Program Name : **All Branches of Diploma in Engineering and Technology.**

Program Code : **CE/CR/CS/CH/CM/CO/IF/CW/DE/EJ/EN/EQ/ET/EX/IE/ MU/EE/EP/EU/IS/IC/AE/FG/ME/PG/PT/DC/TX/TC**

Semester : **Fifth**

Course Title : **Capstone Project – Planning**

Course Code : **22058**

1. RATIONALE

To develop "learning to learn" skill in the students so that they continue to acquire on their own new knowledge and skills from different 'on the job experiences' during their career in industry. An educational 'project' just does that and may be defined as ***'a purposeful student activity, planned, designed and performed by a student or group of students to solve/ complete the identified problem/task, which require students to integrate the various skills acquired over a period to accomplish higher level cognitive and affective domain outcomes and sometimes the psychomotor domain outcomes as well'***. Projects mainly serve this purpose of developing learning-to-learn skills with an aim to develop the following attributes in the students:

a) Initiative, confidence and ability to tackle new problems
b) Spirit of enquiry
c) Creativity and innovativeness
d) Planning and decision making skills
e) Ability to work in a team and to lead a team
f) Ability of self directed learning which is required for lifelong learning
g) Persistence (habit of not giving up quickly and trying different solutions in case of momentary failures, till success is achieved)
h) Resourcefulness
i) Habit of keeping proper records of events and to present a formal comprehensive report of their work.

(Rational should not contain attributes and these attributes are repeated in CO s therefore may be eliminated)

2. COMPETENCY

The course should be taught and implemented with the aim to develop the required course outcomes (COs) so that students will acquire following competency needed by the industry:

- **Plan innovative/creative solutions independently and/or collaboratively to integrate various competencies acquired during the semesters to solve/complete the identified problems/task/shortcomings faced by industry/user related to the concerned occupation.**

3. COURSE OUTCOMES (COs)

The following could be some of the major course outcomes depending upon the nature of the projects undertaken. However, in case of some projects few of the following course outcomes may not be applicable.

a) Write the problem/task specification in existing systems related to the occupation.
b) Select, collect and use required information/knowledge to solve the problem/complete the task.
c) Logically choose relevant possible solution(s).
d) Consider the ethical issues related to the project (if there are any).
e) Assess the impact of the project on society (if there is any).

f) Prepare 'project proposals' with action plan.
g) Communicate effectively and confidently as a member and leader of team.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
-	-	2	2	--	--	--	--	--	--	--	25@	10	25	10	50	20

@ - Internal Examination
Legends: L-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment

5. Capstones Project

One of the dictionary meaning is the 'crown' or the stone placed on top of the building structure like 'kalash on top of Temples and Mosques' or 'Cross on top of churches'. Capstone projects are culminating experiences in which students synthesize the competencies acquired over whole programme. In some cases they also integrate cross-disciplinary knowledge. Thus Capstone projects prepare students for entry into a career and can be described as a 'rite of passage' or 'minimal threshold' through which participants change their status from student to graduate. A capstone project therefore should serve as a synthesis — reflection and integration— to bridge the real-world preparatory experience to real life. Thus capstone project should have emphasis on integration, experiential learning, and real-world problem solving and hence these projects are very important for students. To develop the highly essential industry oriented skills and competencies in the students, the capstone projects are offered in the last two semesters to serve for following purposes:

a) Integrate the competencies acquired by the students in the previous and current semesters.
b) Provide opportunities for interdisciplinary work in tackling problems likely to be faced by them in industry which are exciting and challenging.

6. Capstone Project Planning

Students are supposed to find out a suitable project and prepare a detailed plan in fifth semester so that it can be executed smoothly in sixth semester. The main characteristic of any project whether small or big is that it requires simultaneous application of various types of skills in the different domains of learning. In the process of arriving at a particular solution, the student must be required to make a number of decisions after scrutiny of the information s/he has accumulated from experiments, analysis, survey and other sources.

The projects will have a detailed project proposal, which must be executed or implemented within the time allocated, simultaneously maintaining a project diary periodically monitored by the teacher. A detailed project report is to be prepared as project progresses, which has to be submitted after the project is over. Project diary will be assessed by teacher

During the guidance and supervision of the project work, teachers' should ensure that students acquire following ***learning outcomes*** (depending upon the nature of the project work some of these learning outcomes may not be applicable):

a) Identify the problems in the area related to their programme.
b) Identify the information suggesting the cause of the problem and possible solutions.
c) Assess the feasibility of different solutions and the financial implications.
d) Collect relevant data from different sources (books/internet/market/suppliers/experts etc. through surveys/interviews).

e) Prepare required drawings and detailed plan for execution of the work.
f) Prepare seminar presentations to present findings/features of the project.

During the guidance and supervision of the project work, teachers' should ensure that the given rubrics are observed

If students are able to acquire these *learning outcomes*, then they would be able to acquire the COs as discussed in section 3.

7. Scopes of Projects

Scope of the project work should be decided based on following criteria:

a) **Relation to diploma programme curriculum:**
b) **Abilities possessed by the group of students:**
c) **Resources Available:**
d) **Suggested Type of Capstone Projects**

In general, the projects that the students can take up could be of the following types;

i. Design projects
ii. Prototype (design, make, test and evaluate).
iii. Field works: This could include surveys, using equipment, charting data and information from visual observation and prepare a case study.
iv. Fabrication of some equipment/machine etc.
v. Construction of some structure.
vi. Application development using hardware/software.

The best practice is that teacher should guide students about the above factors to be considered for choosing the project and based on these factors students should do the ground work and identify the possible projects and teachers should work as only facilitator and Guide in final selection of the project title and its scope.

8. GUIDELINES FOR UNDERTAKING A PROJECT

The selection of the *Capstone Project title* must have emphasis to attain with respect to CO's , PO's and PSO's of the programme. The students will then work on the identified problem/task through a rigorous process of understanding and analyzing the problem, conducting a literature search, deriving and discussing under the supervision of project guide. The project team will prepare the **Project Proposal** with the following sub-titles:

a) Rationale (one page)
b) Introduction
c) Literature Survey
d) Problem Definition
e) Proposed Methodology of solving Identified problem
f) Resources and consumables required.
g) Action Plan (sequential list of activities with probable dates of completion)

Project Idea shall be approved by the teacher and HOD. The student will begin to maintain a dated Project Diary comprising of 15-20 pages for the whole semester. This diary should be assessed by teacher timely.

Suggested Project Activities to be performed in Semester V (Project Planning)

a) Finalization of project team and allocation of project guide
b) Identify project domain /area
c) Submission of Project Proposals/ Project Ideas by the project team
d) Finalization of Project Idea by project guide and HOD
e) Weekly interaction of project team and project guide
f) Project team should perform activities as mentioned in criteria no 8 and record in project diary (appendix D)
g) Before the end of semester V, Project team should prepare and submit Project Planning Report as mentioned in criteria no 9.

h) Project team should prepare and submit detailed schedule of Project Execution and Report writing of Semester VI in consultation with project guide.

9. Project Planning Report

At the end of fifth Semester, the student will prepare a Semester V ,**Project Planning Report** with the following sub-titles:

- Certificate (in the Format given in this document as annexure A)
- Acknowledgements
- Abstract (in one paragraph not more than 150 words)
- Content Page
- Chapter-1 Introduction and background of the Industry or User based Problem
- Chapter-2 Literature Survey for Problem Identification and Specification,
- Chapter-3 Proposed Detailed Methodology of solving the identified problem with action plan
- References and Bibliography

Note: The report should contain relevant diagrams and figures, charts.

10. ASSESSMENT OF CAPSTONE PROJECT – PLANNING

Like other courses, assessment of Project work also has two components, first is progressive assessment, while another is end of the term assessment. The faculty will undertake the progressive assessment to develop the COs in the students. They can give oral informal feedback about their performance and their interpersonal behaviour while guiding them on their project work every week. There will also be regular progressive assessment by the teacher as per the criteria no 12 and 13 on the basis of rubrics mentioned in **Appendix –C** and in the formats as shown in **Appendix-B** and also for the end-of-semester examination.

11. PROGRESSIVE ASSESSMENT (PA) GUIDELINES AND CRITERIA

The assessment of the students in the fifth semester Progressive Assessment (PA) for 25 marks is to be done based on following criteria.

S. No.	Criteria	Marks
1	**Problem Identification/Project Title**	**10**
2	**Industrial Survey and Literature Review**	
3	**Punctuality and overall contribution**	
4	**Project Diary**	
5	**Report writing including documentation.**	**10**
6	**Presentation**	**05**
	Total	**25**

12 END-SEMESTER-EXAMINATION (ESE) ASSESSENT CRITERIA

The assessment of the students in the fifth semester end-semester-examination (ESE) for 25 marks is to be done based on following criteria. This assessment shall be done by the HOD/Senior Faculty in the presence of Project guide.

S. No.	Criteria	Marks
1	**Report writing including documentation.**	**10**
2	**Presentation**	**15**
	Total	**25**

Annexure- A
CERTIFICATE

This is to certify that Mr./Ms.....

from (institute)..... having Enrolment No: .....

has completed ***Project Planning Report*** having title .....

Individually/ in a group consisting of..... Candidates under the guidance of the Faculty Guide.

Name & Signature of Guide.....

.Name & Signature of HOD: .....

Appendix–B
Evaluation Sheet (ESE)

for

Capstone Project Planning

Name of Student: .....Enrollment No.....

Name of Program..... **Semester:** .....

Course Title and Code:.....

Title of the Capstone Project: .....

A. POs addressed by the Capstone Project (Mention only those predominant POs)

a) .....
b) .....
c) .....
d) .....

B. COs addressed by the Capstone Project (Mention only those predominant POs)

a) .....
b) .....
c) .....
d) .....

C. Other learning outcomes achieved through this project

1. Unit Outcomes (Cognitive Domain)

a) .....
b) .....
c) .....
d) .....

2. Practical Outcomes (in Psychomotor Domain)

a).....
b) .....
c).....
d) .....

3. Affective Domain Outcomes

a) .....
b) .....
c) .....
d) .....

PROGRESSIVE ASSESSMENT (PA) Sheet			
S. No.	**Criteria**	**Max Marks**	**Marks Obtained**
1	**Problem Identification/Project Title**	**10**	
2	**Industrial Survey and Literature Review**		
3	**Punctuality and overall contribution**		
4	**Project Diary**		
5	**Report writing including documentation.**	**10**	
6	**Presentation**	**05**	
	Total	**25**	

Name and Signature of Project Guide:

Appendix–C

SUGGESTED RUBRIC FOR ASSESSMENT OF CAPSTONE PROJECT

S. No.	Characteristic to be assessed	Poor	Average	Good	Excellent
1	**Problem/Task Identification (Project Title)**	Relate to very few POs Scope of Problem not clear at all	i. Related to some POs ii. Scope of Problem/Task vague	i. Take care of at-least Three POs ii. Scope of Problem/task not very specific	i. Take care of more than three POs ii. Scope of problem/task very clear
2	**Literature Survey /Industrial Survey**	Not more than ten sources (primary and secondary), very old reference	At-least 10 relevant sources, at least 5 latest	At –least 15 relevant sources, most latest	About 20 relevant sources, most latest
3	**Project proposal**	Methods are not appropriate, All steps not mentioned, Design of prototype not started (if applicable).	Appropriate plan but not in much detail. Plan B for critical activities not mentioned. Time line is not developed. Design of Prototype is not complete. (if applicable)	Appropriate and detailed plan with Plan B for critical activities mentioned, but clarity is not there in methods, time line is given but not appropriate. Design of prototype is not detailed (if applicable)	Appropriate and detailed plan with Plan B for critical activities mentioned, clarity in methods with time line, Detailed design of prototype (if applicable)

S. No.	Characteristic to be assessed	Poor	Average	Good	Excellent
4	**Project Diary**	Entries for most weeks are missing. There is no proper sequence and details are not correct.	Entries for some weeks are missing, details are not appropriate, not signed regularly by the guide.	Entries were made every week but are not in detail. Signed and approved by guide every week	Entries were made every week in detail, signed and approved by guide every week
5	**Final Report Preparation**	Very short, poor quality sketches, Details about methods, material, precaution and conclusions omitted, some details are wrong	Detailed, correct and clear description of methods, materials, precautions and	Conclusions. Sufficient Graphic Description.	Very detailed, correct, clear description of methods, materials, precautions and conclusions. Enough tables, charts and sketches
6	**Presentation**	Major information is not included, information is not well organized .	Includes major information but not well organized and not presented well	Includes major information and well organized but not presented well	Well organized, includes major information ,well presented
7	**Question and Answer session**	Could not reply to considerable number of question.	Replied to considerable number of questions but not very properly	Replied properly to considerable number of question.	Replied to most of the questions properly

Appendix D
Suggestive Project Diary format

Week no:
Activities planned:
Activities Executed:
Reason for delay if any
Corrective measures adopted
Remark and Signature of the Guide

Program Name : **Diploma in Mechanical Engineering / Electrical Engineering Group / Chemical Engineering / Plastic Engineering**

Program Code : **ME / EE / EP / EU / CH / PS**

Semester : **Fifth**

Course Title : **Management**

Course Code : **22509**

1. RATIONALE

An engineer has to work in industry with human capital and machines. Therefore, managerial skills are essential for enhancing their employability and career growth. This course is therefore designed to provide the basic concepts in management principles, safety aspects and Industrial Acts.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Use relevant managerial skills for ensuring efficient and effective management.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Use basic management principles to execute daily activities.
b. Use principles of planning and organising for accomplishment of tasks.
c. Use principles of directing and controlling for implementing the plans.
d. Apply principles of safety management in all activities.
e. Understand various provisions of industrial acts.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory						Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	-	3	90 Min	70*#	28	30*	00	100	40	--	--	--	--	--	--

(*#) Online Theory Examination.

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the Cos.(#): Online examination*

***Legends:** L-Lecture; T – Tutorial/Teacher Guided Theory Practice; P - Practical; C – Credit, ESE - End Semester Examination; PA - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

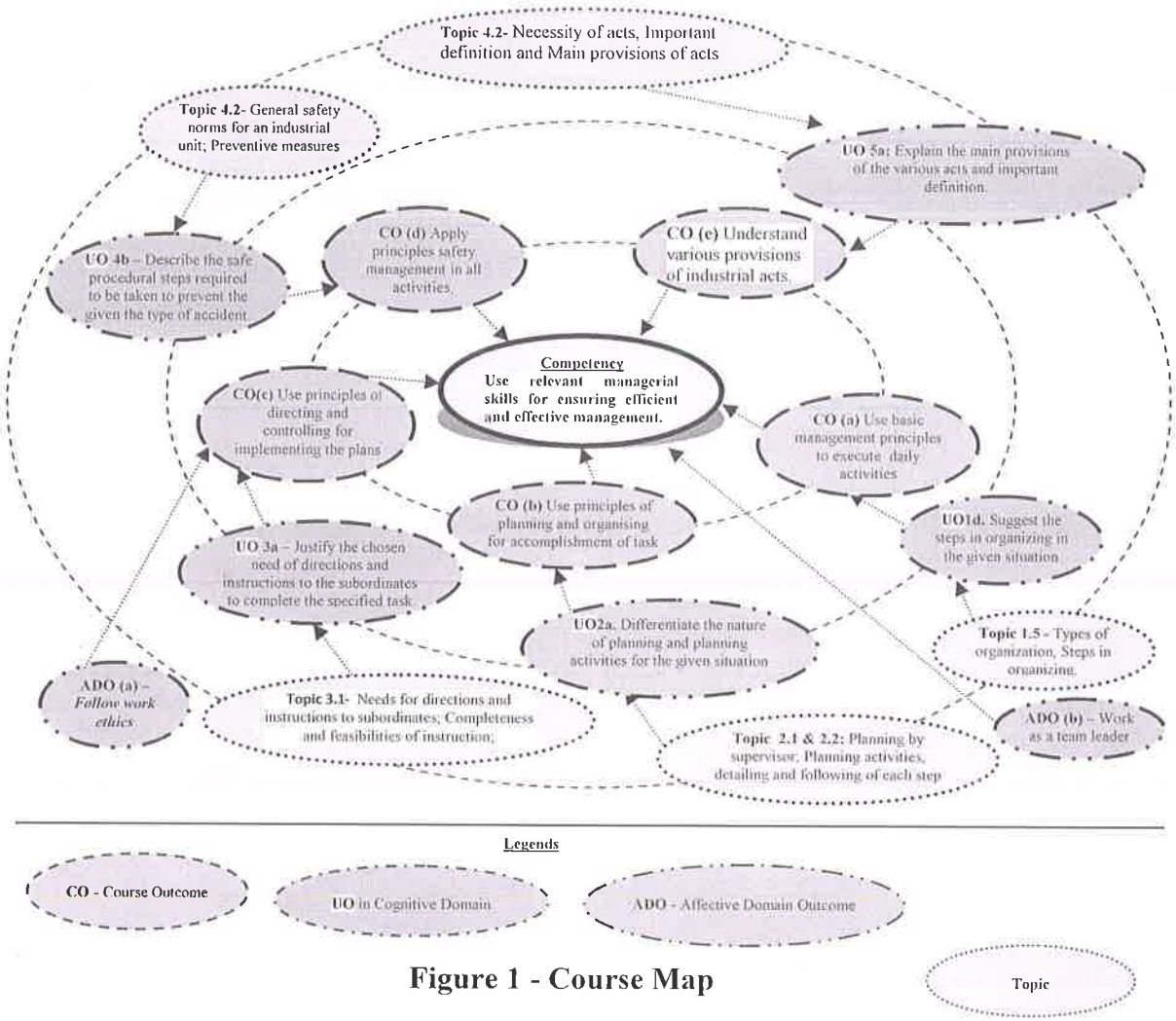

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

- Not applicable -

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

- Not applicable -

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Introduction to management concepts and managerial skills	1a. Differentiate the concept and principles of management for the given situation. 1b. Explain functions of management for given situation. 1c. Compare the features of the given types of planning 1d. Suggest the steps in organizing in the given situation. 1e. Suggest suitable type of organization for the given example. 1f. Identify the functional areas of management for the given situation 1g. Suggest suitable managerial skills for given situation with justification	1.1 Definitions of management, role and importance of management. 1.2 Management characteristics and principles, levels of management and their functions; management, administration and organization, relation between management and administration. 1.3 Functions of management: planning, organizing, leading/directing, staffing and controlling. 1.4 Types of planning and steps in planning 1.5 Types of organization, Steps in organizing 1.6 Functional areas of management. 1.7 Managerial skills.
Unit – II Planning and organizing at supervisory level	2a. Differentiate the nature of planning and planning activities for the given situation. 2b. Suggest the step wise procedure to complete the given activity in the shop floor. 2c. Prepare materials and manpower budget for the given production activity. 2d. Describe with block diagrams the organization of the physical resources required for the given situation. 2e. Describe the human needs to satisfy the job needs for the specified situation. 2f. List the tasks to be done by the concerned individuals for completing the given activity.	**Planning at supervisory level** 2.1 Planning by supervisor. 2.2 Planning activities, detailing and following of each step. 2.3 Prescribing standard forms for various activities. 2.4 Budgeting for materials and manpower. **Organizing at supervisory level** 2.5 Organizing the physical resources. 2.6 Matching human need with job needs. 2.7 Allotment of tasks to individuals and establishing relationship among persons working in a group
Unit– III Directing and Controlling at supervisory level	3a. Justify the chosen need of directions and instructions to the subordinates to complete the specified task. 3b. Select the feasible set of instructions to complete the given simple task, with justification 3c. Predict the possible mistakes for completing the given simple activity. 3d. Describe the managerial control	**Directing at supervisory level** 3.1 Needs for directions and instructions to subordinates; Completeness and feasibilities of instructions 3.2 Personal counselling advanced predictions of possible mistakes. 3.3 Elaborating decisions, laying disciplinary standards in overall working **Controlling at supervisory level**

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	actions and remedial measures required to be taken for completing the given task successfully.	3.4 Managerial control; Understanding team and link between various departments in respect of process and quality standards; Steps in control process 3.5 Controlling methods; Control over the performance in respect of quality, quantity of production, time and cost. Measuring performance, comparing with standards, correcting unfavorable deviations.
Unit – IV Safety Management	4a. State the general safety norms required to be taken in the given case. 4b. Suggest preventive measures of plant activities in the given situation. 4c. Describe the safe procedural steps required to be taken to prevent the given the type of accident. 4d. Prepare a work permit in to conduct the given maintenance activity. 4e. Explain the causes of the specified type of accident in the given situation. 4f. Prepare the specifications of the firefighting equipment required for the given type of fire.	4.1 Need for safety management measures 4.2 General safety norms for an industrial unit; Preventive measures. 4.3 Definition of accident, types of industrial accident; Causes of accidents; 4.4 Fire hazards; Fire drill. 4.5 Safety procedure 4.6 Work permits.
Unit – V Legislative Acts	5a. Explain the purpose of the act 5b. Explain the main provisions of the various acts and important definition.	5.1 Necessity of acts, Important definition and Main provisions of acts. 5.2 Industrial Acts: a. Indian Factory Act b. Industrial Dispute Act c. Workman Compensation Act d. Minimum Wages Act

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to management	12	06	06	04	16

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
	concepts and managerial skills					
II	Planning and organizing at supervisory level	08	04	06	04	14
III	Directing and controlling at supervisory level	08	04	06	04	14
IV	Safety Management	08	04	06	04	14
V	Legislative Acts	12	02	06	04	12
Total		**48**	**20**	**30**	**20**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Write assignments based on the theory taught in classrooms. Assignments consist of ten questions having long answers including charts, symbols, drawing, observations etc.
b. Prepare/Download information about various industrial acts.
c. Visit to any Manufacturing industry and prepare a report consisting of:
    i. Organization structure of the organization/ Dept.
    ii. Safety measures taken in organization.
    iii. Mechanism to handle the disputes.
    iv. Any specific observation you have noticed.
d. Give seminar on relevant topic.
e. Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.
f. Demonstrate students thoroughly before they start doing the practice.

g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. Study of management principles applied to a small scale industry.
b. Study of management principles applied to a medium scale industry.
c. Study of management principles applied to a large scale industry.
d. Prepare case studies of Safety measures followed in different types of organization.
e. Study of measures to be taken for ensuring cyber security.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Management and entrepreneurship	Veerabhadrappa, Havinal	New age international publishers, New Delhi, 2014: ISBN: 978-81-224-2602-1
2	Principles of management	Chaudhry omvir Singh prakash	New Age international publishers, 2012, New Delhi ISBN: 978-81-224-3039-4
3	Industrial Engineering and management	Dr. O. P. Khanna	Dhanpath ray and sons, New Delhi
4	Industrial Engineering and management	Banga and Sharma	Khanna Publication, New Delhi

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. https://www.versesolutions.com/
b. https://www.books.google.co.in/books?isbn=817758412X
c. https://www. www.educba.com › Courses › Business › Management

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Heat Transfer Operations**

Course Code : **22510**

1. RATIONALE

Chemical technologists work as Plant operator/process engineer in various process industries. The processes and operations involve the exchange of heat and need to calculate the amount of heat transferred. To operate a plant efficiently and economically, knowledge of heat transfer is essential. Moreover the handling and operation of heat transfer equipment also play an important role in energy saving. Proper selection of heat exchange equipment improves efficiency of the plant. By learning this subject they will be familiar with different modes of heat transfer and equipment used for it in Chemical industry.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Apply heat transfer principles for increased efficiency and energy saving in chemical industry.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a) Determine the rate of heat transfer by conduction.
b) Apply the concept of convection to operate heat exchangers.
c) Determine the amount of heat transfer by radiation.
d) Choose proper heat transfer equipment for various applications.
e) Calculate energy associated with evaporators.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends:* L-Lecture; T** – *Tutorial/Teacher Guided Theory Practice;* **P** - *Practical;* **C** – *Credit,* ***ESE - *End Semester Examination;* ***PA*** - *Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

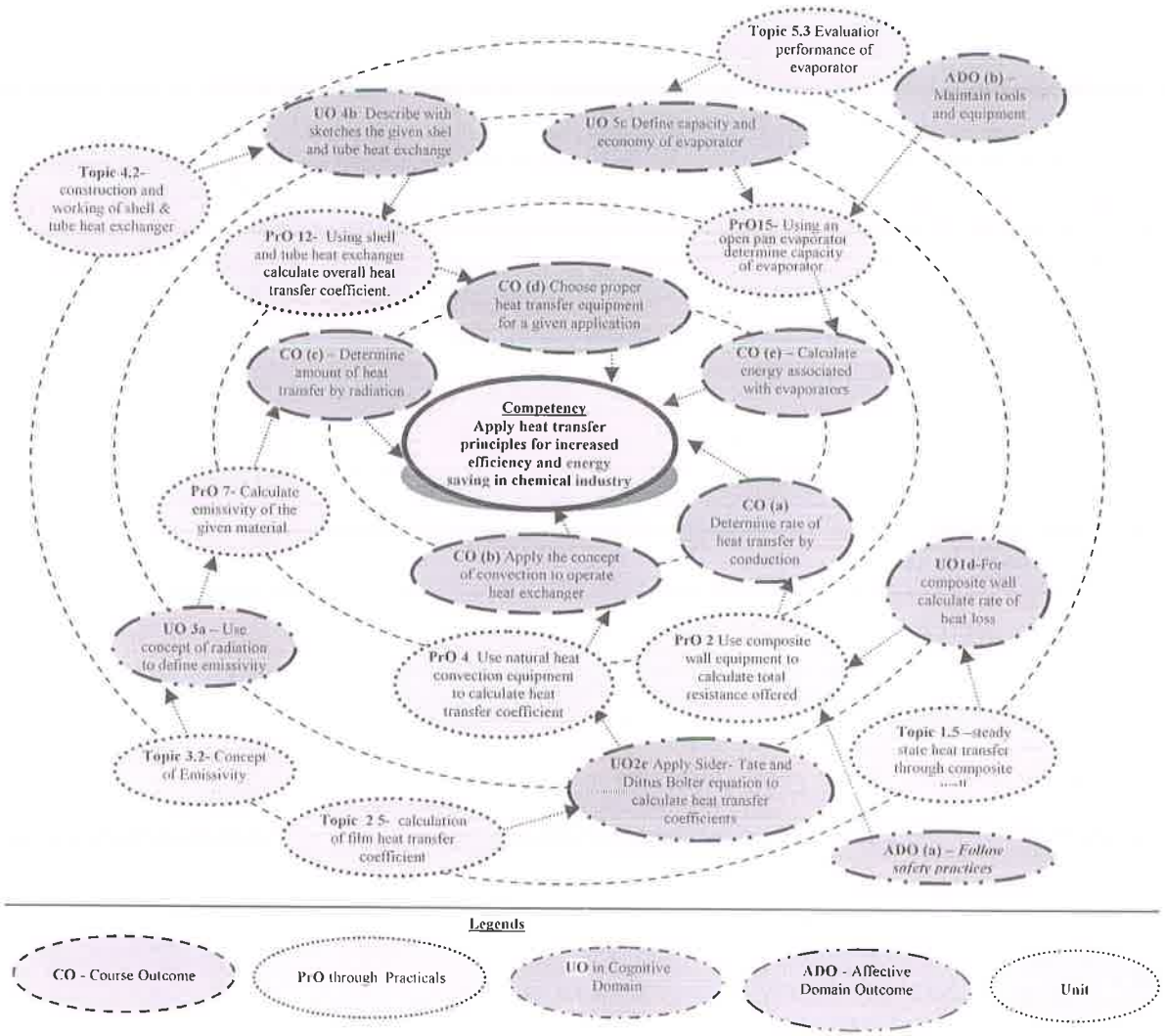

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Use thermal conductivity equipment consisting of solid metallic rod to calculate thermal conductivity.	I	04 *
2.	Use composite wall equipment to calculate total resistance offered by composite wall.	I	04
3.	Use composite wall equipment to calculate rate of heat loss through composite wall	I	04*
4.	Use natural heat convection equipment to calculate heat transfer	II	04*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	coefficient		
5.	Use forced heat convection equipment to calculate heat transfer coefficient.	II	04*
6.	Measure various parameter controlled in a heat exchanger using process simulator.	II	04*
7.	Calculate emissivity of the given material.	III	04*
8.	Use Stefan-Boltzman law apparatus determine Stefan-Boltzmann constant.	III	04*
9.	Using emissivity measurement apparatus compare the outside surface temperatures of black body and test plate	III	04
10.	Use double pipe heat exchanger calculate overall heat transfer coefficient for co-current flow.	IV	04*
11.	Use double pipe heat exchanger calculate overall heat transfer coefficient for counter-current flow.	IV	04*
12.	Use shell and tube heat exchanger calculate overall heat transfer coefficient.	IV	04*
13.	Use finned tube heat exchanger calculate overall heat transfer coefficient.	IV	04*
14.	Compare the values of Overall heat transfer coefficients for co current and counter current in any heat exchanger	IV	04
15.	Use open pan evaporator determine capacity of evaporator.	V	04*
16.	Use evaporator calculate overall heat transfer coefficient.	V	04
	Total		**64**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1.	Preparation of experimental set up	20
2.	Setting and operation	20
3.	Safety measures	10
4.	Observations and recording	10
5.	Interpretation of result and conclusion	20
6.	Answer to sample questions	10
7.	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1.1	Thermal conductivity equipment. material, Diameter of rod=0.028m , Length of rod = 0.2m, No. of thermocouples=4	1
1.2	Composite wall of three layers. Thermal conductivity of 1st layer =k1 , thermal conductivity of 2nd layer=k2 , thermal conductivity of 3rd layer=k3, thickness of 1st layer=0.02m , thickness of 2nd layer=0.01m , thickness of 3rd layer= 0.017m, Diameter of disc =0.18m, No. of thermocouples=8	2,3
1.3	Natural convection apparatus. Diameter of pipe =0.038m,length of pipe = 0.5m, duct size = 0.02m*0.02m*0.75m, no. of thermocouples=8	4
1.4	Forced convection apparatus. Inside diameter =0.026m,outer diameter= 0.033m, length of pipe =0.4m, diameter of orifice =0.016m, no. of thermocouples=6	5
1.5	PC with simulation software	6
1.6	Emissivity apparatus. Diameter of plate = 0.15 m, No. of thermocouples=4	7,9
1.7	Stefan-Boltzmann law apparatus	8
1.8	Double pipe heat exchanger. Outer pipe:D_0= 0.076 , Di= 0.068 Inner pipe: D_0= 0.043 , Di= 0.026, length of tube= 1.2m	10,11
1.9	Shell and tube heat exchange. Diameter of shell= 0.25m , No. of baffles =2, passes=1-2, Outer diameter of tube = 0.032m,Inner diameter of tube = 0.026m,No. of tubes=14, triangular pitch	12
1.10	Finned tube heat exchanger. Outer pipe:D_0= 0.075 , Di= 0.070 Inner pipe: D_0= 0.0225 , Di= 0.0205, , Area of fin =1m*0.012m*0.001m , Number of fins= 6, Tube length = 1m, diameter od orifice =0.03m, rotameter (2.5 to 25 lpm)	13
1.11	Open pan evaporator. pan volume = 1.5 lit ,	15
1.12	Calendria type evaporator: Shell diameter: 0.3m, height: 0.3m, S.S.304, 5mm thick sheet. Tube sheet: 10mm thick triangular pitch, inside diameter: 15mm o.d.: 17 to 18 mm, Number of tubes: 30 Downcomer: 75mm dia. Separator: height:0.45m, 5mm thick,	16

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Conduction	1a. Calculate the rate of heat transfer for the given process. 1b. Use concept of thermal conductivity to select relevant material of insulation for the given application with justification. 1c. Calculate rate of heat loss through the composite wall of the given thickness and specified material. 1d. Calculate rate of heat transfer when fluid is flowing through cylinder and sphere for given set of parameters.	1.1 Heat transfer- modes with industrial examples 1.2 Conduction-Fourier's law statement and mathematical expression, concept of thermal conductivity and its units 1.3 Examples of conductors and insulators commonly used in industry. Effect of temperature on thermal conductivity. 1.4 Concept of Steady state and unsteady heat transfer, thermal resistance 1.5 Steady state heat transfer by conduction through plain wall, composite wall, cylinder and sphere. 1.6 Characteristics of insulating materials and concept of optimum thickness of insulation.
Unit– II Convection	2a Apply Sider- Tate and Dittus Bolter equation to calculate heat transfer coefficients for the given application. 2b Draw temperature line diagram for the given co-current and counter current flow. 2c Calculate log mean temperature difference, area of heat transfer and rate of heat transfer for the given application. 2d Interpret the drawn boiling curve and for the given regimes in it.	2.1 Types of convection: 2.2 film heat transfer coefficient. 2.3 Relation between overall and individual heat transfer coefficients, effect of fouling. 2.4 Dimensional analysis for calculating film heat transfer coefficient using dimensionless numbers. 2.5 Sider - Tate and Dittus Bolter equations for calculating heat transfer coefficients in laminar and turbulent flow. 2.6 Co current and counter current flow: temperature line diagram 2.7 log mean temperature difference; Pool boiling of saturated liquid: definition, boiling curve 2.8 Condensation: Types, features
Unit III- Radiation	3a. Use concept of radiation to define absorptivity, emissivity, reflectivity, transmissivity, for the given type of body. 3b. Explain different laws of black body radiation. 3c. Calculate rate of heat transfer by radiation between two given surfaces.	3.1 Radiation: with industrial examples. 3.2 absorptivity, reflectivity, transmissivity, emissive power, monochromatic emissive power, emissivity and monochromatic emissivity of black body, grey body. 3.3 Kirchhoff's laws. 3.4 Laws of black body radiation: Stefan-Boltzmann law, Plank's law, Wien's displacement law, numerical. 3.5 Mathematical expression for rate of radiation between two surfaces.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit-IV Heat Exchangers	4a. Describe with sketches the given type of heat exchanger with labels. 4b. Explain with a labeled diagram of the given type of shell & tube heat exchanger. 4c. Describe with labeled sketches the construction of the given type of heat exchanger. 4d. Select the relevant heat exchanger for the given application with justification	4.1 Types of heat transfer equipment 4.2 Double pipe heat exchanger: construction, working, 4.3 Shell and tube heat exchanger: construction, types, guidelines for directing fluid. 4.4 Construction and working of different types of shell and tube heat exchangers (Fixed tube sheet, Floating head, U tube, Kettle/ Reboiler), 1-2 and 2-4 shell and tube heat exchangers. 4.5 Construction, working and application of Graphite block heat exchanger, plate type heat exchanger, and scrapped surface heat exchanger and finned tube (extended surface) heat exchanger.
Unit –V Evaporation	5a. Explain properties of solution and its effects on evaporation. 5b. Explain with sketches the method to improve economy of the given type of evaporator. 5c. Explain with sketches the feeding arrangements of the given type of evaporation system. 5d. Calculate area of evaporator in the given situation. 5e. Describe with sketches the construction of the given type of evaporator.	5.1 Evaporation: comparison of evaporation with drying. 5.2 Properties of solution that influences evaporation. 5.3 Evaluation of performance of evaporator: capacity and economy 5.4 Methods to improve economy of evaporators: multiple effect evaporator and vapour recompression. 5.5 Multiple effect evaporators- feeding arrangements diagram and comparison. 5.6 Material and enthalpy balance over single effect evaporator. 5.7 Construction, working and application of different types of evaporators (open pan, horizontal tube, short tube vertical/ Calendria, long tube vertical, forced circulation evaporator)

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Conduction	12	02	02	08	12
II	Convection	18	04	04	12	20
III	Radiation	6	02	02	04	8
IV	Heat exchangers	14	02	04	10	16
V	Evaporation	14	02	04	08	14
Total		**64**	**12**	**16**	**42**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare journals based on practical performed in laboratory.
b) Give seminar on relevant topic.
c) Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.
i) Demonstrate students thoroughly before they start doing the practice.
j) Encourage students to refer different websites to have deeper understanding of the subject.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) **Fabricate tube sheet**: Fabricate tube sheet with triangular pitch arrangement and square pitch arrangement.
b) **Prepare model**: Prepare a model of any one type of heat exchanger.
c) **Prepare model**: Prepare a model of any one type of evaporator.
d) Any other micro-projects suggested by subject faculty on similar line.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Introduction to Chemical Engineering	Badger W. L., Banchero J.T.	Mc Graw Hill Publication, New York, 2011, ISBN 9780074630501
2	Unit Operations of Chemical Engineering	Mc Cabe W. L. Smith	Mc Graw Hill Publication, New York, 2005, ISBN 97899339213237
3	Process heat transfer	D. Q. Kern	Mc Graw Hill Publication, New York, ISBN 978-0070341906
4	Heat and Mass transfer	Rajput R.K.	S. Chand and company , Ramnagar, New Delhi ISBN: 9788121926171
5	Chemical Engineering Design	Coulson J. M. and Richardson J.F.	Butterworth-Heinemann Publication, ISBN 9780750665384

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) https://byjus.com/chemistry/Heat-transfer
b) https://me-mechanicalengineering.com/modes-of-heat-transfer/amp/
c) https://www.che.utah.edu/undergraduate/projects_lab/equipmet/heat_conduction
d) https://engineeringoperation.blogspot.in/2010/08/conduction-heat-transfermechanism-and.html?m=1
e) https://www.thomasnet.com/articles/process-equipment/heat exchanger-types/

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Environmental Technology**

Course Code : **22511**

1. RATIONALE

Chemical technologists have to deal with Environmental Pollution and control in chemical process industries. They have to apply environmental science, environmental monitoring and electronic devices used for monitoring and analysis of environmental pollution generated by various sources. Information about the environmental Pollution and control methods may used to control air and water pollution. They have to undertake waste water treatment, solid waste management and environmental audit with ISO 14000. This course is designed to equip the students with necessary knowledge and skills related to the environmental pollution and control for effectively performing the job role.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Conserve environment using various pollution control measures.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Identify the source of global warming and ozone depletion.
b. Use relevant equipment for the control of air pollution in chemical process industry.
c. Test the different properties of waste water.
d. Use land fill and incineration methods for treatment of industrial solid waste.
e. Apply ISO14000 environmental protection norms for chemical industry.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

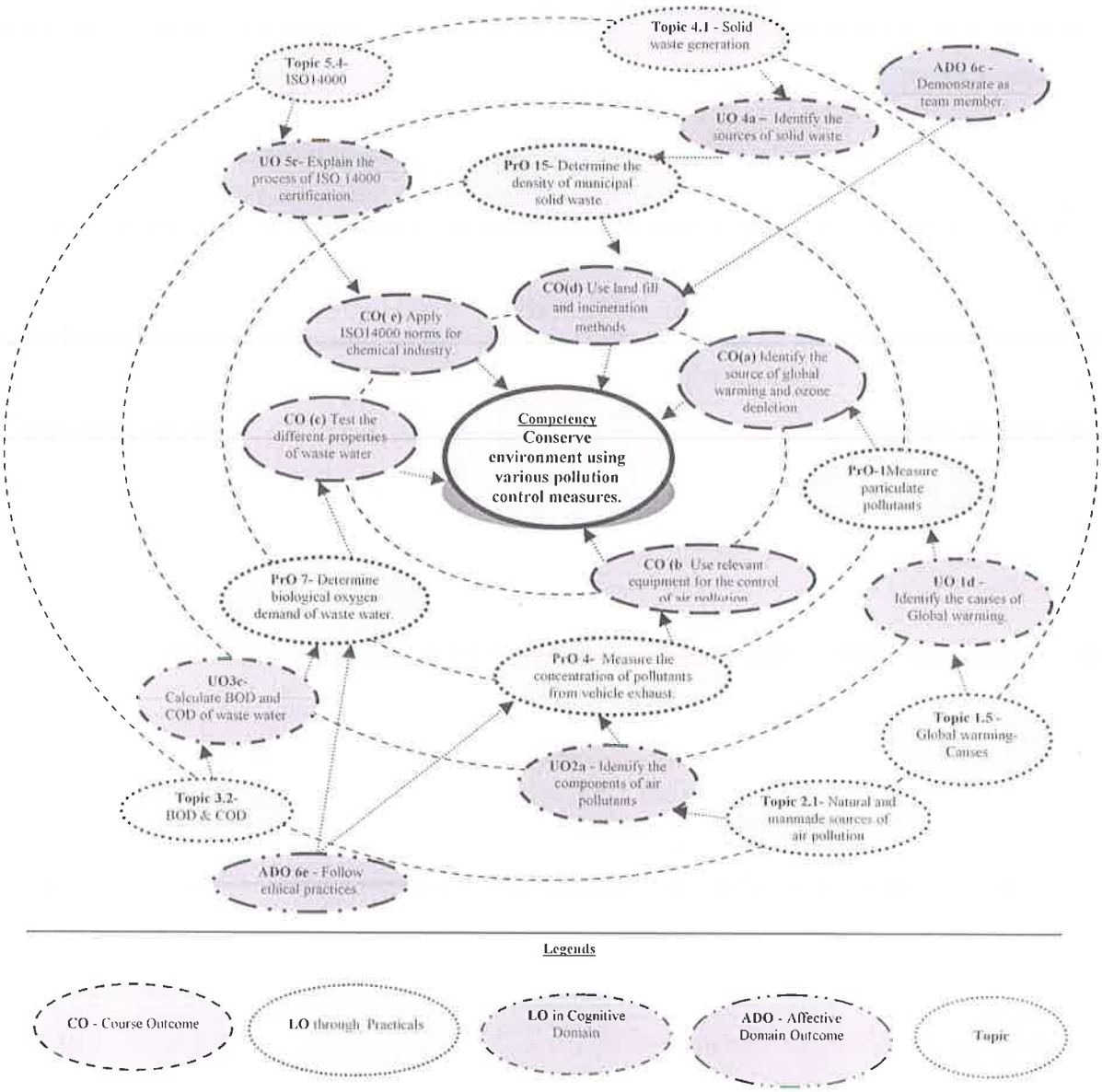

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals/exercises/tutorials in this section are psychomotor domain LOs (i.e.sub-components of the COs) are to be developed and assessed in the student to lead to the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Measure particulate pollutants using High Volume Sampler.	I	02
2	Determine the composition of flue gases using Orsat apparatus	I	02
3	Determine the total nitrogen content in waste water using Kjeldahl apparatus	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
4	Measure the concentration of pollutants from vehicle exhaust.	II	02
5	Determine the chloride content in waste water.	III	02
6	Determine the total solids in waste water.	III	02
7	Determine the dissolved oxygen in waste water.	III	02
8	Determine biological oxygen demand of waste water.	III	02
9	Determine the Chemical oxygen demand of waste water.	III	02
10	Determine the turbidity of waste water using turbidity meter.	III	02
11	Measure the appropriate dosage of alum for raw water using jar test method.	III	02
12	Determine the Sulphate content in waste water	III	02
13	Determine the neutralization point for charcoal treatment of acidic waste water.	III	02
14	Determine the strength of alkaline material in waste water using acid base titration.	III	02
15	Determine the density of municipal solid waste.	IV	02
16	Determine the density of hazardous waste.	IV	02
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 24 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and Recording	10
5	Interpretation of result and Conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs

according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

S. No.	Equipment Name with Broad Specifications	PrO. S.No.
1	High volume sampler Motor: 0.6 HP, Power: 6.25amp, 750W, Flow set point: 40SFCM, Mass flow control accuracy: +/-2.5% deviation(24 Hrs), Power source: 110 V 1 Phase, 60 HZ ,Weight: 61kg , For laboratory purpose	01
2	Orsat Apparatus: Three absorption pipette, Two compartment type, 100ml gas burette with outer jacket, manifold with stopcocks and aspirator bottle for the analysis of CO, O_2, CO_2 particularly in fuel and furnace gas. Wooden cabinet with sliding doors.	02
3	B.O.D. incubator: Chamber Volume: 285lit, Cu. Ft-10, Internal size: CMS-57X57 X 88, External size: CMS 70X85X166, Shelves-2: Range :+5°C to 60°C	07
4	C.O.D. digester: Multifunction dry bath fitting, Temperature control from ambient +5°C to 150°C with +1°C accuracy	08
5	Zeldal Apparatus	03
6	DO meter : Temperature range: -5°C to 55°C, Resolution: 0.1°C , Accuracy: +/-0.3°C, Range: 0 to 500%	09
7	PUC Kit Component — Range — Resolution CO — 0-15% — 0.01% CO2 — 0-19.9% — 0.1% HC — 0-20000ppm — 1 ppm O2 — 0-25% — 0.01% NOx — 0-5000ppm — 1 ppm Power Supply — 12V DC, 230VAC, Single Phase, 50-60Hz Power: 25W	04
8	Turbidity Meter: Range: 0-10000NTU, Principle: Nephelometric, Ratio: Full time ON or OFF, Accuracy +/- 2% of reading + 0.01NTU, Resolution: 0.0001NTU Response time <6sec, sample size: 30ml, light source :IR, temperature: 0°C to 50°C, Air purge: External dryer supply	11
9	Weighing Balance: Accuracy 0.1mg to 500gm	All Practicals
10	Stop Watch	
11	Desicator	07
12	Oven: Max Temperature 1000 °C, minimum Temperature +30 °C, Volume 28 to 128 Litres.	06
13	Reflux Condenser: 500ml flask with condenser assembly	08
14	Filter Paper	06
15	Heater	06, 07
16	Galssware: Burrete, Pippette, Conical Flask, Beaker, Measuring Cylinder, Specific gravity Bottle etc.	All experiment

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Unit – I Ecosystem	1a. Identify the components of Biotic and Abiotic system. 1b. Differentiate the Aquatic and Terrestrial ecosystem 1c. Identify the relevant chemical cycles in given Ecosystem 1d. Identify the causes of Global warming.	1.1 Structure of Ecosystem, Biotic and Abiotic components 1.2 Food Chain and Food web 1.3 Aquatic(Lentic and Lotic) and Terrestrial ecosystem 1.4 Carbon, Nitrogen, Sulphur, Phosphorus Cycle. 1.5 Global warming-Causes, effects, process, Green House Effect, Ozone depletion
Unit– II Air Pollution and Control	2a. Identify the components of air pollutants 2b. Apply relevant separator for air pollution control in chemical process industry. 2c. Apply the method for stack analysis for given system. 2d. Identify the effects of air pollution on human health.	2.1 Natural and manmade sources of air pollution, 2.2 Air Pollutants: Types, measurement of particulate pollutants, 2.3 Particulate Pollution control: Bag filter, Cyclone separator, Electrostatic Precipitator, Wet Scrubber 2.4 Gaseous Pollution Control: Absorber, Catalytic Converter, Thermal Incinerator(Flare), Stack Analysis 2.5 Air pollution and control in industries: Sulfuric Acid Plant, Nitric Acid Plant, Cement Plant 2.6 Effects of air pollution on human health
Unit– III Water Pollution And Control	3a. Identify sources of water pollution 3b. Identify the pollutants in waste water 3c. Calculate BOD and COD of waste water 3d. Apply the Bioreactor for given chemical system. 3e. Identify relevant method for treatment of given waste water.	3.1 Sources of water pollution, Types of water pollutants, Characteristics of water pollutants: Turbidity, pH, total suspended solids, total solids 3.2 BOD and COD: Definition, calculation 3.3 Waste Water Treatment: Primary methods: sedimentation, froth floatation, Secondary methods: Activated sludge treatment, Trickling filter, Bioreactor, Tertiary Method: Membrane separation technology, Application of RO in waste water treatment
Unit-IV Solid Waste Management	4a. Identify the sources of solid waste. 4b. Differentiate the various types of solid waste. 4c. Apply the principle of 3R	4.1 Solid waste generation 4.2 Sources and characteristics of : Municipal solid waste, Hazardous waste, Biomedical waste. 4.3 Collection and disposal : MSW(3R,

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
	4d. Apply the scientific method of sanitary landfill	principles, energy recovery, sanitary landfill), Hazardous waste, Biomedical waste 4.4 Love canal episode
Unit-V ISO 14000 and Environmental Management	5a. Apply the air and water pollution control act in given industry. 5b. Identify the role of different pollution control boards for given application. 5c. Explain the process of ISO 14000 certification. 5d. Apply various pollution control act for chemical industry.	5.1 Air quality act2004, air pollution control act 1981 and water pollution and control act1996. 5.2 Structure and role of Central and state pollution control board 5.3 Environmental management in industry 5.4 ISO14000: Implementation in industries, Benefits.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Ecosystem	10	04	04	04	12
II	Air Pollution and Control	11	06	06	06	18
III	Water Pollution and control	12	04	08	06	18
IV	Solid Waste Management	10	04	04	06	14
V	ISO14000and Environmental Management	05	02	04	02	08
Total		**48**	**20**	**26**	**24**	**70**

Legends: R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of LOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Following is the list of proposed student activities like:

a) List any five types of ecosystems near the institute.
b) Identify the possible air pollutants from your MIDC area/vehicle
c) Preparation of artificial waste water and suggest treatment method.
d) Visit to nearest water purification/Effluent treatment plant.
e) Prepare the chart of solid waste management showing effects on environment.

11. SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Use animations to demonstrate the various environmental pollution and control processes.
b) Use videos available on the internet to teach some topics.

c) Guide student(s) in undertaking micro-projects.
d) Give Mini projects to students.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Dust Fall Jar:** Construction and analysis of pollution trend in the selected area.
b. **Collection of Data from Internet :** Respiratory suspended particulate matter (RSPM) in various metro cities in India
c. **Fabrication:** Fabricate Sedimentation Tank in the laboratory.
d. **Effluent and Influent:** Collect information on Effluent and Influent composition of petrochemical industry.
e. **Sample collection:** Collect the sample from municipal solid waste.
f. **Identify Industry:** Identify and list the industries using the solid waste as raw material.
g. **ISO Implementation:** List and categorize the industries certified with ISO 14000 in India.
h. **Environmental Audit:** Prepare the sample document for environmental Audit of any Organization.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Waste Water Treatment for Pollution Control and Reuse	Arceivala, Soli Asolekar, Shyam	Mc-Graw Hill Education India. New Delhi, 2015, ISBN:978-07-062099-5
2	Environmental Engineering Science	Nazaroff, William Cohen, Lisa	Wiley, Newyork, 2000, ISBN 10: 0471144940
3	Environmental Pollution Control and Engineering	Rao, C. S.	New Age International Publication, New Delhi, 2015,, ISBN: 81-224-1835-X
4	Air Pollution	Rao, M. N. Rao, H.V.N.	Mc-Graw Hill Education India., New delhi, 1988, ISBN: 0-07-451871-8
5	Waste Water Engineering	Metcalf and Eddy	Mc-Graw Hill, 2013, ISBN:0077441208
6	Industrial Solid Waste	Patvardhan, A.D.	Teri Press, New Delhi, 2013 ISBN:978-81-7993-502-6

14. SOFTWARE/LEARNING WEBSITES

a) www.eco-prayer.org
b) www.teriin.org
c) www.cpcp.nic.in
d) www.cpcp.gov.in
e) www.indiaenvironmentportal.org.in
f) www.whatis.techtarget.com
g) www.sustainabledevelopment.un.org
h) www.conserve-energy-future.com

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Chemical Reaction Engineering**

Course Code : **22512**

1. RATIONALE

Chemical reaction engineering is that engineering activity concerned with the exploitation of chemical reactions on a commercial scale. Its goal is the successful design and operation of chemical reactors, and more than any other activity it sets chemical engineering apart as a distinct branch of the engineering profession. The knowledge of the subject helps in selecting the optimum reactor design for any process by taking into consideration the kinetics of the reaction, heat and mass transfer effects and economics of the process.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain chemical reactor operations to obtain quality products.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a. Maintain the kinetic parameters of various reactions.
b. Use the batch reactor data to determine the order of reactions.
c. Use the relevant parameters for the design of reactors.
d. Select suitable reactor for various applications.
e. Use proper catalyst for various chemical reactions.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	2	-	6	3	70	28	30*	00	100	40	--	--	--	--	--	--

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

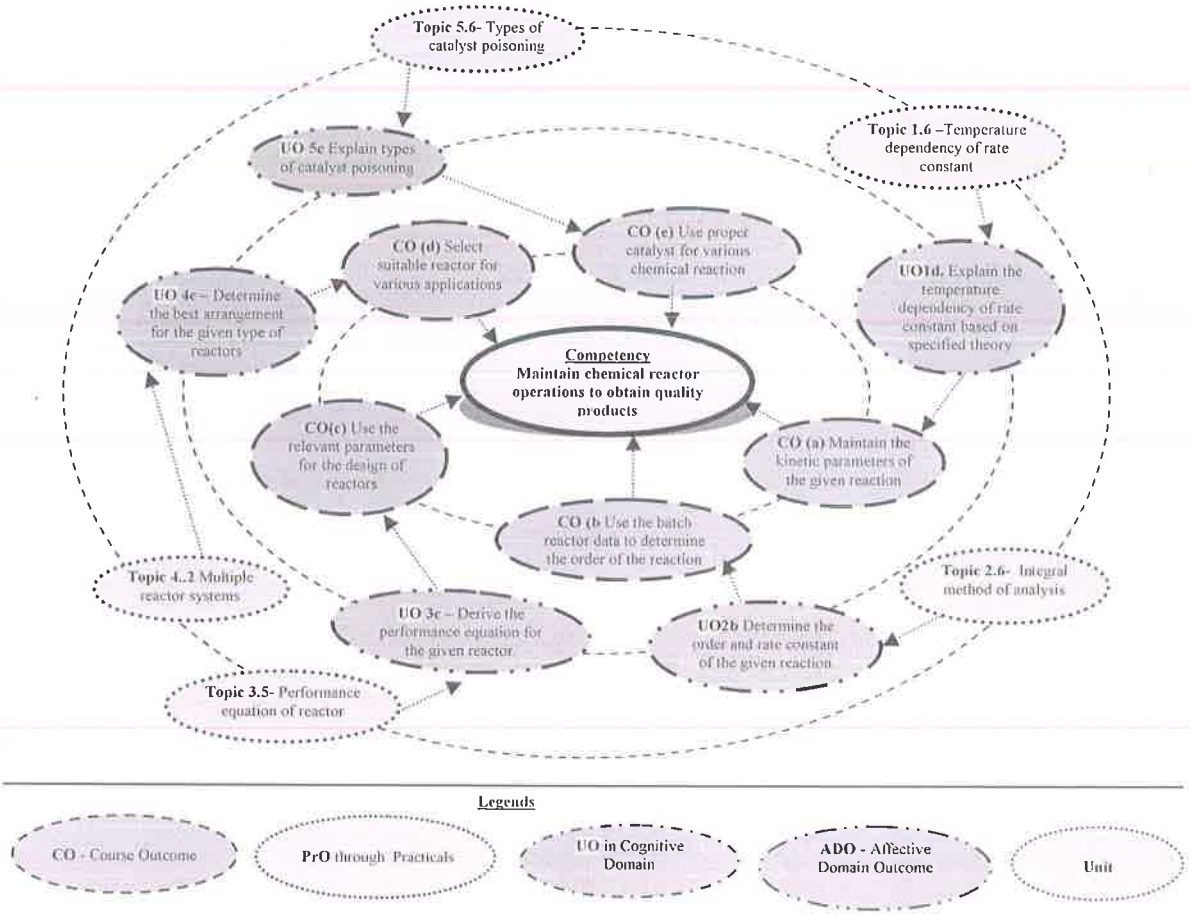

Figure 1 - Course Map

6. SUGGESTED TUTORIALS

The tutorials in this section which are subcomponents of the COs are to be developed and assessed in the student for the attainment of the competency.

S. No.	Tutorials	Unit No.	Approx. Hrs. Required
1.	Solve the problem based on Arrhenius law analytically	I	02
2.	Solve the problem based on Arrhenius law graphically	I	02
3.	Estimate the rate constant from the given data for first order and second order reaction.	II	02
4.	Estimate the time required to achieve a desired conversion from the given data for constant volume first order and second order reaction.	II	02
5.	Predict the order and rate constant of the reaction from the given concentration-time data	II	02
6.	Predict the order and rate constant of the reaction from the given conversion-time data,	II	02

S. No.	Tutorials	Unit No.	Approx. Hrs. Required
7.	Calculate ϵ_A for the given reactions	II	02
8.	Determine the order and rate constant of the reaction, based on half life method	II	02
9.	Given rate of reaction and concentration data, predict the order of the reaction	II	02
10.	Find out rate constant from the given data for variable volume system for the given problem.	II	02
11.	Determine the time required to achieve the desired outlet concentration in a batch reactor graphically.	III	02
12.	Estimate the volume of PFR required to achieve the desired conversion graphically for the given fractional conversion-rate of reaction data.	II!	02
13.	Estimate the volume of PFR required to achieve the desired outlet concentration graphically for the given concentration-rate of reaction data.	III	02
14.	Estimate the volume of MFR required to achieve the desired outlet concentration graphically for the given concentration-rate of reaction data.	III	02
15.	Compare the volume of MFR and PFR required to achieve a desired conversion from the given data.	IV	02
16.	Estimate the fraction of feed to be supplied to each branch for the given series-parallel arrangement of PFRs	IV	02
	Total		**32**

Note

A suggestive list of tutorials are given in the above table. More such tutorials can be added to attain the COs and competency. All the above listed tutorials need to be performed compulsorily, so that the student reaches the 'Applying Level' of Blooms's 'Cognitive Domain Taxonomy' as generally required by the industry.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

Not applicable

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Kinetics of homogeneous reactions	1a. Determine the reaction rate based on the specified parameter. 1b. List the variables affecting the rate of the given reaction. 1c. Describe the unit of rate constant for the given order of reaction.	1.1 Scope of Chemical reaction Engineering 1.2 Variables affecting the rate of reaction. 1.3 Reaction rate , Rate of reaction in various forms, rate equation, rate constant , units of rate constant, Concentration dependent term of rate equation 1.4 Types of Reactions: a. Homogeneous and Heterogeneous reaction b. Single and multiple reaction.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	1d. Explain the temperature dependency of rate constant based on the specified theory. 1e. Calculate the frequency factor and activation energy for the reaction using given data analytically and graphically.	c. Elementary and non-elementary reaction, d. Molecularity and Order of reaction, e. Chain and non chain reaction, f. Types of intermediates formed in non-elementary reactions. 1.5 Activation energy and its significance 1.6 Temperature dependent term of rate equation Temperature dependency of rate constant from- a. Arrhenius law b. Transition state theory c. Collision theory d. Comparison of different theories
Unit II- Interpretation of batch reactor data	2a. Derive the integrated rate expression for the given order reactions 2b. Determine the order and rate constant of the reaction from the given data. 2c. Give the value of slope of the graph plotted between concentration term and time for the given reaction. 2d. Estimate the time required to obtain the fractional conversion from the given data.	2.1 Constant volume batch reactor-Reaction rate 2.2 Analysis of total pressure data obtained in a constant volume system 2.3 Concept of fractional Conversion x_A 2.4 Methods for analyzing kinetic data General procedure for Integral method of analysis of data, general procedure for differential method of analysis of data, Method of isolation, method of initial rate, method of least square, method of excess 2.6 Integral method of analysis – Integrated rate expression for irreversible unimolecular first order reaction, irreversible bimolecular second order reaction of the type A + B –› Product and 2 A –›Product, nth order reaction, zero order reaction, autocatalytic reactions 2.7 Parallel and series reaction, Application of half life method for- Zero order, First order, Second order and nth order irreversible reactions. 2.8 Variable volume batch reactor, Concept of ϵ_A, Integral method of analysis based on variable volume system for zero order reaction, first order reaction and second order reaction.
Unit-III Introduction to reactor design	3a. Give the material balance equation for the specified reactor 3b. List the applications of any given reactor 3c. Derive the performance equation for the given reactor. 3d. Calculate the reactor volume for a specified conversion using the given data	3.1 Factors to be considered while designing a reactor, material balance equation for a reactor 3.2 Types of reactors- Batch reactor, Semi batch reactor, Continuous stirred tank reactor, Plug flow reactor . application of different reactors 3.3 Relation between C_A and X_A for constant density and changing density systems at constant temperature and pressure for batch system. 3.4 Performance equation for ideal batch reactor (constant and variable volume system) 3.5 Concept of space time and space velocity

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		3.6 Performance equation for Steady state (MFR) Mixed Flow Reactor (constant and variable volume system) 3.7 Performance equation for steady state (PFR) Plug Flow Reactor (constant and variable volume system), Holding time and space time for flow reactors
Unit –IV Design for single reactions	4a. Compare the specified types of reactors according to the given parameters. 4b. Compare the volume of MFR and PFR required for obtaining the given conversion of reactants. 4c. Determine the optimized arrangement for the given types of reactors for obtaining a specified conversion. 4d. Estimate the fraction of feed to be admitted to each branch when PFR's for the given parameters.	4.1 Size comparison of single reactors- Batch reactor v/s PFR, MFR v/s PFR 4.2 Multiple reactor systems- a. Plug Flow Reactors in Series and/or in Parallel, b. PFR's in parallel-series combination, c. Equal size MFR in series, d. MFR's of different size in series- i. Finding the conversion for a given system, ii. Determining the best system for a given conversion 4.3 Different types of reactors in series- Best Arrangement for set of Ideal Reactors
Unit-V Catalysis	5a. Describe the specified property required for any ideal catalyst. 5b. Explain the role of the given ingredient for the specified catalyst 5c. Explain the catalyst poisoning of the given type(s).	5.1 Nature of catalytic reactions, Important properties of catalyst- Specificity, activity, porous structure. 5.2 Promoters, accelerators and inhibitors. 5.3 Mechanism of solid catalyzed gas phase reactions. 5.4 Different methods of catalyst preparation- Precipitation, Gel formation, Simple mixing, Impregnation, Types of Catalyst poisoning –. Diffusion, Deposited, Stability, Selectivity, Sintering, Chemisorbed 5.5 Methods of Catalyst regeneration; Fluidized bed reactor; Packed bed reactor- concept of hot spot formation in packed bed reactor, application of the above reactors.

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Kinetics of homogeneous reactions	10	02	04	04	10

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
II	Interpretation of batch reactor data	20	02	04	14	20
III	Introduction to reactor design	14	02	04	10	16
IV	Design for single reactions	16	02	04	10	16
V	Catalysis	04	02	02	04	08
Total		**64**	**10**	**18**	**42**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare report on the reactors used in specific chemical processes.
b) Give seminar on relevant topic.
c) Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) **Prepare model**: Prepare a model of any given type of reactor .
b) **Prepare a report**: Prepare the report on the catalysts used in various processes(Minimum 5) and state its properties, poisoning, life and regeneration
c) **Prepare chart**: Prepare a chart of different promoters, inhibitors and accelerators used along with the catalyst in chemical reaction.
d) Any other micro-projects suggested by subject faculty on similar line.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Chemical Reaction Engineering	Octave Levenspiel	Wiley India, New Delhi, 2015 ISBN-978-81-265-1000-9
2	Elements of Chemical Reaction Engineering	H. Scott Fogler	Pearson New Delhi, 2015 ISBN 978-81-317-1430-0
3	Chemical Engineering Kinetics	J.M.Smith	Mc-Graw Hill New Delhi, 2015 ISBN 0-07-066574-5
4	Elements of Chemical Reaction Engineering	Srivastav R.P.S.	Khanna Pulblishers, New Delhi, 2015 ISBN 81-7409-083-5

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) www.quora.com
b) https://authors.library.caltech.edu
c) https://terpconnect.umd.edu
d) https://chem.libertexts.org>core>chem
e) www.thoughtco.com/types-of-chemical-reactions-604038
f) www.the-seventh-dimension.com>testlev
g) www.che.iitb.ac.in
h) www.acadenia.edu/12091631/Interretation_of_Batch_Reaction_Data
i) www.scibd.com/mobile/doc/33996988/3-Batch-reactor
j) www.che.utah.edu>~ring>Lecture_Ppts
k) https://archieve.org/details/AnintroductionToChemicalEngineeringKineticsReactorDesign
l) www.chemguide.co.uk/physical/catalysis/intoduction.html
m) www.britannica.com/science/catalysis


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Membrane Technology (Elective)**

Course Code : **22513**

1. RATIONALE

Chemical Technologists deal with the various separation processes. Separation of liquid from liquid, important operation in Chemical Engineering. Separation at ionic level and Nano level. Waste water treatment is another area, where membrane technology plays an important role. Design and development of membrane a new area, where chemical engineer can play important role. Various types of membrane and module are available in market to separate the compounds at ionic level. Purification of drinking water done all the way by membrane. Ultrafiltration, microfiltration, Nano filtration are various operations involved in membrane technology.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Use membrane technology principles for separation in Chemical Process.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Use the relevant membrane for various chemical processes.
b. Apply membrane technology in process industries.
c. Use appropriate method to reduce membrane fouling.
d. Apply concept of economics and feasibility to membrane technology.
e. Interpret concept of advance membrane technology and nanotechnology.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course; in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

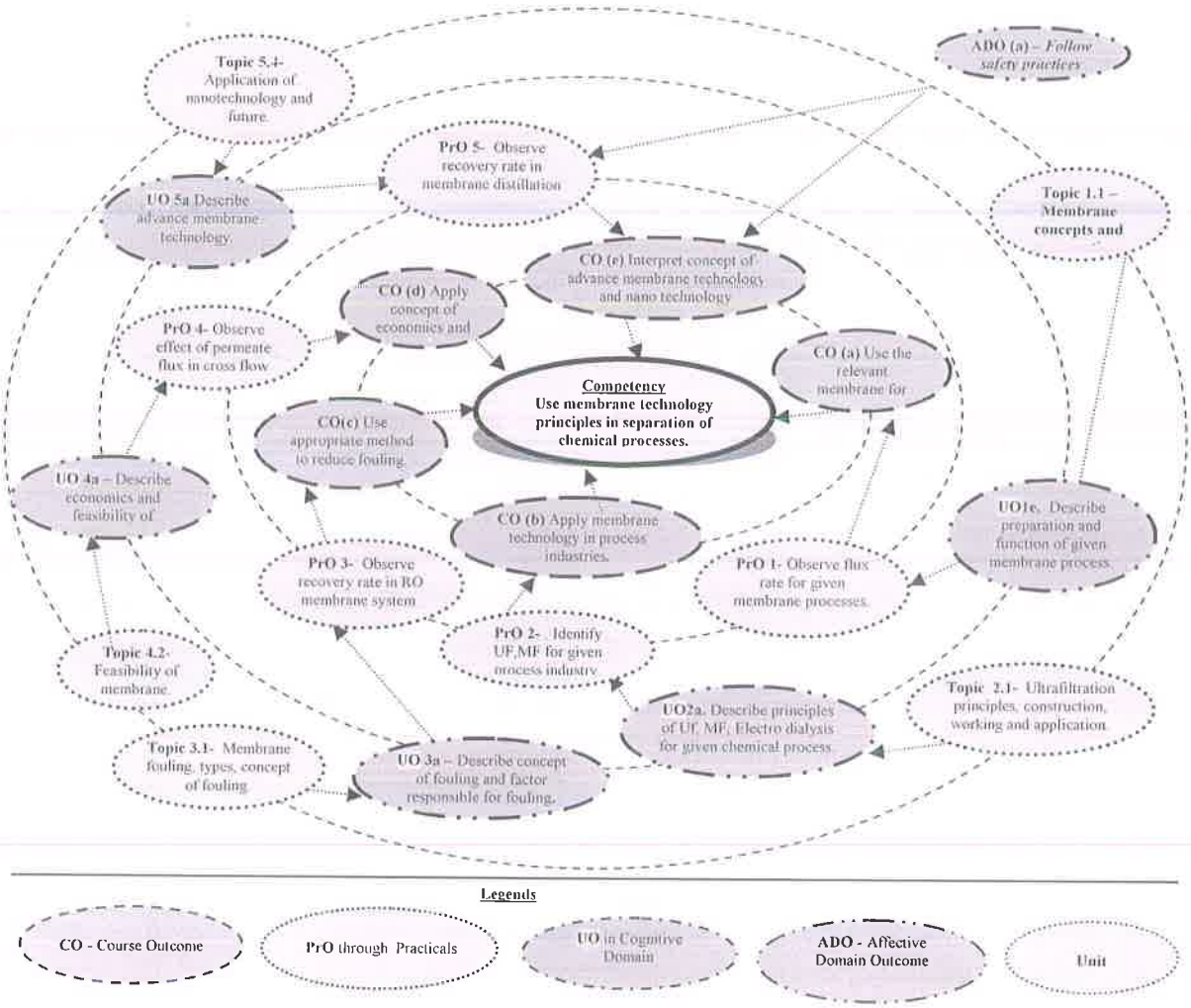

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Determine feed flux, retentate flux and permeate flux in RO.	I	02*
2.	Determine feed flux, retentate flux and permeate flux in NF.	II	02
3.	Determine feed flux, retentate flux and permeate flux in UF.	II	02*
4.	Determine feed flux, retentate flux and permeate flux in MF.	II	02*
5.	Determine feed flux, retentate flux and permeate flux in pervaporation.	III	02*
6.	Determine recovery rate in RO membrane system.	III	02*
7.	Determine retention, efficiency of membrane in RO membrane system.	III	02*
8.	Determine trans membrane pressure in UF membrane system.	III	02*
9.	Determine membrane permeability using different membrane.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
10.	Prepare membrane (polymeric, ceramic, composite or liquid)(Any one)	III	02
11.	Determine effect of permeate flux in dead end membrane process.	IV	02*
12.	Determine effect of permeate flux in cross flow membrane process.	IV	02
13.	Determine the recovery rate of permeate by using membrane distillation.	IV	02*
14.	Determine the recovery rate of permeate by using membrane bioreactor.	IV	02*
15.	Determine feed flux, retentate flux and permeate flux in pervaporation.	IV	02*
16.	Determine recovery rate in membrane bioreactor.	V	02
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1.	Selection of suitable component, apparatus/instrument	20
2.	Preparation of experimental set up	10
3.	Setting and operation	10
4.	Safety measures	10
5.	Observations and Recording	10
6.	Interpretation of result and Conclusion	20
7.	Answer to sample questions	10
8.	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year

- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	Pro.no.
1	UF test rig: Hallow fiber, UF model, provided with feed and backwash pump, compact and table top mounted.	3,8
2	Membrane Bioreactor: Submerged Hallow fiber MBR. Compact and table top mounted (Pump on ground)	4,14,16
3	Membrane Distillation: Hydrophobic membrane of composite membrane. Hallow fiber membrane module.	6
4	RO test rig: Membrane material Composite membrane (Polyamide) Permeate flux and MWCO characteristic study provided with high pressure pump. Compact and table top mounted (Pump on ground)	1,7
5	Pervaporation: 1 lit (consist of 2 half, 500 ml each). Glass flange vessel. ID 90 mm, OD 100 mm. Length 125 mm. SS 316 perforated membrane support plate Teflon gaskets.	5

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Introduction to Membrane.	1a. Describe the function of given membrane 1b. Identify preparation of membrane from given material. 1c. Explain with sketches the use of given type of membrane processes with sketches. 1d. Describe with sketches the working of given membrane module.	1.1 Membrane concepts, energy for membrane process. 1.2 Synthetic material (Hydrophobic and hydrophilic), Inorganic materials (oxides, metal,carbon, aluminosilicates), Advanced materials (Mixed matrix membrane, carbon nanomaterials). 1.3 Application of membrane in water treatment, pharmaceutical industry, chemical industry. 1.4 Plate and frame module, tubular module, Hollow fiber module, spiral wound module.
Unit– II Industrial Membrane processes.	2a. Describe with sketches principle of reverse osmosis for given process. 2b. Describe with sketches principle of ultra and microfiltration for given process. 2c. Describe with sketches principle of Micro filtration for given	2.1 Reverse osmosis principle, construction, working, application. 2.2 Ultrafiltration principle, construction, working, application. 2.3 Micro filtration principle, construction, working.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	process. 2d. Describe with sketches principle of dialysis and electro dialysis for given process.	application. 2.4 Dialysis, Electro dialysis principle, construction, working, application.
Unit– III Membrane Fouling	3a. Describe with sketches concept of fouling for given membrane. 3b. Identify factor responsible for fouling of given membrane. 3c. Describe with sketches mechanism of fouling for given membrane. 3d. Describe with sketches concept of bio fouling for given membrane	3.1 Membrane fouling, concept, types of fouling. 3.2 Factor responsible for fouling such as temperature, pressure, materials used for fouling, concentration of feed. 3.3 Mechanism involved effect of fouling, reversible, irreversible fouling. 3.4 Concept of bio fouling factor responsible for bio fouling, control of bio fouling.
Unit-IV Economics and feasibility of membrane technology.	4a. Describe economics of given membrane technology 4b. Describe feasibility of given membrane technology 4c. Compare given membrane technology with other separation methods 4d. Write scope of given membrane technology in future.	4.1 Economics of membrane, cost of membrane 4.2 Feasibility of membrane. 4.3 Compare membrane with conventional processes. 4.4 Scope of membrane, future to membrane technology.
Unit –V Advanced membrane technology and Nano technology.	5a. Describe with sketches given Ion exchange process. 5b. Describe with sketches given advance membrane technology. 5c. Describe with sketches given process of nanotechnology. 5d. Describe application, future scope of given nanotechnology process.	5.1 Concept of Ion exchange, cation, anion exchange resins, equipment available. 5.2 Membrane bioreactor, distillation principle, construction, working. 5.3 Concept of nanotechnology, nano scale materials, organic and inorganic nano structure. 5.4 Application of nanotechnology, future scope of nanotechnology.

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to membrane	10	02	06	04	12
II	Industrial Membrane Processes.	12	02	08	10	20
III	Membrane Fouling	08	04	04	04	12
IV	Economics and feasibility of membrane technology	08	02	04	04	10

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
V	Advanced membrane technology and nano technology.	10	04	06	06	16
	Total	48	**14**	**28**	**28**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) List different names and types of membrane material.
b) Identify membrane process for dehydration of ethanol.
c) List membrane module and draw any one of them.
d) Identify membrane material for desalination of water.
e) Identify the methods of cleaning of membrane.
f) List the factors which affect the performance of membrane.
g) Identify the formulae of TMP, recovery rate, rejection efficiency and water permeability of membrane.
h) List the advantages of membrane technology over conventional processes.
i) List types of bioreactor with diagram.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are

group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Preparation of model: Prepare working model of RO/UF/NF/MF.
b) Fabricate dead end membrane process in laboratory.
c) Collect the used membrane housing from market. Clean the housing and check water quality obtained from it. Prepare detail report.
d) Fabricate cross flow membrane process with membrane material used, membrane module used in laboratory.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Membrane technology and application	Baker, Richard W.	Wiley 2004, New Delhi, 2014 ISBN: 9780470020395
2	Basic principles of Membrane Technology	Mulder ,Marcel	Kluwer Academic Publisher 2014 ISBN:9780792309790s
3	Materials science of membranes for gas and vapour separarion.	Yampolskii, Y. I.pinnau, B.D. Freeman	Wiley Publication New Delhi, 2014 ISBN: 9780470853450
4	Membrane Technology and application	Baker, R.	John Wiley and Sons New Delhi, 2014 ISBN:9780470743720
5	Membrane and desalination technology	Wang, K. and J P chen	Humana Press ISBN: 9781597452786
6	Handbook of industrial membrane technology	Porter, M. C.	Noyes Publications Springers ISBN: 9780815517559 ISBN: 9780815512059
7	Membrane Handbook	Ho, W. S. K.K. Sirkar	Kluver Academic Publishers ISBN:0781461535485

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) https://en.wikipedia.org/wiki/Membrane_technology
b) https://www.journals.elsevier.com/membrane-technology.
c) http://gpcb.gov.in/images/pdf/ZLD_PRESENTATION_8.PDF
d) https://www.appliedmembranes.com/ultrafiltration-membranes-uf-membranes.htm
e) https://www.nano.gov/nanotech-101/what/definition
f) https://en.wikipedia.org/wiki/Nanotechnology


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Renewable Energy Technologies (Elective)**

Course Code : **22514**

1. RATIONALE

Chemical technologists have to deal with various process and operations which deals with various sources of energy to be used to carried out the process. As there is limitations to non renewable energy sources in the universe the alternative is only renewable energy. This course will give knowledge of technologies related to renewable energy like wind, solar, biomass and fuel cell where chemical engineering principles and products will be applicable.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Use renewable energy technologies as applicable in chemical industry.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a. Use wind power technologies wherever feasible
b. Use solar power technologies wherever feasible.
c. Use solid biomass power technologies wherever feasible.
d. Use liquid biomass power technologies wherever feasible
e. Use microhydro power technologies wherever feasible.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA; Out of 30 marks, 10 marks of theory PA are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

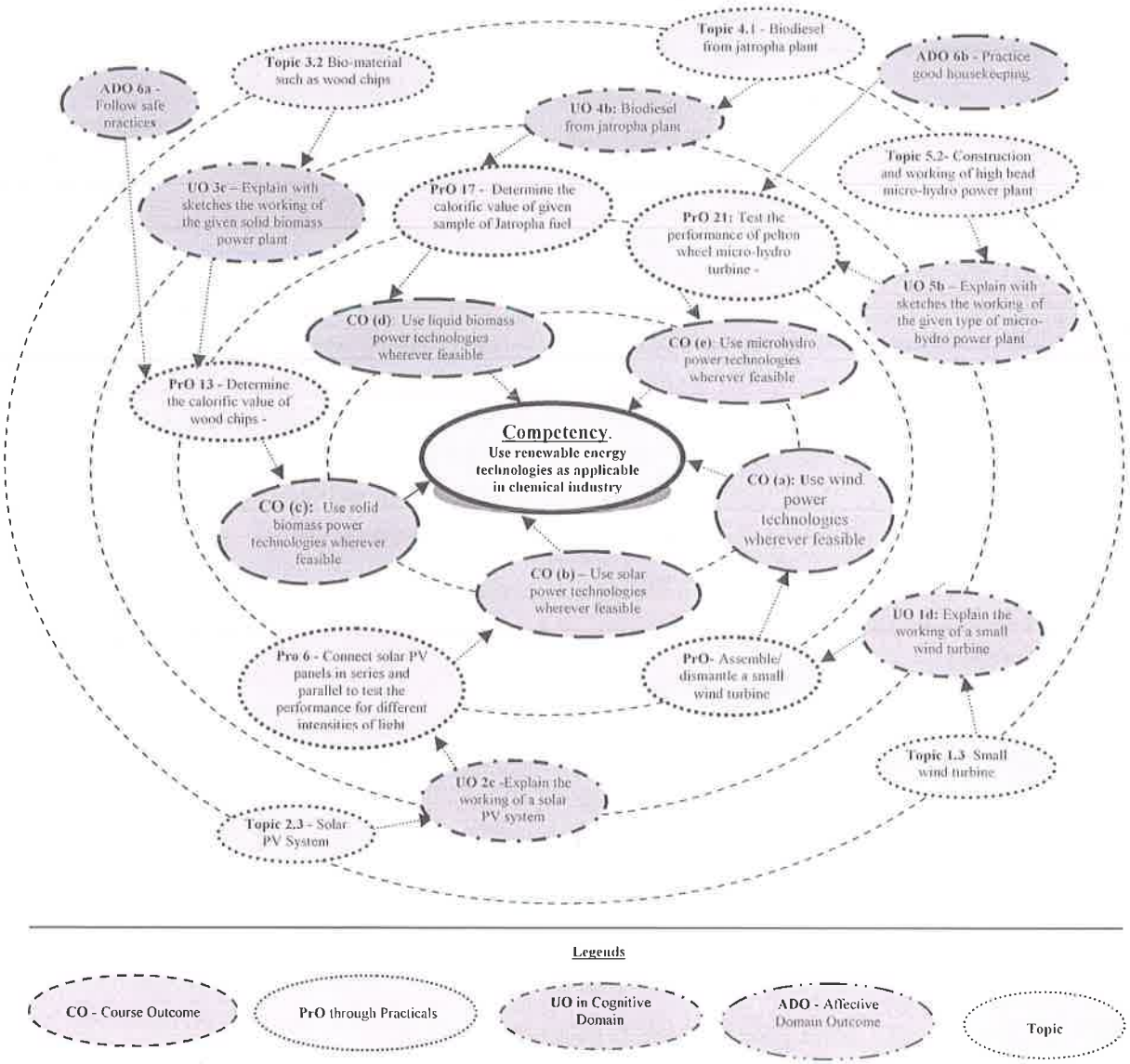

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Identify Components and sub Components of Wind turbine	I	02*
2.	Assemble/dismantle a small wind turbine	I	02
3.	Lubricate the various parts of wind turbine	I	02*
4.	Test the performance of the small wind turbine for different load.	I	02
5.	Identify the parts of the large wind turbine after viewing the relevant video	I	02*
6.	Connect solar PV panels in series and parallel to test the performance for different intensities of light	II	02
7.	Test the given Battery Charger used to charge the battery	II	02*
8.	Test the performance of given inverter of Solar PV power system	II	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
9.	Perform preventive and scheduled maintenance of given Solar PV lighting system	II	02
10.	Measure current by grid connected solar PV system	II	02
11.	Measurement of temperature of water by using solar heater.	II	02*
12.	Determine the carbon content of solid biomass.	III	02
13.	Determine the calorific value of wood chips	IV	02*
14.	Determine the pour point of given sample of fuel.	IV	02
15.	Determine the cloud point of given sample of fuel.	IV	02
16.	Determine the viscosity of given sample of fuel.	IV	02*
17.	Determine the calorific value of given sample of Jatropha fuel	IV	02*
18.	Determine the acid value of given sample of fuel.	IV	02*
19.	Determine the aniline point of given sample of fuel.	IV	02*
20.	Determine the specific gravity of biofuel.	IV	02*
21.	Test the performance of pelton wheel micro-hydro turbine	V	02*
	Total		**42**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. All the above listed practical need to be performed compulsorily, so that the student reaches the 'Applying Level' of Blooms's 'Cognitive Domain Taxonomy' as generally required by the industry.

ii. The 'Process' and 'Product' related skills associated with each PrO are to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
a.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observation and recording	20
e.	Interpretation of results and conclusion	10
f.	Answer to sample questions	10
g.	Submission of report on time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year

- 'Organising Level' in 2nd year and
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	Pro. S. No.
1.1	Small wind turbine of 3 kW	1 to 5
1.2	Roof top solar PV system of of 3 kW	6 to 9
1.3	Microhydro turbine of 1 to 3 kW	V
1.4	Thermometer& stopwatch.	ALL
1.5	Cleveland open cup for fuel oil below 79 degree centigrade (boiling point)	I,II
1.6	Abels closed cup for fuel oil below 49degree centigrade (boiling point)	I,II
1.7	Flat bottomed tube (3cm diameter&20cm high)	III.IV
1.8	Water jaket	III,IV
1.9	Bomb calorimeter with accessories.	XI

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Construction and Working of Wind turbines	1a. Explain the given terms related to wind power. 1b. Describe the function(s) of the specified Wind turbine component(s). 1c. Explain with sketches the specified principle of the rotation of the wind turbine rotor. 1d. Distinguish the features of the given type of small wind turbine. 1e. Describe with sketches the functions of the given part(s) of the specified SWT.	1.1 **Wind Turbine Terminologies:** Cut-in, cut-out and survival wind speeds, Threshold wind speeds, rated power, nominal power, Wind Power Curve, 1.2 **Types of Wind Turbines**: Small and large wind turbines; Horizontal and Vertical axis; Upwind and Downwind, One, Two and Three blades; constant and variable Speed; Geared, Direct-Drive 1.3 **Major parts and Functions of Wind Turbines:** Rotor blades, hub, nacelle, tower, electric sub-station, nacelle layouts of Geared, Direct-Drive and Main shaft, gearbox, electric generator, electronic control panels 1.4 **Rotation principles**: Drag and Lift principle, thrust and torque of wind turbine rotor. 1.5 **Parts of SWTs:** Rotor, generator, gearbox, tower, electric control panel, tale vane, anemometer, wind vane, temperature and rpm sensors.
Unit– II Solar	2a. Describe the components and function of the given solar power	2.1 Features of roof top home solar system

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Power	plant. 2b. Describe the features of the given component solar power plant 2c. Interpret the specifications of the given type of battery 2d. Describe the features of a hybrid wind solar system 2e. Make the use of solar distillation and cooling in chemical industry.	2.2 Features hybrid wind solar system 2.3 Photo Voltaic(PV): Cell, module, array and panel 2.4 .Types of batteries used in solar PV system 2.5 Solar application: solar distillation, solar cooling.
Unit - III Bioenergy from solid biomass.	3a. Explain with sketches the formation of energy from the given type of solid biomass. 3b. Describe with sketches the construction of the given type of solid biomass power plant 3c. Explain with sketches the working of the given solid biomass power plant 3d. Compare the performance of the two types of solid biomass power plants	3.1 Concept and application of bio-energy. 3.2 Power from agri-based bio-material such as wood chips, animal excreta and others - construction and working. 3.3 Power from kitchen biomass - construction and working. 3.4 Power from municipal waste - construction and working.
Unit-IV Bioenergy from liquid biomass.	4a. Choose proper principle for preparation of bio-energy. 4b. Explain preparation of biodiesel from jatropha plant. 4c. Describe with sketches the construction of the given type of liquid biomass power plant 4d. Explain with sketches the working of the given Liquid biomass power plant 4e. Explain preparation of biodiesel from plastic waste. 4f. Identify merits and demerits of liquid biomass.	4.1 Biodiesel from jatropha plant. 4.2 Biodiesel from plastic waste plant. - construction and working 4.3 Power from liquid biomass power plant- construction and working 4.4 Merits and demerits bio energy from liquid biomass.
Unit –V Micro-hydro power plants	5a. Describe with sketches the construction of the given type of micro-hydro power plant. 5b. Explain with sketches the working of the given type of micro-hydro power plant. 5c. Select the micro-hydro power plant for the given situation with justification 5d. Describe the routing maintenance of given micro-hydro turbine.	5.1 Concept and principle of micro-hydro plant 5.2 Construction and working of high head micro-hydro power plant 5.3 Construction and working of medium head micro-hydro power plant 5.4 Site selection of micro-hydro power plant 5.5 Routine maintenance of microhydro power plant

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Construction and Working of Wind turbines	12	02	08	08	18
II	Solar Power	12	02	08	08	18
III	Bio-energy from solid biomass.	08	04	04	04	12
IV	Bio-energy from liquid biomass.	08	02	02	08	12
V	Micro-hydro power plants	08	02	04	04	10
Total		**48**	**12**	**26**	**32**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare journals based on practical performed in laboratory.
b) Give seminar on relevant topic.
c) Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various learning outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.
i) Demonstrate students thoroughly before they start doing the practice.

j) Encourage students to refer different websites to have deeper understanding of the subject.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be *individually* undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

Suggestive lists of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Make working model of wind mill.
b) Develop a roof top solar PV system.
c) Develop a gobar gas system
d) Make a model for microhydro turbine.

13. SUGGESTED LEARNING RESOURCES :

S. No.	Title of Book	Author	Publication
1	Renewable Energy Sources and Emerging Technologies.	Kothari D.P., Singal K.C.	PrenticeHall of India PvtLtd-2008, ISBN-8120333578
2	Wind Power Technology	Earnest, Joshua	PHI Learning, New Delhi, 2016, ISBN:978-81-203-5166-0
3	Energy Resources and system	Tushar Ghosh	Mark prelas.ISBN-10-9400714017
4	Solar Electricity Handbook	Michael Boxwel	Greenstream Publishing; 2015 ISBN:9781907670459
5	Advanced Renewable energy sources		RSC Publications, , ISBN-978149733809

14. SOFTWARE/LEARNING WEBSITES

a) www.freesunpower.com
b) https://learn.adafruit.com/collins-lab-solar
c) www.tutorialspoint.com/power_electronics/
d) www.nptelvideos.in/2012/11/energy-resources-and-technology.htm
e) www.learnerstv.com/free-engineering
f) www.instructables.com
g) www.efxkits.com/blog/working-of-solar-wind-hybrid-system
h) https://4-h.org/parents/curriculum/wind-energy/
i) www.homepower.com
j) www.rpc.com.au/pdf/Solar%20PV%20Maintenance.pdf

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Numerical Methods in Chemical Engineering (Elective)**

Course Code : **22515**

1. RATIONALE

The numerical methods give the solution of applied problems when ordinary analytical methods fail. The increasing importance of numerical methods has led to enhanced demand for courses dealing with the techniques of numerical analysis in the area of chemical engineering. It is therefore clear that engineering would be incomplete without an adequate understanding of numerical methods. The students should gain ability which enables them to select the appropriate numerical technique to solve a given engineering problem.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Apply Numerical methods to solve chemical engineering problems.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a) Use SCILAB to visualize data and to solve problems.
b) Use Gaussian elimination and Gauss-Seidel iteration methods to solve linear systems equations in chemical processes.
c) Calculate Numerical Integration applying the Trapezoidal Rule, Simpson's Rule used in chemical processes.
d) Use Bisection and Newton-Raphson methods to find approximate roots of algebraic equation for given chemical processes.
e) Apply numerical methods to solve ordinary differential equations related to chemical processes.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

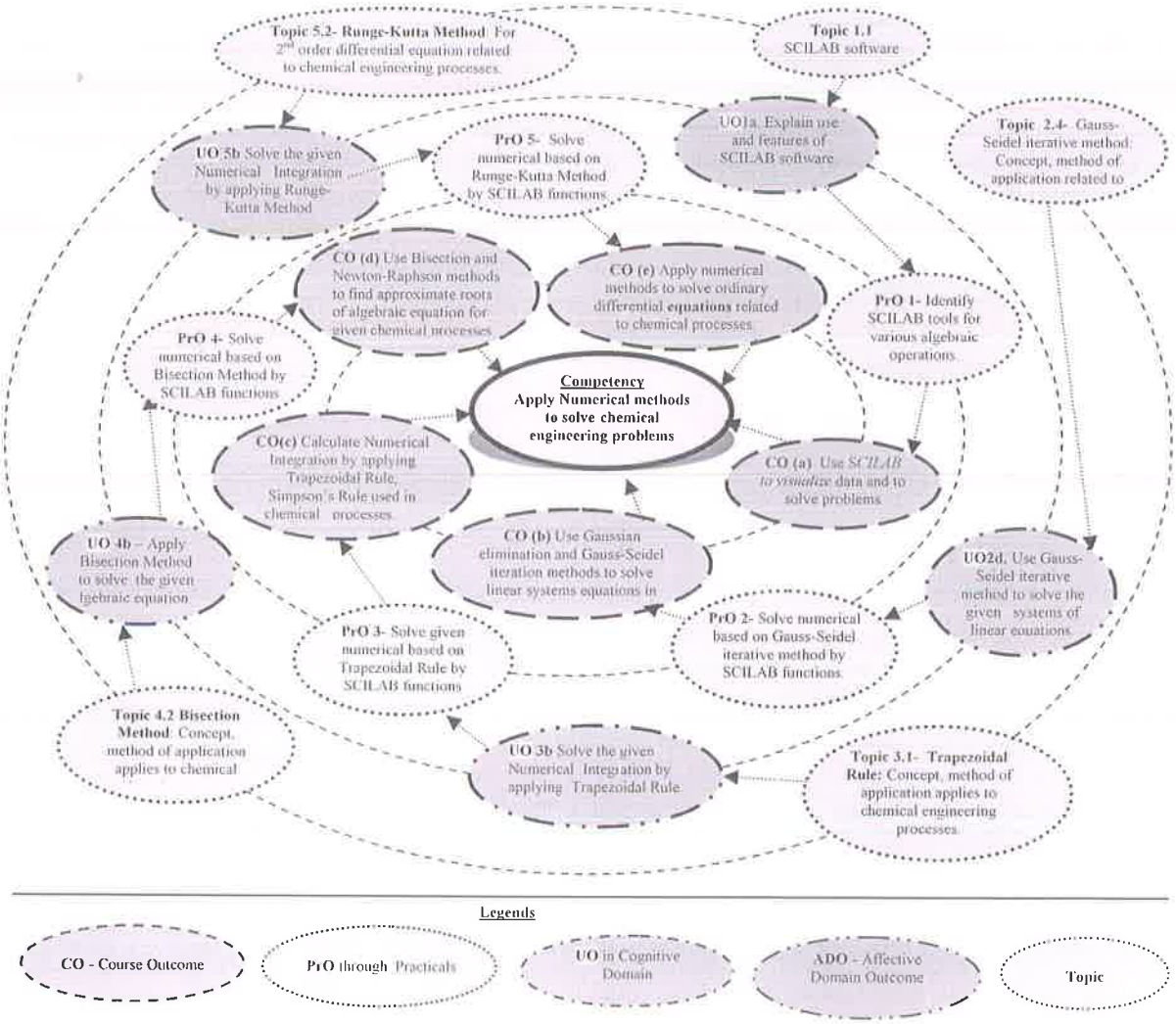

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Show starting and exiting sessions of SCILAB software.	I	02 *
2.	Identify major tools within or accessible from the desktop of SCILAB software.	I	02 *
3.	Identify SCILAB tools for various algebraic operations	I	02 *
4.	Develop structure code in SCILAB.	I	02 *
5.	Solve numerical based on Gauss elimination method by SCILAB functions for simple chemical engineering applications	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
6.	Solve numerical based on Matrix Inversion by SCILAB functions for simple chemical engineering applications	II	02 *
7.	Solve numerical based on Gauss-Seidel iterative method by SCILAB functions for simple chemical engineering applications	II	02 *
8.	Solve numerical based on Gauss-Jordan method by SCILAB functions for simple chemical engineering applications	II	02*
9.	Solve given numerical based on Trapezoidal Rule by SCILAB functions for simple chemical engineering applications	III	02
10.	Solve numerical based on Simpson's 1/3 Rule by SCILAB functions for simple chemical engineering applications	III	02 *
11.	Solve numerical based on Bisection Method by SCILAB functions.	IV	02 *
12.	Solve numerical based on Regula-Falsi Method by SCILAB functions for simple chemical engineering applications	IV	02
13.	Solve numerical based on Newton –Raphson Method by SCILAB functions for simple chemical engineering applications	IV	02 *
14.	Solve numerical based on Runge-Kutta Method by SCILAB functions for simple chemical engineering applications	V	02 *
15.	Solve numerical based on Euler's Method by SCILAB functions for simple chemical engineering applications	V	02
16.	Solve numerical based on Taylor's Series by SCILAB functions for simple chemical engineering applications	V	02 *
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1.	Identify major tools within or accessible from the desktop of SCILAB software.	10
2.	Develop structure code in SCILAB relevant to chemical engineering processes.	20
3.	Solve given Numerical related to chemical processes by various numerical methods.	50
4.	Interpretation of result and conclusion.	10
5.	Submission of report in time.	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Practice good housekeeping.

b. Work as a leader/a team member.
c. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Computer system (Any computer system with basic configuration)	All
2	Any SCILAB software	

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit –I Introduction to SCILAB software	1a. Explain use and features of SCILAB software. 1b. Apply SCILAB software to solve various numerical methods for the given simple chemical engineering applications	**1.1 SCILAB software** **1.2** Application of numerical methods and solutions of equations (algebraic – differential -integral) using SCILAB software.
Unit–II Numerical solution of a System of linear equations	2a. Solve the given simple problem based on linear equation for the given simple chemical engineering applications 2b. Use Gaussian elimination method to solve the given systems of linear equations for the given simple chemical engineering applications 2c. Apply Matrix Inversion to solve given systems of linear equations for the given simple chemical engineering applications. 2d. Use Gauss-Seidel	2.1 **Linear equations.** 2.2 **Gauss elimination method** (Direct Method): Concept, method of application related to chemical engineering processes. 2.3 **Matrix Inversion:** Concept, method related to chemical engineering processes. 2.4 **Gauss-Seidel iterative method:** Concept, method of application related to chemical engineering processes. 2.5 **Gauss-Jordan method:** Concept, method of

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	iterative method to solve given systems of linear equations for the given simple chemical engineering applications. 2e. Apply Gauss-Jordan method to solve given systems of linear equations for the given simple chemical engineering applications.	application related to chemical engineering processes.
Unit– III Numerical Integration	3a. Employ the concept of Numerical Integration for the given simple chemical engineering applications. 3b. Solve given Numerical Integration by applying Trapezoidal Rule for the given simple chemical engineering applications. 3c. Apply Simpson's 1/3 Rule to solve given Numerical Integration for the given simple chemical engineering applications. 3d. Use Simpson's 3/8 Rule to solve given Numerical Integration for the given simple chemical engineering applications.	**3.1 Numerical Integration Method** **3.2 Trapezoidal Rule:** Concept, method of application applies to chemical engineering processes. **3.3 Simpson's 1/3 Rule:** Concept, method of application applies to chemical engineering processes. **3.4 Simpson's 3/8 Rule:** Concept, method of application applies to chemical engineering processes.
Unit IV- Numerical solution of Algebraic equation	4a. Determine the Roots of given Algebraic equation for the given simple chemical engineering applications. 4b. Apply Bisection Method to solve given algebraic Equation for the given simple chemical engineering applications. 4c. Use Regula-Falsi Method to solve given algebraic equation for the given simple chemical engineering application. 4d. Apply Newton –Raphson Method to solve given algebraic equation for the given simple chemical engineering application.	**4.1 Concept of Algebraic equation** **4.2 Bisection Method**: Concept, method of application applies to chemical engineering processes. **4.3 Regula-Falsi Method:** Concept, method of application applies to chemical engineering processes. **4.4 Newton –Raphson Method:** Concept, method of application applies to chemical engineering processes.
Unit-V Numerical solution of Ordinary differential equation	5a. Employ the concept of Ordinary differential equation for the given for simple chemical engineering application. 5b. Solve given Numerical Integration by applying	**5.1 Concept of Ordinary differential equation.** **5.2 Runge-Kutta Method**: For 2nd order differential equation related to chemical engineering processes.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	Runge- Kutta Method for the given simple chemical engineering application. 5c. Calculate given Numerical Integration by applying Euler's Method for the given simple chemical engineering application. 5d. Calculate given numerical Integration by applying Taylor's Series for the given simple chemical engineering application.	**5.3 Euler's Method:** Error estimate for the Euler's method, Modified Euler's method applies to chemical engineering processes. **5.4 Taylor's Series**: For 2^{nd} order and 4^{th} order differential equation related to chemical engineering processes.

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to SCILAB software	08	04	04	04	12
II	Numerical solution of a System of linear equations	10	02	04	04	10
III	Numerical Integration	10	02	04	10	16
IV	Numerical solution of Algebraic equation	10	04	06	06	16
V	Numerical solution of Ordinary differential equation	10	04	06	06	16
Total		**48**	**16**	**24**	**30**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare journal based on practical performed in laboratory.
b) Undertake micro-projects.
c) List down the SCILAB tools for various algebraic operations.
d) Prepare a chart of structure code in SCILAB relevant to chemical engineering processes.

e) Give seminar on relevant topics.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Ideal and Non-ideal Gas Laws- Case study
b) Integration to Determine the Total Quantity of Heat- Case study.
c) Steady- State Analysis of a system of Reactors -Case study
d) One-Dimensional Mass Balance of a Reactor- Case study.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Introductory Methods of Numerical Analysis.	Sastry S.S.	PHI Learning, New Delhi-110001, ISBN-81-203-1266-X
2	Numerical Methods for Engineers.	Chapra, Steven C., Canale Raymond P.	McGraw Hill Publishing Company Limited, New Delhi, 2005. ISBN

S. No.	Title of Book	Author	Publication
			13: 9781259027444
3	Numerical Methods	Jain , M.K., Jain R.K., Iyengar,S.R.K.	New Age International(P) Limited, Publishers, , New Delhi, 2014, /ISBN 13: 9788122433234
4	Introduction to SCILAB	Nagar, Sandeep	Independently Published, 2016. ISBN:152015111X,9781520151113
5	Scilab from Theory to Practice - I. Fundamentals	Roux, Philippe	Scilab Enterprises, ISBN-#2822702934

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) www.tutorialpoint.com (Important website)
b) https://www.scilab.org/resourses/documentation/books
c) www.scilab.en.softonic.com
d) www.scilab.org >file>introscilab
e) www.scilab.org/en/download/latest

Maharashtra State Board of Technical Education, Mumbai

Teaching and Examination Scheme for Post S.S.C. Diploma Courses

Program Name : Diploma in Chemical Engineering

Program Code : CH **With Effect From Academic Year: 2017 - 18**

Duration of Program : 6 Semesters **Duration : 16 Weeks**

Semester : Fifth **Scheme - I**

S. N.	Course Title	Course Abbreviation	Course Code	Teaching Scheme			Credit (L+T+P)	Examination Scheme												Grand Total
								Theory						Practical						
				L	T	P		Exam Duration in Hrs.	ESE		PA		Total		ESE		PA		Total	
									Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	
1	Management	MAN	22509	3	-	-	3	90 Min.	70*#	28	30*	00	100	40	--	--	--	--	--	--	100
2	Heat Transfer Operation	HTO	22510	4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40	200
3	Environmental Technology	EPC	22511	3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	150
4	Chemical Reaction Engineering	CRE	22512	4	2	-	6	3	70	28	30*	00	100	40	--	--	--	--	--	--	100
	Elective (Any One)																				
5	Membrane Technology	MTE	22513	3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	150
	Renewable Energy Technologies	RET	22514	3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	150
	Numerical Methods in Chemical Engineering	NMC	22515	3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	150
6	Industrial Training	ITR	22057	-	-	6	6	--	--	--	--	--	--	--	75#	30	75	30	150	60	150
7	Capstone Project Planning	CPP	22058	-	-	2	2	--	--	--	--	--	--	--	25@	10	25	10	50	20	50
		Total		**17**	**2**	**16**	**35**	--	**350**	--	**150**	--	**500**	--	**200**	--	**200**	--	**400**	--	**900**

Student Contact Hours Per Week: **35 Hrs.** Medium of Instruction: **English**

Theory and practical periods of 60 minutes each. Total Marks : **900**

Abbreviations: ESE- End Semester Exam, PA- Progressive Assessment, L - Lectures, T - Tutorial, P - Practical

@ Internal Assessment, # External Assessment, *# On Line Examination , ^ Computer Based Assessment

* Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain LOs required for the attainment of the COs.

~ For the courses having ONLY Practical Examination, the PA marks Practical Part - with 60% weightage and Micro-Project Part with 40% weightage

- **If Candidate not securing minimum marks for passing in the "PA" part of practical of any course of any semester then the candidate shall be declared as "Detained" for that semester.**
- **Evalution of Industrial Training and its reports is to done after completion of Industrial Training. Credits of Industrial Training will not affect the framing of time table.**