3.160 The air-cushion vehicle in Fig. P3.160 brings in sea-level standard air through a fan and discharges it at high velocity through an annular skirt of 3-cm clearance. If the vehicle weighs 50 kN, estimate (a) the required airflow rate and (b) the fan power in kW.

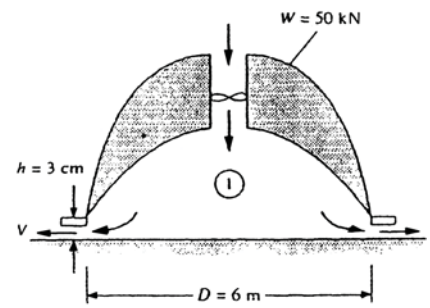


Fig. P3.160

Solution: The air inside at section 1 is nearly stagnant (V ≈ 0) and supports the weight and also drives the flow out of the interior into the atmosphere:

$$p_1 \approx p_{o1}: \quad p_{o1} - p_{atm} = \frac{\text{weight}}{\text{area}} = \frac{50{,}000\ \text{N}}{\pi(3\ \text{m})^2} = \frac{1}{2}\rho V_{exit}^2 = \frac{1}{2}(1.205)V_{exit}^2 \approx 1768\ \text{Pa}$$

$$\text{Solve for} \quad V_{exit} \approx 54.2\ \text{m/s, whence} \quad Q_e = A_e V_e = \pi(6)(0.03)(54.2) = 30.6\ \frac{\text{m}^3}{\text{s}}$$

Then the power required by the fan is $P = Q_e\Delta p = (30.6)(1768) \approx$ **54000 W** *Ans.*

3.161 A necked-down section in a pipe flow, called a *venturi*, develops a low throat pressure which can aspirate fluid upward from a reservoir, as in Fig. P3.161. Using Bernoulli's equation with no losses, derive an expression for the velocity V_1 which is just sufficient to bring reservoir fluid into the throat.

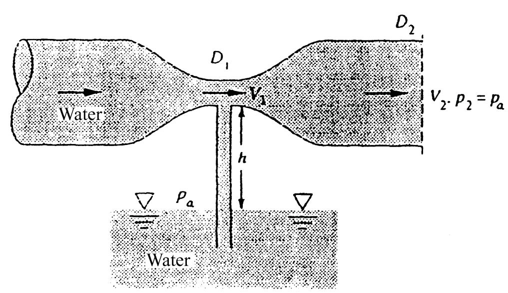


Fig. P3.161

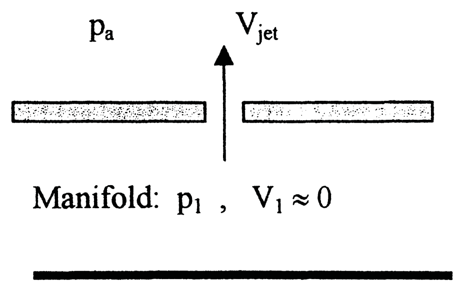
Solution: Water will begin to aspirate into the throat when $p_a - p_1 = \rho gh$. Hence:

$$\text{Volume flow:} \quad V_1 = V_2(D_2/D_1)^2; \quad \text{Bernoulli } (\Delta z = 0): \quad p_1 + \frac{1}{2}\rho V_1^2 \approx p_{atm} + \frac{1}{2}\rho V_2^2$$

$$\text{Solve for}\quad p_a - p_1 = \frac{\rho}{2}(\alpha^4 - 1)V_2^2 \geq \rho gh,\quad \alpha = \frac{D_2}{D_1},\quad \text{or:}\quad \mathbf{V_2 \geq \sqrt{\frac{2gh}{\alpha^4 - 1}}}\quad \textit{Ans.}$$

$$\textit{Similarly},\quad \mathbf{V_{1,\,min} = \alpha^2 V_{2,\,min} = \sqrt{\frac{2gh}{1 - (D_1/D_2)^4}}}\quad \textit{Ans.}$$

3.162 Suppose you are designing a 3 × 6-ft air-hockey table, with 1/16-inch-diameter holes spaced every inch in a rectangular pattern (2592 holes total), the required jet speed from each hole is 50 ft/s. You must select an appropriate blower. Estimate the volumetric flow rate (in ft³/min) and pressure rise (in psi) required. *Hint*: Assume the air is stagnant in the large manifold under the table surface, and neglect frictional losses.



Solution: Assume an air density of about sea-level, **0.00235 slug/ft³**. Apply Bernoulli's equation through any single hole, as in the figure:

$$p_1 + \frac{\rho}{2}V_1^2 = p_a + \frac{\rho}{2}V_{jet}^2,\quad or:$$

$$\Delta p_{required} = p_1 - p_a = \frac{\rho}{2}V_{jet}^2 = \frac{0.00235}{2}(50)^2 = 2.94\ \frac{lbf}{ft^2} = \mathbf{0.0204\ \frac{lbf}{in^2}}\quad \textit{Ans.}$$

The total volume flow required is

$$Q = VA_{1-hole}(\#\ of\ holes) = \left(50\ \frac{ft}{s}\right)\frac{\pi}{4}\left(\frac{1/16}{12}\ ft\right)^2(2592\ holes)$$

$$= 2.76\ \frac{ft^3}{s} = \mathbf{166\ \frac{ft^3}{min}}\quad \textit{Ans.}$$

It wasn't asked, but the power required would be $P = Q\Delta p$ = (2.76 ft³/s)(2.94 lbf/ft²) = 8.1 ft·lbf/s, or about 11 watts.
