(Set-1)

M. Tech - 2nd(HPE)

Convective Heat Transfer

Full Marks : 70

Time : 3 hours

Answer any six questions including Q. No. 1

The figures in the right-hand margin indicate marks

1. Answer the following questions : 2 × 10

   (*i*) Write down two-dimensional momentum and energy equation in cylindrical (*r-z*) coordinate system.

   (*ii*) Define Prandtl number and its significance in convection heat transfer. Sketch laminar thermal and hydrodynamic boundary layers over a flat plate for $Pr << 1$, $Pr = 1$ and $Pr >> 1$.

   (*iii*) State Reynolds analogy and explain its application in convection heat transfer.

(Turn Over)

Under what conditions both Colburn analogy and Reynolds analogy are the same ?

(*iv*) Explain the physical significance of viscous dissipation term in the energy equation and when it be neglected ?

(*v*) Explain Boussinesq approximation in the field of buoyancy-driven flow.

(*vi*) Discuss various methods may be employed to control the boundary layer separation that occurs due to the adverse pressure gradient.

(*vii*) Discuss the importance of relative magnitude of buoyancy force and inertia force in convective heat transfer and write down its order of magnitude for natural, forced and mixed convection.

(*viii*) Explain the concept of the bulk-mean temperature with regard to adiabatic mixing of the fluid. What is its significance in internal flows ?

(*ix*) Using suitable boundary conditions derive a quadratic expression for the temperature profile in the thermal boundary layer.

(*x*) Discuss differences between advection, diffusion and convection.

2. For steady, laminar and incompressible flow of a viscous fluid through a parallel-plate channel, separated by a distance $2h$ (Poiseuille flow), the momentum and energy equations are given by

$$\frac{dp}{dx} = \mu\frac{d^2u}{dy^2} \text{ and } k\frac{d^2T}{dy^2} + \mu\left(\frac{du}{dy}\right)^2 = 0$$

The lower wall is maintained at a uniform temperature of T_0, while the upper wall temperature is T_1. Derive expressions for velocity and temperature profiles. 10

3. The thermal energy equation in flow past a body is written as :

$$\rho Cp\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right)$$

Using an order of magnitude analysis for fluid flow, reduce the given thermal equation to its boundary layer form. 10

4. Write the two-dimensional continuity, momentum and energy equation with viscous dissipation in the boundary layer form. Integrate the energy equation in the y-direction from 0 to δ_t and, using Leibnitz rule, derive the resultant energy-integral equation. 10

5. Using energy-integral equation, derive an expression for local Nusselt number for laminar parallel flow of a constant property fluid over a flat plate. The heating starts at a distance x_0 from the leading edge of the plate. Assume linear velocity and temperature profiles. 10

6. A highly viscous fluid is forced through a straight circular pipe of inner radius R. Due to viscous heat generation, the fluid tends to warm up as it flows through the pipe. Assuming constant wall

temperature boundary condition and the flow is hydrodynamically and thermally fully-developed, the energy equation for the fluid reduces to

$$\frac{k}{r}\frac{d}{dr}\left(r\frac{dT}{dr}\right)+\mu\left(\frac{du}{dr}\right)^2=0$$

Determine the temperature distribution $T(r)$ in the fluid. Calculate the value of Nusselt number with heat transfer coefficient based on centre-line temperature. 10

7. Consider laminar free convection over a vertical plate at uniform surface temperature T_W. Assume $\delta = \delta_t$ and following velocity and temperature profiles :

$$u(x,y)=u_0(x)\times\frac{y}{\delta}\left(1-\frac{y}{\delta}\right)^2, \quad \frac{T-T_\infty}{T_W-T_\infty}=\left(1-\frac{y}{\delta}\right)^2$$

From an integral solution, show that the local Nusselt number is a function of local Rayleigh number and Prandtl number. 10

(Turn Over)

8. Using Reynolds-Colburn analogy, derive expressions for Nusselt number for turbulent flow over a flat plate and turbulent flow through a circular pipe. 10