HEAT TRANSFER
(MEC3102)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Thermal diffusivity of a medium is
(a) directly proportional to its thermal conductivity
(b) inversely proportional to its density
(c) inversely proportional to its specific heat
(d) all of these

(ii) A composite wall of a furnace has two layers of same thickness having thermalconductivity values in the ratio of 2:5. Theratio of temperature drop across the layers in the same order will be
(a) 2:5 (b) 5:2
(c) 2:7 (d) 7:2

(iii) Heat diffusion equation through a medium is given in its simplest form as $\frac{1}{r}\frac{d}{dr}\left(rk\frac{dT}{dr}\right) + q_G = 0$.
Select the wrong statement below.
(a) The medium is of cylindrical shape
(b) The thermal conductivity of the medium is constant
(c) Heat transfer through the medium is steady
(d) There is heat generation within the medium

(iv) For acceptance of lumped capacitance method, the following must be satisfied
(a) Bi = 1 (b) Bi < 1
(c) Bi < 0.1 (d) 0.1 <Bi <1

(v) The conduction boundary condition for an adiabatic surface with direction $\vec{n}$ being normal to the surface is given by the equation
(a) $T = 0$ (b) $-k\frac{dT}{dn} = 1$ (c) $\frac{dT}{dn} = 0$ (d) $\frac{d^2T}{dn^2} = 0$

(vi) The value of Prandtl number for air is about
(a) 0.1 (b) 0.3 (c) 0.7 (d) 1.7

(vii) For forced convection heat transfer, the Nusselt number is a function of
(a) Prandtl number and Biot number
(b) Reynolds number and Grashof number
(c) Prandtl number and Grashof number
(d) Reynolds number and Prandtl number

(viii) The unit of overall coefficient of heat transfer is
(a) W/m^2K (b) W/m^2 (c) W/m·K (d) W/m

(ix) In a counter-flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C.The hot fluid enters at 150°C and leaves at 130°C. The mean temperaturedifference for the setup is
(a) 20°C (b) 80°C (c) 60°C (d) 100°C

(x) A coolant fluid at 30°C flows over a heated flat plate maintained at a constant temperature of 100°C. The boundary layer temperature distribution at a given location on the plate may be approximated as T = 30 + 70 exp (−y) where y (in m) is the distance normal to the plate and T is in °C. If thermal conductivity of the fluid is 1.0 W/m·K, the local convective heat transfer coefficient (in W/m^2K) at that location will be:
(a) 0.2 (b) 1 (c) 5 (d) 10

Fill in the blanks with the correct word

(xi) In steady conduction through a plane, steeper temperature gradient suggests _________value of thermal conductivity.

(xii) The expression of Bi (Biot Number) with usual symbols is _________.

(xiii) ________ number represents the ratio of kinematic viscosity to thermal diffusivity.

(xiv) In counter current flow heat exchanger, the logarithmic temperaturedifference between the fluids is _______ as compared to parallel flowheat exchanger.

(xv) The ratio of total emissive power of a body to that of a black body is called ________.

Group - B

2. (a) A composite wall of an oven consists of three materials A, B, C in sequence, withk_A = $20\ W/m.K$ and $k_C = 50\ W/m.K$. The thicknesses of the individual walls are uniform and are 0.30 m, 0.15 m and 0.15 m respectively. Under steady state, measurements reveal that the outer surface temperature on the wallC is 20°C. Inner surface temperature of wall A is 60°Cwhile air temperature in the oven is 800°C. The inside convective heat transfer coefficient$h = 25\ W/m^2.K$. Determine the value ofk_B. *[(CO2)(Apply/IOCQ)]*

(b) A certain material 200 mm thick with a cross sectional area of 0.1 m^2, has one side maintained at 35°C and the other at 95°C under steady state. The temperature of the central plane of the material is 62°C, and the heat flow through the material is 10 kW. Assuming the thermal conductivity of the material as a linear function of temperature, find its expression. *[(CO2)(Analyze/IOCQ)]*

6 + 6 = 12

3. (a) The left and right side of a 20 mm thick plate with constant heat generation of 80 MW/m^3 are found to be at 160°C and 120°C at steady state. The plate has a constant thermal conductivity of200 $W/m.K$. Determine (a) the temperature distribution in the plate along the thickness (b) the location and the value of maximum temperature (c) the rates of heat transfer at both ends.

[(CO2)(Analyze/IOCQ)]

(b) A 1 m long steel tube ($k = 15\ W/m.K$) with an outer diameter of 760 mm and of thickness 130 mm is covered with an insulation material ($k = 0.2\ W/m.K$) of 20 mm thickness. A hot gas with a heat transfer coefficient 400 $W/(m^2.K)$ flows inside the tube and the outer surface of insulation is exposed to cooler air with a heat transfer coefficient of60 $W/(m^2.K)$. Calculate the total thermal resistance of the system for heat transfer from the hot gas to cooler air. *[(CO2)(Apply/IOCQ)]*

6 + 6 = 12

Group - C

4. (a) Consider two large parallel plates, one at T_1 = 800 K with emissivityε_1 = 0.9 and the other at T_2 =300 K with emissivity ε_2 = 0.5. It is proposed that a radiation shield be placed between the two plates. (i) Calculate the heat transfer rate per unit area without using the radiation shield in between. (ii) Calculate the emissivity of the radiation shield in order to reduce the radiative heat transfer to 10 % of that without the shield. (iii) Calculate the temperature of the radiation shield. *[(CO4)(Analyze/HOCQ)]*

(b) Obtain an expression from the governing equation for the temperature distribution and heat transfer from an infinitely long fin with standard parameters. Given, the governing equation for a fin of uniform cross section is $\frac{d^2\theta}{dx^2}$ - $m^2\theta$ = 0 with usual notations. *[(CO5)(Apply/IOCQ)]*

6 + 6 = 12

5. (a) Consider an elemental and horizontal surface of area dA_1. A circular and parallel flat disk of area $A_2$is placed with its centre exactly below a vertical distance H from dA_1. Thesurface $dA_1$is designated 1 and surface A_2 is designated 2. Determine the value of F_{12}. *[(CO4)(Apply/IOCQ)]*

(b) Show that the number of independent shape factors for an N- surface enclosure is $N(N-1)/2$. *[(CO3)(Remember/LOCQ)]*

7 + 5 = 12

Group - D

6. (a) When 0.6 kg of water per minute is passed through a tube of 2 cm diameter, it is found to be heated from 20°C to 60°C. The heating is achieved by condensing steam on the surface of the tube and subsequently the surface temperature of the tube is maintained at 90°C. Determine the length of the tube required for fully developed flow.

Properties of water at 40°C:

ρ = 995 kg/m^3

$\nu = 0.657 \times 10^{-6}\ m^2/s$
$Pr = 4.340$
$k = 0.628 W/m{\cdot}K$
$C_p = 4178 J/kgK$. *[(CO4)(Analyse/IOCQ)]*

(b) Explain the Reynolds Colburn analogy for laminar flow over a flat plate. *[(CO3)(Apply/IOCQ)]*

8 + 4 = 12

7. (a) Engine oil at 55°C flows with a velocity of 1 m/s over a 5 m long flat plate whose temperature is 35°C. The flow is parallel to the length of the plate. Determine the rate of heat transfer per unit width of the entire plate. The properties of the engine oil at a film temperature of 45°C are as follows:
$\rho = 870\ kg/m^3$; $Pr = 2850$;
$k = 0.145\ W/(m°C)$; $\nu = 250 \times 10^{-6}\ m^2/s$. *[(CO4)(Analyse/IOCQ)]*

(b) Show physical significance of following non-dimensional numbers:
Pe (Peclet Number), St (Stanton Number). *[(CO3)(Apply/IOCQ)]*

8 + 4 = 12

Group - E

8. (a) Water flows at the rate of 65 kg/min through a double pipe counter flow heat exchanger. Water is heated from 50°C to75°C by an oil flowing through the tube. The specific heat of the oil is 1.780 kJ/kgK. Specific heat of water is 4186 J/kg K. The oil enters at 115°C and leaves at 70°C. The overall heat transfer co-efficient is 340 W/m^2K. Calculate the following:
(i) Heat exchanger area
(ii) Rate of heat transfer. *[(CO6)(Evaluate/IOCQ)]*

(b) Distinguish between Nucleate and film boiling. *[(CO2)(Understand/LOCQ)]*

8 + 4 = 12

9. (a) Estimate the heat loss from a vertical wall exposed to nitrogen gas at 1 atm pressure and 25°C. The wall is 2.0 m high and 2.5 m wide, and is maintained at uniform temperature 35°C. The properties for nitrogen at the mean film temperature are given as: $k = 0.026\ W/mK$; $\rho = 1.142\ kg/m^3$; $\nu = 15.630 \times 10^{-6}\ m^2/s$; $Pr = 0.713$.
Use Equation $Nu = 0.59(Ra_L)^{1/4}$, if the flow is laminar or
$Nu = 0.1(Ra_L)^{1/3}$, if the flow is turbulent. *[(CO4)(Analyse/IOCQ)]*

(b) Explain the following in detail:
Film wise condensation and drop wise condensation. *[(CO2)(Understand/LOCQ)]*

8 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	13.54	80.21	6.25