GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering
Level: PG
Branch: Chemical Engineering
Subject Code:
Subject Name: Advanced Transport Phenomena in Chemical Engineering

W.E.F. Academic Year:	A.Y. 2024-25
Semester:	2
Category of the Course:	PCC-04

Prerequisite:	Students should have a foundational understanding of the basics of Fluid Mechanics, Heat Transfer and Mass Transfer Operations
Rationale:	This course enables students to understand Momentum, Heat and Mass Transfer in chemical engineering. It is essential to understand mathematical modelling and analogical aspects of chemical process systems where these transport processes occur simultaneously. This course focuses on such typical situations and thereby its complete understanding on axial as well as radial profiles

Course Outcome:

Upon successful completion of this course, students will be able to:

No	Course Outcomes
01	Understand the mechanism of momentum, heat and mass transport for steady and unsteady flow.
02	Perform momentum, energy and mass balances for a given system at macroscopic and microscopic scales.
03	Solve the governing equations to obtain velocity, temperature and concentration profiles.
04	Model the momentum, heat and mass transport under turbulent conditions.
05	Develop analogies among momentum, energy and mass transport.

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+(PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial/ Practical		
L	T	PR	C	ESE (E)	PA/ CA (M)	PA/CA(I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	%of Weightage
1.	**Analogies in Momentum, Heat and Mass Transfer:** Introduction, Reynolds analogy, Prandtl Taylor analogy, Van Karman analogy	**3**	**7**
2.	**Principles of Momentum Transport:** Molecular and convective momentum transport, Molecular theory of viscosity in gases and liquids. **Shell Momentum Balances and Velocity Distributions in Laminar Flow**: Shell momentum balances and boundary conditions, Flow of a falling film, Flow through a circular tube, Flow through an annulus, Flow of two adjacent immiscible fluids, Creeping flow around a sphere, **The Equations of Change for Isothermal Systems and its application to solve flow problems** **Velocity Distributions with More Than One Independent Variable:**Time-dependent flow of Newtonian fluids**:** Unsteady Laminar Flow between two parallel plates. Flow near a Wall suddenly set in motion, Unsteady Laminar Flow near an Oscillating Plate. Solving flow problems using a stream function **Turbulent flow:** Reynolds stress, Time-Smoothed Equations of Change for Incompressible Fluids and Velocity distributions, Boundary layer flow.	**14**	31
3.	**Principles of Energy Transport:** Molecular and convective energy transport, Theory of thermal conductivity in solids, gases and liquids, Shell energy balances, Heat conduction with various heat sources, Equation of changes in non-isothermal systems and its applications to solve steady-state forced and free convection and viscous heat generation problem, Unsteady state heat conduction, transient conduction, temperature distributions in laminar tube flow and laminar forced convection near the heated flat plate. Temperature distributions in turbulent flow: time smoothened equation of changes and time smoothened temperature profile near wall. Temperature distribution in boundary layer.	**14**	31
4.	**Principles of Mass Transport:** Molecular and convective mass transport, Theory of binary and multicomponent diffusion in gases and liquids, Shell mass balances and concentration distribution in laminar flow, Diffusion in a homogeneous and heterogeneous chemical reaction, diffusion in falling liquid film, diffusion and chemical reaction inside porous catalyst,	**14**	31

	diffusion in three component gas system, equation of changes for multicomponent systems, Use of the Equations of Changes to solve Simultaneous heat and mass transport and concentration profile in a tubular reactor principles of unsteady state diffusion.		
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
07	17	18	14	14	00

Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. Bird R.B., Stewart W.E., Lightfoot E.N., Transport Phenomena, 2nd Edition, John Wiley & Sons, 2002
2. James Welty, Charles E. Wicks and Wilson, Gregory L Rorrer, "Fundamentals of Momentum, Heat and Mass transfer", 5th Edition, 2008.
3. Frank P.U., David P.D., Theodore L. B. "Fundamentals of heat and mass transfer",6th edition, John Wiley & Sons, 2005.
4. Geankoplis C.J., Transport Processes and Separation Process Principles,4th Edition
5. Slattery J.C., Advanced Transport Phenomena, Cambridge University Press.

(b) Open-source software and website:

To enhance learning, students can use the following open-source software tools and websites for modelling and simulation in transport phenomena.

Open-Source Software

- Scilab: Numerical computation for the transport process.
- OpenFOAM:For computational fluid dynamics involving heat, momentum and mass transport.
- FIAT: Finite Element Analysis Tool for solving partial differential equations in diffusion, heat conduction, and fluid dynamics problems.

- SU2 :Stanford University Unstructured for turbulence and structural mechanics.
- MFiX:Multiphase Flow with Interphase eXchanges for multi-phase transport problems.
- Elmer FEM: For heat and mass transfer.

Websites and Resources

- NPTEL https://archive.nptel.ac.in/courses/103/106/103106068/
- NPTEL https://nptel.ac.in/courses/103108123
- MIT https://ocw.mit.edu/courses/10-302-transport-processes-fall-2004/pages/syllabus/
- MIT https://mitxonline.mit.edu/programs/program-v1:MITxT+10.50x/

Suggested Course Practical List:

1. Determination of kinematic viscosity of mixture using different viscometers.
2. Determination of Efflux time for various fluids.
3. Efflux time for a given fluid in different systems.
4. Experiments with flow through concentric pipe and modelling for shear stress and velocity distribution.
5. Experiments with flow through slit and modelling for shear stress and velocity distribution.
6. Experiments with flow through inclined plane and modelling for shear stress and velocity distribution.
7. Determination of thermal conductivity of metal rods and modelling heat flux and temperature distribution.
8. Experiment and modelling on Free and forced convection heat transfer.
9. Determination of diffusion from the stagnant fluid at room and at elevated temperature,
10. Determination of mass transfer coefficient with and without chemical reaction.
11. Experiment on the performance of the cooling tower.
12. Experiments on unsteady state heat conduction.

Equipments: Redwood Visco meter, capillary U tube viscometer, Efflux time system such as cylindrical and conical system with and without extended pipe, Slit and concentric pipe, inclined plane system. Thermal conductivity apparatus, Free convection apparatus, forced convection apparatus, diffusion cell, autoclave, cooling tower setup etc.

List of Laboratory/ Learning Resources Required:

Laboratory Facilities

1. Chemical Storage Cabinets
2. Personal Protective Equipment (PPE)

Suggested Project List:

- Computational Fluid Dynamics (CFD) of Pipe Flow.
- Drag Reduction in Flow over a Flat Plate
- Flow through Porous Media
- Diffusion in a Solid Matrix
- Diffusion in a mesoporous catalytic system.
- Unsteady state flow for parallel pates
- Heat and mass transfer in turbulence.
- Unsteady laminar flow between parallel plates.
- Unsteady laminar flow near an oscillating plates.
- Unsteady state heat conduction in solid.
- Concentration profile in a tubular reactor.
- Catalytic oxidation of carbon monoxide.
- Unsteady state evaporation of liquid.

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