A wind tunnel has a test section 1 m square by 6 m long with air at 20°C moving at an average velocity of 30 m/s. To account for the growing boundary layer, the walls are slanted slightly outward. At what angle should the walls be slanted between x=2 m and x=4 m to keep the test-section velocity constant?

SOLUTION:

Determine the displacement boundary layer thickness assuming flat plate flow. First check the flow Reynolds number to determine whether or not the flow is laminar.

$$\mathrm{Re}_{x=2\ \mathrm{m}} = \frac{Ux}{\nu} = \frac{(30\ \mathrm{m/s})(2\ \mathrm{m})}{(1.5e\text{-}5\ \mathrm{m^2/s})} = 4.0e6 \tag{1}$$

$$\mathrm{Re}_{x=4\ \mathrm{m}} = \frac{Ux}{\nu} = \frac{(30\ \mathrm{m/s})(4\ \mathrm{m})}{(1.5e\text{-}5\ \mathrm{m^2/s})} = 8.0e6$$

Thus the flow in the tunnel is turbulent in the range of interest.

Use the following correlation for turbulent flat plate flow to determine the displacement boundary layer thickness.

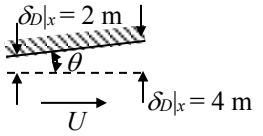
$$\frac{\delta_D}{x} = \frac{0.0478}{\mathrm{Re}_x^{1/5}} \tag{2}$$

$x = 2$ m: $\mathrm{Re}_x = 4.0e6 \Rightarrow \delta_D = 4.6e\text{-}3$ m

$x = 4$ m: $\mathrm{Re}_x = 8.0e6 \Rightarrow \delta_D = 8.0e\text{-}3$ m

As an approximation, assume that the boundary layer grows linearly between $x = 2$ m and $x = 4$ m so that the angle the walls need to be slanted outward is:

$$\tan\theta = \frac{\delta_D\big|_{x=4\ \mathrm{m}} - \delta_D\big|_{x=4\ \mathrm{m}}}{4\ \mathrm{m} - 2\ \mathrm{m}} \tag{3}$$



$$\boxed{\therefore \theta = 0.1} \tag{4}$$