# Indian Institute of Engineering Science and Technology Shibpur

ME (Mech) 2nd Semester Examination 2013

Advanced Convective Heat Transfer (ME 1001)

Answer All Questions

Time 3 hrs | Full Marks 70

1. Derive the following energy equation:

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

2. Show that if the turbulent velocity profile in a round duct of radius R is given by

$\frac{u}{U_{CL}}=\left(\frac{y}{R}\right)^{\frac{1}{n}}$, the average velocity, $U_{av}$ is related to the centerline velocity $U_{CL}$ by

$$\frac{U_{av}}{U_{CL}}=2n^2(n+1)^{-1}(2n+1)^{-1}$$

3. Consider parallel flow of a constant property fluid over a flat plate. Prove the following:

$$\frac{C_f}{2}=\frac{0.0128}{\left(\frac{U}{\delta_2 \nu}\right)^{\frac{1}{4}}}$$

where the symbols have their usual meaning.

4. An integral formulation of the two dimensional laminar boundary layer equations is needed for treatment of the unsteady state. For a constant property fluid, prove the following from the continuity, x-motion and energy equations:

$$v=v_w-\frac{\partial}{\partial x}\left(\int_0^y u\,dy\right)$$

$$\frac{\partial}{\partial t}\left[U\int_0^\delta\left(1-\frac{u}{U}\right)dy\right]+\frac{\partial}{\partial x}\left[U^2\int_0^\delta\frac{u}{U}\left(1-\frac{u}{U}\right)dy\right]+\left[\int_0^\delta\left(1-\frac{u}{U}\right)dy\right]U\frac{\partial U}{\partial x}=\frac{\tau_w+\rho U v_w}{\rho}$$

$$\delta_T\frac{\partial T_\infty}{\partial t}+\frac{\partial}{\partial t}\left[\int_0^{\delta_T}(T-T_\infty)dy\right]+\frac{\partial}{\partial x}\left[\int_0^{\delta_T}u(T-T_\infty)dy\right]$$

$$+\left[\int_0^{\delta_T}u\,dy\right]\frac{\partial T_\infty}{\partial x}=\frac{q_w+\rho C_p v_w(T_w-T_\infty)}{\rho C_p}$$