symmetrically along the barrier. Calculate the horizontal force F needed, per unit thickness into the paper, to hold the barrier stationary.

Solution: For water take ρ = 998 kg/m. The control volume (see figure) cuts through all four jets, which are numbered. The velocity of all jets follows from the weight flow at (1):

$$V_{1,2,3,4} = V_1 = \frac{\dot{w}_1}{\rho g A_1} = \frac{1960\,N/s}{(9.81m/s^2)(998kg/m^3)(0.04m)(1m)} = 5.0\frac{m}{s}$$

$$\dot{m}_1 = \frac{\dot{w}_1}{g} = \frac{1960N/s-m}{9.81N/s^2} = 200\frac{kg}{s-m}\ ;\ \dot{m}_2 = 0.3\dot{m}_1 = 60\frac{kg}{s-m}\ ;\ \dot{m}_3 = \dot{m}_4 = 70\frac{kg}{s-m}$$

Then the x-momentum relation for this control volume yields

$$\Sigma F_x = -F = \dot{m}_2 u_2 + \dot{m}_3 u_3 + \dot{m}_4 u_4 - \dot{m}_1 u_1 =$$

$$-F = (60)(5.0)+(70)(-5.0\cos 55^\circ) + (70)(-5.0\cos 55^\circ) - 200(5.0)\text{ , or :}$$

$$F = 1000 + 201 + 201 - 300 \approx \textbf{1100 N} \text{ per meter of width} \quad \textit{Ans.}$$

3.31 A bellows may be modeled as a deforming wedge-shaped volume as in Fig. P3.31. The check valve on the left (pleated) end is closed during the stroke. If b is the bellows width into the paper, derive an expression for outlet mass flow $\dot{m}_o$ as a function of stroke $\theta(t)$.

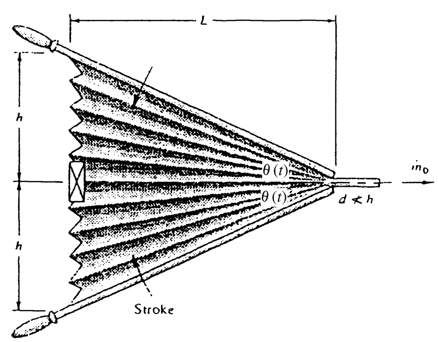

Fig. P3.31

Solution: For a control volume enclosing the bellows and the outlet flow, we obtain

$$\frac{d}{dt}(\rho \upsilon) + \dot{m}_{out} = 0, \quad \text{where } \upsilon = bhL = bL^2 \tan\theta$$

since L is constant, solve for $\dot{m}_o = -\frac{d}{dt}(\rho b L^2 \tan\theta) = \boldsymbol{-\rho b L^2 \sec^2\theta \frac{d\theta}{dt}}$ *Ans.*
