MIDTERM #3 EQN. SHEET

NAVIER STOKES ($\rho, \mu = $ const.) $\rho \dfrac{Du_i}{Dt} = -\dfrac{\partial P}{\partial x_i} + \rho g_i + \mu \dfrac{\partial^2 u_i}{\partial x_j^2}$

$$\frac{Du_i}{Dt} = \frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j}$$

General Integral Eqn. $\dfrac{d}{dx}(U^2 \delta_2) + \delta_1 U \dfrac{dU}{dx} = \dfrac{\tau_w}{\rho}$

$$\delta_1 = \int_0^\delta \left(1 - \frac{u}{U}\right) dy \qquad \delta_2 = \int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy$$

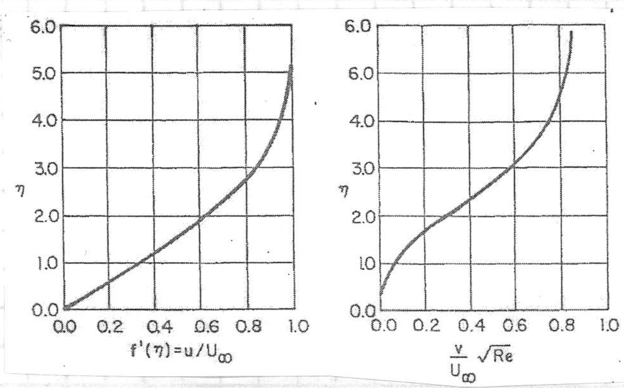
$$\tau_w = \mu \left.\frac{du}{dy}\right|_{y=0} \qquad c_f = \tau_w / \tfrac{1}{2}\rho U^2$$

Laminar boundary layer flow:

$$\eta = y \Big/ \left(\frac{\nu x}{U}\right)^{1/2} \qquad f' = \frac{u}{U} \qquad \frac{v}{U} = -\frac{1}{2} Re_x^{1/2} (f - \eta f)$$

$$c_f = .664 / Re_x^{1/2} \qquad \delta / x = 5 / Re_x^{1/2}$$

Blasius Soln. →



Turbulent boundary layer:

$Re_{crit_x} \cong 5 \times 10^5$ Reynolds stress $= (-\rho \overline{u'v'})$

$$\frac{u}{v_{*0}} = 8.74\left(\frac{y v_{*0}}{\nu}\right)^{1/n} : \text{for } n=7: \begin{cases} c_f = .045 / Re_\delta^{1/4} \\ Re_\delta = U\delta/\nu \\ \delta_2/\delta = 7/72 \end{cases}$$

Flat plate friction drag:

$$\frac{F_D}{\frac{1}{2}\rho U^2 A_{plate}} = C_f = C_{f_{tt}} - \frac{x_{crit}}{L}\left(C_{f_{t x_c}} - C_{f_{l x_c}}\right)$$

subscripts: tt — total plate turbulent

$t x_c$ — turbulent until x_{crit}

$l x_c$ — laminar until x_{crit}