9.52 A liquid flows tangentially past a flat plate. The fluid properties are $\mu = 10^{-5}\ \mathrm{N \cdot s/m^2}$ and $\rho = 1.5\ \mathrm{kg/m^3}$. Find the skin-friction drag on the plate per unit width if the plate is 2 m long and the approach velocity is 20 m/s. Also, what is the velocity gradient at a point that is 1 m downstream of the leading edge and just next to the plate ($y = 0$)?

Information and assumptions:

Provided in problem statement

Find:

Skin friction drag per unit width of plate and velocity gradient at surface 1m downstream from leading edge.

Solution:

$$\mathrm{Re}_L = U_0 L\rho/\mu = 20\times 2\times 1.5/10^{-5} = 6\times 10^6$$

$$C_f = \frac{0.074}{\mathrm{Re}_L^{1/5}} - \frac{1700}{\mathrm{Re}_L} = 0.00298$$

$$F_s = C_f\left(2BL\right)\rho U_0^2/2$$

$$= 0.00298\times\left(2\times 1\times 2\right)\left(1.5\times 20^2/2\right) = 3.58N$$

$$\mathrm{Re}_{1m} = 6\times 10^6\times\left(1/2\right) = 3\times 10^6$$

$$c_f = \left(2\log \mathrm{Re}_{1m} - 0.65\right)^{-2.3} = 0.00311$$

$$\tau_0 = c_f\rho U_0^2/2 = 0.00311\times 1.5\times 20^2/2 = 0.933\,N/m^2$$

But

$$\tau_0 = \mu\, du/dy$$

$$du/dy = \tau_0/\mu = 0.933/10^{-5} = 9.33\times 10^4\, s^{-1}$$