Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fourth**

Course Title : **Chemical Engineering Thermodynamics**

Course Code : **22406**

1. RATIONALE

Diploma chemical engineer (also called technologists) have to deal with the interrelation of heat and work with respect to Chemical reactions. To perform the chemical process, they have to use different chemical engineering properties. Chemical thermodynamics based on laws of thermodynamics. This helps diploma chemical engineer to relate thermodynamic properties to the thermodynamic systems. This course is designed to provide understanding about the concept of chemical energy which involve in transformation through chemical reaction or evolved/absorbed from chemical system, internal energy, Enthalpy, Entropy those are required to understand the chemical kinetics.

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 the principles of chemical engineering thermodynamics in Chemical Process 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 the concept of equilibrium in chemical thermodynamic process.
b. Apply first law of thermodynamics in Chemical process industry.
c. Analyze basic thermodynamic quantity.
d. Use second law of thermodynamics in process industry.
e. Use concept of chemical equilibrium in chemical process.

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.

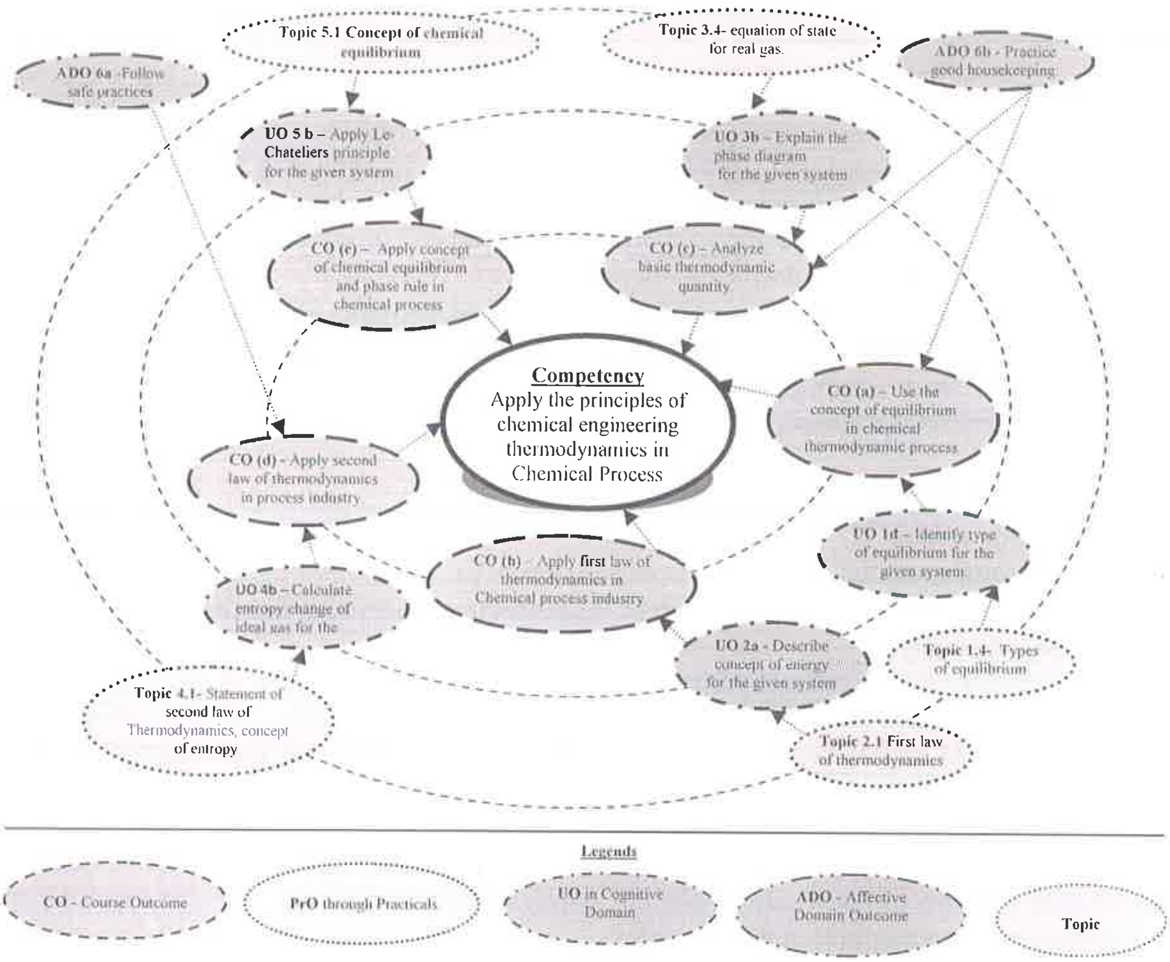

Figure 1 - Course Map

6. SUGGESTED TUTORIALS

The tutorials in this section are sub-components of the COs to be developed and assessed in the student for the attainment of the competency.

S. No.	Tutorial	Unit No.	Approx. Hrs. Required
1	List various thermodynamic properties and thermodynamic processes	I	2
2	Numerical for calculating W,Q,ΔU for heat exchange between system and surroundings	II	2
3	Numerical based on the relation ΔH = U + PV	II	2
4	Numerical for calculating ΔU, Q, W for various processes	II	2
5	Numerical for calculating ΔU, Q, W for various processes	II	2
6	Numerical for finding degree of freedom	III	2
7	Explain the phase diagram for various systems	III	2

S. No.	Tutorial	Unit No.	Approx. Hrs. Required
8	Numerical for calculating pressure(or volume) by ideal gas law and Van der Waals equation	III	2
9	Explain the different thermodynamic diagrams	III	2
10	Numerical based on entropy change of an ideal gas	IV	2
11	Numerical for calculating entropy change during adiabatic mixing, isothermal mixing, chemical reaction	IV	2
12	Numerical to calculate entropy change of a substance at temperature T	IV	2
13	Numerical based on Kp,Kc and Ky.	V	2
14	Numerical to calculate Kp for a reaction from conversion	V	2
15	Numerical to calculate ΔG.	V	2
16	Numerical based on Van't Hoff equation.	V	2
	Total		**32**

Note: The above tutorial sessions are for guideline only. The remaining tutorial hours are for revision and practice

The above tutorials 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. Demonstrate working as a leader/a team member.
b. Follow ethical Practices.

The development of the attitude related UOs of Krathwohl's 'Affective Domain Taxonomy', the achievement level may reach:

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

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED:

- Not applicable –

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Thermodynamic Systems and Equlibrium.	1a. Describe the Thermodynamics properties for the given system. 1b. Differentiate extensive and intensive property for the given system. 1c. Identify thermodynamic process for the given	1.1 Scope and limitations of thermodynamics. Basic concepts: System, surrounding, boundary, process, thermodynamic properties, open system, closed system and isolated system, homogenous and heterogeneous system. 1.2 Extensive properties, intensive properties. 1.3 Thermodynamic process: Isothermal

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	system. 1d. Identify type of equilibrium for the given system.	process, Adiabatic process, Isochoric process, Isobaric process, Cyclic process, reversible and irreversible process, quasi static process (definitions) 1.4 Types of equilibrium: stable, unstable, meta stable, thermal, chemical, mechanical, thermodynamic. Thermodynamic function: state function, path function. Macroscopic versus microscopic view.
Unit– II First Law of Thermodynamics	2a. Describe concept of energy for the given system. 2b. Calculate work done for the given system. 2c. Identify heat change for the given system. 2d. Differentiate C_p and C_v for the given system.	2.1 First law of thermodynamics: Law of conservation of Energy, mathematical statement. Concept of different forms of energy, Internal energy, Internal energy as a state function, numerical 2.2 Work and heat as path function. Sign convention used for work and heat, Enthalpy, Heat capacity, specific heat, heat capacity at constant volume, heat capacity at constant pressure. Temperature dependence of heat capacity, relation between Cp and Cv. Numerical for calculating enthalpy. 2.3 Equation of state and concept of ideal gas, processes involving ideal gases: Constant volume process, Constant pressure process, Constant temperature process, Adiabatic process, Polytropic process (Determining ΔU, Q, W for the above processes), numerical 2.4 Throttling process(Joule-Thomson Expansion): Joule-Thomson coefficient, Joule-Thomson porous plug experiment 2.5 Zeroth law of Thermodynamics: statement.
Unit– III Thermodynamic Quantities.	3a. Calculate the degree of freedom for the given system. 3b.Explain the phase diagram for the given system. 3c. Calculate pressure or volume for the given system by Van der Waals equation. 3d. Explain the given thermodynamics diagram.	3.1 Phase, P-V-T behavior of pure fluids: P-V diagram for a pure substance, P-T diagram for a pure substance, T-V diagram for a pure substance 3.2 Degree of freedom, Gibb's phase rule, numerical 3.3 Phase diagram for : Water system , carbon dioxide system and Sulphur system 3.4 Equation of state for real gases: Van der Waals equation, Van der Waals constant. Numerical

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		3.5 Thermodynamic diagrams: P-H diagram, H-T diagram, T-S diagram, H-S diagram (or Mollier diagram) (stepwise construction not required)
Unit-IV Second Law of Thermodynamics	4a. Apply concept of entropy for the given system. 4b. Calculate entropy change of the ideal gas for the given system. 4c. Apply entropy change for the given system. 4d. Calculate entropy of reaction for the given system.	4.1 Statement of second law of Thermodynamics, concept of entropy. mathematical expression of entropy, standard entropy, relation between first and second law of thermodynamics 4.2 Entropy change of an ideal gas, numerical. 4.3 Clausius inequality: statement and mathematical expression. Calculation of entropy changes during: phase change, adiabatic mixing process, isothermal mixing of ideal gases, chemical reaction, numerical. 4.4 Third law of Thermodynamics: statement, Total entropy change of a substance at temperature T, numerical.
Unit –V Chemical Equilibria	5a. Describe chemical equilibrium for the given system. 5b. Apply Le-Chatelier's principle for the given situation. 5c. Explain the temperature dependency of equilibrium constant for a reaction based on Van't Hoff equation 5d. Derive the relation between thermodynamic equilibrium constant and conversion for the given reaction.	5.1 Concept of chemical equilibrium, relation between K_p, K_c and K_y, numerical. Gibbs free energy change and feasibility of chemical reaction from free energy change. Le-Chatelier's principle. 5.2 Chemical potential, Law of mass action, relation between ΔG and K. Van't Hoff's equation (Derivation), Variation of equilibrium constant with temperature for exothermic and endothermic reaction(based on Van't Hoff's equation), numerical. 5.3 Relation between conversion and thermodynamic equilibrium constant for first order and second order reversible reaction.

***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 (INTERNAL) DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Thermodynamic system and equilibrium	08	02	02	04	08
II	First law of Thermodynamics	12	04	04	06	14

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
III	Thermodynamic Quantity.	16	02	04	14	20
IV	Second Law of Thermodynamics	14	04	04	06	14
V	Chemical Equlibria	14	04	04	06	14
Total		64	**16**	**18**	**36**	**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 the presentation based on chemical thermodynamic process.
b. Conduct/ participate in MCQ/Quiz
c. Search the different thermodynamic simulation tools.

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 LOs/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. No. of practical's selection to be performed should cover all units.

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. **Visit to plant**: Visit the nearby industry and prepare report about various Thermodynamic operations.
b. **Preparation of model**: Prepare model of reactor showing the thermodynamic operation.
c. **Preparation of chart:** Prepare a chart showing the relationship between first and second law of thermodynamics.
d. **Collection of data**: Collect the data related to thermodynamic for the process industries/Laboratory.
e. **Prepare report:** Prepare a report on difference between enthalpy and internal energy considering example of Hair dryer and filling tank.
f. **Prepare report:** Prepare a report on difference between steady state and equilibrium with example of Hot pot.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	A Textbook of Chemical Engineering Thermodynamics	Narayan, K. V.	PHI Learning PVT Ltd. New Delhi, 2013, ISBN 9788120317321
2	Introduction to Chemical Engineering Thermodynamics	Smith J. M., Van Ness H.C., Abott M.M.	Mc Graw Hill Publication, New York, 1996, ISBN 13:9780073104454,
3	Chemical and Engineering Thermodynamics	Stanley. I. Sandler	Wiley Publication, New Jersey, 1998, ISBN 13:9780471182108
4	Chemical Engineering Thermodynamics	Rao Y. V. C.	Sangam Books, Hyderabad, 1997, ISBN 9780863116889
5	Engineering Thermodynamics	P.K.Nag	Tata Mc-Graw –Hill Publishing Company Ltd,New Delhi ISBN 0-07-059114-8
6	Principles of Physical Chemistry	Puri,Sharma, Pathania	Vishal Publishing Company, Jalandhar. ISBN-13:978-9382956013

14. SOFTWARE/LEARNING WEBSITES

a. www.nptel.ac.in
b. www.msubbu.in
c. http://ocw.mit.edu
d. http://freevideolectures.com