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Question Paper Code : 10932

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2025.

Sixth / Eighth Semester

Mechanical Engineering

ME 8693 — HEAT AND MASS TRANSFER

(Common to Mechanical Engineering (Sandwich))

(Regulations 2017)

Time : Three hours

Maximum : 100 marks

Use of Approved HMT Data book is permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Define Fourier law of heat conduction. Also, write the equation of the same.
2. What do you understand from unsteady heat conduction?
3. Define hydrodynamic and thermal boundary layer.
4. Differentiate between free and forced convection.
5. What are the heat transfer mechanisms involved during heat transfer from the hot fluid to the cold fluid in a heat exchanger?
6. Differentiate pool boiling and flow boiling.
7. State Stephen Boltzmann law of radiation.
8. Mention the use of radiation shields.
9. Define Fick's law of diffusion. Mention its limitations.
10. List the various modes of mass transfer.

PART B — ($5 \times 13 = 65$ marks)

11. (a) With the help of suitable diagram, derive the 3D heat conduction equation for cylindrical coordinate system and deduce to one dimensional heat conduction equation.

Or

- (b) Fig. 1 represents composite wall of an oven consisting of three materials, two of which are of known thermal conductivity, $k_A = 25 \text{ W/mK}$ and $k_C = 55 \text{ W/mK}$, and known thickness, $L_A = 0.35 \text{ m}$ and $L_C = 0.2 \text{ m}$. The third material, B, which is sandwiched between materials A and C, is of known thickness, $L_B = 0.2 \text{ m}$, but unknown thermal conductivity k_B . Under steady-state operating conditions, measurements reveal an outer surface temperature of $T_{s,o} = 25^\circ\text{C}$, an inner surface temperature of $T_{s,i} = 650^\circ\text{C}$, and an oven air temperature of $T_\infty = 850^\circ\text{C}$. The inside convection coefficient (h) is known to be $30 \text{ W/m}^2\text{K}$. What is the value of k_B ?

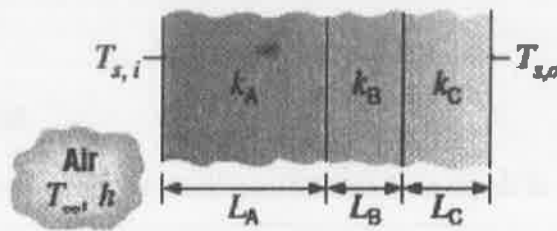


Fig.1

12. (a) Air at 25°C flows over a flat plate with a velocity of 3 m/s . The dimensions of the plate are measured as $600 \text{ mm} \times 300 \text{ mm}$. The plate is maintained at a temperature of 100°C . Determine the loss of heat from the plate, if the air moves over the side of 600 mm . How his heat loss would be affected if the flow of air is made parallel to the 300 mm side?

Or

- (b) The height and diameter of a vertical pipe is 80 mm and 2 m . The pipe is maintained at a constant temperature of 130°C and the still atmospheric temperature is 30°C . Determine the loss of heat by natural convection.
13. (a) With the help of neat sketch, explain the different regimes of pool boiling. Also, write the equation for critical heat flux.

Or

- (b) 3000 kg/h of furnace oil is heated from 10°C to 90°C in a shell and tube heat exchanger. The oil is to flow inside the tube while the steam at 120°C is to flown through the shell.

The tubes of ID = 1.65 cm and OD = 1.9 cm are used. The heat transfer coefficient of oil and steam sides is $85 \text{ W/m}^2\text{K}$ and $7420 \text{ W/m}^2\text{K}$ respectively. Find the number of passes and the number of tubes in each pass, if the length of each tube is limited to 2.85 m due to space limitations. The velocity of oil is limited to 5 cm/s . Take the following for oil: $\rho = 900 \text{ kg/m}^3$, $c = 1970 \text{ J/kgK}$.

14. (a) A cryogenic fluid flows through a long tube of 20 mm diameter, the outer surface of which is diffuse and gray with $\epsilon_1 = 0.02$ and $T_1 = 77$ K. This tube is concentric with a larger tube of 50 mm diameter, the inner surface of which is diffuse and gray with $\epsilon_2 = 0.05$ and $T_2 = 300$ K. The space between the surfaces is evacuated. Refer Fig. 2 for other specifications. Calculate the heat gain by the cryogenic fluid per unit length of tubes. If a thin radiation shield of 35 mm diameter and $\epsilon_3 = 0.02$ (both sides) is inserted midway between the inner and outer surfaces, calculate the percentage in heat gain per unit length of the tubes.

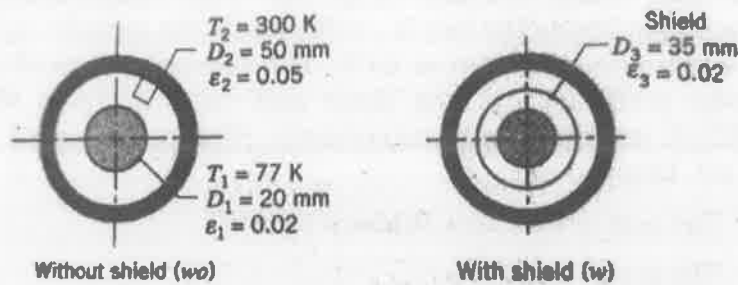


Fig. 2

Or

- (b) Two large parallel plates with $\epsilon = 0.6$ each, are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiation shields with surface emissivity 0.06 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer.
15. (a) The molecular weights of the two components A and B of a gas mixture are 24 and 28 respectively. The molecular weight of gas mixture is found to be 30. If the mass concentration of the mixture is 1.2 kg/m^3 determine the following
- Molar fractions (4)
 - Mass fractions (4)
 - Total pressure if the temperature of the mixture is 290 K. (5)

Or

- (b) Air at 1 atmosphere and 25°C , containing small quantities of iodine, flows with a velocity of 6.2 m/s inside a 35 mm diameter tube, calculate mass transfer co-efficient for iodine. The thermophysical properties of air are : Kinematic viscosity $= 15.5 \times 10^{-6} \text{ m}^2/\text{s}$; $D = 0.82 \times 10^{-5} \text{ m}^2/\text{s}$.

PART C — ($1 \times 15 = 15$ marks)

16. (a) 12 thin brass fins with $k = 75.5 \text{ W/mK}$ of 0.8 mm thickness are placed axially on a 5 cm diameter cylinder which stands vertically and is surrounded by air at 40°C . The fin extends 2.5 cm from the cylinder. What is the heat transfer to the air per meter length of the cylinder when the surface is at 150°C ? Take $h = 24.5 \text{ W/m}^2\text{K}$. (15)

Or

- (b) A plane wall of a refrigerated van is made of 1.5 mm steel sheet ($k_s = 25 \text{ W/mK}$) at the outer surface, 10 mm plywood ($k_p = 0.05 \text{ W/mK}$) at the inner surface and 20 mm glass wool ($k_G = 0.01 \text{ W/mK}$) in between the outer and inner surfaces (Fig. 3). The temperature of the cold environment inside the van is -15°C , while the outside surface is exposed to a surrounding ambient at 24°C . The average values of convective heat transfer coefficients at the inner and outer surfaces of the wall are 12 W/mK and 20 W/mK respectively. The surface area of the wall is 0.75 m^2 . Determine :

(i) The rate of heat flow through the wall. (7)

(ii) The temperatures at (8)

- (1) the outer surface of the wall,
- (2) the interface between steel sheet and glass wool,
- (3) the interface between glass wool and plywood, and
- (4) the inner surface of the wall.

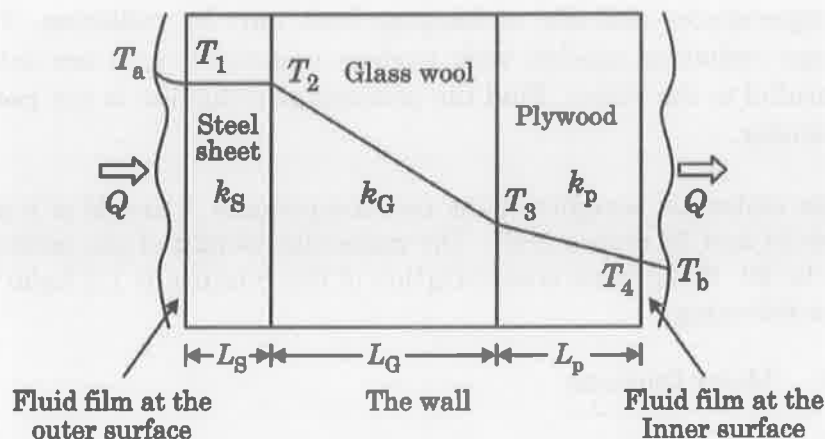


Fig .3