Assume that a boundary layer over a smooth, flat plate is laminar at first and then becomes turbulent at a critical Reynolds number of 5×10^5. If we have a plate 3 m long and 1 m wide and if air, at 20°C and normal atmospheric pressure, flows past this plate with a velocity of 30 m/s, what will be the average resistance coefficient C_f for the plate? Also, what will be the total shearing resistance of one side of the plate and what will be the resistance due to the turbulent part and the laminar part of the boundary layer?

Solution:

The total resistance is $F_s = C_f\left(BL\right)\rho U_0^2/2$

In addition,

$$\mathrm{Re}_L = \frac{U_0 L}{\nu} = \frac{30\times 3}{1.51\times 10^{-5}} = 5.96\times 10^6$$

The average resistance coefficient is

$$C_f = \frac{0.074}{\mathrm{Re}_L^{1/5}} - \frac{1700}{\mathrm{Re}_L} = 0.00327 - 0.00029 = 0.00298$$

The total resistance is

$$F_s = C_f\left(BL\right)\rho U_0^2/2 = 0.00298\times 1\times 3\times 1.2\times \frac{30^2}{2} = 4.83N$$

Then x_{cr} is determined:

$$\frac{U_0 x_{cr}}{\nu} = 500,000$$

Or $$x_{cr} = \frac{500,000\times 1.51\times 10^{-5}}{30} = 0.252m$$

Thus the laminar resistance will be

$$F_{s,lam} = \frac{1.33}{\left(5\times 10^5\right)^{1/2}}\times 1\times 0.252\times 1.2\times \frac{30^2}{2} = 0.256N$$

Then $F_{s,turb} = 4.83 - 0.256 = 4.57N$