Ref. No. : Ex/PG/MEC/PE/T/122F/2025

M.E. MECHANICAL ENGINEERING FIRST YEAR SECOND SEMESTER – 2025

Subject: CONVECTIVE HEAT TRANSFER

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

Answer any FIVE questions.

Q.1	(a)	Consider a flow over a flat plate. Stating all necessary assumptions, find respective boundary layer equations from the continuity, momentum and energy conservation equations.	6
	(b)	Define Reynolds and Prandtl numbers along with their expressions.	2
	(c)	Explain Reynolds analogy, and find a relation between the Stanton number and friction coefficient. State assumptions, if required.	4
	(d)	Derive an expression for the energy integral equation stating all necessary conditions.	8
Q.2	(a)	Consider a flow over a flat plate. Sketch typical variations of respective velocity and temperature profiles. Hence, find (i) a suitable expression for respective velocity profile, and (ii) a suitable expression for the temperature profile also in case of a constant wall temperature condition, stating all necessary assumptions and boundary conditions.	10
	(b)	Define the Nusselt and Peclet numbers along with their expressions.	2
	(c)	Considering the energy integral equation, find a relation among the local Nusselt, Remolds and Prandtl numbers in case of a flow over a flat plate of constant wall temperature when Pr = 1.	8
Q.3	(a)	Consider a flow over a flat plate. Find a suitable expression for the temperature profile in case of a constant wall heat flux condition, stating all necessary assumptions and boundary conditions.	8
	(b)	Considering the energy integral equation, find a relation among the local Nusselt, Reynolds and Prandtl numbers in case of a flow over a flat plate of constant wall heat flux condition when Pr = 1.	8
	(c)	State the reason behind higher heat transfer in the case of constant wall heat flux condition than that of a constant wall temperature condition.	2
	(d)	Plot a schematic variation of the heat transfer coefficient along length of the flat plate.	2
Q.4	(a)	Explain the condition for thermally fully developed flow in case of an internal flow. Hence, show that the heat transfer coefficient remains constant for an internal flow.	3
	(b)	Define the average velocity and mixed-cup/mean temperature for an internal flow with their expressions.	2
	(c)	Show that the temperature, mean temperature and wall temperature vary linearly with the flow length (x) in the case of a constant wall heat flux condition.	3
	(d)	Considering the constant wall heat flux condition for a pipe flow, find (i) an expression for the velocity profile using the continuity and momentum equations stating necessary boundary conditions, and (ii) an expression for the Nusselt number using the energy equation.	12

[Turn over

Ref. No. : Ex/PG/MEC/PE/T/122F/2025

Q.5	(a)	Consider a viscous flow between two parallel plates at different uniform temperatures, and separated by a distance of H. One of the plates is stationary and the other plate moves with a high velocity (U). Considering the continuity, momentum and energy equations, derive an expression for the temperature variation across the plates.	12
	(b)	Define the Eckert number along with its expression.	2
	(c)	Find respective expressions for the heat transfer from both the plates. Hence, find a condition (or Eckert number) for an adiabatic wall.	4
	(d)	Find a condition (distance from one plate) for respective attainment of the maximum temperature.	2
Q.6	(a)	Draw schematically the development of boundary layer in case of a vertical hot plate labeling different zones of the flow. Hence, draw respective velocity and temperature profiles schematically at a section.	5
	(b)	Considering the continuity, momentum and energy conservation equations, derive respective boundary layer equations stating all assumptions.	10
	(c)	Hence, define the Grashof and Rayleigh numbers, and find their expressions.	3
	(d)	Explain the double diffusive convection with neat sketches.	2
Q.7	(a)	Define time-averaged turbulent flow field and state its necessary features.	4
	(b)	Hence, considering the laminar boundary layer equations, derive related boundary layer equations in case turbulent flow.	10
	(c)	In case of $Pr = 1$, find an approximate value of the heat transfer coefficient in case of near wall condition stating necessary assumptions.	6

*****X*****