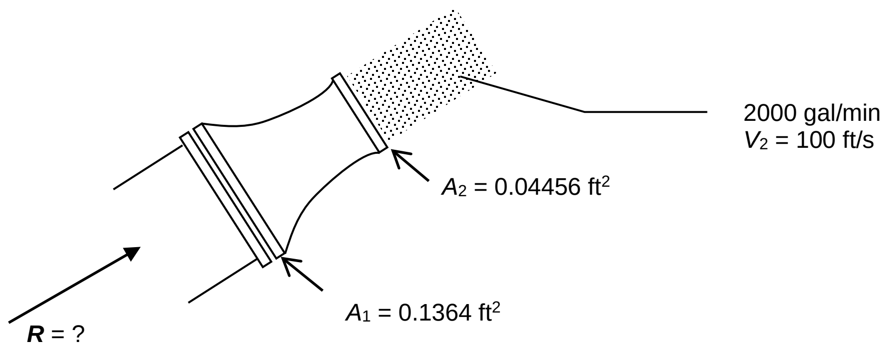
Active learning exercise

The nozzle on the firehose in the boat problem is pictured below. If the pressure at the inlet of the nozzle is 40 psi (lbf/in^2), calculate the reaction force needed to keep the nozzle stationary. Other conditions are the same as in the original problem. (P_{atm} = 14.7 psi, ρ_{wat} = 62.4 lbm/ft^3)



1. Draw a system boundary and draw all relevant mass and linear momentum related transport terms on it. Be sure to indicate a **coordinate system** on your diagram.

2. Apply **conservation of mass** to the system and any related equations. What can you use these to solve for?

$$\frac{d}{dt}(m_{sys}) = \sum \dot{m}_{in} - \sum \dot{m}_{out}$$

$$\dot{m}_2 = \rho \dot{\forall}_2$$

$$= 62.4\frac{lbm}{ft^3} 2000\frac{gal}{\min}\left\langle\frac{\underline{\qquad\qquad}}{\underline{\qquad\qquad}}\right\rangle\left\langle\frac{\underline{\qquad\qquad}}{\underline{\qquad\qquad}}\right\rangle = 278\frac{lbm}{s}$$

$$V_1 = \frac{\dot{m}_1}{\rho A_1} = \frac{278\frac{\text{lbm}}{\text{s}}}{\left(62.4\frac{\text{lbm}}{\text{ft}^3}\right)(0.1364\text{ft})} = 32.7\frac{\text{ft}}{\text{s}}$$

3. Apply *flow direction component* of **conservation of linear momentum** to the system. Be careful with pressures. Use this to solve for R.

$$\frac{d}{dt}(P_{x,sys}) = \sum F_{x,ext} + \sum_{in} \dot{m} \cdot V_x - \sum_{out} \dot{m} \cdot V_x$$

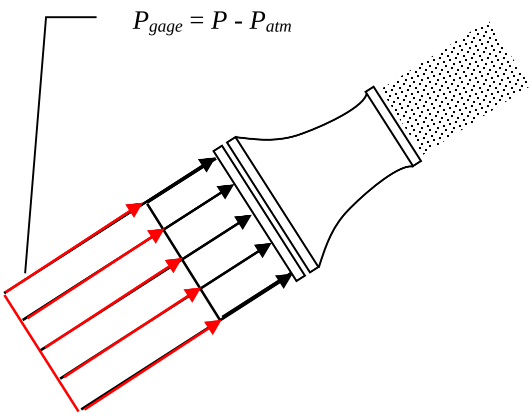
$$= \underbrace{\qquad\qquad\qquad}\ \underbrace{\qquad\qquad}\ \underbrace{\qquad\qquad}$$

$$R = \dot{m}(V_2 - V_1) - (P_1 - P_{atm})A_1$$

$$= \left(275\frac{\text{lbm}}{\text{s}}\right)(100 - 32.4)\frac{\text{ft}}{\text{s}}\left\langle \frac{\quad}{\quad} \right\rangle - (40 - 14.7)\frac{\text{lbf}}{\text{in}^2}\left(0.1364\ \text{ft}^2\right)\left\langle \frac{\quad}{\quad} \right\rangle$$

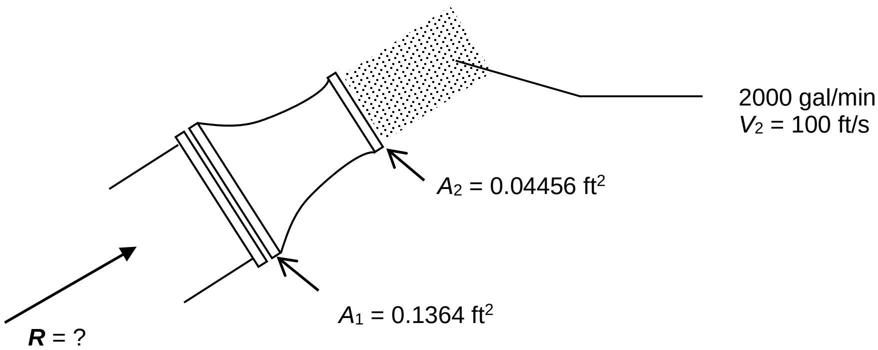
$$= 84.3\ \text{lbf}$$

4. Dealing with the pressures was a bit tedious. Here is a short cut we can use when *systems are almost completely surrounded by atmospheric pressure*. Treat the pressure at the inlet as the sum of two pressures, P_{atm} and the pressure above atmospheric, also called the **gage pressure**.



What is the resultant force due to P_{atm} and the atmospheric component of the inlet pressure?

5. Using the result of part 4., redraw your system and the any relevant transports. (I.e., use P_{gage} at the inlet.) Apply the *flow direction component* of conservation of linear momentum again and solve for R. Do you get the same answer? Which way was easier?



$$\frac{d}{dt}(P_{x,sys}) = \sum F_{x,ext} + \sum_{in} \dot{m} \cdot V_x - \sum_{out} \dot{m} \cdot V_x$$

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