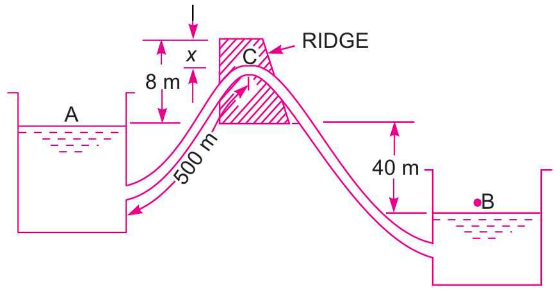

Fig. 11.15 (*b*)

Applying Bernoulli's equation to points A and B and taking datum line passing through B, we have

$$\frac{p_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{p_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \text{head loss due to friction } A \text{ to } B$$

or
$$0 + 0 + 40 = 0 + 0 + 0 + \frac{4 \times f \times L \times V^2}{d \times 2g}$$

$\therefore$
$$40 = \frac{4 \times 0.006 \times 8000 \times V^2}{0.2 \times 2 \times 9.81}$$

$\therefore$
$$V = \sqrt{\frac{40 \times 0.2 \times 2 \times 9.81}{4 \times .006 \times 8000}} = 0.904 \text{ m/s}$$

Now applying Bernoulli's equation to points A and C and assuming datum line passing through A, we have

$$\frac{p_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{p_c}{\rho g} + \frac{V_c^2}{2g} + z_c + \text{head loss due to friction from } A \text{ to } C$$

Substituting $\frac{p_A}{\rho g}$ and $\frac{p_c}{\rho g}$ in terms of absolute pressure

$$10.3 + 0 + 0 = 3.0 + \frac{V^2}{2g} + (8 - x) + \frac{4 \times f \times L_1 \times V^2}{d \times 2g}$$

or
$$10.3 = 3.0 + \frac{(0.904)^2}{2 \times 9.81} + (8 - x) + \frac{4 \times .006 \times 500 \times (0.904)^2}{0.2 \times 2 \times 9.81}$$

$$= 3.0 + 0.041 + (8 - x) + 2.499 = 13.54 - x$$

$\therefore$
$$x = 13.54 - 10.3 = \mathbf{3.24 \text{ m. Ans.}}$$

Discharge,
$$Q = \text{Area} \times \text{Velocity} = \frac{\pi}{4} \times (.2)^2 \times 0.904 = \mathbf{0.0283 \text{ m}^3\text{/s. Ans.}}$$

▶ 11.7 FLOW THROUGH PIPES IN SERIES OR FLOW THROUGH COMPOUND PIPES

Pipes in series or compound pipes are defined as the pipes of different lengths and different diameters connected end to end (in series) to form a pipe line as shown in Fig. 11.16.

Let, L_1, L_2, L_3 = length of pipes 1, 2 and 3 respectively

d_1, d_2, d_3 = diameter of pipes 1, 2, 3 respectively

V_1, V_2, V_3 = velocity of flow through pipes 1, 2, 3

f_1, f_2, f_3 = co-efficient of frictions for pipes 1, 2, 3

H = difference of water level in the two tanks.

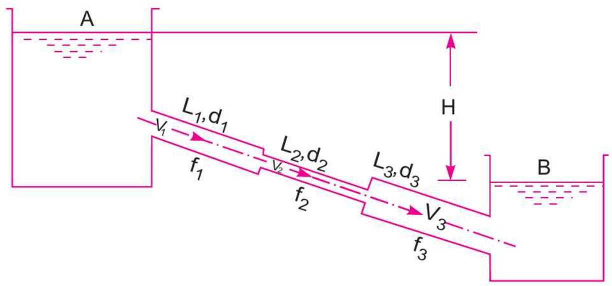

Fig. 11.16

The discharge passing through each pipe is same.

$\therefore$ $$Q = A_1V_1 = A_2V_2 = A_3V_3$$

The difference in liquid surface levels is equal to the sum of the total head loss in the pipes.

$\therefore$ $$H = \frac{0.5\,V_1^2}{2g} + \frac{4f_1L_1V_1^2}{d_1 \times 2g} + \frac{0.5\,V_2^2}{2g} + \frac{4f_2L_2V_2^2}{d_2 \times 2g} + \frac{(V_2 - V_3)^2}{2g} + \frac{4f_3L_3V_3^2}{d_3 \times 2g} + \frac{V_3^2}{2g} \quad \text{...(11.12)}$$

If minor losses are neglected, then above equation becomes as

$$H = \frac{4f_1L_1V_1^2}{d_1 \times 2g} + \frac{4f_2L_2V_2^2}{d_2 \times 2g} + \frac{4f_3L_3V_3^2}{d_3 \times 2g} \quad \text{...(11.13)}$$

If the co-efficient of friction is same for all pipes

i.e., $f_1 = f_2 = f_3 = f$, then equation (11.13) becomes as

$$H = \frac{4fL_1V_1^2}{d_1 \times 2g} + \frac{4fL_2V_2^2}{d_2 \times 2g} + \frac{4fL_3V_3^2}{d_3 \times 2g}$$

$$= \frac{4f}{2g}\left[\frac{L_1V_1^2}{d_1} + \frac{L_2V_2^2}{d_2} + \frac{L_3V_3^2}{d_3}\right] \quad \text{...(11.14)}$$

Problem 11.30 *The difference in water surface levels in two tanks, which are connected by three pipes in series of lengths 300 m, 170 m and 210 m and of diameters 300 mm, 200 mm and 400 mm respectively, is 12 m. Determine the rate of flow of water if co-efficient of friction are .005, .0052 and .0048 respectively, considering : (i) minor losses also (ii) neglecting minor losses.*

Solution. Given :

Difference of water level, $H = 12$ m

Length of pipe 1, $L_1 = 300$ m and dia., $d_1 = 300$ mm$= 0.3$ m

Length of pipe 2, $L_2 = 170$ m and dia., $d_2 = 200$ mm $= 0.2$ m

Length of pipe 3, $L_3 = 210$ m and dia., $d_3 = 400$ mm $= 0.4$ m

Also, $f_1 = .005, f_2 = .0052$ and $f_3 = .0048$

(*i*) **Considering Minor Losses.** Let V_1, V_2 and V_3 are the velocities in the 1st, 2nd and 3rd pipe respectively.

From continuity, we have $A_1V_1 = A_2V_2 = A_3V_3$

$$\therefore \quad V_2 = \frac{A_1V_1}{A_2} = \frac{\frac{\pi}{4}d_1^2}{\frac{\pi}{4}d_2^2}V_1 = \frac{d_1^2}{d_2^2}V_1 = \left(\frac{0.3}{.2}\right)^2 \times V_1 = 2.25\ V_1$$

and
$$V_3 = \frac{A_1V_1}{A_3} = \frac{d_1^2}{d_3^2}V_1 = \left(\frac{0.3}{0.4}\right)^2 V_1 = 0.5625\ V_1$$

Now using equation (11.12), we have

$$H = \frac{0.5\,V_1^2}{2g} + \frac{4f_1L_1V_1^2}{d_1 \times 2g} + \frac{0.5\,V_2^2}{2g} + \frac{4f_2L_2V_2^2}{d_2 \times 2g} + \frac{(V_2 - V_3)^2}{2g} + \frac{4f_3L_3V_3^2}{d_3 \times 2g} + \frac{V_3^2}{2g}$$

Substituting V_2 and V_3,
$$12.0 = \frac{0.5\,V_1^2}{2g} + \frac{4 \times .005 \times 300 \times V_1^2}{0.3 \times 2g} + \frac{0.5 \times \left(2.25 V_1^2\right)^2}{2g}$$

$$+ 4 \times 0.0052 \times 170 \times \frac{(2.25\,V_1)^2}{0.2 \times 2g} + \frac{(2.25\,V_1 - .562\,V_1)^2}{2g} + \frac{4 \times .0048 \times 210 \times (.5625\,V_1)^2}{0.4 \times 2g} + \frac{(.5625\,V_1)^2}{2g}$$

or
$$12.0 = \frac{V_1^2}{2g}\ [0.5 + 20.0 + 2.53 + 89.505 + 2.847 + 3.189 + 0.316]$$

$$= \frac{V_1^2}{2g}\ [118.887]$$

$$\therefore \quad V_1 = \sqrt{\frac{12 \times 2 \times 9.81}{118.887}} = 1.407 \text{ m/s}$$

$\therefore$ Rate of flow, Q = Area $\times$ Velocity $= A_1 \times V_1$

$$= \frac{\pi}{4}\ (d_1)^2 \times V_1 = \frac{\pi}{4}\ (.3)^2 \times 1.407 = 0.09945 \text{ m}^3\text{/s}$$

= 99.45 litres/s. Ans.

(*ii*) **Neglecting Minor Losses.** Using equation (11.13), we have

$$H = \frac{4f_1L_1V_1^2}{d_1 \times 2g} + \frac{4f_2L_2V_2^2}{d_2 \times 2g} + \frac{4f_3L_3V_3^2}{d_3 \times 2g}$$

or
$$12.0 = \frac{V_1^2}{2g}\left[\frac{4 \times .005 \times 300}{0.3} + \frac{4 \times .0052 \times 170 \times (2.25)^2}{0.2} + \frac{4 \times .0048 \times 210 \times (.5625)^2}{0.4}\right]$$

$$= \frac{V_1^2}{2g}[20.0 + 89.505 + 3.189] = \frac{V_1^2}{2g} \times 112.694$$

$$\therefore \qquad V_1 = \sqrt{\frac{2 \times 9.81 \times 12.0}{112.694}} = 1.445 \text{ m/s}$$

$$\therefore \qquad \text{Discharge, } Q = V_1 \times A_1 = 1.445 \times \frac{\pi}{4}(.3)^2 = 0.1021 \text{ m}^3\text{/s} = \textbf{102.1 litres/s. Ans.}$$

Problem 11.30 (A). *Three pipes of 400 mm, 200 mm and 300 mm diameters have lengths of 400 m, 200 m, and 300 m respectively. They are connected in series to make a compound pipe. The ends of this compound pipe are connected with two tanks whose difference of water levels is 16 m. If co-efficient of friction for these pipes is same and equal to 0.005, determine the discharge through the compound pipe neglecting first the minor losses and then including them.*

Solution. Given :

Difference of water levels, $H = 16$ m

Length and dia. of pipe 1, $L_1 = 400$ m and $d_1 = 400$ mm $= 0.4$ m

Length and dia. of pipe 2, $L_2 = 200$ m and $d_2 = 200$ mm $= 0.2$ m

Length and dia. of pipe 3, $L_3 = 300$ m and $d_3 = 300$ mm $= 0.3$ m

Also $f_1 = f_2 = f_3 = 0.005$

(*i*) **Discharge through the compound pipe first neglecting minor losses.**

Let V_1, V_2 and V_3 are the velocities in the 1st, 2nd and 3rd pipe respectively.

From continuity, we have $A_1V_1 = A_2V_2 = A_3V_3$

$$\therefore \qquad V_2 = \frac{A_1V_1}{A_2} = \frac{\frac{\pi}{4}d_1^2}{\frac{\pi}{4}d_2^2} \times V_1 = \frac{d_1^2}{d_2^2}V_1 = \left(\frac{0.4}{0.2}\right)^2 V_1 = 4V_1$$

and

$$V_3 = \frac{A_1V_1}{A_3} = \frac{\frac{\pi}{4}d_1^2}{\frac{\pi}{4}d_3^2} \times V_1 = \frac{d_1^2}{d_3^2}V_1 = \left(\frac{0.4}{0.2}\right)^2 V_1 = 1.77V_1$$

Now using equation (11.13), we have

$$H = \frac{4f_1L_1V_1^2}{d_1 \times 2g} + \frac{4f_2L_2V_2^2}{d_2 \times 2g} + \frac{4f_3L_3V_3^2}{d_3 \times 2g}$$

or

$$16 = \frac{4 \times 0.005 \times 400 \times V_1^2}{0.4 \times 2 \times 9.81} + \frac{4 \times 0.005 \times 200 \times (4V_1)^2}{0.2 \times 2 \times 9.81} + \frac{4 \times 0.005 \times 300}{0.3 \times 2 \times 9.81} \times (1.77\, V_1)^2$$

$$= \frac{V_1^2}{2 \times 9.81}\left(\frac{4 \times 0.005 \times 400}{0.4} + \frac{4 \times 0.005 \times 200 \times 16}{0.2} + \frac{4 \times 0.005 \times 300 \times 3.157}{0.3}\right)$$

$$16 = \frac{V_1^2}{2 \times 9.81}(20 + 320 + 63.14) = \frac{V_1^2}{2 \times 9.81} \times 403.14$$

$$\therefore \qquad V_1 = \sqrt{\frac{16 \times 2 \times 9.81}{403.14}} = 0.882 \text{ m/s}$$

∴ Discharge, $Q = A_1 \times V_1 = \dfrac{\pi}{4}(0.4)^2 \times 0.882 =$ **0.1108 m³/s. Ans.**

(*ii*) **Discharge through the compound pipe considering minor losses also.**

Minor losses are :

(*a*) At inlet, $h_i = \dfrac{0.5\, V_1^2}{2g}$

(*b*) Between 1st pipe and 2nd pipe, due to contraction,

$$h_c = \frac{0.5\, V_2^2}{2g} = \frac{0.5\left(4V_1^2\right)}{2g} \qquad (\because V_2 = 4V_1)$$

$$= \frac{0.5 \times 16 \times V_1^2}{2g} = 8 \times \frac{V_1^2}{2g}$$

(*c*) Between 2nd pipe and 3rd pipe, due to sudden enlargement,

$$h_e = \frac{\left(V_2 - V_3\right)^2}{2g} = \frac{\left(4V_1 - 1.77V_1\right)^2}{2g} \qquad (\because V_3 = 1.77\, V_1)$$

$$= (2.23)^2 \times \frac{V_1^2}{2g} = 4.973\, \frac{V_1^2}{2g}$$

(*d*) At the outlet of 3rd pipe, $h_o = \dfrac{V_3^2}{2g} = \dfrac{\left(1.77V_1\right)^2}{2g} = 1.77^2 \times \dfrac{V_1^2}{2g} = 3.1329\, \dfrac{V_1^2}{2g}$

The major losses are $= \dfrac{4f_1 \times L_1 \times V_1^2}{d_1 \times 2g} + \dfrac{4f_2 \times L_2 \times V_2^2}{d_2 \times 2g} + \dfrac{4f_3 \times L_3 \times V_3^2}{d_3 \times 2g}$

$$= \frac{4 \times 0.005 \times 400 \times V_1^2}{0.4 \times 2 \times 9.81} + \frac{4 \times 0.005 \times 200 \times \left(4V_1\right)^2}{0.2 \times 2 \times 9.81} + \frac{4 \times 0.005 \times 300 \times \left(1.77V_1\right)^2}{0.3 \times 2 \times 9.81}$$

$$= 403.14 \times \frac{V_1^2}{2 \times 9.81}$$

∴ Sum of minor losses and major losses

$$= \left[\frac{0.5\, V_1^2}{2g} + 8 \times \frac{V_1^2}{2g} + 4.973\,\frac{V_1^2}{2g} + 3.1329\,\frac{V_1^2}{2g}\right] + 403.14\,\frac{V_1^2}{2g}$$

$$= 419.746\,\frac{V_1^2}{2g}$$

But total loss must be equal to H (or 16 m)

$$\therefore \quad 419.746 \times \frac{V_1^2}{2g} = 16 \quad \therefore \quad V_1 = \sqrt{\frac{16 \times 2 \times 9.81}{419.746}} = 0.864 \text{ m/s}$$

∴ Discharge, $Q = A_1 V_1 = \dfrac{\pi}{4}(0.4)^2 \times 0.864 =$ **0.1085 m³/s. Ans.**

▶ 11.8 EQUIVALENT PIPE

This is defined as the pipe of uniform diameter having loss of head and discharge equal to the loss of head and discharge of a compound pipe consisting of several pipes of different lengths and diameters. The uniform diameter of the equivalent pipe is called equivalent size of the pipe. The length of equivalent pipe is equal to sum of lengths of the compound pipe consisting of different pipes.

Let L_1 = length of pipe 1 and d_1 = diameter of pipe 1
L_2 = length of pipe 2 and d_2 = diameter of pipe 2
L_3 = length of pipe 3 and d_3 = diameter of pipe 3
H = total head loss
L = length of equivalent pipe
d = diameter of the equivalent pipe

Then $L = L_1 + L_2 + L_3$

Total head loss in the compound pipe, neglecting minor losses

$$H = \frac{4f_1L_1V_1^2}{d_1\times 2g} + \frac{4f_2L_2V_2^2}{d_2\times 2g} + \frac{4f_3L_3V_3^2}{d_3\times 2g} \qquad \text{...(11.14}A\text{)}$$

Assuming $\quad f_1 = f_2 = f_3 = f$

Discharge, $\quad Q = A_1V_1 = A_2V_2 = A_3V_3 = \frac{\pi}{4}\,d_1{}^2V_1 = \frac{\pi}{4}\,d_2{}^2V_2 = \frac{\pi}{4}\,d_3{}^2V_3$

$\therefore \quad V_1 = \frac{4Q}{\pi d_1^2},\ V_2 = \frac{4Q}{\pi d_2^2}$ and $V_3 = \frac{4Q}{\pi d_3^2}$

Substituting these values in equation (11.14A), we have

$$H = \frac{4fL_1\times\left(\frac{4Q}{\pi d_1^2}\right)^2}{d_1\times 2g} + \frac{4fL_2\left(\frac{4Q}{\pi d_2^2}\right)^2}{d_2\times 2g} + \frac{4fL_3\left(\frac{4Q}{\pi d_3^2}\right)^2}{d_3\times 2g}$$

$$= \frac{4\times 16fQ^2}{\pi^2\times 2g}\left[\frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}\right] \qquad \text{...(11.15)}$$

Head loss in the equivalent pipe, $H = \frac{4f\,.\,L\,.\,V^2}{d\times 2g}$ [Taking same value of f as in compound pipe]

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

$$\therefore \quad H = \frac{4\,f\,.\,L\,.\left(\frac{4Q}{\pi d^2}\right)^2}{d\times 2g} = \frac{4\times 16Q^2f}{\pi^2\times 2g}\left[\frac{L}{d^5}\right] \qquad \text{...(11.16)}$$

Head loss in compound pipe and in equivalent pipe is same hence equating equations (11.15) and (11.16), we have

$$\frac{4\times 16 fQ^2}{\pi^2\times 2g}\left[\frac{L_1}{d_1^5}+\frac{L_2}{d_2^5}+\frac{L_3}{d_3^5}\right]=\frac{4\times 16Q^2 f}{\pi^2\times 2g}\left[\frac{L}{d^5}\right]$$

or $$\frac{L_1}{d_1^5}+\frac{L_2}{d_2^5}+\frac{L_3}{d_3^5}=\frac{L}{d^5} \quad \text{or} \quad \frac{L}{d^5}=\frac{L_1}{d_1^5}+\frac{L_2}{d_2^5}+\frac{L_3}{d_3^5} \qquad \text{...(11.17)}$$

Equation (11.17) is known as Dupuit's equation. In this equation $L = L_1 + L_2 + L_3$ and d_1, d_2 and d_3 are known. Hence the equivalent size of the pipe, *i.e.*, value of d can be obtained.

Problem 11.31 *Three pipes of lengths 800 m, 500 m and 400 m and of diameters 500 mm, 400 mm and 300 mm respectively are connected in series. These pipes are to be replaced by a single pipe of length 1700 m. Find the diameter of the single pipe.*

Solution. Given :

Length of pipe 1, $L_1 = 800$ m and dia., $d_1 = 500$ mm $= 0.5$ m

Length of pipe 2, $L_2 = 500$ m and dia., $d_2 = 400$ mm $= 0.4$ m

Length of pipe 3, $L_3 = 400$ m and dia., $d_3 = 300$ mm $= 0.3$ m

Length of single pipe, $L = 1700$ m

Let the diameter of equivalent single pipe $= d$

Applying equation (11.17), $$\frac{L}{d^5}=\frac{L_1}{d_1^5}+\frac{L_2}{d_2^5}+\frac{L_3}{d_3^5}$$

or $$\frac{1700}{d^5}=\frac{800}{.5^5}+\frac{500}{.4^5}+\frac{400}{0.3^5}=25600+48828.125+164609=239037$$

$\therefore$ $$d^5=\frac{1700}{239037}=.007118$$

$\therefore$ $$d=(.007188)^{0.2}=0.3718=\mathbf{371.8\ mm.\ Ans.}$$

▶ 11.9 FLOW THROUGH PARALLEL PIPES

Consider a main pipe which divides into two or more branches as shown in Fig. 11.17 and again join together downstream to form a single pipe, then the branch pipes are said to be connected in parallel. The discharge through the main is increased by connecting pipes in parallel.

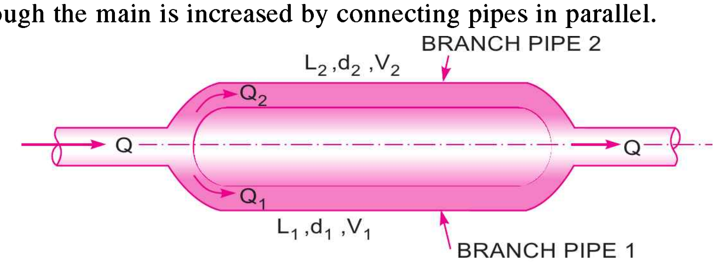

Fig. 11.17

The rate of flow in the main pipe is equal to the sum of rate of flow through branch pipes. Hence from Fig. 11.17, we have

$$Q = Q_1 + Q_2 \qquad \text{...(11.18)}$$

In this, arrangement, the loss of head for each branch pipe is same.

$\therefore$ Loss of head for branch pipe 1 = Loss of head for branch pipe 2 or $$\frac{4f_1L_1V_1^2}{d_1\times 2g}=\frac{4f_2L_2V_2^2}{d_2\times 2g} \quad ...(11.19)$$

If $$f_1=f_2, \text{ then } \frac{L_1V_1^2}{d_1\times 2g}=\frac{L_2V_2^2}{d_2\times 2g} \quad ...(11.20)$$

Problem 11.32 *A main pipe divides into two parallel pipes which again forms one pipe as shown in Fig. 11.17. The length and diameter for the first parallel pipe are 2000 m and 1.0 m respectively, while the length and diameter of 2nd parallel pipe are 2000 m and 0.8 m. Find the rate of flow in each parallel pipe, if total flow in the main is 3.0 m³/s. The co-efficient of friction for each parallel pipe is same and equal to .005.*

Solution. Given :

Length of pipe 1, $L_1 = 2000$ m

Dia. of pipe 1, $d_1 = 1.0$ m

Length of pipe 2, $L_2 = 2000$ m

Dia. of pipe 2, $d_2 = 0.8$ m

Total flow, $Q = 3.0$ m³/s

$f_1 = f_2 = f = .005$

Let Q_1 = discharge in pipe 1

Q_2 = discharge in pipe 2

From equation (11.18), $Q = Q_1 + Q_2 = 3.0$ ...(*i*)

Using equation (11.19), we have

$$\frac{4f_1L_1V_1^2}{d_1\times 2g}=\frac{4f_2L_2V_2^2}{d_2\times 2g}$$

$$\frac{4\times .005\times 2000\times V_1}{1.0\times 2\times 9.81}=\frac{4\times .005\times 2000\times V_2^2}{0.8\times 2\times 9.81}$$

or $$\frac{V_1^2}{1.0}=\frac{V_2^2}{0.8} \text{ or } V_1{}^2=\frac{V_2^2}{0.8}$$

$\therefore$ $$V_1=\frac{V_2}{\sqrt{0.8}}=\frac{V_2}{.894} \quad ...(ii)$$

Now $$Q_1=\frac{\pi}{4}d_1{}^2\times V_1=\frac{\pi}{4}(1)^2\times\frac{V_2}{.894} \quad \left[\because V_1=\frac{V_2}{.894}\right]$$

and $$Q_2=\frac{\pi}{4}d_2{}^2\times V_2=\frac{\pi}{4}(.8)^2\times V_2=\frac{\pi}{4}\times .64\times V_2$$

Substituting the value of Q_1 and Q_2 in equation (*i*), we get

$$\frac{\pi}{4}\times\frac{V_2}{0.894}+\frac{\pi}{4}\times .64\ V_2=3.0 \text{ or } 0.8785\ V_2+0.5026\ V_2=3.0$$

or $$V_2[.8785+.5026]=3.0 \text{ or } V=\frac{3.0}{1.3811}=2.17 \text{ m/s.}$$

Substituting this value in equation (*ii*),

$$V_1 = \frac{V_2}{.894} = \frac{2.17}{0.894} = 2.427 \text{ m/s}$$

Hence $$Q_1 = \frac{\pi}{4} d_1^2 \times V_1 = \frac{\pi}{4} \times 1^2 \times 2.427 = \mathbf{1.906 \text{ m}^3\text{/s. Ans.}}$$

$\therefore$ $$Q_2 = Q - Q_1 = 3.0 - 1.906 = \mathbf{1.094 \text{ m}^3\text{/s. Ans.}}$$

Problem 11.33 *A pipe line of 0.6 m diameter is 1.5 km long. To increase the discharge, another line of the same diameter is introduced parallel to the first in the second half of the length. Neglecting minor losses, find the increase in discharge if 4f = 0.04. The head at inlet is 300 mm.*

Solution. Given :

Dia. of pipe line, $D = 0.6$ m

Length of pipe line, $L = 1.5 \text{ km} = 1.5 \times 1000 = 1500$ m

$4f = 0.04$ or $f = .01$

Head at inlet, $h = 300 \text{ mm} = 0.3$ m

Head at outlet, = atmospheric head = 0

$\therefore$ Head loss, $h_f = 0.3$ m

Length of another parallel pipe, $L_1 = \frac{1500}{2} = 750$ m

Dia. of another parallel pipe, $d_1 = 0.6$ m

Fig. 11.18 shows the arrangement of pipe system.

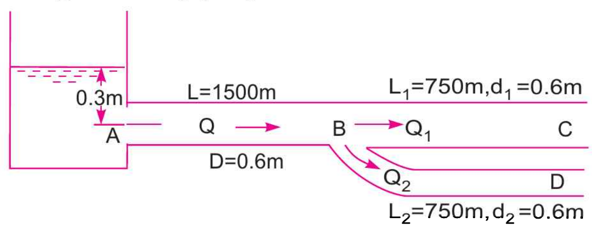

Fig. 11.18

1st Case. Discharge for a single pipe of length 1500 m and dia. = 0.6 m.

This head lost due to friction in single pipe is $h_f = \frac{4fLV^{*2}}{d \times 2g}$

where V^* = velocity of flow for single pipe

or $$0.3 = \frac{4 \times .01 \times 1500 \times V^{*2}}{0.6 \times 2g}$$

$\therefore$ $$V^* = \sqrt{\frac{0.3 \times 0.6 \times 2 \times 9.81}{4 \times .01 \times 1500}} = 0.2426 \text{ m/s}$$

$\therefore$ Discharge, $Q^* = V^* \times \text{Area} = 0.2426 \times \frac{\pi}{4} (.6)^2 = 0.0685 \text{ m}^3\text{/s}$ ...(*i*)

2nd Case. When an additional pipe of length 750 m and diameter 0.6 m is connected in parallel with the last half length of the pipe.