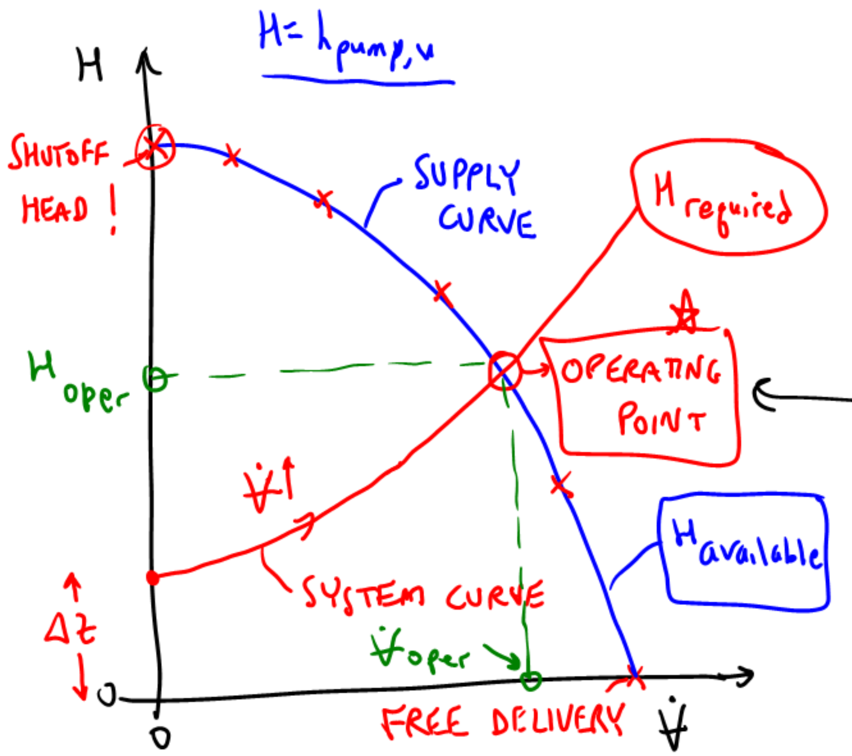
MATCHING PUMP TO SYSTEM

In this lesson, we will:

- Review and demonstrate the **Pump Performance Curve** using a submersible water pump
- Compare **System Curve** to **Supply Curve** and thus obtain the **Operating Point**
- Do an example problem

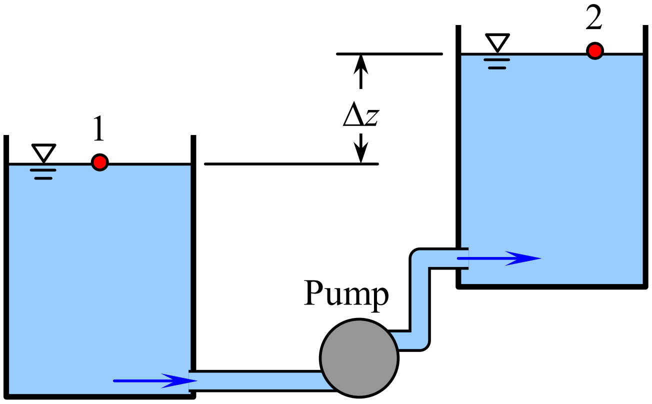
Review – Pump Performance Curve

In the previous lesson we used a small axial fan to demonstrate a pump curve. Now we will use a small submersible water pump to demonstrate free delivery, shutoff head, and all points in between.



$\dot{V}$ will adjust automatically to where the two curves intersect (the operating point)

As $\dot{V}\uparrow$, the system requires a larger H from the pump



Typically we do not know the volume flow rate

To calculate the operating volume flow rate, we match system & supply curves

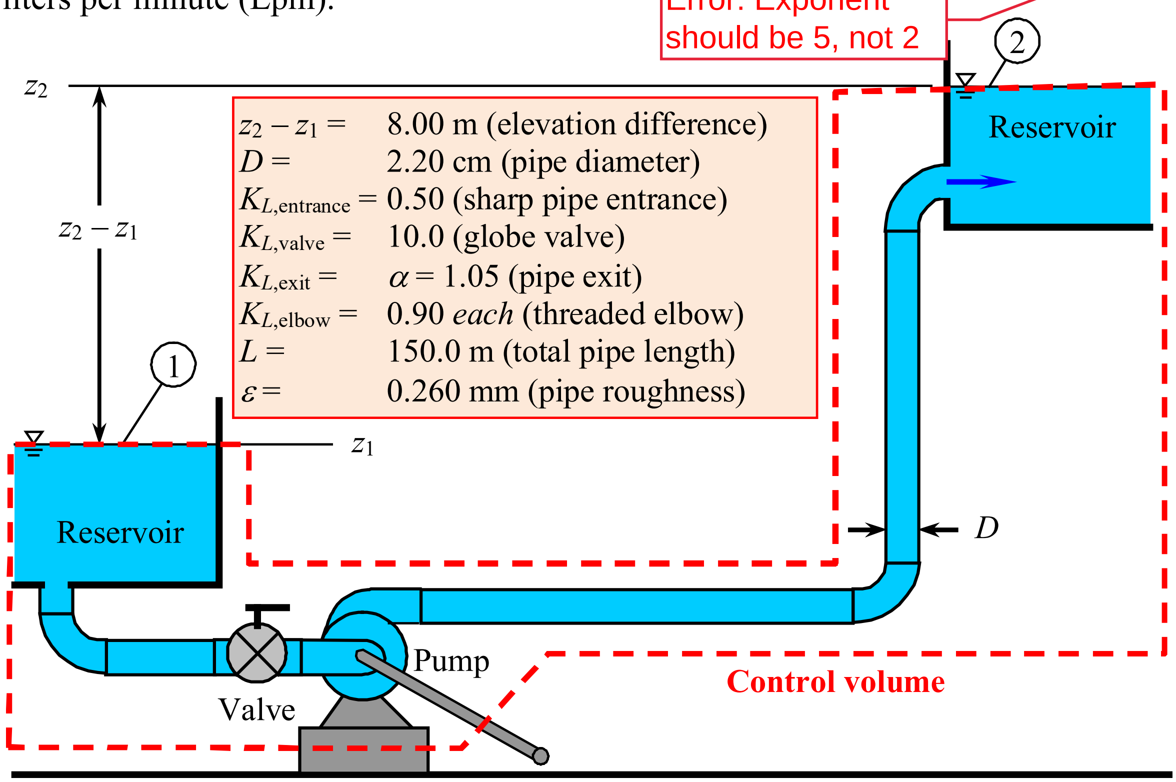
Example: Matching a Pump to a Piping System

Given: Water ($\rho = 1000$ kg/m^3, $\mu = 1.00 \times 10^{-3}$ kg/m·s) is pumped from one large reservoir to another large reservoir that is at higher elevation, as sketched. The free surfaces of both reservoirs are exposed to atmospheric pressure. The dimensions and minor loss coefficients are provided in the figure. The pipe is 2.20 cm I.D. cast iron pipe. The total pipe length is 150.0 m. The entrance and exit are sharp. There are three regular threaded 90-degree elbows, and one fully open threaded globe valve. A curve-fit of the manufacturer's pump performance curve results in the expression

$$H_{\text{available}} = h_{\text{pump,u, supply}} = H_0 - a\dot{V}^2$$ SUPPLY CURVE ☆

where shutoff head $H_0 = 20.0$ m of water column, coefficient $a = 0.0720$ m/Lpm^2 = 2.592×10^8 s^2/~~m^2~~, available pump head $H_{\text{available}}$ is in units of meters of water column, and volume flow rate $\dot{V}$ is in units of liters per minute (Lpm).

Error: Exponent should be 5, not 2



To do: Calculate the volume flow rate through this piping system.

Solution:

- First, we draw a wise control volume, as shown. We cut through the pump shaft and through the surface of both reservoirs (inlet 1 and outlet 2), where we know that the velocity is nearly zero and the pressure is atmospheric. The rest of the control volume simply surrounds the piping system.
- We apply the head form of the energy equation from the inlet (1) to the outlet (2):

$$\cancel{\frac{P_1}{\rho_1 g}} + \alpha_1 \underbrace{\cancel{\frac{V_1^2}{2g}}}_{\approx 0} + z_1 + h_{\text{pump, u}} = \cancel{\frac{P_2}{\rho_2 g}} + \alpha_2 \underbrace{\cancel{\frac{V_2^2}{2g}}}_{\approx 0} + z_2 + \cancel{h_{\text{turbine, e}}} + h_{L,\text{ total}}$$

We call this $\boldsymbol{h_{\text{pump, u, system}} = H_{\text{required}}}$ since it is the *required* pump head for the given piping system. When plotted vs. volume flow rate we call it the **system curve**.

$$H_{required} = h_{L,total} + (z_2 - z_1)$$

$$= \frac{V^2}{2g}\left(f\frac{L}{D} + \Sigma K_L\right) + (z_2 - z_1)$$

$\dot{\forall}$ is our unknown

$$\dot{\forall} = V\frac{\pi D^2}{4} \rightarrow V^2 = \frac{16\dot{\forall}^2}{\pi^2 D^4}$$

$$\boxed{H_{required} = \frac{8\dot{\forall}^2}{\pi^2 D^4 g}\left(f\frac{L}{D} + \Sigma K_L\right) + (z_2 - z_1)}$$

SYSTEM CURVE

$\Sigma K_L = 0.50 + 10.0 + 3(0.90) + 1.05 = \underline{\underline{14.25}}$ 8.00 m

Need Moody Chart or Churchill Eq. to get $f \rightarrow \underline{\underline{f(Re, \varepsilon/D)}}$

where $\boxed{Re = \frac{\rho V D}{\mu}}$

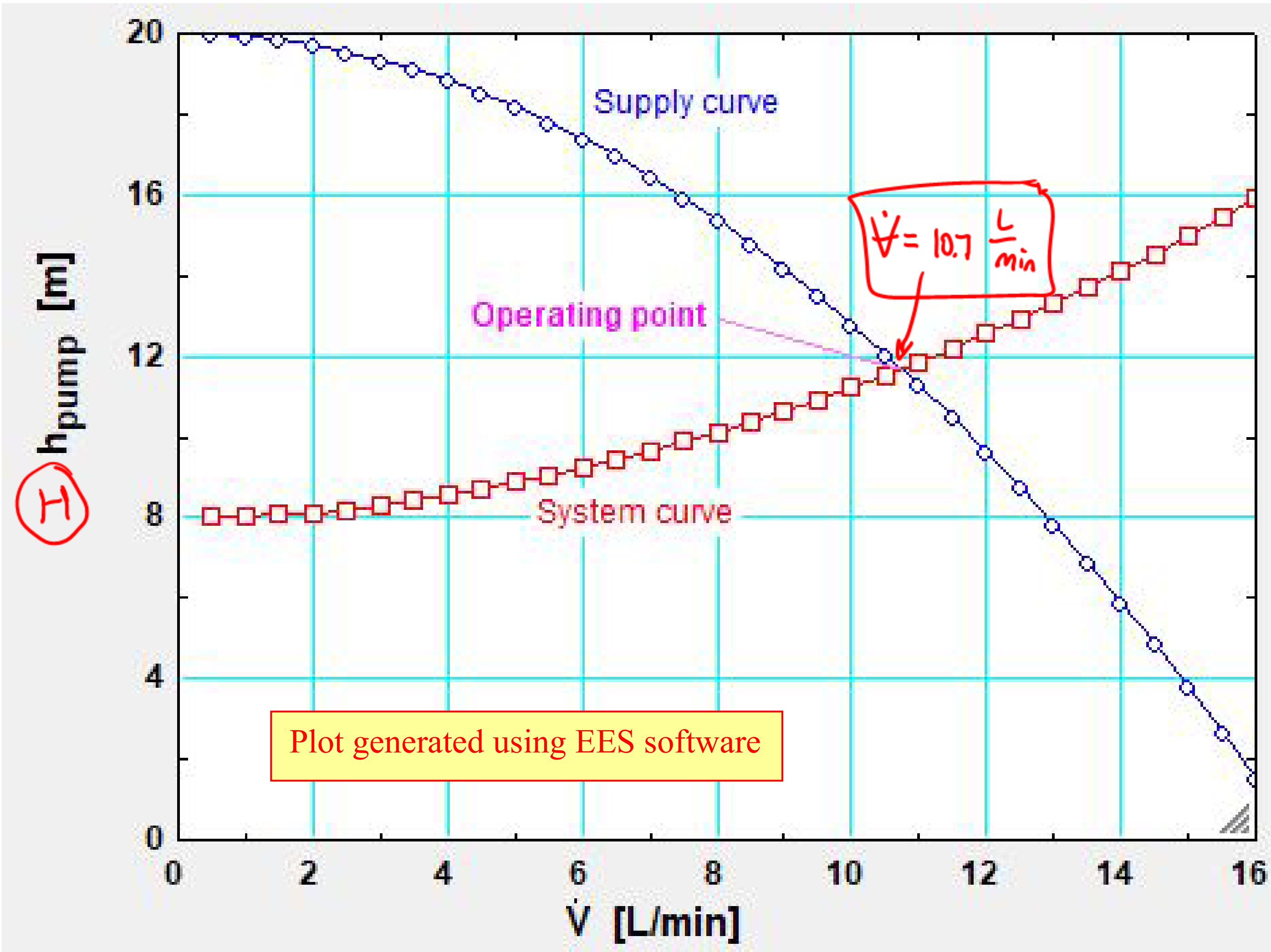
MATCH SUPPLY CURVE TO SYSTEM CURVE $\left(H_{avail} = H_{required}\right)$

$$\boxed{H_o - a\dot{\forall}^2 = \frac{8\dot{\forall}^2}{\pi^2 D^4 g}\left(f\frac{L}{D} + \Sigma K_L\right) + (z_2 - z_1)}$$

ANS IN VARIABLES

Result after iteration $\rightarrow$ $\boxed{\dot{\forall} = 10.7 \text{ L/min}}$ ANS. = OPERATING POINT

$\underline{Re = 1.04 \times 10^4, \ f = 0.0457}$



Plot showing where the operating point is, namely where the system curve and supply curve intersect.