PUMP SYSTEM

Theorectical and tutorial

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

$$H = 70 + 0.16Q - 0.001Q^2 \tag{1}$$

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.

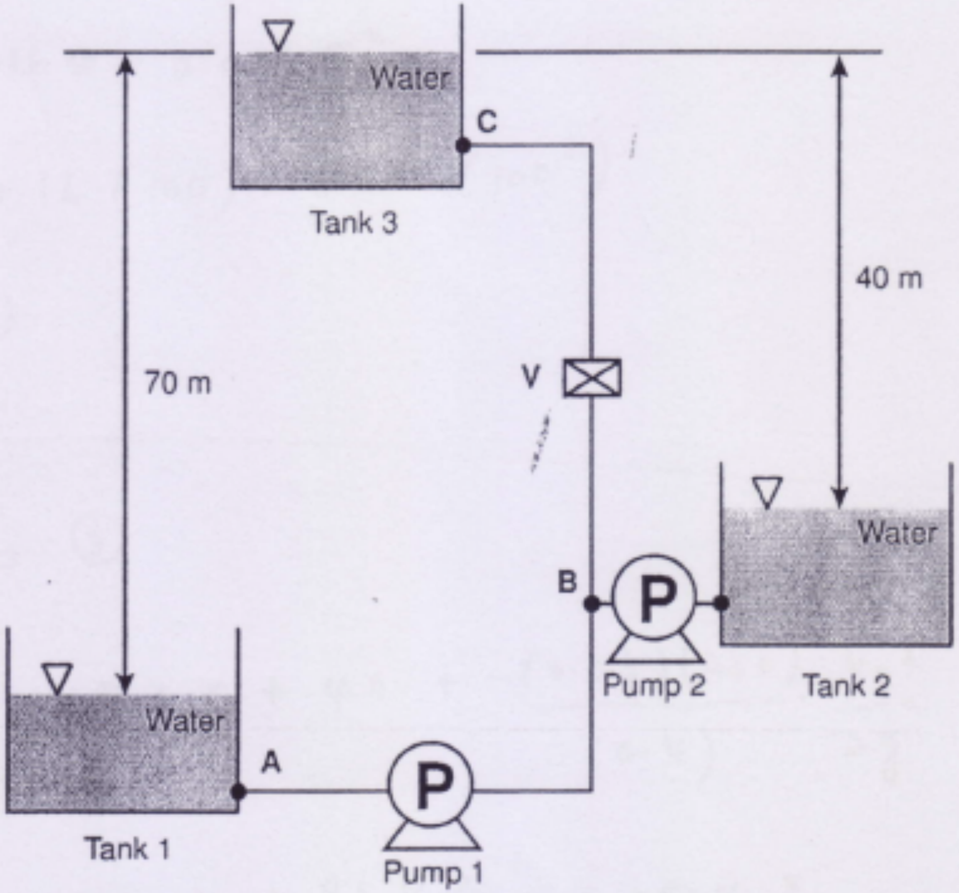

Water
C
Tank 3
40 m
70 m
V
Water
B
P
Pump 2
Tank 2
Water
A
P
Tank 1
Pump 1

Figure Q4

Solution

Tank (1) to Tank (3)

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

$$Q=0.1\ m^3/s$$

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

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

$H_p=70+0.16Q-0.001Q^2$ (This equation is given in the question)

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

Tank (2) to Tank (3)

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

$$H_{p2}=40+0.96{v_B}^2+0.05K{v_B}^2 \qquad (3)$$

$$H_{p2}-40=0.96{v_B}^2+0.05K{v_B}^2 \qquad (4)$$

From equation (1) and (2)

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

$$76=70+1.52+0.96{v_B}^2+0.05K{v_B}^2$$

$$4.48=0.96{v_B}^2+0.05K{v_B}^2$$

From equation (4)

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

$$H_{p2}-40=4.48\ m$$

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

Then,

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

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

$Q = \; 258.5 \quad or \quad -98.5$ (We can ignore the negative value)

Discharge for pump 2 is 258.5 liter/s or 0.2585 m^3/s

$$Q = A_B v_B$$

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

From equation (4)

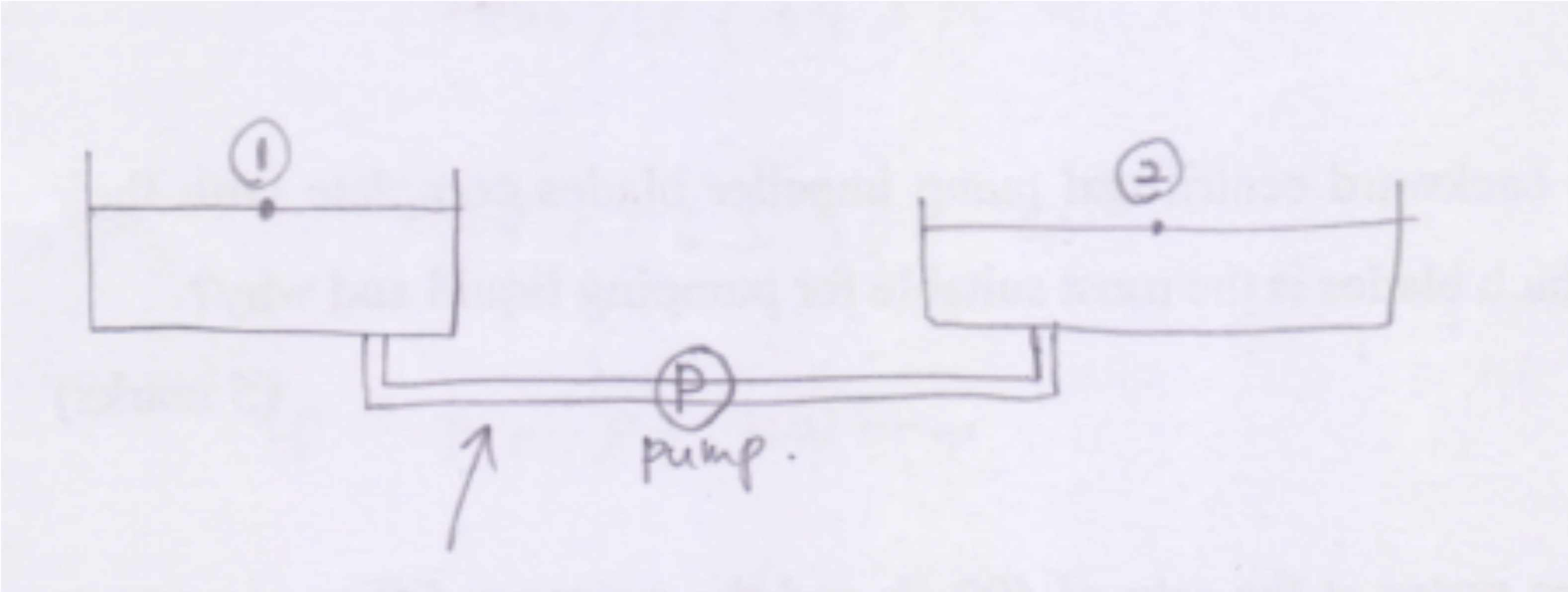
$$H_{p2} - 40 = 0.96{v_B}^2 + 0.05K{v_B}^2$$

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

$$4.48 = 4.07 + 0.212K$$

$$K = 1.93$$

PUMP SYSTEM #2



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

Calculate the maximum flow rate in the pump

$$Power, P = \rho g Q H$$

Bernoulli equation:

$$0 + 0 + 0 + H_P = 0 + 0 + 0 + \sum h_L$$

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

$$Q = Av$$

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

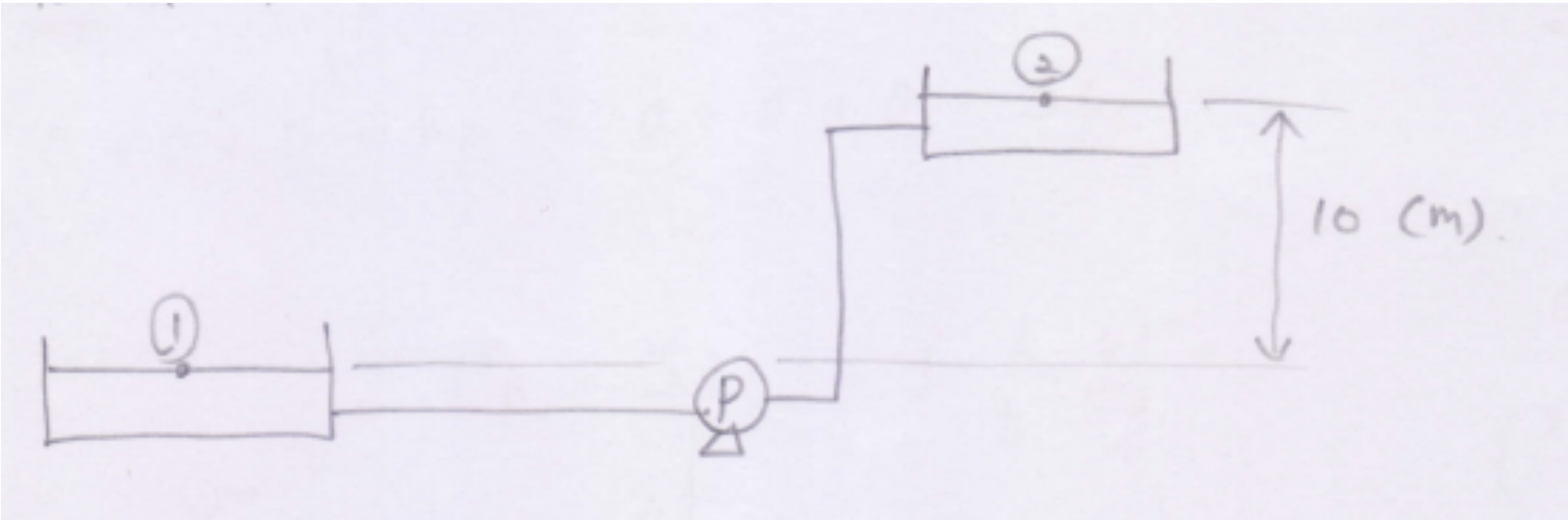
$$H_P = f\left(\frac{l}{D}\right)\left(\frac{16Q^2}{\pi^2 D^4}\right) = f\left(\frac{l}{D^5}\right)\left(\frac{16Q^2}{2g\pi^2}\right) = 0.05\left(\frac{1000}{0.15^5}\right)\left(\frac{16Q^2}{2g\pi^2}\right)$$

$$H_P = 54390Q^2$$

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

$$
\begin{aligned}
\text{If } P &= 80\ kW \\
80000 &= 533565900Q^3 \\
Q^3 &= 6669.57 \\
Q &= 18.82 \quad m^3/s
\end{aligned}
$$

If water level was different:



Bernoulli equation becomes:

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