BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani

Pilani Campus

AUGS/AGSR Division

SECOND SEMESTER 2020-2021
COURSE HANDOUT (PART II)

Date: 18.1.2021

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 F414**
Course Title : **Transport Phenomena**
Instructor In-charge : **BHANU VARDHAN REDDY KUNCHARAM**

1. Course Description

Analogy for momentum, heat and mass transport; shell balance approach for analysis of individual and simultaneous momentum, heat and mass transport; hydrodynamic and thermal boundary layers; velocity, temperature and concentration distributions in turbulent flow; interphase transport for isothermal and non-isothermal systems.

2. Scope and Objectives

- The primary objective of the course is to develop an understanding of a unified approach to study three closely related topics: fluid dynamics, heat transfer, and mass transfer. Also, analyze the analogy in these three transport mechanisms in terms of governing laws.
- The scope of the course is to represent the process behavior mathematically by applying the following transport phenomena fundamentals:
  - Apply the shell balance (mass, momentum and energy) to develop a system of partial/ordinary differential equations.
  - Find the required boundary conditions based on the understanding of the physics of the system.
  - Solve governing equations to find velocity/concentration/temperature/pressure profile using appropriate analytical methods.
- Develop the equation of continuity and equation of change for mass, momentum and energy.
- Apply the equation of change to a real physical system and deduce the governing equation by eliminating few terms representing phenomena not occurring in the process.
- Familiarize with computational tools (CFD) available to solve transport phenomena problems.

3. Prescribed Text Book

T.1 Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2007). Transport phenomena. John Wiley & Sons, 2nd Edition

4. Reference Books

R.1 Fox and McDonald, 'Introduction to fluid dynamics,' John Wiley & Sons, 2008, 7th Ed.
R.2 Holman, J.P., 'Heat transfer', McGraw Hill, 1997, 8th edition
R.3 McCabe, W. L., Smith, J. C., & Harriott, P. Unit operations of chemical engineering, McGraw-Hill, 7th Edition

5. Course Plan

Module	Lecture session	Reference	Learning Outcomes
1. Basics of Momentum Transport	**L1.** Introduction to transport phenomena	T1:0.1-0.4	Revise the basics of heat, mass and momentum transport and their governing laws
	L2. Mechanisms of momentum transport	T1: 1.1, 1.7	Understand the various mechanism of momentum transport
	L3. Generalization of Newton's law of viscosity	T1:1.2	Develop the generalized form of Newton's law of viscosity
2. Shell Momentum Balances and Velocity Distributions in Laminar Flow	**L4.** Concepts of shell momentum balance and boundary conditions	T1:2.1-2.2	To find the velocity profile in a laminar flow for various systems To apply the shell momentum balance and develop the governing equation and find out appropriate boundary conditions To solve the resulting set of equation with appropriate analytical method and boundary conditions
	L5. Example Problem: Flow through a circular tube	T1:2.3	
	L6. Example Problem: Flow through an annulus	T1:2.4	
	L7. Example Problem: Flow of two adjacent immiscible fluids	T1:2.5	
	L8. Application of shell momentum balance on narrow slit system with and without moving wall	T1: Ex 2B3-2B4	
	L9. Application of shell momentum balance on flow of a film on outside circular tube and annular flow with inner cylinder moving axially	T1: Ex 2B6-2B7	
3. Equation of Change for isothermal systems	**L10.** Equation of Continuity	T1:3.1	To apply the equation of continuity and equation of motion and develop the governing equation and find out appropriate boundary conditions To solve the resulting set of equation with appropriate analytical
	L11. Equation of Motion and types of derivatives	T1:3.2-3.5	
	L12. Use of Equation of change to solve flow problems	T1:3.6	
	L13. Dimensional analysis and velocity profile development in flow near rotating sphere and cone and plate viscometer	T1:3.7	

	L14. Velocity profile development for flow near rotating sphere and creeping flow around a sphere	T1: Ex 3.6.5 and Ex 3.7.1	method and boundary conditions and develop velocity profile To familiarize with numerical tools to solve transport phenomena (momentum flow) problems.
	L15. Demonstration of numerical tools (ANSYS, Matlab) to analyze momentum flow problems.	--	
4. Boundary layer theory and velocity distribution in turbulent flow	**L16.** Introduction to Boundary Layer theory	T1: 4.4	To understand the Boundary Layer theory and its application to flow problems. To develop the model for the turbulent flow system using Reynolds decomposition phenomena To apply the time smoothed equation of change and develop the velocity profile for turbulent system
	L17. Examples applying the Boundary Layer theory	T1: 4.4	
	L18. Basics of turbulent flow and Reynolds decomposition and time-smoothed equation of change for incompressible fluids	T1: 5.1-5.2	
	L19. Time smoothed velocity profile near a wall	T1: 5.3	
5. Basic of Energy Transport and Temperature Distributions in Solids and Laminar Flow	**L20.** Mechanisms of Energy Transport	T1: 9.1,9.7, 9.8,	To find the temperature profile in solid and in a laminar flow for various systems To apply the shell energy balance and develop the governing equation and find out appropriate boundary conditions To solve the resulting set of equation with appropriate analytical method and boundary conditions
	L21. Concepts of Shell Energy balance and boundary conditions	T1: 10.1	
	L22. Temperature distributions in Solids: Heat conduction with electrical heat source	T1: 10.2-10.3	
	L23. Temperature distributions in Solids: Heat conduction with nuclear heat source	T1: 10.3	
	L24. Temperature distribution in solids with viscous heat source	T1: 10.4	
	L25. Temperature distribution in a cooling fin	T1: 10.7	
	L26. Forced Convection	T1: 10.8	
	L27. Free convection	T1: 10.9	

	L28. Example Problems: Forced convection heat transfer in parallel plates	T1: 10B.7	
6. Equation of change for non-isothermal systems	**L29.** Development of Energy Equation	T1: 11.1-11.3	To apply the equation of change of energy and equation of motion and develop the governing equation and find out appropriate boundary conditions To solve the resulting set of equation with appropriate analytical method and boundary conditions and develop temperature profile To familiarize with numerical tools to solve energy transport problems and non-isothermal systems.
	L30. Use of Equations of change of energy to solve steady state problems: Laminar flow in circular tube	T1:11.4.1	
	L31. Use of Equations of change of energy to solve steady state problems: Tangential flow in annulus with viscous heat generation	T1:11.4.2	
	L32. Use of Equations of change of energy to solve steady state problems: Transpiration cooling	T1:11.4.3	
	L33. Use of Equations of change of energy to solve steady state problems: Free convection heat transfer from a vertical plate	T1: 11.4.5	
	L34. Dimensional analysis of the equation of change for non-isothermal system	T1:11.5	
	L35. Demonstration of numerical tools (ANSYS, Matlab) to analyze Energy transport and non-isothermal systems.	--	
7. Basics of Mass Transport, Shell Balance and Equation of Change for multi-component system	**L36.** Mechanics of Mass Transport	T1: 17.1,17.7, 17.8,17.9	To find the concentration profile in stagnant and in a laminar flow for various systems To apply the shell mass balance and develop the governing equation and find out appropriate boundary conditions To solve the resulting set of equation with
	L37. Shell Mass Balance and Boundary conditions	T1: 18.1	
	L38. Diffusion with a stagnant film	T1: 18.2	
	L39. Diffusion with heterogeneous/homogeneous chemical reaction	T1: 18.3-18.4	
	L40. Diffusion into a falling liquid film and diffusion and chemical reaction inside a porous catalyst	T1: 18.5, 18.7	

	L41. Equation of Change for multi component system	T1: 19.1	appropriate analytical method and boundary conditions. To familiarize with numerical/CFD tools available to solve mass transport (diffusion and reaction in porous media).
	L42. Summary of multi component equation of change	T1:19.2	
	L43. Illustration of diffusion and reaction in a porous catalyst using CFD software.	---	

Overall Course Learning Outcomes:

1. Identify and develop analogy between momentum, mass and heat transport phenomena.
2. Write shell balances for 1D momentum, heat and mass transport problems,
3. Develop ordinary and partial differential equations from the shell balances and identify the boundary conditions to solve the ODEs and PDEs.
4. Develop continuity, equation of change for isothermal and non-isothermal systems for momentum, heat and mass transport problems.
5. Apply equation of change to real systems and develop the governing equation by eliminating terms that are not necessary or negligible.
6. Use CFD software to solve transport phenomena problems and appreciate the know-how behind the CFD.

6. Evaluation Scheme:

EC No.	Evaluation Component	Duration	Weightage (%)	Date & Time	Remarks
1.	Mid Semester Test	90 min	30	TBA	Open Book
2.	Assignments (2)	-	5	Throughout Semester	Open Book/Take Home
3.	Quizzes (2)	15 min	10	Throughout Semester	Closed Book
4.	Design Project and Seminar using CFD software	-	15	Throughout Semester	Open Book/Take Home
5.	Comprehensive Exam	120 min	40	TBA	Open Book

Closed Book Test:

No reference material of any kind will be permitted inside the exam hall.

Open Book Exam:

Use of any printed/written reference material (books and notebooks) will be permitted inside the exam hall. Loose sheets of paper will not be permitted. Computers or electronic devices of any kind will not be allowed inside the exam hall. Use of calculators will be allowed in all exams. No exchange of any material will be allowed.

7. Chamber Consultation Hours:

TBA

8. Notices:

All announcements, notices will be posted on the Nalanda portal or Google Classroom only.

9. Make-up Policy:

Make-up is granted only for genuine cases with valid justification and prior permission of the Instructor-in-charge. Certificate from authenticated doctor, say from the Medical Center, must accompany make-up application (only prescription or vouchers for medicines will not be sufficient). Prior permission from IC, barring emergencies, is mandatory. *There is no makeup for Project, Assignment, and surprise quiz/discussion components.*

10. Note:

Any changes made to the above handout will be notified earlier in the class.

(BHANU VARDHAN REDDY KUNCHARAM)

Instructor-In-Charge
CHE F414