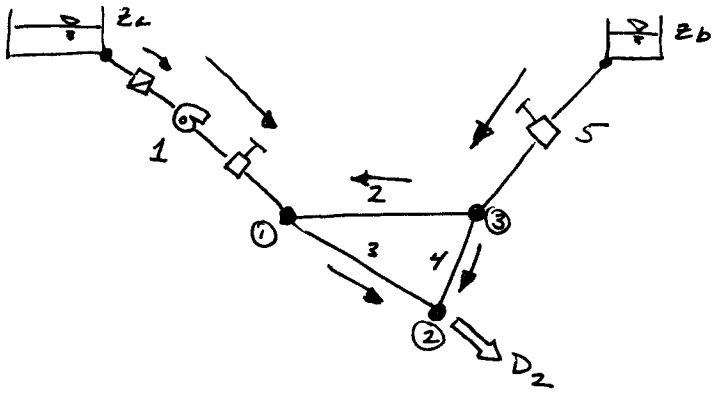
(Q5)

5. In Daytime



Node Equations:

① $Q_1 + Q_2 - Q_3 = 0$

② $Q_3 + Q_4 - D_2 = 0$

③ $-Q_2 - Q_4 + Q_5 = 0$

Closed-Loop Eqn:

$+K_2 Q_2^2 - K_4 Q_4^2 + K_3 Q_3^2 = 0$

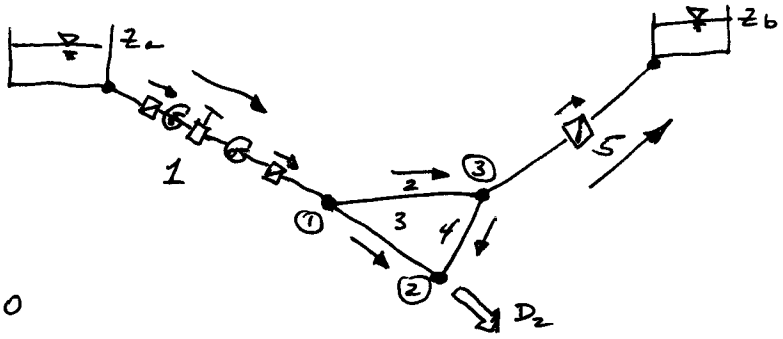
Pseudo-loop Eqn:

$z_a - K_1 Q_1^2 + E_p + K_2 Q_2^2 + K_5 Q_5^2 - z_b = 0$

Note: K_1 and K_5 include appropriate minor loss elements as well as pipe friction.

Note: If $Q_1 < 0$, then $Q_1 = 0$ and pipe 1 is removed (check valve).

In Nighttime



Node Equations:

① $Q_1 - Q_2 - Q_3 = 0$

② $Q_3 + Q_4 - D_2 = 0$

③ $Q_2 - Q_4 - Q_5 = 0$

Closed-loop Eqn:

$-K_2 Q_2^2 - K_4 Q_4^2 + K_3 Q_3^2 = 0$

P-L Eqn:

$z_a - K_1 Q_1^2 - K_2 Q_2^2 - K_5 Q_5^2 + 2E_p - z_b = 0$

Note: K_1 & K_5 include minor losses.

Note: Q_1 and $Q_5 \geq 0$ or they become 0 and are removed (check valved).

Note: P-L Eqn includes "$2E_p$". E_p is single-stage pump for Q_1.

5. (continued)

(6) (1) Daytime

$$K_1 = \frac{fL}{D\,2gA^2} + \frac{\sum K_m}{2gA^2} = \frac{(0.013)(200)}{(2)\,2(32.2)\left(\frac{\pi}{4}2^2\right)^2} + \frac{(2.0+0.2)}{2(32.2)\left(\frac{\pi}{4}2^2\right)^2} = 0.0055\ \frac{ft}{cfs^2}$$

$$K_2 = K_3 = K_4 = \frac{(0.013)(2000)}{(2)(2)(32.2)\left(\frac{\pi}{4}2^2\right)^2} = 0.0205\ \frac{ft}{cfs^2}$$

$$K_5 = \frac{fL}{D\,2gA^2} + \frac{\sum K_m}{2gA^2} = \frac{(0.013)(200)}{(2)\,2(32.2)\left(\frac{\pi}{4}2^2\right)^2} + \frac{0.2}{2(32.2)\left(\frac{\pi}{4}2^2\right)^2} = 0.00236\ \frac{ft}{cfs^2}$$

$Q_1 = 0.98$ cfs
$Q_5 = 14.02$ cfs
} which leaves 3 unknowns: Q_2, Q_3, and Q_4. While it is tempting to use the 3 node equations to solve for the 3 unknowns, it won't work. To see why, add the 3 equations together and you get:

$$Q_1 + Q_2 - Q_3 + Q_3 + Q_4 - D_2 - Q_2 - Q_4 + Q_5 = 0$$

$$Q_1 + Q_5 - D_2 = 0$$, but we already know Q_1 and Q_5.

You must solve the pseudo-loop equation for Q_2: $\left(E_p(0.98\text{cfs}) = 98.9\text{ft}\right)$

$$Q_2 = \sqrt{\frac{Z_b - Z_a + K_1 Q_1^2 + E_p - K_5 Q_5^2}{K_2}} = \sqrt{\frac{200 - 100 + 0.0055(0.98)^2 - 98.9 - 0.00236(14.02)^2}{0.0205}}$$

$$Q_2 = 5.59\ \text{cfs}$$

From ① Eqn: $Q_3 = Q_1 + Q_2 = 0.98 + 5.59 = 6.57$ cfs

From ③ Eqn: $Q_4 = Q_5 - Q_2 = 14.02 - 5.59 = 8.43$ cfs

→

(b) (ii) Nighttime

$$K_1 = \frac{fL}{D 2gA^2} + \frac{\Sigma K_m}{2gA^2} = \frac{(0.013)(200)}{(2)\,2(32.2)\left(\frac{\pi}{4}2^2\right)^2} + \frac{(2.0+0.2+2.0)}{2(32.2)\left(\frac{\pi}{4}2^2\right)^2} = 0.0087$$

$$K_5 = \frac{fL}{D 2gA^2} + \frac{\Sigma K_m}{2gA^2} = (\quad) + \frac{2.0}{2(32.2)\left(\frac{\pi}{4}2^2\right)^2} = 0.0052$$

$K_2 = K_3 = K_4$ unchanged from Daytime.

Solving pseudo-loop equation for Q_2: $E_{p,1\text{-stage}}(22.91\,cfs) = 24.60\,ft$

$$Q_2 = \sqrt{\frac{-Z_b + Z_a - K_1 Q_1^2 + 2E_p - K_5 Q_5^2}{K_2}} = \sqrt{\frac{-140 + 100 - 0.0087(22.91)^2 + 2(24.60) - 0.0052(17.91)^2}{0.0205}}$$

$$Q_2 = 12.03\,cfs$$

From ① Eqn: $Q_3 = Q_1 - Q_2 = 22.91 - 12.03 = 10.88\,cfs$

From ③ Eqn: $Q_4 = Q_2 - Q_5 = 12.03 - 17.91 = -5.88\,cfs$