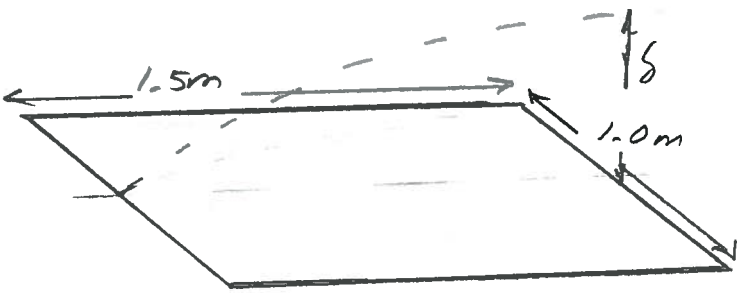
CE 3305 Engineering Fluid Mechanics
Exercise Set 28
Spring 2014

1. Problem 9.42, pg 355
2. Problem 9.48, pg 355

9.42 A FLAT PLATE 1.5m LONG AND 1.0m WIDE IS TOWED IN WATER AT 20°C ALONG ITS LONG AXIS AT 15 cm/s. FIND RESISTANCE OF THE PLATE AND THE BOUNDARY LAYER THICKNESS AT THE TRAILING EDGE

SKETCH



$\rho_w = 1000 kg/m^3$

$\nu_w = 1.02 \cdot 10^{-6} m^2/s$

GIVEN

$V_0 = 15 cm/s = 0.15 m/s$

DIMENSIONS

FIND

δ, F_s

SOLUTION

$$Re_L = \frac{(0.15 m/s)(1.5 m)}{1.02 \cdot 10^{-6} m^2/s} = 220588 < 10^6 \therefore \text{Laminar}$$

$$C_f = \frac{1.33}{(220588)^{1/2}} = 0.0028$$

$$F_{S(\text{ONE SIDE})} = C_f A_p \left(\frac{\rho U_0^2}{2}\right)$$

$$= (0.0028)(1.5\text{m})(1.0\text{m})\left(1000\frac{\text{kg}}{\text{m}^3}\cdot\left(\frac{0.15\text{m}}{\text{s}}\right)^2\cdot\frac{1}{2}\right)$$

$$= 0.047\,\frac{\text{kg}\cdot\text{m}}{\text{s}^2} = 0.047\text{N}$$

$$F_{S(\text{BOTH SIDES})} = 2(0.047\text{N}) = \underline{0.094\text{N}} \leftarrow F$$

$$\delta = \frac{5\cdot L}{(Re_L)^{1/2}} = \frac{5(1.5\text{m})}{(220588)^{1/2}} = 0.0159\text{ m}$$

$$= \underline{15.9\text{mm}} \leftarrow \delta$$

9.48 AIRPLANE WING 2m CHORD LENGTH, 11M SPAN FLIES 200 km/hr IN AIR AT 30°C

TREAT WING AS FLAT PLATE, FIND

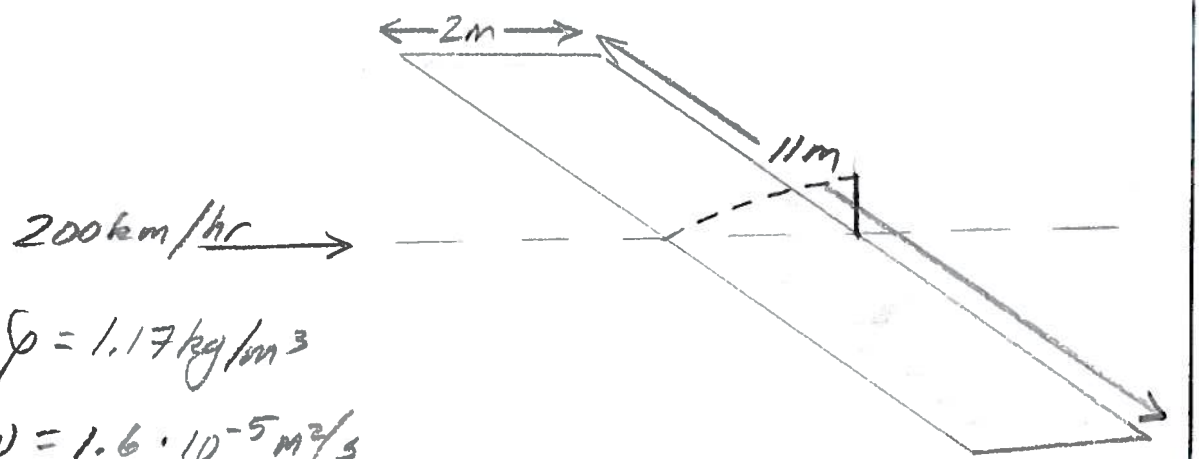
a) FRICTIONAL DRAG

b) POWER TO EQUAL DRAG

c) FRACTION CHORD LAMINAR

d) DRAG CHANGE IF TURBULENT LAYER IS TRIPPED AT LEADING EDGE

SKETCH



$\rho = 1.17 kg/m^3$

$\nu = 1.6 \cdot 10^{-5} m^2/s$

SOLUTION

USE FIG 9.13 TO ESTIMATE AVERAGE SHEAR, WITH/WITHOUT TRIP WIRE

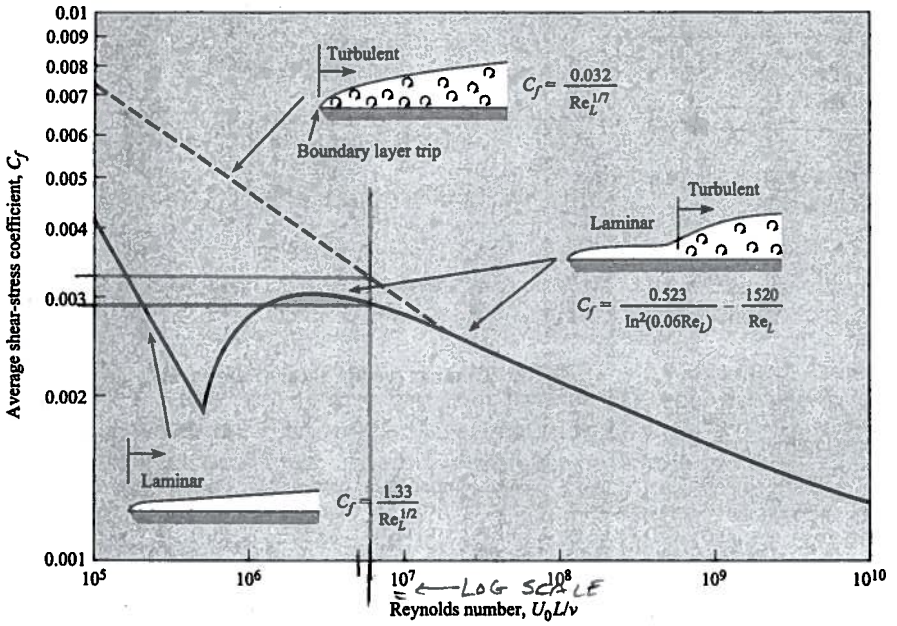


FIGURE 9.13
Average shear-stress coefficients.

$$Re_L = \frac{\left(\frac{200\cdot10^3 m}{3600 sec}\right)(2m)}{(1.6\cdot10^{-5} m^2/sec)} = 6,944,444 = 6.9\cdot10^6$$

(TRANSITION

$C_f = 0.0029$

$$C_f = \frac{0.523}{\ln^2(0.06Re_L)} - \frac{1520}{Re_L}$$

$$= \frac{0.523}{\ln^2(0.06\cdot6.9\cdot10^6)} - \frac{1520}{6.9\cdot10^6} = 0.0029$$

(NOT BAD, USE CHART - !)

$$F_{S(ONE\ SIDE)} = 0.0029(2m)(11m)\left(1.17\frac{kg}{m^3}\cdot\left(\frac{200\cdot10^3}{3600}\right)^2\left(\frac{1}{2}\right)\right)$$

$$= 115N$$

$F_{2\ (BOTH\ SIDES)} = 2(115N) = \underline{230N}$ ← F_S

$P = F \cdot V$

$= (230N)(55.56 m/s) = 12.8 \cdot 10^3 Nm/s$

$= \underline{12.8 kW}$ ← P

TRANSITION AT $Re_L \approx 5 \cdot 10^5$ (pg 335)

$Re_L = 5 \cdot 10^5 = \frac{Ux}{\nu} = \frac{55.56\ x}{1.6 \cdot 10^{-5} m^2/s}$

SOLVE FOR x

$x = 0.0144 m$

$\therefore \frac{0.0144}{2} = 0.0072 = \underline{0.72\%}$ LAMINAR ← FRACTION LAMINAR

99.28% TRANSITION - TURBULENT

F_s IF BOUNDARY LAYER TRIPPED

$C_f = 0.0033$

$F_s = (0.0033)(2\pi)(11m)\left(\frac{1.17 kg}{m^3}(55.56)^2 \cdot \frac{1}{2}\right)(2)$

$= \underline{266.8 N}$ ← ~16% INCREASE