9.20 Air enters a square duct through a 1-ft opening as is shown in Fig. P9.20. Because the boundary layer displacement thickness increases in the direction of flow, it is necessary to increase the cross-sectional size of the duct if a constant $U = 2$ ft/s velocity is to be maintained outside the boundary layer. Plot a graph of the duct size, d, as a function of x for $0 \le x \le 10$ ft if U is to remain constant. Assume laminar flow.

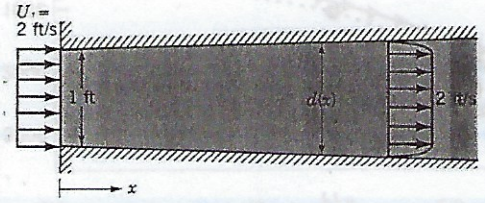
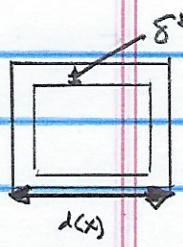


FIGURE P9.20



$Q = UA(x) = 2 \times A(x=0) = 2 \times 1^2 = 2$ ft^3/s

$A(x) = (d - 2\delta^*)^2$

= effective area allowing for decreased flow rate in the boundary layer

$\nu = 1.57 \times 10^{-4}$ ft^2/s $\quad \delta^* = 1.721\sqrt{\frac{\nu x}{U}} = .0152\sqrt{x}$

$U = 2$ ft/s

$Q = 2 \times (d - 2\delta^*)^2 = 2$

$d(x) = 1 + 2\delta^*$

$= 1 + .0304\sqrt{x}$