GUJARATTECHNOLOGICALUNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021(COGC-2021)

Semester-IV

Course Title: Process Heat Transfer

(Course Code: 4340501)

Diploma Programme in which this course is offered	Semester in which offered
Chemical Engineering	4th Semester

1. RATIONALE

In almost every chemical plant heat transfer takes place (sometimes it is intentional while sometimes it is unintentional). Study of heat transfer at steady state and unsteady state is therefore important. The knowledge of the basic concepts and principles of heat transfer helps smooth and proper operation of various heat exchangers, evaporators and condensers. Using the concepts of conduction, convection and radiation heat losses through pipes, equipments and storage tanks can be estimated. Hence the course has been designed to develop this competency and its associated cognitive, practical and affective domain learning outcomes

2. COMPETENCY

The course should be taught and curriculum should be implemented with the aim to develop required skills so that students are able to acquire following competency:

- **Use principles of heat transfer operations for safe, reliable and efficient operation of chemical plant.**

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) Classify modes of heat transfer, steady state, unsteady state and types of heat transfer equipment.
b) Apply laws of heat transfer to various chemical engineering problems without phase change.
c) Apply principles of heat transfer with phase change and dimensionless group.
d) Estimate the design parameters for heat transfer equipment.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits(L+T+P)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	-	4	5	30*	70	50	50	200

(*):Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate the integration of COs, and the remaining 20 marks are the average of 2 tests to be taken during the semester for assessing the attainment 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,* ***CA*** *-Continuous Assessment;* ***ESE****-End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. *Some of the* ***PrOs*** *marked* ***'*'*** *(in approx. Hrs column) are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

Sr. No.	**Practical/Exercise** (Course Outcomes in Psychomotor Domain according to NBA Terminology)	Unit No.	Approx. Hrs Required
1	Determine the thermal conductivity of Metal Rod	II	4
2	Determine the thermal conductivity of concentric sphere **OR** Determine the thermal conductivity of non-metal (solids)(Insulating Material).	II	4
3	To determine the thermal conductivity of given liquid.	II	4
4	Determine the thermal conductivity of composite wall	II	4
5	Determine critical radius of insulating material	II	4
6	Determine the specific heat of Air by forced convection.	III	4
7	To determine convective heat transfer coefficient in natural convection.	III	4
8	To determine convective heat transfer coefficient in forced convection.	III	4
9	To Measure the Emissivity of the Test plate Surface.	IV	4
10	To determine the value of Stefan Boltzmann constant for radiation heat transfer	IV	4
11	To study the phenomenon of boiling heat transfer and to plot the graph of heat flux versus temperature difference. (Critical Heat Flux Apparatus)	V	4
12	To determine overall heat transfer coefficients obtained by operating the double pipe heat exchanger	VI	4
13	To determine LMTD of the heat exchanger under parallel and counter Flow arrangement.	VI	4
14	To calculate the overall heat transfer coefficient of the shell and tube heat exchanger	VI	4
15	Determine economy of open pan evaporator.	VII	4
16	Study and compare different types of Evaporators.	VII	4
		Total	**56**

Note

i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list**.**

ii. The following are some **sample** 'Process' and '#Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No.	Sample Performance Indicators for the PrOs	Weight age in %
1	Handling of apparatus for precise measurements	10
2	Record observations correctly	20
3	Practice and adapt good and safe measuring techniques	10
4	Calculations, Interpretation of results and their conclusion.	20
5	Prepare report of practical in prescribed format	10
6	Solve assignment questions.	20
7	Viva-voce	10
	Total	**100**

6. MAJOR EQUIPMENT/INSTRUMENTS AND SOFTWARE REQUIRED

These major equipment/instruments and Software required to develop PrOs are given below with broad specifications to facilitate procurement of them by the administrators/management of the institutes. This will ensure the conduction Of practice in all institutions across the state in a proper way so that the desired skills are developed in students.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	T**hermal conductivity metal rod apparatus** : Bar-445 mm, Dia 25mm, test length of bar 175 mm, 9 thermocouples on bar and 4 on insulation, Ni-chrome heater 400 watt, Cooling jacket 90 mm dia, Temp. Indicator 0-200˚C, V-meter 0-200 V, A-meter 0-2 Amp	1
2	**Thermal Conductivity Of nonmetal apparatus:**, Dia 25mm, test length of bar 175 mm, 9 thermocouples on bar and 4 on insulation, Ni-chrome heater 400 watt, Cooling jacket 90 mm dia, Temp. Indicator 0-200˚C, V-meter 0-200 V, A-meter 0-2 Amp	2
3	**Thermal conductivity of liquid:** The aluminum cylinder is of size 100 mm in diameter and 100 mm in length. The thermocouples are placed to measure the oil temperature at intervals of 25 mm. The outer surface is properly insulated to avoid heat loss.	3
4	**Thermal conductivity composite wall apparatus :** Heater Assembly-1000W, Round coil, Sandwiched, Dia-300mm; Test Specimen-Dia. 300mm, MS 20mm, Asbestos 15 mm, Wood 10mm; 8 nos. J type thermocouple, 8 Channel Digital Temperature Indicator; Assembly shall be covered with Wooden Chamber	4
5	**Critical radius of insulating material apparatus :** Heater 500 W Ni-Cr 500 mm length, Test specimen MS, Dia 50 mm,500mm; Insulation over pipe; J thermocouple 12 nos., Digital temperature Indicator; The whole assembly shall be covered with wooden chamber	5
6	**Specific heat of air apparatus :** 2 inch Cylindrical test section, 0.5 HP air blower, 3 phase 440 V Air heater, U-tube manometer with orifice; Thermocouples	6
7	**Heat transfer coefficient in natural convection:** metallic tube of diameter (d) 45 mm and length (L) 450mm with an electrical heater coil along the axis of the tube. Seven thermocouples are fixed on the tube surface. Control panel instrumentation consists of multichannel digital display	7
8	**Heat transfer coefficient in forced convection:** O.D. of the pipe, Do = 38 mm I.D. of the pipe, Di = 35 mm Length of test section, L = 400 mm, Orifice diameter, d= 20 mm, Duct size = 150 mm x 100 mm, Coefficient of discharge= 0.62	8
9	**Emissivity apparatus: A**luminium plates, of equal dimensions. Ni-Cr heaters sandwiched in Mica sheets one plate blackbody another natural finish, Dia. 160 mm, thickness 12mm, heater 500W, Digital temp. Indicator	9

10	**Stefan Boltzmann apparatus :** Copper hemispherical enclosure, Non-conducting base plate made of asbestos, Thermocouples, iron – constantan type to measures temperature on the copper hemisphere T1 and T2 on the disc and T3 on specimen and T4 of hot water, Disc mounted in insulated Bakelite sleeve, made of aluminum.	10
11	**Critical Heat Flux Apparatus:** Length of Ni-chrome wire, L = 40 mm. Diameter of Ni-chrome wire, D - 0.25 mm (33 gauge) Distilled water quantity = 4 liters, Thermometer range- 0 to 100˚C, Heating coil capacity (bulk water heater)= 2 kw	11
12	**Double pipe heat exchanger :** Inner tube SS304 -1000mm × 25mm; Outer tube – SS304, 1000mm × 25mm, 25 mm glass wool with SS304 cover; Hot and cold water tanks - inner SS304, outer MS, 50Litre, Cold water tank, Heater 3 KW; Pumps -2 nos. mono block 0.5 HP SS304; Rota meter – 1-10 lpm, Glass tube, float SS 316	12
13	**Shell and tube heat exchanger :** 1-1 pass; Shell- ID 150 mm SS, 4 baffles with 180 mm spacing, glass wool insulation, Tubes – copper 19 nos., ID 9.5 mm, 900 mm Length; Tanks -2 nos.100 liter HDPE; Pumps- 0.25 HP; Rota meters – 2nos. 1.5-15 lpm; Thermocouple -4 Nos., Digital temp. Indicator – 0-100˚C	13,14
14	**Open Pan Evaporator :** Pan-Hemispherical SS 304 500mm dia, 3mm thick, Jacket- MS 525 mm dia, 3mm thick; Lagging- glass wool 40 mm with SS sheet cladding, 12.5 mm steam trap.	15

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow ethical practices
c) Observe safety measures
d) Good house keeping
e) Time management
f) Practice environmentally friendly methods and processes.

The ADOs are best developed through laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDER PINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the Cos and competency. If required, more such higher-level UOs could be included by the course teacher to focus on the attainment of COs and competency.

Unit	Major Learning Outcomes(Course Outcomes in Cognitive Domain according to NBA terminology)	Topics and Sub-topics
Unit – I Fundamental of Heat Transfer	1a. Define Heat Transfer & Process Heat Transfer with its' importance	1.1 Definition and importance of process heat transfer
	1b. Classify Modes of heat transfer and describe laws of heat transfer	1.2 Basic modes of heat transfer and the laws governing (a) Conduction (b) Convection (c) Radiation 1.2.1 Thermal conductance and thermal resistance, (a) conductive (b) Convective (c) radiative
	1c. Differentiate steady state and unsteady state heat transfer	1.3 Steady state and unsteady state heat transfer
Unit – II Heat Transfer by Conduction	2a. Explain Concept of heat conduction	2.1 Concept of heat conduction
	2b. Describe Fourier's Law	2.2 Fourier's law of heat conduction
	2c. Describe thermal conductivity and define Thermal storage capacity and Thermal Diffusivity	2.2 concept of Thermal conductivity, Thermal storage capacity and Thermal Diffusivity
	2d. Derive equations of steady state Heat conduction through composite wall, through composite cylinder and through composite sphere,	2.3 One dimensional Steady state conduction through (a) plane and composite wall (b) plane and composite cylinder (c) plane and composite sphere
	2e. Calculate heat transfer rate	2.4 Simple problems of conduction
	2f. Describe Thermal insulation	2.5 Thermal Insulation 2.5.1 Optimum thickness of insulation
	2g. Calculate critical radius of insulation	2.6 Derivation of equation for critical radius of insulation
	2h. Explain Extended surface - fins	2.7 Extended surface - fins 2.7.1 types of extended surface
Unit – III Heat Transfer by Convection	3a. Describe types of convection	3.1 Types of Convection (a) Free convection (Natural convection) (b) Force convection
	3b. Explain Newton's Law	3.2 Newton's Law of convective heat transfer
	3c. Derive equation of overall heat transfer coefficient	3.3 Individual and Overall heat transfer coefficient
	3d. Explain dimensionless groups	3.4 Significance of dimensionless groups (a) Prandtl No. (b) Reynold No. (c) Grashoff No. (d) Nusselt No.
	3e. Calculation for convection	3.5 Simple Problems of Convection

Unit – IV Heat Transfer by Thermal Radiation	4a. Explain radiation facts	4.1 Fundamental facts of radiation
	4b. Define radiation terms	4.2 Concepts of thermal radiation (a) Absorptivity (b) reflectivity (c) Transmittivity (d) Emissive power (e) Black body (f) Gray body (g) White body (h) Opaque body (i) Monochromatic wave length (j) Emissivity
	4c. Describe radiation laws	4.3 Radiation laws (a) Stefan Boltzmann Law (b) Wien's displacement law (c) Kirchhoff's Law (d) Plank's Law
	4d. Calculate radiation based on radiation laws	4.4 Simple calculations of radiation
Unit – V Heat Transfer with Phase Change	5a. Explain heat transfer with phase change	5.1 Heat transfer with phase change
	5b. Describe boiling	5.2 Phenomena of Boiling 5.2.1 Pool boiling
	5c. Describe condensation and condensers	5.3 Phenomena of Condensation (a) Drop wise and film wise Condensation
Unit – VI Heat exchangers	6a. Classify heat exchanger	6.1 Types of heat exchanger based on flow pattern, function and construction
	6b. Describe Double pipe heat exchanger	6.2 Double pipe heat exchanger
	6c. Explain shell and tube heat exchangers and its components	6.3. Shell and tube heat exchanger
	6d. Describe plate type heat exchanger	6.4 Plate type heat exchanger
	6e. Derive equation and Calculate L.M.T.D.	6.5 L.M.T.D. : derivation of equation and simple calculations (a) Counter current (b) Co-current 6.6 L.M.T.D correction factors.
	6f. Calculate overall heat transfer co-efficient	6.7 Overall heat transfer co-efficient of heat exchangers 6.8 Effect of scale formation.
Unit – VII Evaporation	7a. Define evaporation	7.1 Introduction of evaporation
	7b. Explain characteristics of liquid	7.2 Characteristics of liquid for evaporation
	7c. Explain evaporator capacity	7.3 Evaporator capacity and economy
	7d. Describe boiling point elevation and duhring's rule	7.4 Boiling point elevation and duhring's rule
	7e. Differentiate single and multi-effect evaporation	7.5 Single and multi effect evaporation with flow arrangement
	7.f Explain short tube and long tube evaporators	7.6 short tube evaporator 7.7 long tube evaporator

9. SUGGESTEDS PECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Fundamentals of Heat Transfer	4	2	4	0	6
II	Heat Transfer by Conduction	10	2	4	8	14
III	Heat Transfer by Convection	4	2	3	3	8
IV	Heat Transfer by radiation	5	2	4	4	10
V	Heat Transfer with Phase Change	4	2	6	0	8
VI	Heat Exchangers	9	2	6	6	14
VII	Evaporation	6	2	4	4	10
	Total	**42**	**14**	**31**	**25**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A)in the question paper may slightly vary from above table.*

10. SUGGESTEDSTUDENTACTIVITIES

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 perform following activities in group and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

Following is the list of proposed student activities like:

1. Assignments
2. Technical Quiz/MCQ Test
3. Presentation on some course topic
4. I-net based assignments
5. Undertake micro-Project in team/individually

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/subtopics.
b) Guide student(s) in undertaking micro-projects/activities.
c) Different types of teaching methods i.e. video demonstration, activity based learning, case study, m-learning need to be employed by teachers to develop the outcomes.
d) Some *of the topics/sub-topics* which are relatively simpler or descriptive are to be given to the students for *self-learning* but to be assessed using different assessment methods.
e) Teachers need to ensure to create opportunities and provisions for *co-curricular activities*.
f) Guide students to address issues on environment and sustainability with reference to using the knowledge of this course
g) OERs, Vlab, and Olabs may be used to teach for the teaching of different concepts.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-project is group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 the integration of PrOs, UOs, and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16 *(fourteen to sixteen) student engagement hours*** during the course. The student sought to submit micro-project by the end of the semester (so that they develop industry-oriented COs.

A suggestive list of micro-projects is given here. This should relate highly to the competency of the course and the COs. Similar micro-projects could be added by the concerned course teacher.

1. Prepare chart/model of modes of heat transfer along with their Mechanism and applications.
2. Prepare chart of law of heat transfer.
3. Prepare chart/model types of Heat exchanger and Evaporator.
4. Draw suitable chart for various heat transfer equipment
5. Prepare 15-20 slides power point presentation showing mode of heat transfer along with their examples.
6. Prepare 15-20 slides power point presentation on topic of heat transfer
7. Prepare Laboratory set up for conduction, convection, radiation, boiling, condensation and heat transfer equipment.(heat exchanger and evaporator)
8. Prepare a demonstrative model of conduction, convection and radiation.
9. Prepare a demonstrative model of any heat transfer equipment.
10. Prepare Working model of any heat transfer equipment.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Books	Author	Publication with place, year and ISBN
1	Unit Operations of Chemical Engineering	McCabe, Warren L., Julian C. Smith	McGraw Hill Publication, New York 2004(Seventh Edition)
2	Engineering heat transfer	Gupta & Prakash	Nem Chand & Brothers, Roorkee, India,20007 (Eighth Edition)
3	Process heat transfer	D.Q.Kern	Tata McGraw Hill Publication, New Delhi, (Reprint 2008)
4	Unit Operation	K.A. Gavhane	Nirali Prakashan, Pune 2009
5	HEAT TRANSFER	J. P. Holman	McGraw Hill Publication, New York 2010 (Tenth Edition)
6.	HEAT TRANSFER A Practical Approach	YUNUS A. CENGEL	McGraw Hill; 2nd edition

14. SUGGESTED LEARNING WEBSITES

a) https://ndl.iitkgp.ac.in/
b) https://www.vlab.co.in/
c) https://swayam.gov.in/
d) https://onlinecourses.nptel.ac.in

PO-COMPETENCY-CO MAPPING

Semester IV	Process Heat Transfer (4340501)						
	POs						
Competency &Course Outcomes	PO1 Basic & Discipline-specific knowledge	PO2 Problem Analysis	PO3 Design/development of solutions	PO4 Engineering Tools, Experimentation &Testing	PO5 Engineering practices for society ,sustainability& environment	PO6 Project Management	PO7 Life-long learning
Competency	Use principles of heat transfer operations for safe, reliable and efficient operation of chemical plant.						
CO1: Classify modes of heat transfer, steady state, unsteady state and types of heat transfer equipment.	2.00	1.00	-	-	-	-	1.0
CO2: Apply laws of heat transfer to various chemical engineering problems without phase change.	3.00	2.00	1.00	3.00	1.00	2.00	2.00
CO3: Apply principles of heat transfer with phase change and dimensionless group.	2.00	1.00	1.00	1.00	1.00	-	1.00
CO4: Estimate the design parameters for heat transfer equipment.	3.00	2.00	2.00	3.00	1.00	2.00	1.00

15. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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