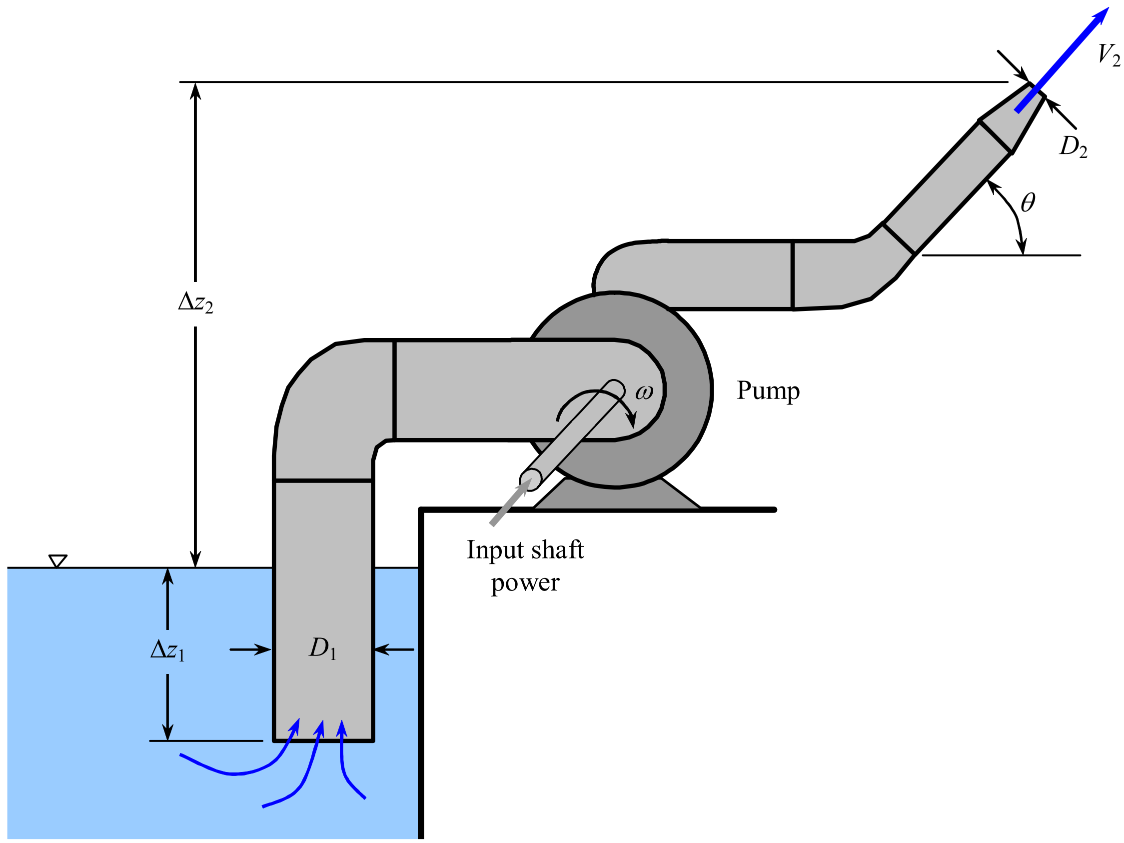
Example – Fire-Fighting Pump

Given: A self-priming pump is used to draw water from a lake and shoot it through a nozzle, as sketched. The diameter of the pump inlet is D_1 = 12.0 cm. The diameter of the nozzle outlet is D_2 = 2.54 cm, and the average velocity at the nozzle outlet is V_2 = 65.8 m/s. The pump efficiency is 80%. The vertical distances are Δz_1 = 1.00 m and Δz_2 = 2.00 m. The irreversible head losses in the piping system (not counting inefficiencies associated with the pump itself) are estimated as h_L = 4.50 m of equivalent water column height. *Note*: Later on, in Chapter 8, you will learn how to calculate the irreversible head losses associated with piping systems on your own. For now, it is given.



(a) **To do**: Calculate the volume flow rate of the water in units of m³/hr and gallons per minute (gpm).

Solution: At the outlet, $\dot{V} = V_{2,\text{ avg}} A_2 = V_2 \frac{\pi D_2^2}{4} = \left(65.8 \frac{\text{m}}{\text{s}}\right) \frac{\pi (0.0254\text{ m})^2}{4} = 0.033341 \frac{\text{m}^3}{\text{s}}$, where we have dropped the subscript "avg" for convenience. We convert to the required units as follows:

$\dot{V} = 0.033341 \frac{\text{m}^3}{\text{s}} \left(\frac{3600\text{ s}}{\text{hr}}\right) = \mathbf{120.}\ \frac{\mathbf{m^3}}{\mathbf{hr}}$ and $\dot{V} = 0.033341 \frac{\text{m}^3}{\text{s}} \left(\frac{15{,}850\text{ gpm}}{\text{m}^3/\text{hr}}\right) = \mathbf{528.\ gpm}$, where both answers are given to three significant digits of precision.

(b) **To do**: Calculate the power delivered by the pump to the water, i.e. calculate the *water horsepower* $\dot{W}_{\text{water horsepower}}$ in units of kW.

(c) **To do**: Calculate the required shaft power to the pump, i.e. calculate the *brake horsepower* bhp in units of kW.

Solutions for parts (b) and (c) to be completed in class.