Course Content Prepared By: Dr. Amit Ranjan

1. GENERAL

1.1 COURSE TITLE: **Advanced Transport Phenomena**

1.2 COURSE NUMBER: CH521

1.3 CONTACT HRS: 3-0-0 Credits: 9

1.4 SEMESTER -OFFERED: MTech 1st Semester

1.5 PREREQUISITE: Thermodynamics, Fluid Mechanics, Heat and Mass Transfer.

OBJECTIVE:

- To understand the similarity in the mathematical formulations of momentum, heat and mass transfer phenomena.
- To understand the origin and nature of convective and diffusive transport in all the three cases.
- To understand the physical interpretation of various terms in equations describing these transport processes.
- To understand the general 3-dimensional tensorial formulation of transport processes.
- To be able to apply the governing equations to and obtain analytical solutions of simple problems in transport phenomena.
- To be able to carry out non-dimensionalization for a given problem.
- To understand the physical origin and implications of various dimensionless numbers when simultaneous transport of any two or more of heat, mass, or momentum occurs, and be able to analyze the problem based on the values of these dimensionless numbers.
- To be able to implement scientific computing to solve relatively complex problems pertaining to transport processes.

3. COURSE CONTENT (Unit wise distribution of content and number of lectures)

No.	Broad Topic	Topics in detail
1.	Introduction	Connecting Molecular picture to macroscopic continuum picture; convective and diffusive transport; Mass, heat, and momentum transports of both kinds
2.	Momentum transport/Flow	Kinematics of flow: Review of Lagrange and Euler's picture; Euler and material derivative; Reynold Transport Theorem. Mass conservation equation (in Lagrangian and Eulerian descriptions)
3.		Momentum balance equation in flows. Tensorial description of velocity field, stresses, and strain fields. Tractions. Relation between traction and stresses.
4.		Relating stresses to strain rates in fluids. Newtonian fluids. Navier Stokes Equation.
5.		Energy Balance Equation. Splitting total Energy balance into mechanical energy and Thermal Energy balance equations…
6.		…*contd*. Physical meaning of various terms in Thermal Energy conservation eqn. Energy balance equation in terms of enthalpy and temperature.
7.		Falling liquid film on an inclined plane problem …
8.		…*contd*. Flow through Pipes: Review important relations. Operation of capillary viscometers. Issue of scaling down (microfluidics) for achieving higher mass transfer.
9.		Gas flow in a circular tube.
10.		Probs 2.B.6, 2.B.7, 2.C.1, 2.C.2 (BSL)
11		Examples 3.6-4, 3.6-5 (BSL), Stokes and Inviscid flows, Section 2.6/BSL Prob 2.A.4
12		Geometric, kinematic, and dynamic similarity. Method of dimensional analysis. Stokes law from dimensional analysis.
13		Stream functions. Physical interpretation of psi. Equations relating stream function and velocity field.
14		Transient problems: Solution method to problem of semi-infinite fluid driven by boundary motion…(*contd.*).
15		…(*contd.*) Transient problems: Solution to fluid flow between two parallel plates driven by the surface movement…(*contd*...)
16		Boundary layers
17		Turbulence. Origin of turbulence. Statistical description
18		Reynold's stress. Velocity profile in turbulent flows. Boundary layer structure in turbulent flows.
19		Friction factors in internal flows and flow around a submerged body.
20		Friction factor in packed bed columns. Ergun eqn.
21		Non-Newtonian fluids description. Velocity profiles.
22		Models of polymeric liquids: Generalized Newtonian Models(Power Law model and Carreau Model), Viscoelastic models (Maxwell, Voigt, and Stress Relaxation models)
23	Energy Transport	Energy transport by: Conduction, convection, and radiation. Energy balance equation in isothermal systems.
24		Application of energy balance to example problems: Line source of heat, Nuclear source of heat, Composite walls. Heat conduction in cooling fins. (Review)
25		Forced convection. Free convection.
26		Energy transfer equation in non-isothermal systems.
27		Example problems. Boussinesq approximation.
28		Unsteady heat conduction in solids. Thermal boundary layer.
29		Simultaneous momentum and heat transfer: Thermal and momentum boundary layers.
30		Von Karman momentum and energy balance in boundary layers. Interrelationship between momentum and thermal boundary layers.
31		Calculation of heat transfer coefficients in various systems: Forced convection through Tubes and slits.
32		Heat transfer coefficients in forced convection through packed beds.
33	Mass transport	Fick's law (Review). Examples of concentration profile calculations: Diffusion and heterogeneous reactions.

34		Homogeneous reaction with diffusion. Diffusion in falling liquid films.
35		Equations for multicomponent mixtures. Simultaneous heat and mass transport.
36		Concentration profile in a tubular reactor.
37		Transient diffusion and binary boundary layers for mass transport.
38		Concentration distribution in turbulent flows.
39		Mass transfer coefficients.
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4. READINGS

4.1 TEXT BOOKS:

1. Advanced Transport Phenomena, Author: Gary Leal.
2. Transport Phenomena, Author: Bird, Stewart, and Lightfoot.

5. OUTCOME OF THE COURSE:

Students are able to:

- Give physical meanings to different kinds of mathematical terms appearing in a transport equation.
- Non-dimensionalize a given problem and identify the dimensionless numbers.
- Understand the physical meaning of various tensorial quantities used in engineering problems.
- Solve problems where various transport processes including those of mass, heat, and momentum may occur.
- Propose a mathematical model by themselves given a problem involving the transport processes.
- Analyze the transport processes occurring in industrial set-ups.