GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Chemical Engineering (Green Technology and Sustainability Engineering)

Subject Code: BE04044011

Subject Name: Heat Transfer Operations

W. E. F. Academic Year:	2024-25
Semester:	4
Category of the Course:	Professional Core

Prerequisite:	A good understanding regarding basic modes of heat transfer viz. conduction, convection and radiation with governing laws underlying this heat transport mechanisms. Mathematical background is also essential in this respect
Rationale:	Heat transfer operation is a necessary process in virtually all forms of energy generation and use; from coal fired to nuclear power stations, from automobile engines to rocket motors, from refrigerating cold stores to air conditioning space vehicles. This subject is intended to make students aware about mechanisms involved in heat transfer process in many of aforementioned applications. This ultimately will enable the students to design the equipments for heat process viz., shell and tube heat exchangers, evaporators, condensers

Course Outcome:

After Completion of the Course, Student will able to:

Sr. No.	CO statement	Marks % weightage
CO-1	To identify different modes of heat transfer and understand basic mechanism of conduction.	22
CO-2	To explain heat transfer under different convective regimes.	22
CO-3	To predict extent of heat flow by radiation through grey, white and real surfaces.	12
CO-4	To analyze heat transfer through different types of heat exchangers used for various applications	18
CO-5	To describe industrial applications and regimes involved in boiling and condensation	12
CO-6	To categorize different types of evaporators with their performance evaluation and to analyze material and energy balance for single and multi-effect systems	14

Teaching and Examination Scheme:

Teaching /Learning Scheme in Hours Per Semester					Total Credits = TH/30	Examination Marks					Total Marks
						Theory Marks		Practical Marks			
L	T	P	PBL*	TH	04	ESE (E)	PA (M)	PA (I)	PBL*	ESE (V)	
60	0	30	30	120		70	30	20	30	50	200

*** Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**

Course Content:

Sr. No.	Content	Total Hrs
1	**Introduction:** Overview of applications of heat transfer in different fields of engineering, modes of heat transfer- conduction, convection and radiation, heat transfer with and without change of phase. **Conduction:** Mechanism of heat conduction, Fourier's law, thermal conductivity of solids, liquids and gases, effect of temperature on thermal conductivity, General heat conduction equation in Cartesian coordinates, Boundary conditions, Formulation of heat transfer problems without generation of heat, Conduction through systems of constant thermal conductivity :- conduction through plane, cylindrical and spherical wall, combined boundary condition systems (conduction-convection systems), conduction through composite slab, cylindrical and spherical shells. Electrical analogy to heat flow, Critical and Optimum thickness of Insulation. Unsteady State heat Conduction	12
2	**Convection:** Mechanism, thermal and velocity boundary layers, boundary layer thickness, relationship between hydrodynamic and thermal boundary layer thickness for flow over flat plates, the convective heat transfer coefficient, reference temperatures, thermal boundary layers for the cases of flow over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance. **Forced Convection:** General methods for estimation of convection heat transfer coefficient, Correlation equations for heat transfer in laminar and turbulent flow for external and internal flows for constant heat flux and wall temperature conditions- flow in a circular tube Analogy between momentum and heat transfer: Development of Reynold's and Prandtl analogy.	12

	Overview of Colburn and Von-A **Natural Convection:** Dimensional analysis, natural convection from vertical and horizontal surfaces under laminar and turbulent conditions for plates, cylinders, physical significance of Grashoff and Rayleigh numbers.	
3	**Heat transfer by radiation:** Introduction- theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission- total emissive power, emissivity. Radiative properties, Emission, irradiation, absorptivity, reflectivity and transmissitivity. Concept of black and grey body, radiation intensity, Laws of black body radiation, non-black surfaces- Grey, white and real surface, radiation between black surfaces and gray surfaces.	**6**
4	**Heat Exchangers:** Classification of heat exchangers: Classification according to transfer processes, number of passes, surface compactness, construction features, flow arrangements, heat transfer mechanisms. Shell and tube heat exchanger, fouling, concept of overall heat transfer coefficient, LMTD, correction factor for LMTD, Sizing and rating problem using LMTD method in parallel flow, counter flow exchanger, cross flow and multi-pass heat exchangers, Temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers. Determination of area, length, number of tubes required for a given duty in different configurations using LMTD method of analysis. Concept of Effectiveness- NTU method, definition of effectiveness, effectiveness NTU relations for single pass exchangers in counter-flow and parallel flow configurations. Double pipe heat exchangers: - construction, various steps for the design of double pipe heat exchangers. Plate and spiral heat exchangers, Condensers	**12**
	Boiling and Condensation: Pool boiling - Boiling curve, hysteresis in the boiling curve, mechanism of nucleate boiling, Forced convection boiling - Brief over view of internal forced convection boiling. Condensation: Physical mechanisms, types of condensation, factors affecting condensation.	**8**
	Evaporation: Principle of Evaporation, types of evaporators- their construction and operation, Natural circulation evaporators, short tube vertical or calendria type evaporators, basket type vertical evaporators, long tube vertical evaporators, forced circulation evaporators, falling film evaporators, climbing or rising film evaporators, agitated thin film evaporators, the plate evaporator. Single effect and multiple effect evaporators, Performance of evaporators, capacity and economy of evaporators, Overall heat transfer coefficient, effect of liquid head and boiling point elevation. Material and energy balances for single effect evaporator and the calculations on single effect evaporator. Multiple effect evaporators, Energy Balance.	**10**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
15	**15**	**20**	**10**	**10**	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

1. Kern D Q, Process Heat Transfer, McGraw Hill Book Co. (1997).
2. Binay. K. Dutta, "Heat Transfer Principles and applications" Prentice Hall of India
3. Coulson J M and Richardson J F, Chemical Engineering Volume 1, Pergamon Press (1999).
4. Holman J. P, "Heat Transfer", McGrawHill.
5. Incropera F. P. and DeWitt D. P, "Introduction to Heat Transfer". John Wiley & Sons.
6. Rao Y.V.C, "Heat Transfer", University Press, India
7. Cengel A. Yunnus. "Heat Transfer – A Practical Approach", McGraw Hill
8. Geankopolis C J, Transport Processes and Separation Process Principles, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004)
9. Kothandaraman C.P, "Heat and Mass Transfer Data Book" New Age International, India
10. Ramesh K. Shah and Dušan P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley & Sons, Inc. 2003

Suggested list of experiments

10 experiments need to be performed during the semester.

1. Determination of thermal conductivity of insulating powder
2. Determination of thermal conductivity of given metal rod
3. Determination of heat transfer coefficient by natural convection
4. Determination of heat transfer coefficient by forced convection
5. Determination of overall heat transfer coefficient for counter flow in laminar regime in double pipe heat exchanger
6. Determination of overall heat transfer coefficient of shell and tube heat exchanger
7. Heat Transfer in Composite walls- Determination of effective thermal conductivity and overall resistance
8. Determination of overall heat transfer coefficient and efficiency in finned tube heat exchanger
9. Determination of overall heat transfer coefficient and efficiency in plate type heat exchanger
10. Determination of heat transfer coefficient in turbulent flow regime in a double pipe heat exchanger

11. Determination of Stephan Boltzmann constant experimentally.
12. Determination of economy and capacity of open pan evaporator.
13. Determination of economy and capacity of multiple effect evaporator

Open source software and website:

Students can refer to video lectures available on the websites including NPTEL.

Activities suggested under Problem Based Learning:

Sl. No.	Name of the activity	No. of hours	Total Hours
1.	Industry/Research laboratory visit	Visit = 5h, Report preparation = 5h	10
2.	Technical Video based learning related to the subject	Duration of video = 5h Report preparation = 5h	10
3.	Assignment writing. Numerical based assignment is preferable.	5 assignments of 2h each.	10
4.	Self learning on-line course	Minimum duration of the course should be 10h.	10
5.	Complex problem solving	Maximum 2 problems. Study of the problem and solution finding.	10
6.	Poster/chart/power point preparation on technical topics		6
7.	Group Discussion on emerging/trending technical topics based on subject		1 hr each

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