Ref. No. **Ex/PG/ME/C/PC/T/114C/2025**

M.E. MECHANICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM 2025

Subject: Heat and Mass Transfer

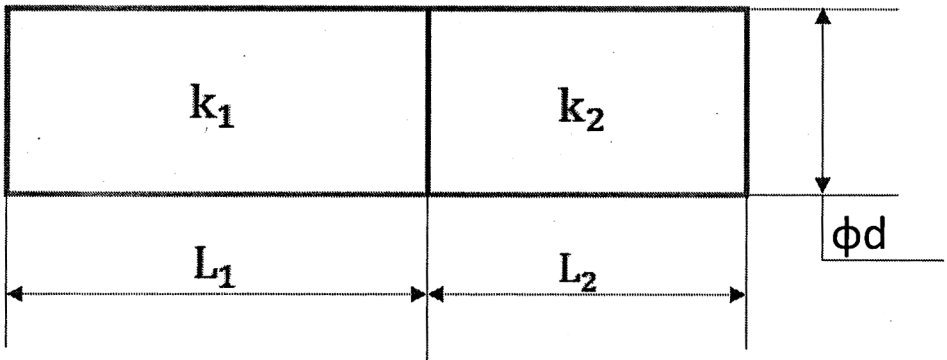
Time: **3** hours | Full Marks: **100**

50 Marks for each Part

Use separate Answer Script for each Part

Part – I

Answer any two questions

1.	A composite solid stationary cylinder (diameter=d) of two parts of different materials having constant thermal conductivities k_1 and k_2, and lengths L_1 and L_2 are joined together, as shown in Fig. 1 below. Two open transverse boundaries (end faces) are maintained at a constant temperature of T_0. The lateral (curved) surfaces release heat due to convection with a uniform convective heat transfer coefficient h into a surrounding cold fluid at a temperature Ta. If one-dimensional and steady state heat transfer occurs in the length direction of the composite cylinder with negligible thermal resistance in the radial direction, determine the object's temperature distribution and heat transfer rate for the absence of radiation effects. The internal volumetric heat generation rate (q''') for the above thermal application is constant in both cylinders. Due to a thermal contact resistance at the joining section, a temperature drop exists by T_d. Also, plot a free-hand sketch for the temperature variation of this object with heat generation to understand the nature of thermal conditions.  Fig. 1: A composite solid cylinder	25

2. (a)	Derive the radiation heat exchange between two actual surfaces maintained at constant temperatures T_1 °C and T_2 °C, and the emissivities of these two surfaces are ε_1 and ε_2, respectively. Explain the geometric aspects that play a significant role in the above heat transfer cases. Derive the geometrical factors involvement in a generalized expression to develop knowledge of radiation phenomena. To establish the above fact, consider assumptions if required.	10
(b)	Define fin efficiency for the internal heat generation inside the fin. Explain how to determine the efficiency of this thermal design situation. Clarify mathematically that heat transfer rate is a scaler, although heat flux is a vector.	7
(c)	When are the curvilinear coordinates to consider heat conduction analysis? How heat flux depends on curvilinear coordinates for the hexagonal crystal system under transient heat transfer.	8
3.	A slab's whole surface maintains a constant initial temperature of T_0, and the two boundary surfaces satisfy a constant temperature of T_1. The length of the slab is L. The one-dimensional transient heat conduction through the slab takes place. The heat is generated inside the slab with a constant volumetric heat generation rate q_g. The thermal conductivity of the slab material is assumed to be nonvariant. Determine the temperature response and the heat transfer rate per unit cross-sectional area.	25

Ref. No Ex/PG/MEC/PC/T/114C/2025

M.E. MECHANICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM 2025
HEAT AND MASS TRANSFER

Time: Three hours **Full Marks 100**

Part – II (FULL MARKS 50)

Use separate answer script for each part

Answer question number 1 and any 2 from the rest.
All parts of the same question must be answered together.

Q:1 Answer any **three** questions 3X6

(a) Draw the sketch of boundary layers over a flat plate under forced convection. for Pr <1. Show that the expression of Nusselt number is equal to non-dimensional temperature gradient at the wall.
(b) What do you mean by Boussinesq approximation? Develop the governing equations for natural convection.
(c) Define mixture velocity, relative flux and absolute flux of multiple species with advection. Write down the bulk continuity equation and continuity equation for i-th specis.
(d) What is thermal entrance length? Develop an appropriate scale for thermal entrance length.

Q:2 Consider a differentially heated rectangular enclosure. Two of its horizontal parts are insulated and left vertical wall is at ΔT/2, while right vertical wall is at -ΔT/2. Write down the governing equations with transient term. Develop the expression for vertical velocity and time required to reach the steady state by a scale analysis. Hence develop the expression for scale of Nusselt number at steady state. 16

Q: 3 Given: $\rho \frac{De}{Dt} = -\hat{\nabla}.\hat{q} - p\,\hat{\nabla}.\hat{V} + \mu\phi + q'''$

Derive the energy equation in terms of a) enthalpy and b) temperature from the above form. Explain each term for the final equations. 16

Q:4 A vessel contains liquid water, exposed in atmospheric air. The liquid-air interface is having a definite mass fraction of water vapour as w_{l_0} and the other side of the container is having mass fraction of w_{l_L}. Considering one-dimensional flow, formulate the problem with appropriate boundary condition. Determine the bulk mass flow rate as a function of local species gradient. Show that there is a bulk velocity of the mixture in the upward direction. 16