

PUMP SYSTEM #01

Two identical pumps are connected to a pipe system as shown in Figure Q4. The pumps are used to deliver water into the high-level reservoir. The head discharge characteristic of the pumps is given by equation (1), where Q is the pump discharge in liter per second and H is the head developed by the pump

$$H = 70 + 0.16Q - 0.001Q^2 \quad (1)$$

The pipe AB is 150 m long with a diameter of 300 mm. The pipe BC is 250 m long with a diameter 400 mm. The friction factor for both pipes is 0.03. The regulating valve V is used to regulate flow in pipe BC. The static lifts against which the pumps are working are 40 m and 70 m. For a given of valve, the pump operates against a static lift of 70 m and develops a discharge of 100 liter per second. Determine the discharge of the second pump and the loss of coefficient of the valve. Neglect all minor losses and pipe loss from B to tank 2.

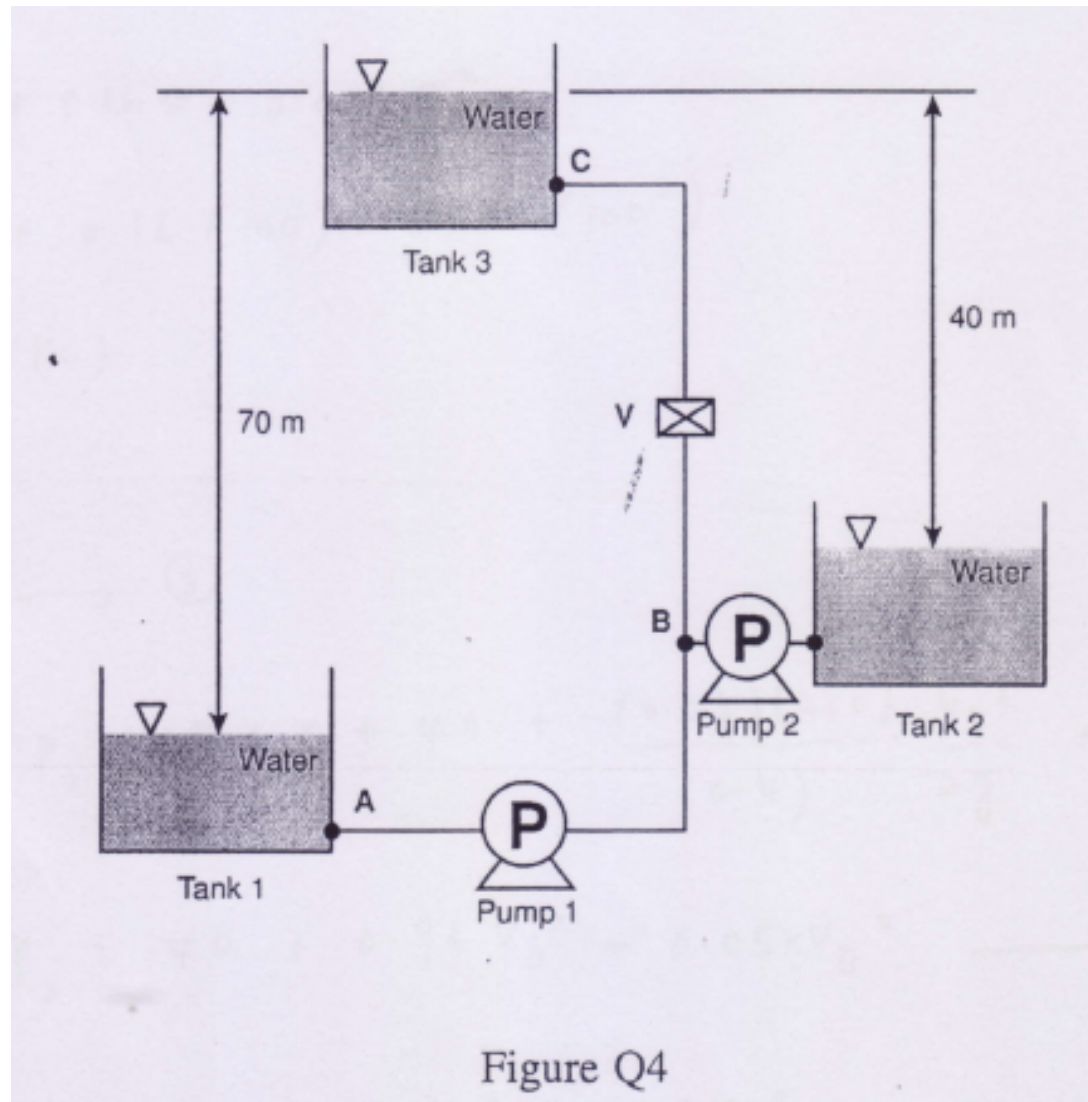


Figure Q4

Solution

Tank (1) to Tank (2)

$$0 + 0 + 0 + H_{p1} = 0 + 0 + 70 + \frac{(0.03)(150)}{0.3} \frac{v_A^2}{2g} + \frac{(0.03)(250)}{0.4} \frac{v_B^2}{2g} + K_{valve} \frac{v_B^2}{2g}$$

$$Q = 0.1 \text{ m}^3/\text{s}$$

$$v_A = \frac{Q}{A_A} = \frac{0.1}{\frac{\pi}{4}(0.3)^2} = 1.41 \text{ m/s}$$

$$H_{p1} = 70 + \frac{(0.03)(150)}{0.3} \frac{1.41^2}{2g} + 0.96v_B^2 + 0.05Kv_B^2 \quad (1)$$

$$H_p = 70 + 0.16Q - 0.001Q^2$$

$$H_{p1} = 70 + 0.16(100) - 0.001(100)^2 = 76 \text{ m}$$

Tank (2) to Tank (3)

$$0 + 0 + 0 + H_{p2} = 0 + 0 + 40 + \frac{(0.03)(250)}{0.4} \frac{v_B^2}{2g} + K \frac{v_B^2}{2g}$$

$$H_{p2} = 40 + 0.96v_B^2 + 0.05Kv_B^2 \quad (2)$$

$$H_{p2} - 40 = 0.96v_B^2 + 0.05Kv_B^2$$

From equation (1) and (2)

$$H_{p1} = 76 = 70 + \frac{(0.03)(150)}{0.3} \frac{1.41^2}{2g} + 0.96v_B^2 + 0.05v_B^2$$

$$= 70 + 1.52 + 0.96v_B^2 + 0.05v_B^2$$

$$4.48 = 0.96v_B^2 + 0.05v_B^2$$

$$= H_{p2} - 40$$

$$H_{p2} = 44.48 \text{ m}$$

Then,

$$h_{p2} = 44.48 = 70 + 0.16Q - 0.001Q^2$$

$$0 = 25.52 + 0.16Q - 0.001Q^2$$

$$Q = 258.5 \text{ or } -98.5 \text{ (We can ignore the negative value)}$$

Discharge for pump 2 is 258.5 liter/s or 0.2585 m³/s

$$Q = A_B v_B$$

$$v_B = \frac{Q}{A_B} = \frac{0.2585}{\frac{\pi}{4}(0.4)^2} = 2.06 \text{ m/s}$$

From

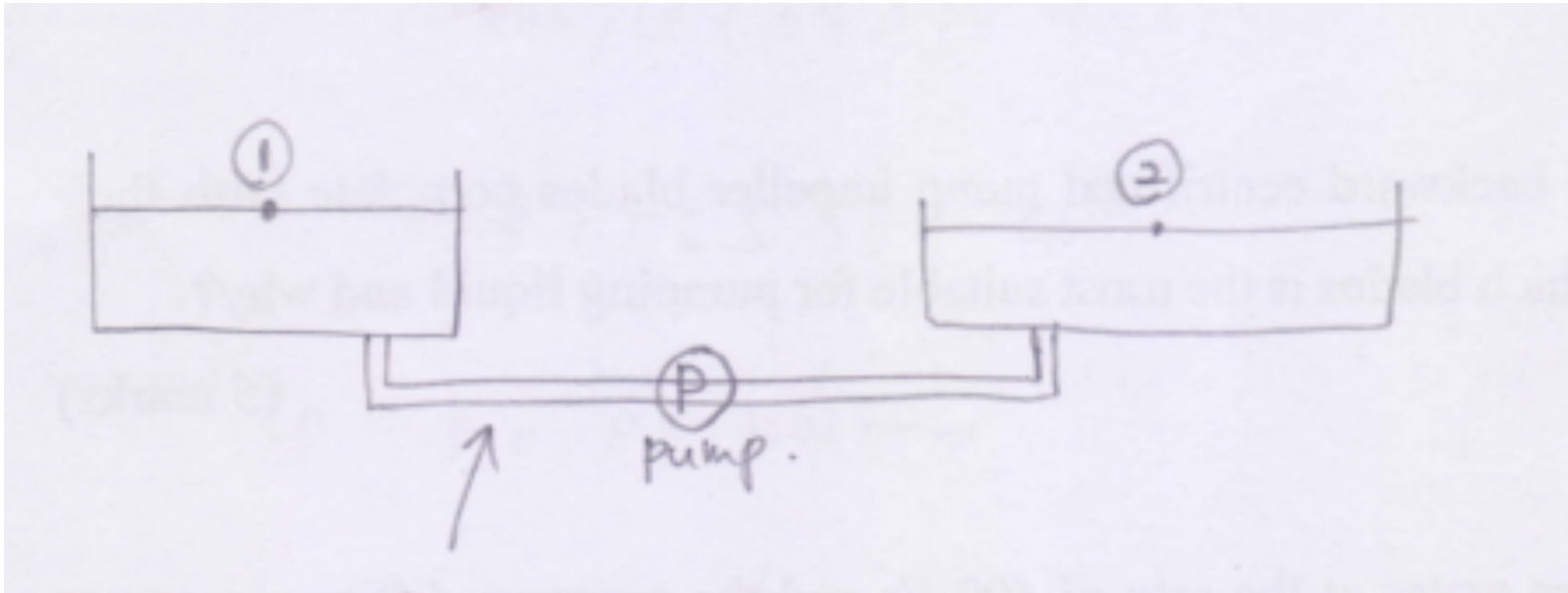
$$H_{p2} - 40 = 0.96v_B^2 + 0.05Kv_B^2$$

$$44.48 - 40 = 0.96(2.06)^2 + 0.05K(2.06)^2$$

$$4.48 = 4.07 + 0.212K$$

$$K = 1.93$$

PUMP SYSTEM #2



$$f = 0.05 \quad l = 1\text{km} \quad D = 0.15\text{m} \quad \text{pump power} = 80\text{kW}$$

Calculate the maximum flow rate in the pump

$$\text{Power, } P = \rho g Q H$$

Bernoulli equation:

$$0 + 0 + 0 + h_p = 0 + 0 + 0 + \sum h_L$$

$$h_p = \sum h_L = f \left(\frac{l}{D} \right) \left(\frac{v^2}{2g} \right)$$

$$Q = Av$$

$$v = \frac{Q}{A} = \frac{4Q}{\pi d^2}$$

$$H_p = f \left(\frac{l}{D} \right) \left(\frac{16Q^2}{\pi^2 D^4} \right) = f \left(\frac{l}{D^5} \right) \left(\frac{16Q^2}{2g\pi^2} \right) = 0.05 \left(\frac{1000}{0.15^5} \right) \left(\frac{16Q^2}{2g\pi^2} \right)$$

$$H_p = 54390Q^2$$

$$\begin{aligned} \text{Power, } P &= \rho g Q H_P \\ &= 9810Q(54390Q^2) \\ &= 533565900Q^3 \end{aligned}$$

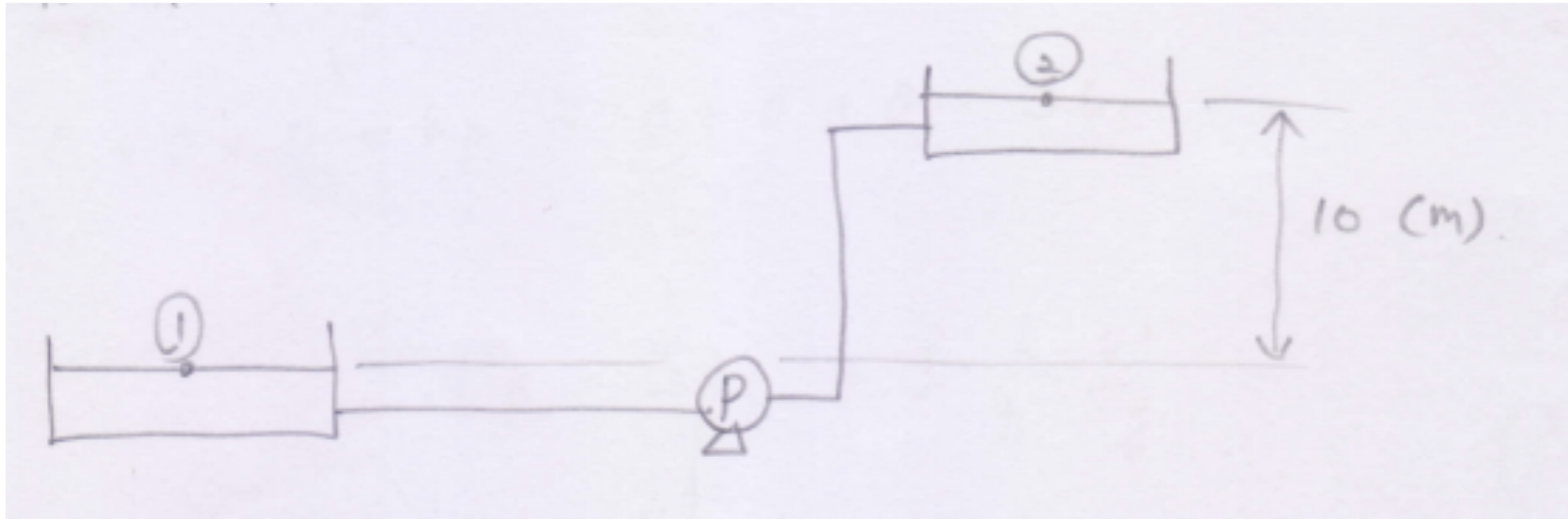
$$\text{If } P = 80 \text{ kW}$$

$$80000 = 533565900Q^3$$

$$Q^3 = 6669.57$$

$$Q = 18.82 \text{ m}^3/\text{s}$$

If water level was different:



Bernoulli equation becomes:

$$0 + 0 + 0 + H_p = 0 + 0 + 10 + \sum h_L$$