

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

CLASS: BTECH  
BRANCH: MECH

SEMESTER : V  
SESSION : MO/2025

**SUBJECT: ME315 HEAT & MASS TRANSFER**

TIME: 3 Hours

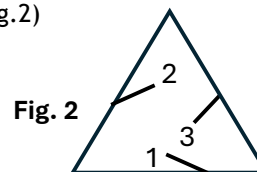
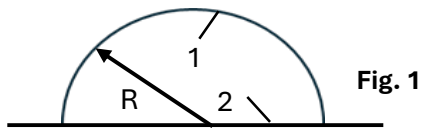
FULL MARKS: 50

**INSTRUCTIONS:**

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

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|---|-----|-----------|---------|
| Q.1(a) A steam pipe is covered with two layers of insulation, first layer being 3 cm thick ( $k = 0.17 \text{ W/m.K}$ ) and second 5 cm thick ( $k = 0.093 \text{ W/m.K}$ ). The pipe is made of steel ( $k = 58 \text{ W/m.K}$ ) having ID of 160 mm and OD of 170 mm. The inside and outside film coefficients are 30 and $5.8 \text{ W/m}^2.\text{K}$ respectively. Determine the heat loss per meter of pipe, if the steam temperature $300 \text{ }^\circ\text{C}$ and ambient air temperature is $50 \text{ }^\circ\text{C}$ .  | [5] | CO<br>CO1 | BL<br>M |
| Q.1(b) A 6 cm diameter, steel ball is at uniform temperature of $800 \text{ }^\circ\text{C}$ . It is to be hardened by suddenly dropping it into an oil bath at a temperature of $50 \text{ }^\circ\text{C}$ with convection heat transfer coefficient of $500 \text{ W/m}^2.\text{K}$ . If the quenching occurs when the ball reaches a temperature of $100 \text{ }^\circ\text{C}$ , determine how long should be kept in oil bath? If 100 balls are to be quenched per minute, determine the rate of heat removed from the oil bath in order to maintain the bath temperature at $50 \text{ }^\circ\text{C}$ . Take thermophysical properties as: $k = 61 \text{ W/m.K}$ , $\rho = 7850 \text{ kg/m}^3$ , $C = 460 \text{ J/kg.K}$ . | [5] | CO1       | M       |

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| Q.2(a) An aluminium alloy fin ( $k = 200 \text{ W/m.K}$ ) of length 2.5 cm protrudes from a wall of temperature $420 \text{ }^\circ\text{C}$ and the temperature of the ambient $30 \text{ }^\circ\text{C}$ . The heat transfer coefficient between fin surface and surrounding $11 \text{ W/m}^2.\text{K}$ . The fin has a rectangular cross section of thickness 3.5 mm. Determine the heat loss per unit width, fin efficiency and effectiveness if the heat loss from the tip is negligible. | [5] | CO2 | M |
| Q.2(b) Find the view factors $F_{1-1}$ , $F_{1-2}$ and $F_{2-1}$ for the following geometry<br>i) Radiation heat exchange between hemisphere and a plane surface (Fig.1)<br>ii) A tube whose section is equilateral triangle (Fig.2)   | [5] | CO2 | M |



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| Q.3(a) Explain the difference between hydrodynamic and thermal boundary layer over a flat plate with suitable sketch.  | [5] | CO3 | L |
| Q.3(b) Atmospheric air at 275 K and free stream velocity of 20 m/s flows over a 1.5 m long flat plate maintained at a uniform temperature of 325 K. Determine i) The average heat transfer coefficient over the region of laminar boundary layer, ii) the average heat transfer coefficient over the entire length of 1.5 m and iii) the total heat transfer rate from the entire plate to air over 1.5 m length and 1 m wide. Take the properties of air at mean film temperature as:<br>$k = 0.026 \text{ W/m.K}$ , $Pr = 0.708$ , $\nu = 16.8 \times 10^{-6} \text{ m}^2/\text{s}$ , $\mu = 1.98 \times 10^{-5} \text{ kg/ms}$ .<br>For laminar flow: $Nu = 0.664 Re^{1/2} Pr^{1/3}$<br>Turbulent flow: $Nu = 0.037 Re^{4/5} Pr^{1/3}$ (Valid for $5 \times 10^5 < Re < 10^7$ and $0.6 < Pr < 60$ )<br>Transition flow: $Nu = (0.037 Re^{4/5} - 871) Pr^{1/3}$ (Valid for $5 \times 10^5 < Re < 10^8$ and $0.6 < Pr < 60$ ) | [5] | CO3 | M |

- Q.4(a) Derive the momentum equation for natural convection over a vertical plate. [5] CO3 M
- Q.4(b) Consider a rectangular plate of 0.2 m x 0.4 m is maintained at uniform temperature of 80 °C. It is placed in atmospheric air at 24 °C. Compare the heat transfer rate from the plate for the cases when the vertical is i) 0.2 m and ii) 0.4 m. At mean film temperature properties of air as:  
 $k = 0.028 \text{ W/m.K}$ ,  $Pr = 0.703$ ,  $\nu = 1.822 \times 10^{-5} \text{ m}^2/\text{s}$   
 $Nu = 0.59Ra^{1/4}$  for  $10^4 < Ra < 10^9$  and  $Nu = 0.1Ra^{1/3}$  for  $10^9 < Ra < 10^{13}$  [5] CO3 M
- Q.5(a) A counter flow heat exchanger consisting of two concentric flow passages used for heating 1110 kg/h of oil (sp. heat = 2.1 kJ/kg.K) from a temperature of 27 °C to 49 °C. The oil flows through the inner pipe made of copper (O.D. = 2.86 cm, I.D. = 2.54 cm) and the surface heat transfer coefficient on oil side is 635 W/m<sup>2</sup>.K. The oil is heated by hot water supplied at the rate of 390 kg/h and at an inlet temperature of 93 °C. The water side heat transfer coefficient is 1270 W/m<sup>2</sup>.K. Take the thermal conductivity of copper to be 350 W/m.K and the fouling factors on oil and water sides to be 0.0001 and 0.0004 m<sup>2</sup>.K/W. Determine the length of the heat exchanger. (Take sp. Heat of water = 4.18 kJ/kg.K) [5] CO4 M
- Q.5(b) State the modes of mass transfer with examples. What are the similarities in heat and mass transfer. Explain Fick's law of diffusion. What is mass diffusivity? [5] CO5 L

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