53 (FPT 403) TPEN

2014

TRANSFER PROCESS ENGINEERING

Paper : FPT 403

Full Marks : 100

Pass Marks : 30

Time : Three hours

The figures in the margin indicate full marks for the questions.

*Answer **any five** questions.*

1. *(a)* Define the terms "kinematic viscosity' and 'convective momentum transport'. Explain the variation of viscosity with temperature for gases and liquids. 1+2+3=6

(b) Prove that the parabolic velocity distribution of a liquid of density (ρ) flowing over a vertical flat plate of length (L) and width (W) is

$$v_z = \frac{pg\delta^2}{2\mu}\left[1-\left(\frac{x}{\delta}\right)^2\right]$$

where, v_z = velocity of fluid in the z-direction

δ = Thickness of the liquid film forming over the flat plate

x = Distance of a shell of the liquid

μ = Viscosity of liquid.

And hence find the average velocity and mass flow rate of the fluid over the plate. 8+3+3=14

2. (a) A fluid enters a nozzle 1 of 40*cm* diameter at a velocity 3*m/s*. Then the fluid splits into two nozzles 2 and 3 connected in a Y-shape. The diameter of nozzle 2 is 30*cm* and the flow rate is 2*m/s*. The diameter of

nozzle 3 is 20*cm*. Find the velocity in the nozzle 3 as shown in *Figure-2a*. 5

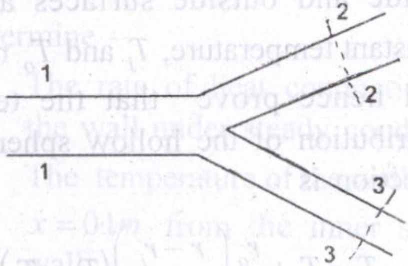

Figure-2a

(*b*) Distinguish between the laminar and turbulent flow. Explain Prandtl's mixing length theory. 2+3=5

(*c*) Derive Von-Karman-Prandtl Universal logarithmic velocity equation as shown below :

$$\frac{\bar{v}_x}{v^*} = 2\cdot5\, ln\left(\frac{yv^*}{\vartheta}\right) + 5\cdot5$$

Where, the symbols have their usual meanings. 10

3. (*a*) What do you mean by thermal conductivity ? Why the thermal conductivity of liquid is less than that of the solids ? How does it vary with temperature for the gases and liquids ? 2+1+2=5

(b) Derive an expression for the radial heat conduction through a hollow sphere whose inside and outside surfaces are held at constant temperature, T_i and T_o respectively and hence prove that the temperature distribution of the hollow sphere in radial direction is

$$T = T_i + \frac{r_o}{r}\left(\frac{r - r_i}{r_o - r_i}\right)(T_o - T_i)$$

where, T = Temperature at any radius (r).

r_o and r_i are the outer and inner radii of hollow sphere respectively. 7

(c) A heat flux meter attached to the inner surface of a $3cm$ thick refrigerator door indicates a heat flux of $25\, W/m^2$ through the door. Also, the temperatures of inner and the outer surfaces of the door are measured to be $7°C$ and $15°C$ respectively. Determine the average thermal conductivity of the refrigerator door. 3

(d) Consider a large plane wall of thickness $L = 0{\cdot}2m$, thermal conductivity $K = 1{\cdot}2$ $W/m°C$ and surface area, $A = 15m^2$. The linner and outer surfaces of the wall are maintained at constant temperatures of $T_1 = 120°C$ and $T_2 = 50°C$ respectively.

Determine —

(i) The rate of heat conduction through the wall under steady conditions.

(ii) The temperature of the wall at distance $x = 0{\cdot}1m$ from the inner side of the wall. 5

4. *(a)* What is a Fin ? Mention *any two* applications of fins. Distinguish between fin efficiency and fin effectiveness. 2+2+2=6

(b) Find the rate of heat flow through the composite wall as shown in *figure 4(c)*. Assume one dimensional flow. Given data :

$K_A = 100\ W/m°C$ $\quad K_C = 60\ W/m°C$

$K_B = 35\ W/m°C$ $\quad K_D = 50\ W/m°C$ 5

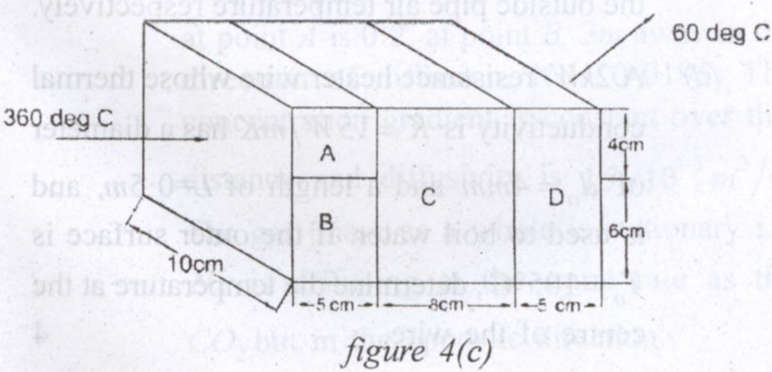

figure 4(c)

(c) Show that the rate of heat flow through a composite cylindrical pipe of length (L) consisting of two co-axial layers of thermal conductivities, K_1 and K_2 if hot milk is flowing inside this pipe is 5

$$Q = \frac{2\pi L\left(T_{\infty 1} - T_{\infty 2}\right)}{\frac{1}{h_1 r_1} + \frac{1}{h_2 r_3} + \frac{ln\left(r_2/r_1\right)}{K_1} + \frac{ln\left(r_3/r_2\right)}{K_2}}$$

where, r_1 and r_2 are the inner and outer radii of inside cylinder and r_3 is the outer radius of outside cylinder,

h_1 and h_2 are the convection heat transfer coefficients at the inner and outer surfaces of the pipe respectively,

$T_{\alpha 1}$ and $T_{\alpha 2}$ are the milk temperature and the outside pipe air temperature respectively.

(d) A $2kW$ resistance heater wire whose thermal conductivity is $K = 15\,W/mK$ has a diameter of $d_o = 4mm$ and a length of $L = 0\cdot 5m$, and is used to boil water. If the outer surface is $T_o = 105°C$, determine the temperature at the centre of the wire. 4

5. *(a)* State Newton's Law of cooling for convection heat transfer. What do you mean by coefficient of convection ? 2+1=3

(b) What is external forced convection ? How does it differ from internal forced convection ? 2

(c) Prove that for fully developed laminar flow in a circular tube subjected to constant surface heat flux, the Nusselt number (*Nu*) is 4·36. 15

6. *(a)* What do you mean by the term "mass diffusion" ? Express the "concentration" in terms of mass basis and mole basis. 1+4=5

(b) CO_2 gas is diffusing through N_2 in one direction at atmosphere pressure and temperature 15°*C*. The mole fraction of CO_2 at point *A* is 0·2, at point *B*, 3*m* away in the direction of diffusion, it is 0·0195. The concentration gradient is constant over this distance and diffusivity is $1{\cdot}5\times10^{-5}\,m^2/s$. The gas phase as a whole is stationary i.e. N_2 is diffusing at the same rate as the CO_2 but in the opposite direction.

(i) What is the molar flux of CO_2 in $Kmol/m^2.s$?

(ii) What is the net mass flux in $Kg/m^2.s$? 10

(c) How does the mass diffusivity of a gas mixture change with temperature and pressure ? Prove that the diffusivities D_{AB} is equal to D_{BA} for an ideal gas where A and B are species. 2+3=5

7. Write short notes on ***any four*** of the following : 5×4=20

(a) Non-Newtonian fluids

(b) Thermal boundary layer on a flat plate

(c) Nusselt number

(d) Grashof number

(e) Reynolds number.
