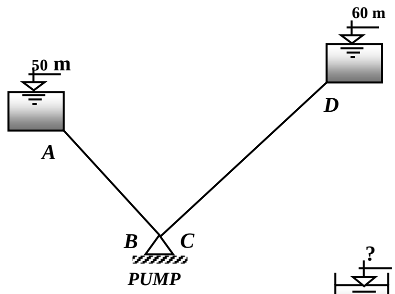
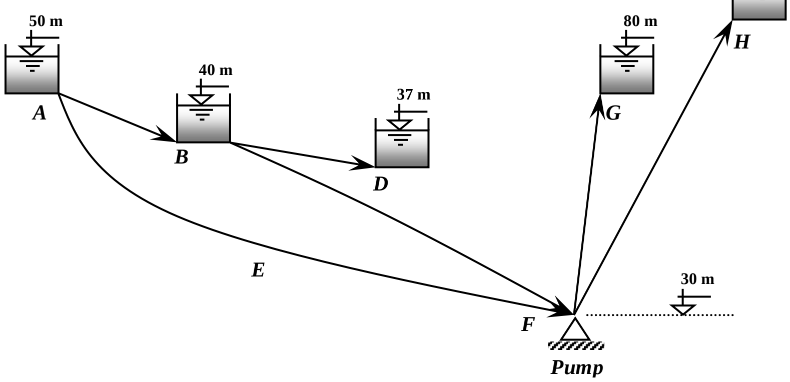
## EXERCISES 6-MULTIPLE RESERVOIR SYSTEMS




**EXERCISE 1:** Oil flows from reservoir A to reservoir D as shown in the figure. Discharge, Q, of the oil is given as 25 l/s. The pipe diameter, D, is constant for all of the system and is equal to 10 cm. The length of the pipes AB, $L_{AB}$, and CD, $L_{CD}$, are 20 m and 30 m, respectively. By neglecting all of the minor losses; ($\rho_{oil}$=0.90 g/cm$^3$; $\nu=10^{-3}$ m$^2$/s)

- Determine the regime of the flow.
- Compute the power that must be given into the system by the pump (Efficiency coefficient of the pump, $\eta$, is 0.70).
- Draw the energy grade line of the system.



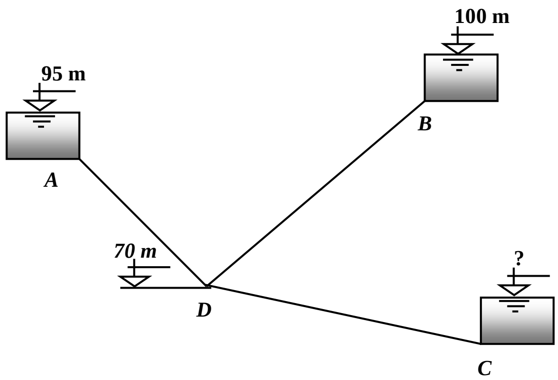

**EXERCISE 2:** Elevations and flow directions are shown in the figure on the right for water flow in a multiple reservoir system. The discharge of the pipe FG, $Q_{FG}$, is 40 l/s. By neglecting all of the minor losses and assuming that the water depths in the reservoirs remain constant;

- Determine the discharge of all pipes.
- Determine the water elevation in the reservoir H.
- Compute the power of the pump (Efficiency coefficient of the pump, $\eta$, is 0.70).
- Draw the energy grade line of the system.

| Pipe | L (m) | D (mm) | f |
|---|---|---|---|
| AB | 500 | 200 | |
| CD | 500 | 150 | |
| CF | 500 | 200 | 0.02 |
| AEF | 1000 | 200 | |
| FG | 1500 | 200 | |
| FH | 2000 | 300 | |

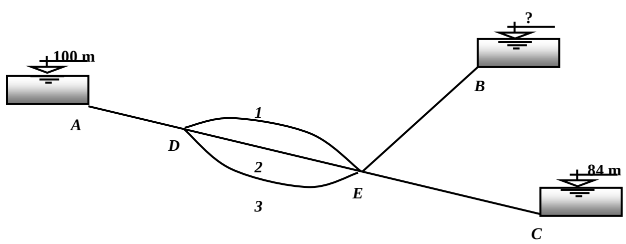
**EXERCISE 3:** Elevations and flow directions are shown in the figure on the right for water flow in a multiple reservoir system. The discharge of the pipe BD, $Q_{BD}$, is 100 l/s. By neglecting all of the minor losses and assuming that the water depths in the reservoirs remain constant;

| Pipe | L (m) | D (mm) | f |
|---|---|---|---|
| AB | 1000 | 300 | |
| DB | 1500 | 300 | 0.02 |
| DC | 2000 | 400 | |




- Compute the discharges of the pipes AD and DC.
- Determine the flow directions.
- Compute the pressure at D.
- Determine the water elevation in the reservoir C.
- Draw the energy grade line of the system.

**EXERCISE 4:** The system shown in the figure is feed by the reservoir A. The discharge of the pipe AD, $Q_{AD}$, is 170 l/s. The water elevations of the reservoirs A and C are given in the figure; the ground elevation of the points D and E are 65 m and 60 m, respectively. By neglecting all of the minor losses and assuming that the water depths in the reservoirs remain constant;




- Determine the water elevation in the reservoir B.
- Compute the piezometric elevations of the points D and E.
- Compute the pressures at points D and E.
- Draw the energy grade line.

| Pipe | L (m) | D (mm) | f |
|---|---|---|---|
| AD | 500 | 400 | |
| D1E | 1000 | 300 | |
| D2E | 2000 | 300 | |
| D3E | 1000 | 300 | 0.03 |
| EB | 600 | 250 | |
| EC | 800 | 200 | |

## SOLUTION 1:

a) Süreklilik denkleminden

$$\mathbf{V} = \frac{\mathbf{Q}}{\mathbf{A}} = \frac{0.025}{\pi 0.1^2}\mathbf{x}4 = 3.183 \text{ m}^3/\text{s}$$

Boru içerisindeki akımın rejimi:

$$N_{Re} = \frac{\mathbf{VD}}{\nu} = \frac{3.183\mathbf{x}0.1}{10^{-3}} = 318.3 < 2000 \quad \text{‘akım laminer’}$$

b) $$\mathbf{h}_{\mathbf{k}_{AB}} = \mathbf{f}\frac{\mathbf{L}_{AB}}{\mathbf{D}}\frac{\mathbf{V}^2}{2\mathbf{g}} = \left(\frac{64}{\mathbf{N}_{Re}}\right)\frac{\mathbf{L}_{AB}}{\mathbf{D}}\frac{\mathbf{V}^2}{2\mathbf{g}} = 20.76 \text{ m}$$

$$\mathbf{h}_{\mathbf{k}_{CD}} = \mathbf{f}\frac{\mathbf{L}_{CD}}{\mathbf{D}}\frac{\mathbf{V}^2}{2\mathbf{g}} = \left(\frac{64}{\mathbf{N}_{Re}}\right)\frac{\mathbf{L}_{CD}}{\mathbf{D}}\frac{\mathbf{V}^2}{2\mathbf{g}} = 31.15 \text{ m}$$

Pompanın sisteme vereceği enerji yüksekliği = [( $H_D$ + $hk_{CD}$ ) – ( $H_A$ – $hk_{AB}$ )]

$H_{pompa}$ = [ (60 + 31.15) – (50 – 20.76)] = 61.91 m

Pompanın şebekeden çekeceği güç = $N_{nominal} = \frac{\gamma Q H_{pompa}}{\eta}$ = <u>1990</u> $kg_f$.m/s

$N_{nominal}$ = 9.81 x 1990 =19521 Watt

$N_{nominal}$ = 1990 / 75 = 26.53 BB.

Pompanın gerçek gücü: $N_{gerçek} = \gamma Q H_{pompa}$ = 900 x 0.025 x 61.91= <u>1393</u> $kg_f$.m/s

## SOLUTION 2:

$h_{kAB} = H_A - H_B = 10\text{ m} = 0.02\dfrac{500}{0.2}\dfrac{\mathbf{V}_{AB}^2}{2\mathbf{g}}$ → $V_{AB} = 1.981$ m/s ; $Q_{AB} = 0.0622$ m$^3$/s

$h_{kCD} = H_C - H_D = 40 - 37 = 3\text{ m} = 0.02\dfrac{500}{0.15}\dfrac{\mathbf{V}_{CD}^2}{2\mathbf{g}}$ → $V_{CD} = 0.94$ m/s ; $Q_{CD} = V_{CD} \,.\, A_{CD} = 0.017$ m$^3$/s

$Q_{AB} = Q_{CD} + Q_{CF}$ → $Q_{CF} = Q_{AB} - Q_{CD} = 0.062 - 0.017 = 0.045$ m$^3$/s

$$\mathbf{V}_{CF} = \frac{\mathbf{Q}_{CF}}{\mathbf{A}_{CF}} = \frac{4\mathbf{Q}_{CF}}{\pi\mathbf{D}_{CF}^2} = \frac{4\mathbf{x}0.045}{\pi 0.2^2} = 1.43\text{ m/s}$$

$$\mathbf{h}_{k_{CF}} = 0.02\frac{500}{0.2}\frac{1.43^2}{19.62} = 5.21\text{ m}$$

$$(h_k)_{AEF} = (h_k)_{AB} + (h_k)_{CF} = 10 + 5.21 = 15.21\text{ m} = 0.02\frac{1000}{0.2}\frac{\mathbf{V}_{AEF}^2}{19.62}$$

$V_{AEF} = 1.73$ m/s
$Q_{AEF} = V_{AEF} \,.\, A_{AEF} = 0.054$ m$^3$/s

$H_{GIRIŞ} = H_A - (h_k)_{AEF} = 50 - 15.21 = 34.79$ m

$Q_{AEF} + Q_{CF} = Q_{FG} + Q_{FH}$
$Q_{FH} = Q_{AEF} + Q_{CF} - Q_{FG} = 0.054 + 0.045 - 0.045 = 0.059$ m$^3$/s

$$\mathbf{V}_{FG} = \frac{\mathbf{Q}_{FG}}{\mathbf{A}_{FG}} = \frac{4\mathbf{Q}_{FG}}{\pi\mathbf{D}_{FG}^2} = \frac{4\mathbf{x}0.04}{\pi 0.2^2} = 1.24\text{ m/s}$$

$$\mathbf{h}_{k_{FG}} = 0.02\frac{1500}{0.2}\frac{1.27^2}{19.62} = 12.33\text{ m}$$

$$\mathbf{V}_{FH} = \frac{\mathbf{Q}_{FH}}{\mathbf{A}_{FH}} = \frac{4\mathbf{Q}_{FH}}{\pi\mathbf{D}_{FH}^2} = \frac{4\mathbf{x}0.059}{\pi 0.3^2} = 0.83\text{ m/s}$$

$$\mathbf{h}_{k_{FH}} = 0.02\frac{2000}{0.3}\frac{0.83^2}{19.62} = 4.68\text{ m}$$

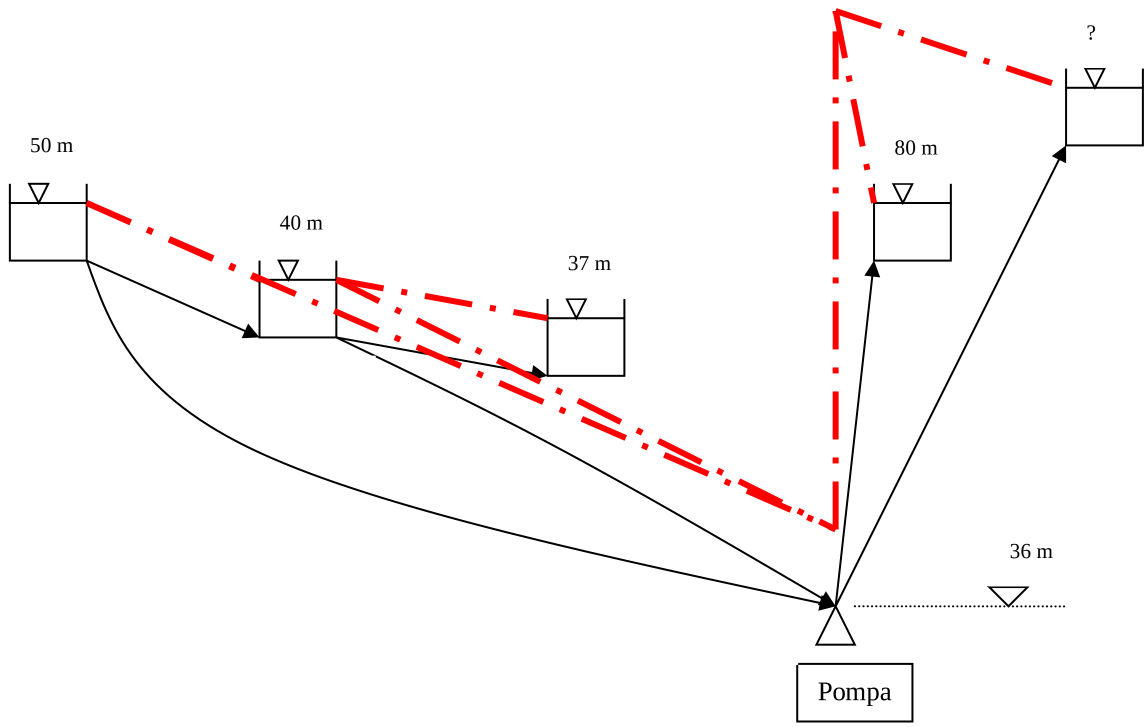
$H_H = H_G - (h_k)_{FG} - (h_k)_{FH} = 80 + 12.33 - 4.68 = 87.65$ m

$(H_F)_{CIKIŞ} = H_H + (h_k)_{FH} = 87.65 + 4.68 = 92.33$ m

$H_{Pompa} = (H_F)_{CIKIŞ} - (H_F)_{GIRIŞ} = 92.33 - 34.79 = 57.54$ m

$$\mathbf{N}_{Pompa} = \frac{\gamma\mathbf{Q}\mathbf{H}_{Pompa}}{\eta.75} = \frac{1000\mathbf{x}(0.054 + 0.045)\mathbf{x}57.54}{0.70\mathbf{x}75} = 108.5\ \textbf{BB}$$

= 8137.8 **kg$_f$.m/s**
= 79.8 **Kw**


?
50 m
80 m
40 m
37 m
36 m
Pompa

## SOLUTION 3:

$$V_{BD} = \frac{Q_{BD}}{A_{BD}} = \frac{4Q_{BD}}{\pi D_{BD}^2} = \frac{4x0.100}{\pi 0.3^2} = 1.41 \text{ m/s}$$

$$h_{k_{BD}} = \frac{f}{D}\frac{V_{BD}^2}{2g}L = \frac{0.02}{0.3}\frac{1.41^2}{2g}1500 = 10.13 \text{ m}$$

$H_D$=100-10.13=89.97 m

$h_{kAD}$=95-89.97=5.13 m

$$h_{k_{AD}} = \frac{f}{D}\frac{V_{AD}^2}{2g}L$$

$$5.13 = \frac{0.02}{0.3}\frac{V_{AD}^2}{2g}1000$$

$$V_{AD} = 1.23 \text{ m/s}$$

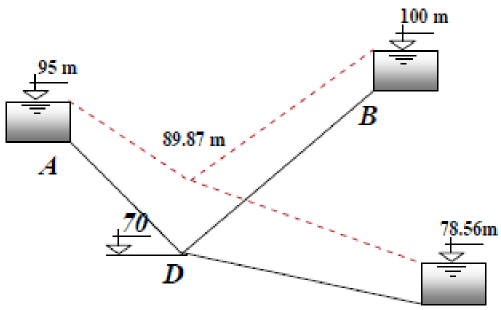
$$Q_{AD} = V_{AD} \cdot A_{AD} = 1.23 \cdot \frac{\pi D_{AD}^2}{4} = 0.087 \text{ m}^3/\text{s}$$

$$Q_{DC} = Q_{AD} + Q_{BD} = 0.187 \text{ m}^3/\text{s}$$

$$V_{DC} = \frac{Q_{DC}}{A_{DC}} = \frac{4Q_{DC}}{\pi D_{DC}^2} = \frac{4x0.187}{\pi 0.4^2} = 1.49 \text{ m/s}$$

$$h_{k_{DC}} = \frac{f}{D}\frac{V_{DC}^2}{2g}L = \frac{0.02}{0.4}\frac{1.49^2}{2g}2000 = 11.31 \text{ m}$$

$H_C$=89.87-11.31=78.56 m



## SOLUTION 4:

$$V_{AD} = \frac{Q_{AD}}{A_{AD}} = \frac{4Q_{AD}}{\pi D_{AD}^2} = \frac{4x0.170}{\pi 0.4^2} = 1.35 \text{ m/s}$$

$$h_{k_{AD}} = \frac{f}{D}\frac{V_{AD}^2}{2g}L = \frac{0.03}{0.4}\frac{1.35^2}{2g}500 = 3.48 \text{ m}$$

$H_D$=100-3.48=96.52 m

$$h_{k_{DE1}} = h_{k_{DE2}} = h_{k_{DE3}}$$

$$\frac{f}{D}\frac{V_{DE1}^2}{2g}L = \frac{f}{D}\frac{V_{DE2}^2}{2g}L = \frac{f}{D}\frac{V_{DE3}^2}{2g}L$$

$$V_{DE1}^2 *1000 = V_{DE1}^2 *2000 = V_{DE1}^2 *1000$$

$$V_{DE1} = \sqrt{2}V_{DE2} = V_{DE3}$$

$$Q_{AD} = Q_{DE1} + Q_{DE2} + Q_{DE3}$$

$$0.170 = V_{DE1}\cdot\frac{\pi 0.3^2}{4} + V_{DE2}\cdot\frac{\pi 0.3^2}{4} + V_{DE3}\cdot\frac{\pi 0.3^2}{4}$$

$$2.707V_{DE1} = \frac{4*0.170}{\pi 0.3^2}$$

$$V_{DE1} = 0.89 \text{ m/s}$$

$$V_{DE2} = 0.63 \text{ m/s}$$

$$V_{DE3} = 0.89 \text{ m/s}$$

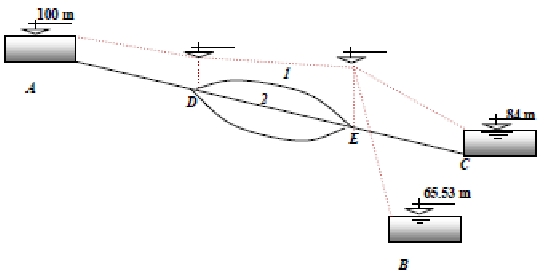
$$h_{k_{DE}} = \frac{f}{D}\frac{V_{DE}^2}{2g}L = \frac{0.03}{0.3}\frac{0.89^2}{2g}1000 = 4.04 \text{ m}$$

$H_E$=96.52-4.04=92.48 m

$$h_{k_{EC}} = 92.48 - 84 = 8.48 \text{ m}$$

$$8.48 = \frac{f}{D}\frac{V_{EC}^2}{2g}L = \frac{0.03}{0.2}\frac{V_{EC}^2}{2g}800$$

$$V_{EC} = 1.18 \text{ m/s}$$




$$Q_{EC} = 1.18\cdot\frac{\pi 0.2^2}{4} = 0.037 \text{ m}^3/\text{s}$$

$$Q_{EB} = 0.170 - 0.037 = 0.133 \text{ m}^3/\text{s}$$

$$V_{EB} = \frac{4*0.133}{\pi 0.25^2} = 2.71 \text{ m/s}$$

$$h_{k_{EB}} = \frac{f}{D}\frac{V_{EB}^2}{2g}L = \frac{0.03}{0.25}\frac{2.71^2}{2g}600 = 26.95 \text{ m}$$

$H_B$=92.48-26.95=65.53 m