1)**	**50**	**3**
4.	Elective I		Elective I	**(2+1)**	**50**	**3**
5.	Elective II		Elective II	**(2+1)**	**50**	**3**
6.	Seminar & Critical Review		Seminar & Critical Review	**6**	**50**	**3**
7.	Practical	GTP2101	Green Chemistry Experiments	**6**	**50**	**3**
8.	Research I		Research Project	**12**	**100**	**6**
TOTAL				**39**	**450**	**27**

Semester II

No.	Contents	Course Code	Subjects	Hours/Week (L+T)	Marks	Credits
1.	Core IV	GTT2004	Advances in Separation Processes	**(2+1)**	**50**	**3**
2.	Core V	GTT2005	Catalysis II	**(2+1)**	**50**	**3**
3.	Core VI	GTT2006	Environmental Engineering & Pollution Control	**(2+1)**	**50**	**3**
4.	Elective III		Elective III	**(2+1)**	**50**	**3**
5.	Elective IV		Elective IV	**(2+1)**	**50**	**3**
6.	Research II		Research Project	**24**	**200**	**12**
TOTAL				**39**	**450**	**27**

Semester III

No.	Course	Hours/Week	Marks	Credits
1.	In-Plant Training (15 weeks)	**40**	**450**	**30**
TOTAL		**40**	**450**	**30**

Semester IV

No.	Course	Hours/Week	Marks	Credits
1.	Research, Thesis Submission & Open Defense	**40**	**450**	**30**
TOTAL		**40**	**450**	**30**

Evaluation for semesters III and IV will be conducted at the end of semester IV.

LIST OF ELECTIVES

No.	Subjects
1	Nano-materials - Fundamentals and Applications
2	Fuels Engineering
3	Biodegradable Materials for Biomedical Applications
4	Fuel Cell Technology and Sustainability
5	Membrane Technology for Pollution Abatement
6	Sono-chemistry for Sustainable Development
7	Colloid and Interfacial Phenomena
8	Renewable Energy Resources
9	Green Biotechnology
10	Instrumental Methods of Analysis
11	Development of Green Industrial Processes
12	Green Product Design
13	Biochemistry - A basic course
14	Organic Chemistry
15	Green Chemistry Experiments
16	Chiral Engineering

SEMESTER I

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core I	GTT2001	Fundamentals of Green Chemistry and Technology	3	50	(30+15)

	Syllabus	L+T
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 recycling Pollution – types, causes, effects and abatement	3 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,	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

Recommended Books

1. Green Chemistry – An introductory text - M. Lancaster, RSC
2. Green Chemistry Metrics - Alexi Lapkin and David Constable (Eds.), Wiley
3. Environmental chemistry - Stanley E Manahan, Lewis Publishers

Course Outcome

On completion of this course, students should be able to:

- Understand the relevance and context of green technology
- Understand the methodologies for sustainable processes with safe reagents and products

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core II	GTT2002	Catalysis I - Heterogeneous Catalysis and Photo-catalysis	3	50	(30+15)

	Syllabus	L+T
1	Types of catalysis: Heterogeneous and homogeneous catalysis, catalytic cycles, TON, TOF, energetic of catalysis	2
2	Synthesis of solid catalysts: synthesis of bulk and supported catalysts, skeletal metal catalysts, un-doped and doped semiconductor photo-catalysts	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 Eley-Rideal mechanisms of surface catalyzed reactions, heterogeneous 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. Applications 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 Heterogeneous catalysis – examples and case studies	3 3
7	Photo catalysis - principles , synthesis and applications in water splitting and environmental clean up	3

Recommended Books

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

Course Outcome

On completion of this course, students should be able to:

- Understand synthesis, characterization, activity and deactivation of heterogeneous catalysts

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core III	GTT2003	Chemical Reaction Engineering	3	50	(30+15)

	Syllabus	L+T
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
9	Choosing the right kind of reactor- objectives and variation of process parameters	2

Recommended 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

On completion of this course, students should be able to:

- Understand chemical reactions, chemical reactors
- Understand the process for design of chemical reactors

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Seminar & Critical Review		Seminar & Critical Review	3	50	6 h/week

	Syllabus	L+T

1. The work is concerned with a detailed and critical review of an area of interest to Green Technology. Typically, the report should contain and will be evaluated based on the following points:

(a) Introduction: 2 pages maximum
(b) Exhaustive review of literature (including figures): 10 – 12 pages: 50% Weightage
(c) Critical analysis of the literature and comments on the analysis Critical analysis should also contain quantitative comparison of observations, results, and conclusion amongst the various papers.

2. Two typed copies of the report on thesis size bond paper (297 mm x 210 mm) are to be submitted to Coordinator on **time to be decided by the coordinator.** The detailed timetable for the presentation would be communicated.

3. The report should be prepared using the Times Roman font (size 12) using 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 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 be started 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 author's name and year. (author – date style) For example:

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

OR

(ii) 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 of seminar 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 on any grounds whatsoever.

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

13. The Seminar 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.

The submitted report will be evaluated by the research guide and an external examiner from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.

Course Outcome

On completion of this course, students should be able to write scientific reports and manuscripts.

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Practical	GTP2101	Green Chemistry Experiments	3	50	6 h/week

	Syllabus	L+T
1	Laboratory experiments relevant to the green chemistry programme: (i) Synthesis and characterization of catalysts and nano-materials (ii) Product analysis by instrumental techniques (iii) Reactions in liquid/vapor phase at ambient and high pressure (iv) Wastewater analysis (v) Methods of water treatment (vi) Reactors for heterogeneous reactions	

Recommended Books

1. DST manual for experiments on green chemistry

Course Outcome

On completion of this course, students should be able to:

- Develop practical skills for performing research work

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
		Research Project I	6	100	12 h/week

Syllabus	L+T
The Research project I is concerned with detailed literature review of the assigned research area in consultation with the guide, developing an experimental/simulation protocol and initiate the actual research work. Based on the outcome, the candidate is expected to submit a report as per similar guidelines provided for Seminar above which will be evaluated by the research guide and an external examiner from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.	

SEMESTER II

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core IV	GTT2004	Advances in Separation Processes	3	50	(30+15)

	Syllabus	L+T
1	General methods of separation , thermodynamics of separation	2
2	Mass transfer and diffusion	2
3	Adsorption – adsorption equilibria, batch adsorption, kinetics of adsorption, adsorption in fixed beds, scale up of adsorption	3
4	Distillation - Vapor-liquid equilibria. Normal and fractional distillation, batch and continuous distillation, heat transfer in distillation. azeotropes and separation of azeotropes. Steam distillation, reactive distillation	5
5	Liquid-liquid extraction with ternary systems- theory, design and scale up	3
6	Chemical, physical and biochemical aspects of isolation and purification of bio-molecules, product release from biological cells.	3
7	Design of downstream processing equipment, downstream process economics, super critical extraction	2
8	Principle of separations through membranes - micro filtration, ultra-filtration. Reverse osmosis, selection of membranes, pre evaporation, mechanism of fouling design and scale-up of membrane equipments, electrophoresis and electro dialysis	3
9	Precipitation, coagulation, and flocculation, sedimentation and	3
10	Crystallization, sublimation, drying	4

Recommended 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 Outcome

On completion of this course, students should be able to:

- Understand the relevance and context of separation processes in green technology

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core V	GTT2005	Catalysis II	3	50	(30+15)

	Syllabus	L+T
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
2	Specific homogeneous catalytic reactions – carbonylation, hydroformylation, polymerization reactions	3
3	Coupling reactions - Suzuki coupling, Heck coupling and related cross coupling reactions	4
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
5	Metal ligand multiple bonds – carbenes and N heterocyclic carbenes	2
6	Asymmetric catalysis – chiral ligands and complexes, asymmetric hydrogenation and epoxidation	
7	Organometallic complexes – carbonyls – synthesis , binding mode and reactions, dioxygen and phosphane ligands , metallacenes and sandwich	3
8	Heterogenised homogeneous catalysts- synthesis, characterization and applications	2
9	Phase Transfer catalysis – basic concepts in phase transfer catalysis- basic steps in PTC, structural factors affecting the distribution of ions, phase transfer catalysts- quarternary salts, macrocyclic ligands, PEG and other soluble polymers, insoluble PTC	4
10	Biocatalysis – enzymes as catalysts – kinetics and mechanism of enzyme catalysis, inhibitor effects, immobilized enzymes as catalysts	3

Recommended Books

1. Phase transfer catalysis – Fundamentals, applications and industrial perspectives - Charles M Starks, Charles L Liotta, Mark Halern- Springer
2. Homogeneous 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

On completion of this course, students should be able to:

- Understand the importance of homogeneous catalysis in green technology

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Core VI	GTT2006	Environmental Engineering and Pollution Prevention	3	50	(30+15)

	Syllabus	L+T
1	Basic concepts- biotic and abiotic environment, Environmental acts and regulations, environment and public health, air quality standards, Environmental impact analysis	4
2	Water pollution – nature and types of water pollutants,-- organic and inorganic water pollutants	4
3	Water treatment- municipal sewage and industrial water treatment, Preliminary primary, secondary and tertiary treatment methods water reuse and recycling	4
4	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
5	Global atmosphere- green house gases, global warming, acid rain, ozone depletion and photochemical smog	4
6	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

Recommended Books

1. Introduction to environmental engineering - P. Aarne Veslind- Cenage learning
2. Environmental engineering - Joseph A. Salvato - wiley
3. Unit operations and processes in environmental engineering - Tom D Reynolds – PWS Publishing

Course Outcome

On completion of this course, students should be able to:

- Understand the relevance of environmental challenges
- Suggest possible solutions

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
		Research Project II	12	200	24 h/week

	Syllabus	L+T

The Research project II is concerned with actual research work of the assigned research area in consultation with the guide. Based on the outcome, the candidate is expected to submit a report as per similar guidelines provided for Seminar above which will be evaluated by the research guide and an external examiner from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.

FOLLOWING COURSES MAY BE OFFERED AS ELECTIVES

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2102	Fuels Engineering	3	50	(30+15)

	Syllabus	L+T
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, bio-ethanol, 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 cycle, Cogeneration (or combined heat and power) Carbon dioxide capture and its chemical recycling to fuels	5
7	Integrated gasification combined cycle (IGCC)	3

Recommended 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 Outcome

On completion of this course, students should be able to:

- Understand fuel classification, properties, production methods and recent advances
- Understand the importance of renewable energy
- Understand emerging concepts such as COGEN, CCS and IGCC

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2106	Green Biotechnology	3	50	(30+15)

	Syllabus	L+T
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 bio-reactions/reactors, Downstream processing in biochemical industry	6
5	Organic synthesis using supported microbes and enzymes. Biopharmaceuticals, bio-refinery and biotechnology, bio-inorganics	6

Recommended 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 Outcome

On completion of this course, students should be able to:

- Understand applications of biotechnology in green chemistry
- Understand recent advances in this subject

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2007	Industrial Safety and Hazard Analysis	3	50	(30+15)

	Syllabus	L+T
1	Introduction ISO standards with reference to chemical industry	4
2	Safety aspects pertaining to the design of chemical plants. Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiations	4
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.	3
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	

Recommended 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 Outcome

On completion of this course, students should be able to:

- Understand the relevance of safety in green technology

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2103	Nano-materials – Fundamentals and Applications	3	50	(30+15)

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

Recommended 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 Outcome

On completion of this course, students should be able to:

- Understand the relevance of nano-materials in green technology

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2105	Renewable Energy Resources	3	50	(30+15)

	Syllabus	L+T
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, Bio-ethanol, Biogas. Types of biomass energy conversion systems waste to energy conversions	6

Recommended 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

On completion of this course, students should be able to:

- Understand the importance and advantages of renewable energy resources

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2113	Biodegradable Materials for Biomedical Applications	3	50	(30+15)

	Syllabus	L+T
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	2
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

Recommended Books

1. Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine. 2nd ed. Burlington, MA: Academic Press

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2107	Fuel Cell Technology and Sustainability	3	50	(30+15)

	Syllabus	L+T
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 losses, 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

Recommended 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 Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2108	Membrane Technology for Pollution Abatement	3	50	(30+15)

	Syllabus	L+T
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

Recommended 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

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2101	Sono-chemistry for Sustainable Development	3	50	(30+15)

	Syllabus	L+T
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

Recommended 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

At the end of the course, the students would have understood the fundamentals of ultra sound and sono chemistry and the application of the same for energy intensive processes and in environmental protection

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2110	Colloid and Interfacial Phenomena	3	50	(30+15)

	Syllabus	L+T
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, BET etc., (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 aggregates- 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 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	5

Recommended 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 outcome

To understand colloid and interfacial phenomena and their applications in industry and daily life

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2109	Instrumental Methods of Analysis	3	50	(30+15)

	Syllabus	L+T
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	5

Course outcome

Understanding the handling, principle of modern analytical instruments

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2104	Analysis and Development of Green Industrial Processes	3	50	(30+15)

	Syllabus	L+T
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, Pharmaceuticals, Cement 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	

Recommended 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 Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2114	Green Product Design	3	50	(30+15)

	Syllabus	L+T
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

Recommended 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 Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2112	Biochemistry - A Basic Course	3	50	(30+15)

	Syllabus	L+T
1	**The Foundations of Biochemistry** Cellular, Foundations Chemical , physical 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	
7	**Lipids:** Structure, classification, characterization, metabolism	

Recommended Books

1. Principles of Biochemistry, Lehninger, 4th Edition
2. Bioorganic Chemistry, Dugas, H, Springer

Course outcome

To understand the basic principles of bio-chemistry and its applications

Course Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2111	Organic Chemistry	3	50	(30+15)

	Syllabus	L+T
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:** Stereo-descriptors, 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	6
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	

Recommended 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 Type	Course Code	Subject	Credit	Marks	Total Hours (L+T)
Elective	GTT2115	Chiral Engineering	3	50	(30+15)

	Syllabus	L+T
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	

Recommended 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

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