3.66 The tank in Fig. P3.66 weighs 500 N empty and contains 600 L of water at 20°C. Pipes 1 and 2 have D = 6 cm and Q = 300 m^3/hr. What should the scale reading W be, in newtons?

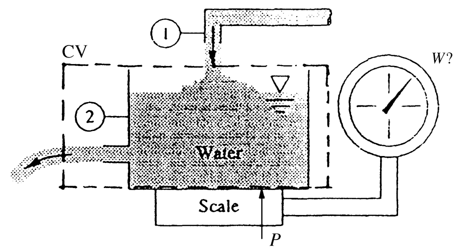

Fig. P3.66

Solution: Let the CV surround the tank, cut through the two jets, and slip just under the tank bottom, as shown. The relevant jet velocities are

$$V_1 = V_2 = \frac{Q}{A} = \frac{(300/3600)\ m^3/s}{(\pi/4)(0.06\ m)^2} \approx 29.5\ m/s$$

The scale reads force "P" on the tank bottom. Then the vertical force balance is

$$\sum F_z = P - W_{tank} - W_{water} = \dot{m}_2 v_2 - \dot{m}_1 v_1 = \dot{m}[0 - (-V_1)]$$

$$\text{Solve for} \quad \mathbf{P} = 500 + 9790(0.6\ m^3) + 998\left(\frac{300}{3600}\right)(29.5) \approx \mathbf{8800\ N} \quad \textit{Ans.}$$

3.67 Gravel is dumped from a hopper, at a rate of 650 N/s, onto a moving belt, as in Fig. P3.67. The gravel then passes off the end of the belt. The drive wheels are 80 cm in diameter and rotate clockwise at 150 r/min. Neglecting system friction and air drag, estimate the power required to drive this belt.

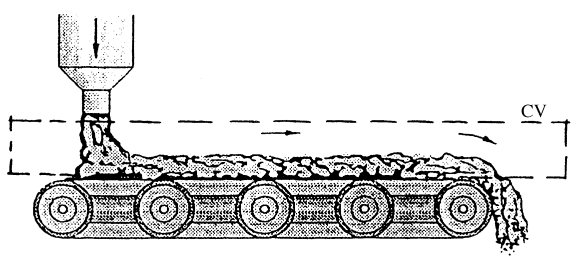

Fig. P3.67

Solution: The CV goes under the gravel on the belt and cuts through the inlet and outlet gravel streams, as shown. The no-slip belt velocity must be

$$V_{belt} = V_{outlet} = \Omega R_{wheel} = \left[150\frac{rev}{min}2\pi\frac{rad}{rev}\frac{1}{60}\frac{min}{s}\right](0.4\ m) \approx 6.28\ \frac{m}{s}$$

Then the belt applies tangential force F to the gravel, and the force balance is

$$\sum F_x = F_{on\ belt} = \dot{m}_{out}u_{out} - \dot{m}_{in}u_{in}, \quad \text{but } u_{in} = 0.$$

$$\text{Then} \quad F_{belt} = \dot{m}V_{out} = \left(\frac{650}{9.81}\ \frac{kg}{s}\right)\left(6.28\ \frac{m}{s}\right) = 416\ N$$

The power required to drive the belt is $\boldsymbol{P} = FV_{belt} = (416)(6.28) \approx \mathbf{2600\ W}$ *Ans.*

3.68 The rocket in Fig. P3.68 has a supersonic exhaust, and the exit pressure p_e is not necessarily equal to p_a. Show that the force F required to hold this rocket on the test stand is $F = \rho_e A_e V_e^2 + A_e(p_e - p_a)$. Is this force F what we term the *thrust* of the rocket?

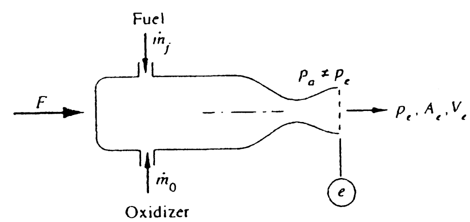

Fig. P3.68

Solution: The appropriate CV surrounds the entire rocket and cuts through the exit jet. Subtract p_a everywhere so only exit pressure ≠ 0. The horizontal force balance is

$$\sum F_x = F - (p_e - p_a)A_e = \dot{m}_e u_e - \dot{m}_f u_f - \dot{m}_o u_o, \quad \text{but } u_f = u_o = 0, \quad \dot{m}_e = \rho_e A_e V_e$$

$$\text{Thus} \quad \mathbf{F = \rho_e A_e V_e^2 + (p_e - p_a)A_e} \quad \textbf{(the } \underline{\textbf{\textit{thrust}}}\textbf{)} \quad \textit{Ans.}$$

3.69 A uniform rectangular plate, 40 cm long and 30 cm deep into the paper, hangs in air from a hinge at its top, 30-cm side. It is struck in its center by a horizontal 3-cm-diameter jet of water moving at 8 m/s. If the gate has a mass of 16 kg, estimate the angle at which the plate will hang from the vertical.

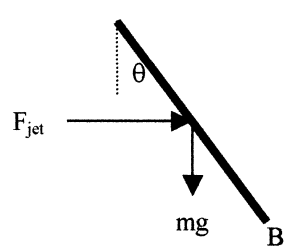

Fig. P3.69

Solution: The plate orientation can be found through force and moment balances,

$$\sum F_x = F_j = -\dot{m}_{in}u_{in} = -(998)\left(\frac{\pi}{4}\right)(0.03^2)(8^2) = 45.1\ N$$

$$\sum M_B = 0 = -(45)(0.02)(\sin\theta) + (16)(9.81)(0.02)(\cos\theta) \quad \boldsymbol{\theta = 16°}$$
