BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani
Pilani Campus
AUGS/ AGSR Division

SECOND SEMESTER 2020-2021
Course Handout (Part II)

Date: 18/01/2021

In addition to Part I (General Handout for all courses appended to the Time Table), this portion gives further specific details regarding the course.

Course No.	**:**	CHE F241
Course Title	**:**	Heat Transfer
Instructor-in-Charge	**:**	BANASRI ROY
Instructors (Tutorial)	**:**	SOMAK CHATTERJEE, SRINIVAS APPARI

1. Course Description

Steady state and unsteady state conduction, Fourier's law, Concepts of resistance to heat transfer and the heat transfer coefficient. Heat transfer in Cartesian, cylindrical and spherical coordinate systems, Insulation, critical radius, Convective heat transfer in laminar and turbulent boundary layers, Theories of heat transfer and analogy between momentum and heat transfer, Heat transfer by natural convection, Boiling and condensation, Radiation, Heat exchangers: LMTD, epsilon-NTU method, Co-current counter-current and cross flows,
NTU – epsilon method for heat exchangers.

2. Scope & Objectives

After completion of this course the students are expected to:

- Estimate the rate of heat transfer for one dimensional steady state systems involving temperature gradient
- Define (both conceptually and mathematically) fundamental mechanisms of three heat transfer modes; Conduction, Convection (free and forced both), and radiation.
- Apply these three mechanisms of heat transfer in solving practically relevant chemical engineering problems; single phase and with phase change (boiling and condensation)
- Perform basic calculations related to the dependence of heat transfer coefficient on various physical and fluid property parameters theoretically and empirically for; free convection, forced convection, and boiling & condensation.
- Recognize and explain the construction and working principle of the various types of heat exchangers
- Apply the Kern's method to perform the process design of the new shell and tube heat exchangers
- Apply epsilon- NTU method to carry out the process design of the existing heat exchanger
- Recognize and explain the construction and working principle of the various types of evaporators

3. Prescribed Textbook (T)

Holman, J.P., Bhattacharyya, S. (2011), "Heat Transfer", 10th Ed., Tata McGraw Hill Education Pvt Ltd, New Delhi.

4. Reference Books

R1 :Sinnot, R.K. (2003), "Coulson & Richardson's chemical engineering vol 6", 3rd edition, Butterworth Heinemann, Oxford.

R2 : Mccabe, W.L., Smith, J.C., Harriott, P. (2005), “Unit operations of chemical engineering”, 7th edition, McGraw Hill International Edition, Singapore.

5. Course Plan

Module Number and Title	Topics to be Covered in Lecture (L)	Reference Ch./Sec.	Learning Outcomes (students be able:)
1. Basics of heat transfer	L1. Introduction to conductive, convective and radiative heat transfer	T: 1.1-1.4	• To define basic mechanisms of heat transfer • To develop the generalized form of energy equation
	L2. Energy Equation Development	T:1.1	
2. One dimensional steady state conduction	L3. Application of Fourier’s law in simple systems and thermal resistance formulation	T:2.1 – 2.3	• To apply the Fourier’s law of heat conduction in plane wall, cylindrical and spherical systems to calculate the heat loss in each case • To calculate the critical thickness of insulation for insulated pipe and spherical tank • To analyze the temperature distribution in systems with heat source and in systems having fin • To calculate the heat loss, efficiency and effectiveness of fin
	L4. Application of Fourier’s law in cylindrical and spherical systems and thermal resistance formulation	T: 2.4 – 2.5	
	L5. Critical thickness of insulation for cylindrical and spherical systems	T: 2.6	
	L6. Temperature distribution in plane wall and cylindrical system with heat source	T: 2.7 – 2.8	
	L7. Temperature distribution in a fin and fin efficiency & its effectiveness	T: 2.9-2.10	
	L8.Thermal contact resistance	T: 2.11	
3. One dimensional unsteady state conduction	L9. Lumped heat capacity System	T: 4.2	To analyze the temperature variation with time using • lumped heat capacity approach • analytical solution of semi-infinite wall/cylinder & sphere (Heisler charts)
	L10. Heat flow in infinite plate and in semi-infinite solid	T: 4.1, 4.3	
	L11. Temperature distribution and heat loss calculation using Heisler charts	T: 4.4	
4. Principles of convection	L12. Laminar Boundary Layer on a flat plate	T:5.4	To develop the relation of • Boundary layer thickness with Reynolds number for laminar flow over a flat plate • Heat transfer coefficient with Reynolds number and Prandtl number for laminar/turbulent flow over a flat plate and in a tube
	L13. Energy Equation of the Boundary Layer	T:5.5	
	L14. Thermal boundary layer on a flat plate and heat transfer coefficient	T:5.6	
	L15. Analogy: fluid friction and heat transfer and its application to turbulent heat transfer	T:5.7 – 5.8	

	L16 Heat transfer in tube flow: laminar and turbulent flow	T: 5.10-5.11	
5. Empirical and practical relations for forced convection heat transfer	L17. Empirical relations for pipe and tube flow	T: 6.2	To estimate the heat transfer coefficient for a given system using most appropriate empirical equations available and compare
	L18. Empirical relations for flow across cylinders and spheres	T: 6.3	
	L19. Empirical relations for flow across tube banks	T:6.4	
	L20. Example problems to estimate heat transfer coefficient	T: 6.2-6.4	
6. Natural convection	L21. Free convection heat transfer on a vertical flat plate	T: 7.2	To estimate the heat transfer coefficient for a given system using different appropriate empirical equation available and compare
	L22. Empirical relations for free convection: planes, cylinders and spheres	T: 7.3-7.6, 7.10	
	L23. Empirical relations for free convection: enclosed spaces & combine free and forced convection	T: 7.11 - 7.12	
7.Condensation and Boiling	L24. Condensation heat transfer phenomena & condensation number	T: 9.1 -9.3	To estimate the heat transfer coefficient and/or heat loss for a given system involving phase change using most appropriate theoretical/empirical equation and compare
	L25. Film condensation inside horizontal tubes and introduction to boiling heat transfer	T: 9.4-9.5	
	L26.boiling heat transfer and its empirical relations	T: 9.5 – 9.6	
8. Heat exchangers	L27. Introduction, LMTD and fouling factor	T:10.1-10.5	• To explain construction and working principle of various types of heat exchangers • Apply Kern's method to perform the process design of the new shell and tube heat exchangers • Apply epsilon- NTU method to carry out the process design of the existing heat exchanger
	L28. Overall heat transfer coefficient and types of heat exchangers	T:10.1-10.5	
	L29. General design considerations & Kern's method	R1:12.5-12.9.3	
	L30. Example Problem: Kern's method	R1:12.5-12.9.3	
	L31. Effectiveness NTU method	T: 10.6	
	L32. Example problem: Effectiveness NTU method	T: 10.6	
9. Radiation heat transfer	L33. Physical mechanisms, radiation properties and governing laws	T: 8.1 – 8.3	• To estimate the rate of steady state heat transfer between two or more nonblack/black bodies • To develop the radiation resistance network and analyze it using electrical analogy
	L34. Radiation shape factors and relation amongst them	T: 8.4 – 8.5	
	L35. Heat exchange radiation network	T: 8.6 – 8.7	

	L36. Radiation shields & Radiation network for an absorbing and transmitting medium	T: 8.8 - 8.10	
10.Evaporation	L37. Introduction, application and types of evaporator	R2: 16	• To explain construction and working principle of the various types of evaporators • To evaluate the performance of evaporators in terms of the capacity, economy and steam consumption
	L38. Performance of evaporator	R2: 16	
	L39. Multiple effect evaporation	R2: 16	
	L40. Effect of boiling point elevation on multiple effect operation and vapor recompression	R2: 16	

6. Evaluation Scheme

Sl No.	Evaluation Component (EC)	Duration	Weightage (Marks/ %)	Date, Time	Remarks
1	Mid semester test	90 min	90/30		CB /OB
2	Tutorial tests (TT) (5 best out of XX conducted)		75/25	During tutorial class. Surprise in nature	CB/OB
3	Assignment (Aspen/Matlab)		15/5%		
4	Comprehensive examination	120 min	120/40		CB/ OB

- **Notes: CB= Closed book, OB= Open book**

Important:
- **Chamber consultation hour:** It will be announced in the class. Prior appointment via email or discussion in class is encouraged.
- The **notices,** if any**,** concerning the course will be displayed on the Google Classroom/Nalanda only.
- **Make-up** will be granted for **genuine cases only**. Proper certificate from authenticated doctor, say from the BITS Medical Center, must accompany make-up application (*only prescription or vouchers for medicines will not be sufficient*). Prior permission of IC is compulsory. **No** make-up will be granted for the **tutorial** tests**.**

Instructor-in-charge
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