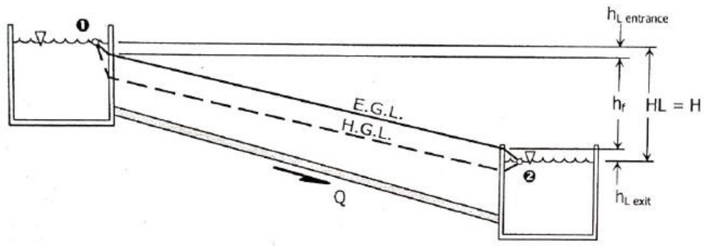
PIPE CONNECTING TWO RESERVOIRS

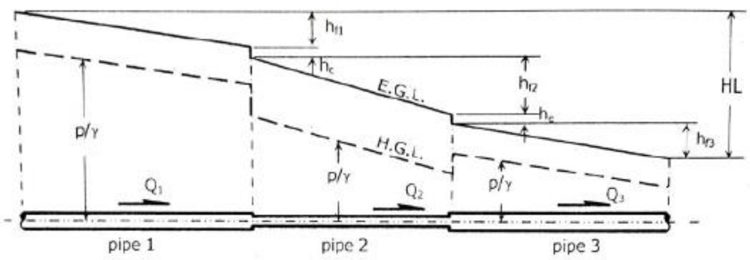
When one or more pipes connects two reservoirs as in the figure shown, the total head lost in all the pipes is equal to the difference in all the pipes is equal to the difference in elevation of the liquid surfaces of the reservoir.



$$HL = H = h_{Lminor} + h_f \qquad \text{Eqn. 43}$$

PIPES CONNECTED IN SERIES

For pipes of different diameters connected in series as shown in the figure below, the discharge in all pipes are all equal and the total head lost is equal to the sum of the individual head losses



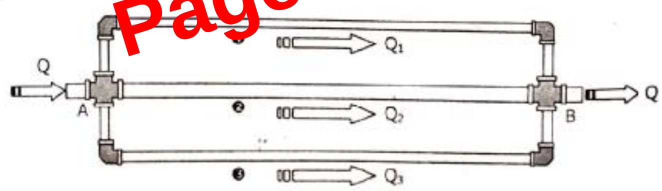
$$Q_1 = Q_2 = Q_3 = Q \qquad \text{Eqn. 44}$$
$$HL = h_{f1} + h_{f2} + h_{f3} + h_{minor} \qquad \text{Eqn. 45}$$

If the pipe length in any problem is about 500 diameters, the error resulting from neglecting minor losses will ordinarily not exceed 5%, and if the pipe length is 1000 diameters or more, the effect of minor losses can usually be considered negligible. Neglecting minor losses, the head lost becomes

$$HL = h_{f1} + h_{f2} + h_{f3}$$

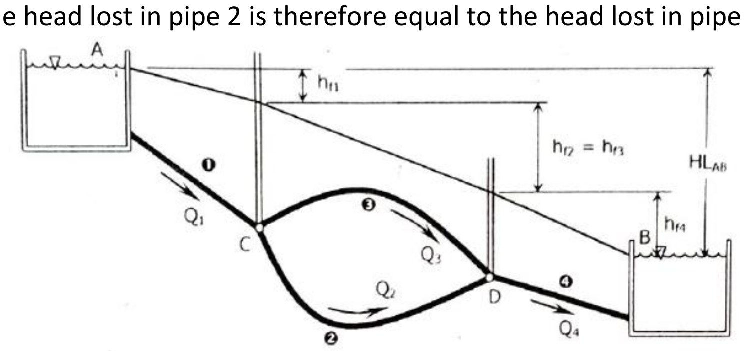
If, however, it is desired to include minor losses, a solution may be made first by neglecting them and correcting the results.

PIPES CONNECTED IN PARALLEL



$$Q = Q_1 + Q_2 + Q_3$$
$$HL = h_{L1} = h_{L2} = h_{L3}$$

In the pipe system shown, pipe 1 draws water from reservoir A and leads to junction C which divides the flow to pipes 2 and 3, which join again in junction D and flows through pipe 4. The sum of the flow in pipes 2 and 3 equals the flow in pipes 1 and 4. Since the drop in the energy grade line between C and D is equal to the difference in the levels of piezometers a and b, then the head lost in pipe 2 is therefore equal to the head lost in pipe 3.



$$\frac{v_A^2}{2g} + \frac{P_A}{\gamma} + z_A - HL = \frac{v_C^2}{2g} + \frac{P_C}{\gamma} + z_C$$

$$0 + \frac{P_A}{\gamma} + 10\,ft - 6370.86\,ft = \frac{\left(137.51\frac{ft}{s}\right)^2}{2\left(32.2\frac{ft}{s^2}\right)} + 0 + 100\,ft$$

$$\frac{P_A}{\gamma} = 6754.48\,ft \qquad \rightarrow\ P_A = 6754.48\,ft\left(62.4\frac{lb_f}{ft^3}\right) = 421{,}479.43\ lb_f/ft^2$$

$$P_A = 421{,}479.43\frac{lb_f}{ft^2}\left(\frac{ft^2}{144\ in^2}\right) = \mathbf{2926.94\ psi}$$

5) Oil ($sg = 0.9$) and dynamic viscosity of $\mu = 0.04\ Pa - s$ flows at the rate of 60 L/s through 50 m of 120-mm-diameter pipe. If the head loss is 6 m, determine: (a) the mean velocity of flow; (b) the type of flow; (c) the friction factor f; (d) velocity at the centerline of the pipe; (e) the shear stress at the wall of the pipe and (f) the velocity 50 mm from the center of the pipe.

Given: $sg = 0.90$ $\qquad \mu = 0.04\ Pa - s$ $\qquad Q = 60\frac{L}{s}\left(\frac{1\ m^3}{1000\ L}\right) = 0.06\frac{m^3}{s}$

$L = 50\ m$ $\qquad D = 120\ mm = 0.12\ m$ $\qquad h_f = 6\ m$

Solution:

(a) Mean velocity

$$v = \frac{Q}{A} = \frac{Q}{\frac{\pi D^2}{4}} = \frac{0.06\frac{m^3}{s}}{\frac{\pi(0.12\ m)^2}{4}} = \mathbf{5.31\ m/s}$$

(b) Type of flow

$$R_e = \frac{vD\rho}{\mu} = \frac{vD\rho_{water}sg}{\mu} = \frac{5.31\frac{m}{s}(0.12\ m)\left(1000\frac{kg}{m^3}\right)(0.90)}{0.04\ Pa - s}$$

$$R_e = 14{,}337 > 2000\ (\textbf{turbulent flow})$$

(c) Friction factor

$$h_f = \frac{0.0826\,fLQ^2}{D^5} \qquad \rightarrow f = \frac{h_f D^5}{0.0826 LQ^2}$$

$$f = \frac{6\ m(0.12\ m)^5}{0.0826\ (50\ m)\left(0.06\frac{m^3}{s}\right)^2} = \mathbf{0.01004}$$

(d) Centerline velocity

$$v_c = v\left(1 + 1.33 f^{\frac{1}{2}}\right) = 5.31\frac{m}{s}\left[1 + 1.33(0.01004)^{\frac{1}{2}}\right]$$

$$\boldsymbol{v_c = 6.02\frac{m}{s}}$$

(e) Shear stress at the wall of the pipe

$$\sqrt{\frac{\tau_o}{\rho}} = \sqrt{\frac{fv^2}{8}}$$

Squaring both sides

$$\frac{\tau_o}{\rho} = \frac{fv^2}{8} \qquad \rightarrow \qquad \tau_o = \frac{\rho f v^2}{8} = \frac{\rho_{water} sg f v^2}{8}$$

$$\tau_o = \frac{1000\frac{kg}{m^3}(0.90)(0.01004)\left(5.31\frac{m}{s}\right)^2}{8} = \mathbf{31.85\ Pa}$$

(f) Velocity $r = 50\ mm$ from the centerline