

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

CLASS: BTECH
BRANCH: MECHANICAL ENGINEERING

SEMESTER: VII
SESSION: MO/2025

SUBJECT: ME479 ADVANCED HEAT TRANSFER

TIME: 3 Hours

FULL MARKS: 50

INSTRUCTIONS:

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
 2. Attempt all questions. The missing data, if any, may be assumed suitably.
 3. Before attempting the question paper, be sure that you have got the correct question paper.
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| Q.1 A two-dimensional rectangular plate of length L in x-direction and width W in y-direction is subjected to prescribed temperature boundary conditions of temperature T_1 on three sides and a uniform heat flux (q_s'') into the plate at the top surface. Using the separation of variables method, derive an expression for the temperature distribution in the plate. Also, derive an expression for the shape factor, S_{\max} , associated with the maximum top surface temperature, such that $q_s'' = S_{\max} k (T_{2,\max} - T_1)$ where $T_{2,\max}$ is the maximum temperature along $y = W$. | [10] 1,2 | 1-4 |
| Q.2 Asphalt pavement may achieve temperatures as high as 50 °C on a hot summer day. Assume that such a temperature exists throughout the pavement, when suddenly a rainstorm reduces the surface temperature to 20 °C. Calculate the total amount of energy (J/m^2) that will be transferred from the asphalt over a 30-minute period in which the surface is maintained at 20 °C. Consider the semi-infinite solid approximation and the properties of asphalt as follows: $\rho = 2115 \text{ kg/m}^3$, $C = 920 \text{ J/kg}\cdot\text{K}$, $k = 0.062 \text{ W/m}\cdot\text{K}$. Determine the minimum thickness of the pavement for which the semi-infinite slab approximation is valid during the 30-minute period. Also, if the thickness is lesser, briefly describe the calculation approach for the total energy, without performing calculations. | [10] 2,3 | 1-5 |
| Q.3 Write down the continuity, momentum, and energy equations for two-dimensional uniform flow over a flat plate. Using the order of magnitude analysis, determine the dependence of the Nusselt No upon the Reynold's No and Prandtl No. for fluids having very high and low Prandtl no. Use the symbols discussed in class. | [10] 1 | 1-3 |
| Q.4 A furnace is shaped like a long equilateral triangular duct, and the width of each side is 1 m. The base surface has a gray emissivity of 0.7 and is maintained at a uniform temperature of 600 K. The heated left-side surface closely approximates a blackbody at 1000 K. The right-side surface has gray emissivity of 0.5 and is well insulated. Show the radiation network diagram for this 3-surface enclosure and determine the rate at which heat must be supplied to the heated left side externally per unit length of the duct in order to maintain these operating conditions. What is the steady state temperature of the right side? Now, if the base surface properties are spectrally dependent with its emissivity as $\epsilon_\lambda = 0.8$ for $0 < \lambda < 3\mu\text{m}$ and $\epsilon_\lambda = 0.2$ for $3\mu\text{m} < \lambda < \infty$, then formulate the governing equations for solving this problem, with spectral symbols discussed in class. | [10] 2,3 | 1-5 |
| Q.5 For a thin slab of thickness L made of clear glass-like transparent material and at room temperature, determine the net transmittance, in terms of its total reflectivity 'ρ', given that the material has a constant value of total absorption coefficient 'α'. Use symbols as discussed in the class. State any assumption, if necessary. | [5] 2 | 1-3 |
| Q.5 State the generalised mathematical form of the radiative transfer equation, clearly mentioning the physical significance of each term involved. Derive the simpler form of the equation assuming no scattering, in terms of the absorptance and transmittance of the media, assuming constant radiative properties. | [5] 1 | 1-2 |