1.75°

9 19 Because of the velocity deficit, U - u, in the boundary layer, the streamlines for flow past a flat plate are not exactly parallel to the plate. This deviation can be determined by use of the displacement thickness, δ^* . For air blowing \pm past the flat plate shown in Fig. P9.19, plot the streamline A-B that passes through the edge of the boundary layer $(y = \delta_B \text{ at } x = \ell)$ at point B. That is, plot y = y(x) for streamline A-B. Assume laminar boundary layer flow.

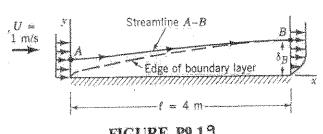
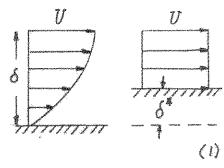


FIGURE P9.19

Since $Re_{\ell} = \frac{T\ell}{V} = \frac{(19)(4m)}{1.46 \times 10^{5}} = 2.74 \times 10^{5} < 5 \times 10^{5}$, the boundary layer flow remains laminar along the entire plate. Hence, $\delta = 5\sqrt{\frac{\nu_X}{U}}$ or $\delta_B = 5\left[\frac{(1.46\times10^{-5} \frac{m^2}{3})(4m)}{1\frac{m}{2}}\right]^{1/2} = 0.0382 m$

The flowrate carried by the actual boundary layer is by definition equal to that carried by a uniform velocity with the plate displaced by an amount 8. Since there is no flow through the plate or streamline A-B.



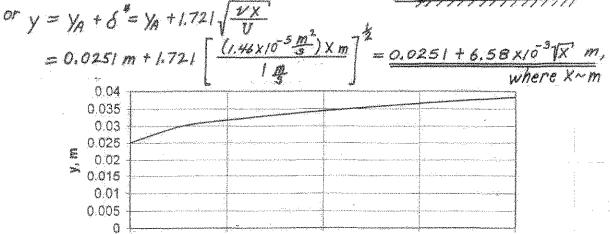
streamline

$$Q_{A} = Q_{B}, \text{ or } U_{A} = (\delta_{B} - \delta_{B}^{*})U$$
where $\delta^{*} = 1.721\sqrt{\frac{VX}{U}}$

$$\delta^{*}_{B} = 1.721\sqrt{\frac{(1.46 \times 10^{-5} \text{m}^{2})(4\text{m})}{|\frac{m}{S}|}} = 0.01315 \text{ m}$$

0

Thus, $y_A = \delta_B - \delta_B^* = 0.0382 \, m - 0.01315 \, m = 0.0251 \, m$ Hence, for any x-location $Q_A = Q$ or $Uy_A = U(y - \delta^*)$



2

3

x, m

*29 The aerodynamic drag on a car depends on the "shape" of the car. For example, the car shown in Fig. P9.39 has a drag coefficient of 0.36 with the windows and roof closed. With the windows and roof open, the drag coefficient increases to 0.45. With the windows and roof open, at what speed is the amount of power needed to overcome aerodynamic drag the same as it is at 65 mph with the windows and roof closed? Assume the frontal area remains the same. Recall that power is force times velocity.



Windows and roof closed: $C_D = 0.35$



Windows open; roof open: $C_D = 0.45$

MFIGURE P9.39

Power = $P = F \cdot V$ The force is the drag force. Let () and () denote closed and open. $D = C_0 \pm \rho U^2 A$

We want to find to when Po = Pc

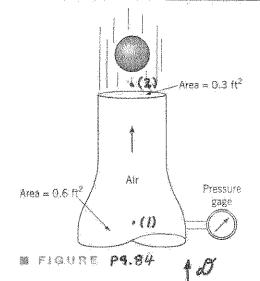
タ。= ひ。か。= 生pひ34。Co。= 兄= ひとか。= シャひ34cCoc

The frontal areas are the same, so Ao = Ac

U.3Co. = U23Co.
U. - Uc (Sec.) 3 = (65 mph) (0.36) 15

U6 = 60.3 mph

9.84 A 2-in.-diameter sphere weighing 0.14 lb is suspended by the jet of air shown in Fig. P9.84 and Video V3.2. The drag coefficient for the sphere is 0.5. Determine the reading on the pressure gage if friction and gravity effects can be neglected for the flow between the pressure gage and the nozzle exit.



ĮW

1/2

For equilibrium, $\mathcal{B} = W$ or $C_D \pm \rho V_2^2 A = W$, where $A = \#D^2$ Thus,

$$V_{2} = \left[\frac{2W}{C_{D} \rho \pi D^{2}/4}\right]^{\frac{1}{2}}$$

$$= \left[\frac{8(0.14/6)}{0.5(0.002385)\pi(\frac{2}{11}4)^{2}}\right]^{\frac{1}{2}} = 104 \frac{4}{5}$$

Also,

$$V_1A_1 = V_2A_2$$
 or $V_2 = V_2 = V_2 = (104 \text{ ft}) \frac{0.3 \text{ ft}^2}{0.6 \text{ ft}^2} = 52.0 \text{ ft}$
and
 $P_1 + \frac{1}{2} \rho V_1^2 = P_2 + \frac{1}{2} \rho V_2^2$ where $P_2 = 0$
Thus,
 $P_1 = \frac{1}{2} \rho \left[V_2^2 - V_1^2 \right] = \frac{1}{2} \left(0.00238 \frac{\text{slvgs}}{\text{ft}^2} \right) \left[\left(104 \frac{\text{ft}}{\text{s}} \right)^2 - \left(52.0 \frac{\text{ft}}{\text{s}} \right)^2 \right]$
 $= 9.65 \frac{\text{ft}}{\text{ft}^2}$

9.105 As shown in Video V? 25 and Fig. P9.105 a spoiler is used on race cars to produce a negative lift, thereby giving a better tractive force. The lift coefficient for the airfoil shown is $C_L = 1.1$, and the coefficient of friction between the wheels and the pavement is 0.6. At a speed of 200 mph, by how much would use of the spoiler increase the maximum tractive force that could be generated between the wheels and ground? Assume the air speed past the spoiler equals the car speed and that the airfoil acts directly over the drive wheels.

b = spoiler length = 4 ft



WFIGURE P9.105

Tractive force = $F_2 = Z N_2$ where Z = coefficient of friction = 0.6Thus,

 $\Delta F_2 = \widetilde{\mu} \Delta N_2 = \widetilde{\mu} \mathcal{L}$, where ΔF_2 is the increase in tractive force due to the (downward) lift. Hence, with $U = 200 \, \text{mph} = 293 \, \text{H/s}$,

 $\chi = \pm \rho U^2 G_2 A = \pm (0.00238 \frac{s \log 5}{H^3}) (293 \frac{4}{4})^2 (1.1) (1.5H) (4H) = 67416,$ and

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| portional designation of the second second | | erintentation television terrory, engage expension technique | | See a succession and the second secon |
|--|---|--|--|--|
| *9 .109 | | x (% c) | y (% c) | u/U |
| The second secon | 9.109 Air blows over the flat-bottomed, two-dimensional object shown in Fig. P9.109. The shape of the object, $y = y(x)$, and the | 0 | 0 | 0 |
| Siahoo Fransis | fluid speed along the surface, $u = u(x)$, are given in the table. | 2.5 | 3.72 | 0.971 |
| mediana | Determine the lift coefficient for this object. | 5.0 7.5 | 5.30 6.48 | 1.232 1.273 |
| The state of the s | • | 10 | 7.43 | 1.271 |
| ADDRESS OF THE PROPERTY OF THE | | 20 | 9.92 | 1.276 |
| Annual Control of the | $A_{\mathbf{x}}$ | 30 | 11.14 | 1.295 |
| | If viscous affects are negligible, then | 40 50 | 11.49 10.45 | 1.307 1.308 |
| A Company of the Comp | * * * | 60 | 9.11 | 1.195 |
| Proping Statement | $Z = \int \rho \cos\theta d\theta - \int \rho \cos\theta dA \qquad (1)$ hower upper | 70 | 6.46 | 1.065 |
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