BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(MID SEMESTER EXAMINATION)

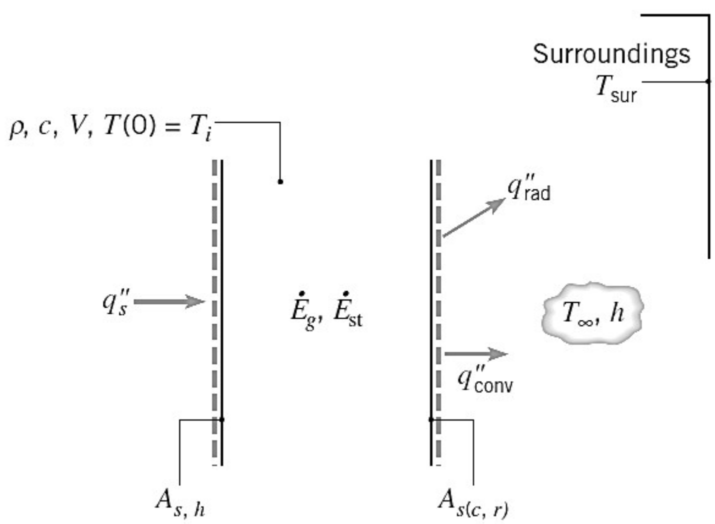
CLASS: B.TECH **SEMESTER : VII**
BRANCH: MECHANICAL ENGINEERING **SESSION : MO/2025**

SUBJECT: ME479 ADVANCED HEAT TRANSFER

TIME: 02 Hours **FULL MARKS: 25**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 5 marks and total 25 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.

			CO	BL
Q.1	A two dimensional rectangular plate is subjected to the boundary conditions: T(x=0,y)=0, T(x,y=0)=0, T(x=a,y)=0, T(x,y=b)=Ax. Derive expressions for the steady-state temperature distribution T(x,y) for 0≤x≤a and 0≤y≤b, and the steady-state heat flux distribution q”(x, y=b) for 0≤x≤a.	[5]	2	1-3
Q.2(a)	An electrical heater 100 mm long and 5 mm in diameter is inserted into a hole drilled normal to the surface of a large block of material having a thermal conductivity of 5 W/m·K. Estimate the temperature reached by the heater when dissipating 50 W with the surface of the block at a temperature of 25°C. See Appendix 1 for determination of the Conduction Shape Factor.	[2]	2	1-3
Q.2(b)	Derive the finite difference equation for a 2-dimensional steady state heat conduction problem with constant heat generation ($\dot{q}$) per unit volume, for an interior node surrounded by 4 other nodes, using both 1) energy balance method, and 2) starting from the governing equation for heat conduction.	[3]	1	1-2
Q.3	Explain the general lumped analysis approach to solved transient heat conduction problems. With reference to the schematic figure shown below, formulate the governing equation to determine temperature of the solid ‘T’ at any instant of time ‘t’, using rectangular coordinate system. All symbols carry usual meaning. Note that $\dot{E_g}$ and $\dot{E_{st}}$ represent the volumetric heat generation and the energy stored in the body at any time instant respectively. $A_{s,h}$ and $A_{s(c,r)}$ represent the surface areas exposed to the heat flux on the left, and to combined convection and radiation heat transfer on the right. Neglecting only radiation heat transfer on the right, use the governing ordinary differential equation to derive the expression for determination of T at any time instant.	[5]	1	1-2



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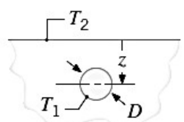
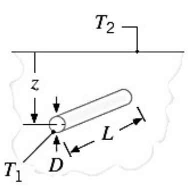
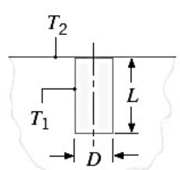
Q.4	Annealing is a process by which steel is heated and then cooled to make it less brittle. Consider the heating stage for a 100-mm-thick steel plate (ρ = 7830 kg/m^3, C = 550 J/kg·K, k = 48 W/m·K), which is initially at a uniform temperature of T_i = 200 °C and is to be heated to a minimum temperature of 550°C. Heating is effected in a gas-fired furnace, where products of combustion at T_∞ = 800°C maintain a convection coefficient of h = 250 W/m^2·K on both surfaces of the plate. How long should the plate be left in the furnace, considering only convection heat transfer between the furnace gases and the steel plate? Neglect the role of radiation heat transfer in the furnace, but comment on its impact on the net heating time, if considered. See Appendix 2 for determination of relevant coefficients.	[5]	3	1-4	2
Q.5(a)	Discuss the advantages of the similarity variable method, and the importance of semi-infinite solid approximation for solving 1-D transient conduction problem. Clearly cite the relevance of the method for application in a thick slab, under various thermal conditions.	[3]	1	1-2	2
Q.5(b)	What is thermal effusivity, and discuss its importance in the context of the equilibrium temperature at the interface contact between two semi-infinite solids.	[2]	1	1-2	2

Appendix 1: Table for Conduction shape factor

System	Schematic	Restrictions	Shape Factor
Case 1 Isothermal sphere buried in a semi-infinite medium		$z > D/2$	$\frac{2\pi D}{1 - D/4z}$
Case 2 Horizontal isothermal cylinder of length L buried in a semi-infinite medium		$L \gg D$	$\frac{2\pi L}{\cosh^{-1}(2z/D)}$
		$L \gg D$, $z > 3D/2$	$\frac{2\pi L}{\ln(4z/D)}$
Case 3 Vertical cylinder in a semi-infinite medium		$L \gg D$	$\frac{2\pi L}{\ln(4L/D)}$

Appendix 2: Coefficients in one-term approximation to series solutions for transient one-dimensional conduction

	Plane Wall	
Bi[a]	ζ_1 (rad)	C_1
0.01	0.0998	1.0017
0.02	0.1410	1.0033
0.03	0.1723	1.0049
0.04	0.1987	1.0066
0.05	0.2218	1.0082
0.06	0.2425	1.0098
0.07	0.2615	1.0114
0.08	0.2791	1.0130
0.09	0.2956	1.0145
0.10	0.3111	1.0161
0.15	0.3779	1.0237
0.20	0.4328	1.0311
0.25	0.4801	1.0382
0.30	0.5218	1.0450
0.4	0.5932	1.0580
0.5	0.6533	1.0701
0.6	0.7051	1.0814
0.7	0.7506	1.0919
0.8	0.7910	1.1016
0.9	0.8274	1.1107
1.0	0.8603	1.1191