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.

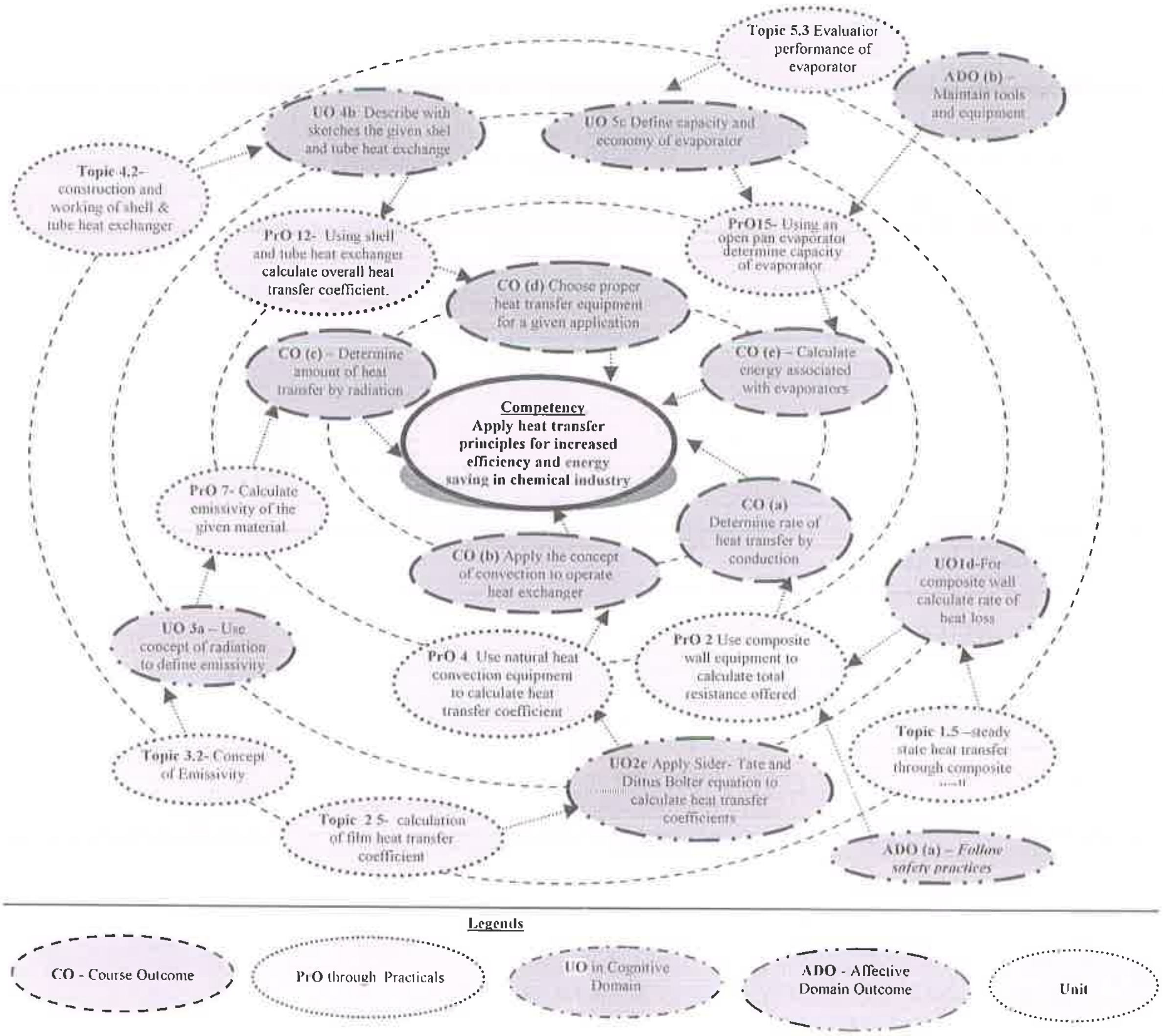

Figure 1 - Course Map

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/