ME 423: FLUIDS ENGINEERING

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Hydraulics of Pipeline Systems

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Branch Piping Network with Multiple Reservoirs

The branching network, illustrated in Figure, is made up of three elements (reservoirs) connected to a single junction (in contrast to the parallel system, no closed loops exist).

In the analysis, **one assumes the direction of flow in each element**; then the **energy equation for each element is written using an equivalent length to account for minor losses**:

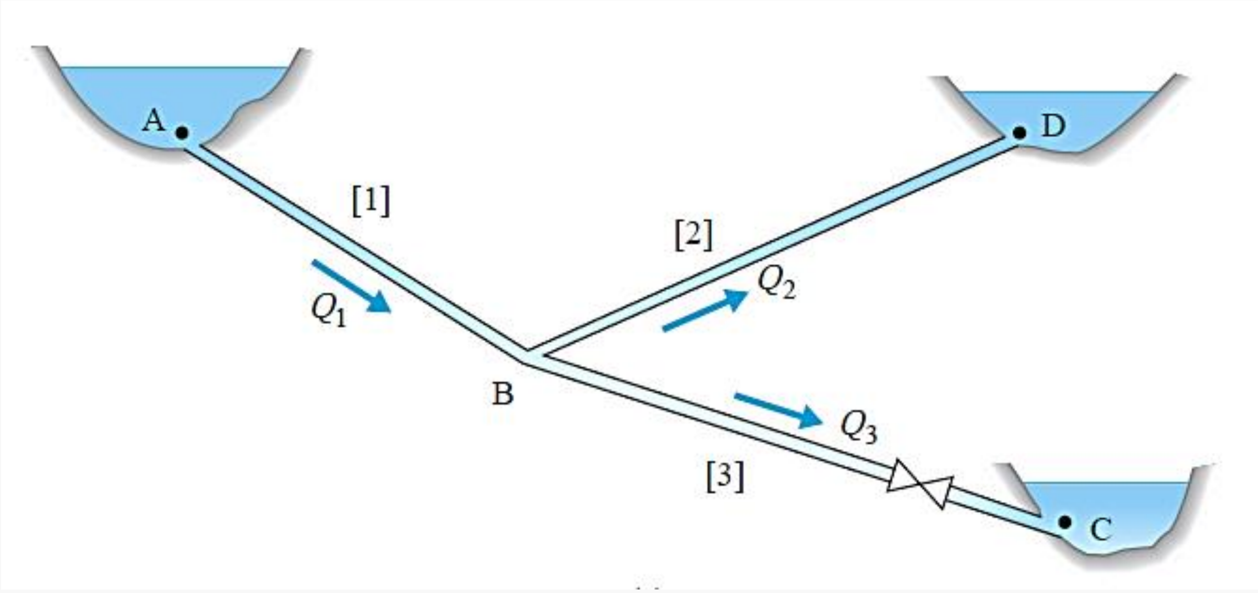


Fig. Branch piping systems with gravity flow

$$\left(\frac{p}{\gamma}+z\right)_A-\left(\frac{p}{\gamma}+z\right)_B=\overline{R}_1Q_1^2 \quad (11.3.12)$$

$$\left(\frac{p}{\gamma}+z\right)_B-\left(\frac{p}{\gamma}+z\right)_C=\overline{R}_2Q_2^2 \quad (11.3.13)$$

$$\left(\frac{p}{\gamma}+z\right)_B-\left(\frac{p}{\gamma}+z\right)_D=\overline{R}_3Q_3^2 \quad (11.3.14)$$

Difference in hydraulic grade line

Modified pipe resistance coefficient x flow rate^2

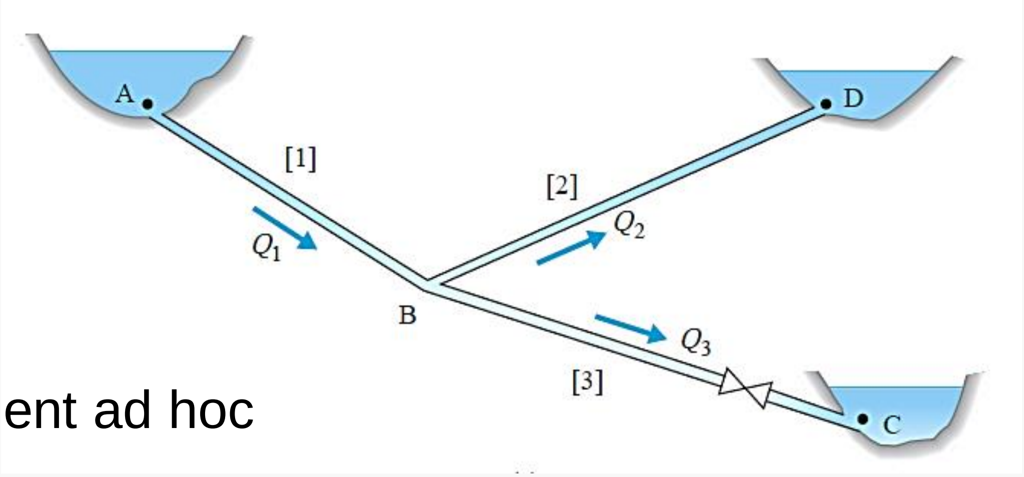
Problems involving pipe flow between more than two reservoirs will always require some form of iterative solution.

The piezometric heads at locations A, C, and D are considered known.

Branch Piping Network with Multiple Reservoirs

The **unknowns are the piezometric head at B and the discharges Q_1, Q_2, and Q_3**.
The additional relation is the continuity balance at location B, which is

$$Q_1 - Q_2 - Q_3 = 0 \qquad (11.3.15)$$



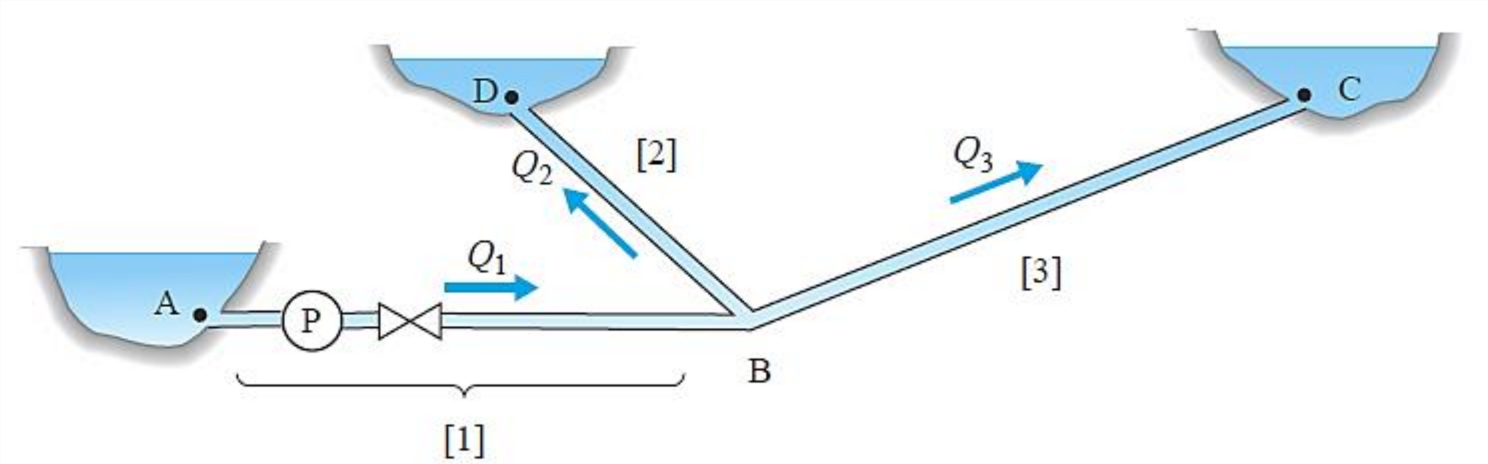
Thus, there are four equations with four unknowns. One convenient ad hoc method of solution is outlined below:

1. Assume a discharge Q_1 in element 1 (with or without a pump). Establish the piezometric head H at the junction by solving Eq. 11.3.12 (a category 1 problem).
2. Compute the discharge Q_i in the remaining branches using Eqs. 11.3.13 and 11.3.14 (a category 2 problem).
3. Substitute the Q_i into Eq. 11.3.15 to check for continuity balance. Generally, the flow imbalance at the junction Q will be nonzero. In Eq. 11.3.15, $\Delta Q = Q_1 - Q_2 - Q_3$.
4. Adjust the flow Q_1 in element 1 and repeat steps 2 and 3 until Q is within desired limits.

Branch Piping Network with Multiple Reservoirs

If a pump exists in pipe 1 as shown below, Eq. 11.3.12 is altered in the manner:

$$\left(\frac{p}{\gamma} + z\right)_A - \left(\frac{p}{\gamma} + z\right)_B + H_P = \overline{R}_1 Q_1^2 \qquad (11.3.16)$$



An additional unknown, namely, the **pump head H_P**, is introduced.
The additional necessary relationship is the head-discharge curve for the pump.

Fig. Branch piping systems with pump-driven flow

Problem

Example 11.4

For the three-branch piping system shown in Fig. E11.4 we have the following data:

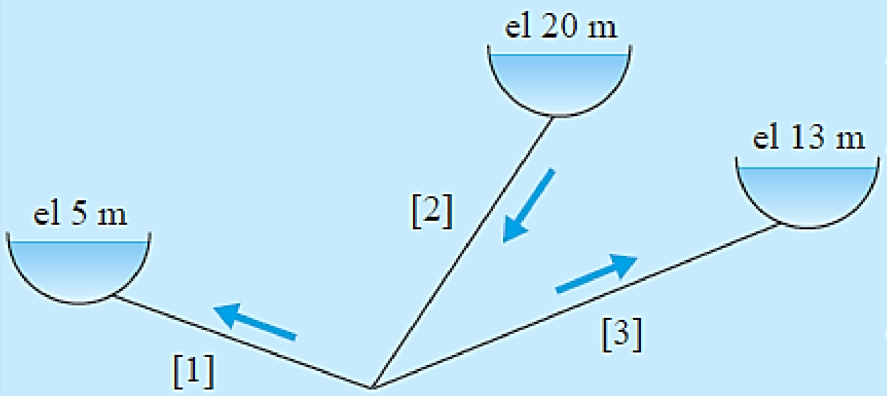


Fig. E11.4

Pipe	*L* (m)	*D* (m)	*f*	ΣK
1	500	0.10	0.025	3
2	750	0.15	0.020	2
3	1000	0.13	0.018	7

Determine the flow rates Q_i and the piezometric head H at the junction. Assume constant friction factors.

Solution:
Follow class note

Problem

Example 11.5

For the system shown in Fig. E11.5, determine the flow distribution Q_i of water and the piezometric head H at the junction. The fluid power input by the pump is constant, equal to $\gamma Q H_P = 20$ kW. Assume constant friction factors.

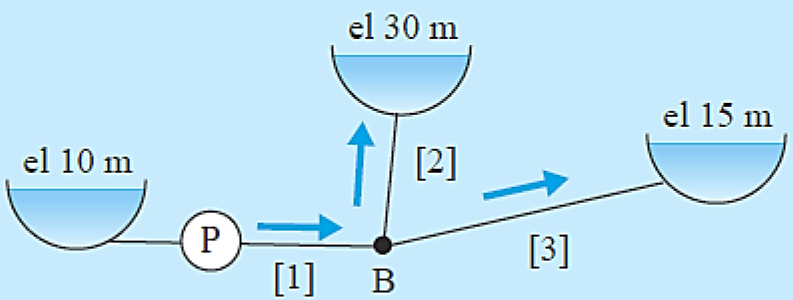


Fig. E11.5

Pipe	L (m)	D (m)	f	ΣK
1	50	0.15	0.02	2
2	100	0.10	0.015	1
3	300	0.10	0.025	1

Solution:
Follow class note

Problem

11.23 Determine the flow distribution of water in the system shown in Fig. P11.23. Assume constant friction factors, with $f = 0.02$. The head-discharge relation for the pump is $H_P = 60 - 10Q^2$, where H_P is in meters and the discharge is in cubic meters per second.

Pipe	L (m)	D (mm)	ΣK
1	100	350	2
2	750	200	0
3	850	200	0
4	500	200	2
5	350	250	2

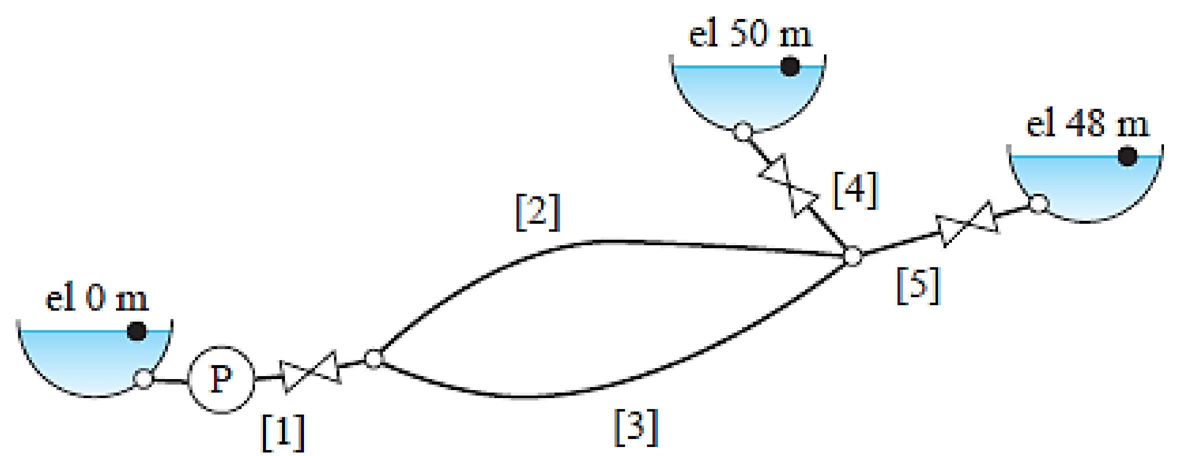


Fig. P11.23

Solution:

Follow class note

Problem

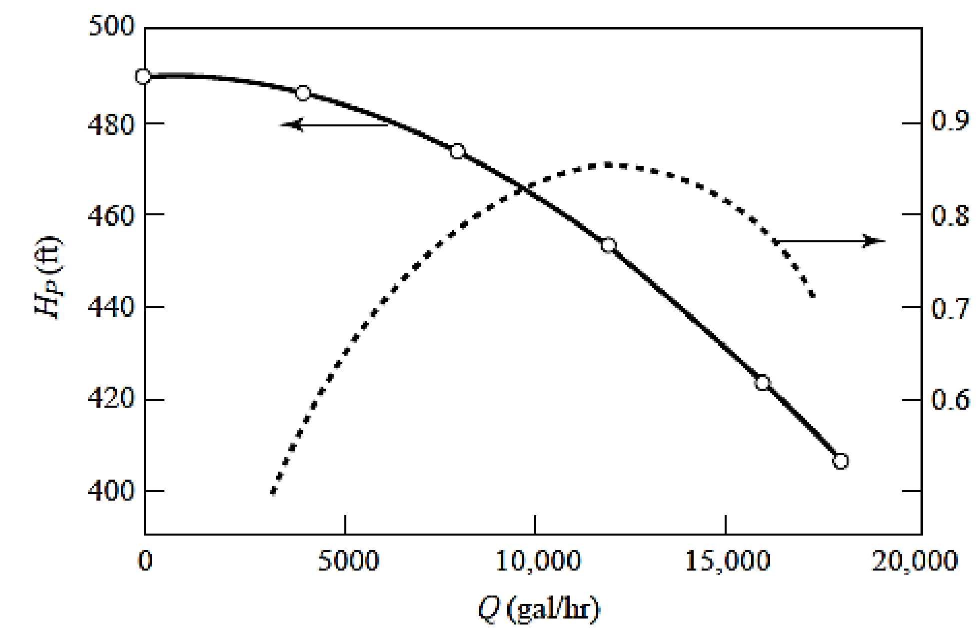
A pump, whose performance and efficiency curves are given in Fig. P11.24a has been selected to deliver water in a piping system. The piping consists of four pipes arranged as shown in Fig. P11.24b. Water at 60°F is being pumped from reservoir A and exists at either reservoir B or at location D, depending whether the valves at those locations are open or closed. The pipe characteristics are shown in accompanying table. All of the pipe diameters are 4 in., and the friction factor in each pipe is assumed to be f = 0.02.

(a) If the discharge through the pump is 5,000 gal/hr, what is the head loss across pipe 2?

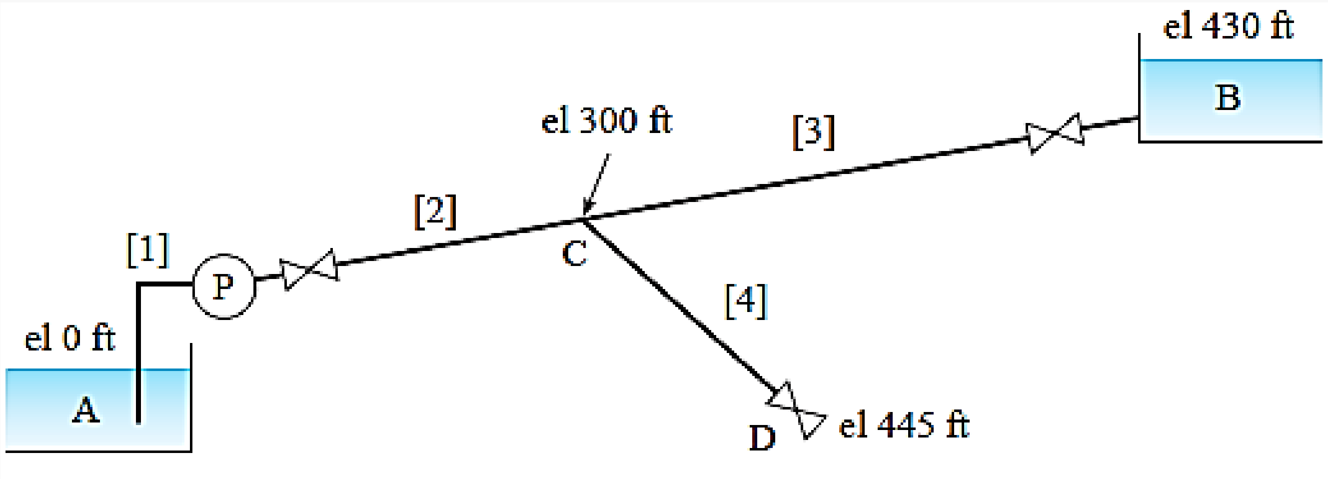
(b) Compute the discharge in the system, assuming that the valve at location D is closed.

(c) If the valve at location D is open and the discharge through the pump is 11,000 gal/hr, determine the discharge in pipe 3 and pipe 4.

Pipe	*L* (ft)	Σ *K*
1	10	1
2	500	2
3	2000	2
4	1750	4



(a)



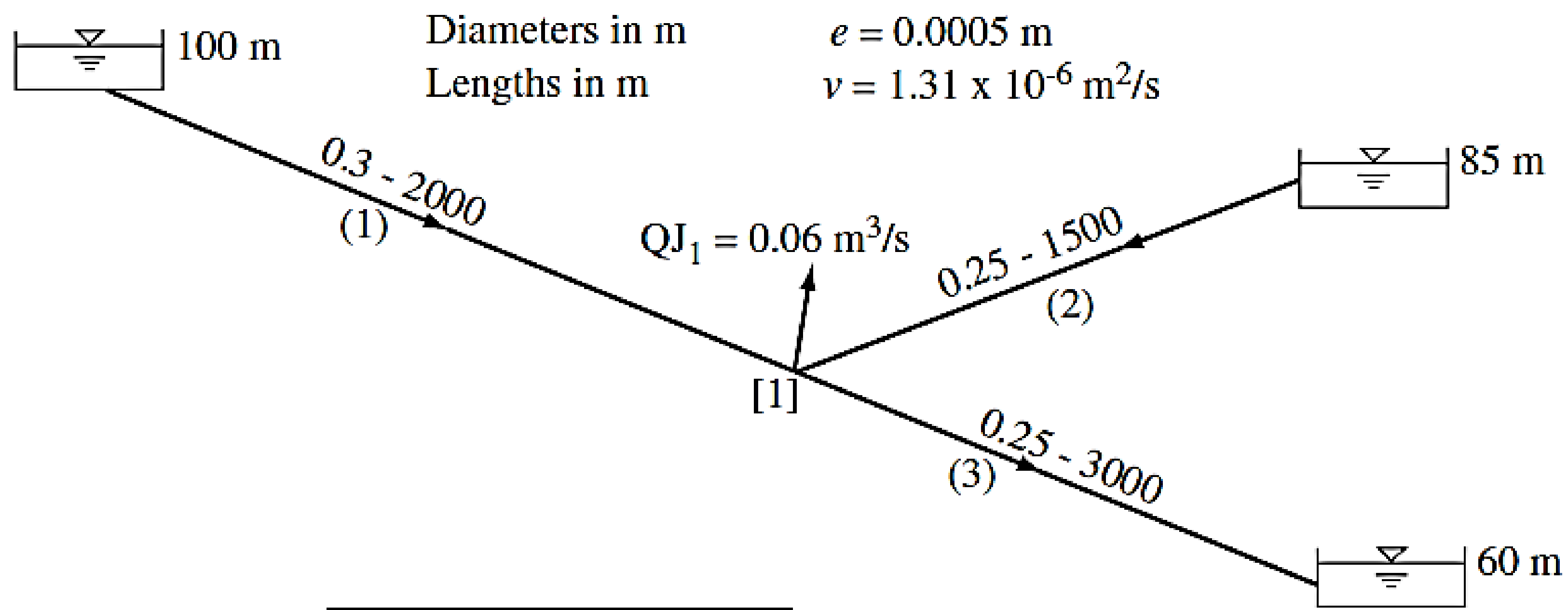
(b)

Fig. P11.24

Problem

Example Problem 2.7

The figure below is a diagram of the three reservoir problem; the reservoirs are connected by three pipes with an external demand at the common junction of the pipes. The highest reservoir has a water surface elevation of 100 m; the middle reservoir water surface elevation is 85 m; and the lowest reservoir has a water surface elevation of 60 m. Determine the discharge in each pipe.



Pipe	K	n
1	1469	1.974
2	2432	1.927
3	5646	1.971

Solution:
Follow class note

K = Modified pipe resistance coefficient
n = exponent to discharge for head loss
$\mathbf{h_L = KQ^n}$
(n = 2 for Darcy-Weisbach eqn.)