# Hydraulics Engineering

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# Module # 2 (a)

## Pipes:-

A pipe is a closed channel (generally of circular section) which is used for carrying fluids under pressure. The fluid completely fills the cross-section of the pipe. When the pipe is partially fill of liquid, it then behaves like an open channel.

## Loss of Head due to Friction in pipe:-

When the water is flowing in a pipe, it experiences some resistance to its motion, whose effect is to reduce the velocity and ultimately loss of head. An emperical formula for the loss of head due to friction was derived by Henry Darcy.

The loss of head due to friction according to Darcy is;

$$h_f = \frac{4flv^2}{2gd}.$$

f = Darcy's Coefficient.
l = length of pipe.
v = Mean velocity of liquid in pipe
d = Diameter of pipe.

## Problem:-

Find the loss of head due to friction in a pipe of 500 mm diameter and 1.5 km Long. The velocity of water in the pipe is 1 m/sec Take Coefficient friction as 0.005.

## Given data:-

dia = $d = 500mm = 0.5m$

$l = 1.5km = 1500 m$.

$v = 1 m/sec$.

$f = 0.005$.

## Required data:-

$h_f = ?$

## Solution:-

As we know that.

$$h_f = \frac{4flv^2}{2gd}$$

$$h_f = \frac{4 \times 0.005 \times 1500 \times (1)^2}{2 \times 9.81 \times 0.5}$$

$$\boxed{h_f = 3.01 m}$$

Loss of head due to friction is 3.01 m.

The major loss of head or energy is due to friction. The minor loss of head includes the following cases:

## Losses of head due to Sudden Enlargement

$$h_e = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{(V_1 - V_2)^2}{2g}$$

**Problem:-** The diameter of a water pipe is suddenly enlarged from 350mm to 700mm. The rate of flow through it is $0.25\ m^3/sec$. and the pressure in the smaller pipe is $7.5 N/m^2$.

Calculate:-

(a) The loss of head in the enlargement.

(b) the power lost due to enlargement

(c) the pressure in the larger pipe if the pipe line is horizontal.

**Given data:-**

$P_1 = 7.5 N/m^2$.

$d_1 = 350mm = 0.35m$.

$A_1 = \frac{\pi}{4} d^2 = \frac{3.14}{4} \times (0.35)^2$

$\boxed{A_1 = 0.0961\ m^2}$

$d_2 = 700mm = 0.70m$

$A_2 = \frac{\pi}{4} d^2 = \frac{3.14}{4} \times (0.70)^2$

$\boxed{A_2 = 0.385\ m^2}$

$$Q = 0.25 \frac{m^3}{sec}.$$

$$Q = AV.$$

$$V = \frac{Q}{A}.$$

$$V_1 = \frac{Q}{A_1} = \frac{0.25}{0.0961}$$

$$\boxed{V_1 = 2.6 \ m/sec}.$$

$$V_2 = \frac{Q}{A_2} = \frac{0.25}{0.385}$$

$$\boxed{V_2 = 0.64 \ m/sec}$$

(a) Head Loss due to Sudden enlargement

$$h_e = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{(V_1 - V_2)^2}{2g}.$$

$$h_e = \left(1 - \frac{0.0961}{0.385}\right)^2 \frac{(2.6 - 0.64)^2}{2g}.$$

$$h_e = (0.75)^2 \frac{(1.96)^2}{2 \times 9.81}$$

$$h_e = 0.5625 \times \frac{3.84}{19.62}$$

$$\boxed{h_e = 0.11 \ m}$$

(b) Power loss due to Sudden enlargement

$P = \rho g Q h_e$

$P = 1000 \times 9.81 \times 0.25 \times 0.11$

$\boxed{P = 269.78 \text{ W}}$

(c) The pressure in the larger pipe - if the pipe line is horizontal.

Apply Bernoulli equation.

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + h_e.$$

$$\frac{7.5}{1000 \times 9.81} + \frac{2.6^2}{2 \times 9.81} = \frac{P_2}{1000 \times 9.81} + \frac{(0.64)^2}{2 \times 9.81} + 0.11$$

$$0.000764 + 0.3445 = \frac{P_2}{9810} + 0.02153 + 0.11$$

$$0.345264 = \frac{P_2}{9810} + 0.02153 + 0.11.$$

$$0.345264 - 0.02153 - 0.11 = \frac{P_2}{9810}$$

$$0.213734 = \frac{P_2}{9810}$$

$P_2 = 0.213734 \times 9810$

$\boxed{P_2 = 2096.73 \text{ N/m}^2}$

# Loss of head due to Sudden Contraction:-

$$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$C_c$ = Coefficient of Contraction.

## Problem:-

Water flowing through pipe of diameter 1050mm after sudden contraction of pipe with dia 460mm. Rate of flow in Larger pipe is $0.80\,m^3/sec$. Consider flow rate as Cons-tant.

(a) Loss of head due to Sudden Contraction.

Take Coefficient of Contraction = 0.90.

## Given data:-

$d_1 = 1050mm = 1.05m.$

$d_2 = 460\,mm = 0.46\,m.$

$A_1 = \frac{\pi}{4} d_1^2 = \frac{3.14}{4} \times (1.05)^2 = 0.785 \times 1.1025$

$\boxed{A_1 = 0.865\,m^2}$

$A_2 = \frac{\pi}{4} d_2^2 = \frac{3.14}{4} (0.46)^2 = 0.785 \times 0.2116$

$\boxed{A_2 = 0.166\,m^2}$

As given in problem.

$$Q_1 = Q_2 = Q$$

$Q = Av$

$v = \frac{Q}{A}$.

$$V_1 = \frac{Q}{A_1} = \frac{0.80}{0.865} = 0.925\ m/sec$$

$$\boxed{V_1 = 0.925\ m/sec}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.80}{0.166}$$

$$\boxed{V_2 = 4.81\ m/sec}$$

## Loss of head due to Sudden Contraction

$$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$$h_c = \frac{(4.81)^2}{2g}\left[\frac{1}{0.05} - 1\right]^2$$

$$h_c = \frac{(4.81)^2}{2 \times 9.81}\left[\frac{1}{0.90} - 1\right]^2$$

$$h_c = \frac{(4.81)^2}{2 \times 9.81} \times (1.11 - 1)^2$$

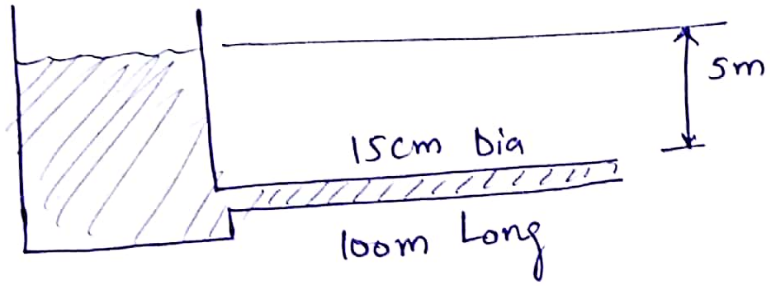
Take $\boxed{C_c = 0.90}$

$$h_c = \frac{23.81 \times 0.0121}{2 \times 9.81}$$

$$\boxed{h_c = 0.001496\ m}$$

# General problems

① Water is discharged from a tank maintained a constant head of 5m above the exit of straight pipe 100m Long, 15cm diameter. Estimate the rate of flow if the friction Coefficient for the pipe is given as 0.01




## Solution:-

As $h_f = \dfrac{4 f l v^2}{2 g d}$

$$5 = \frac{4 \times 0.01 \times 100}{2 \times 9.81 \times 0.15} \times v^2$$

$$5 = \frac{4}{2.943} \times v^2$$

$$V^2 = 5 \times 1.36$$

$$\sqrt{V^2} = \sqrt{6.796}$$

$$\boxed{V = 2.61 \text{ m/sec}}$$

$$Q = AV$$

$$Q = \frac{\pi}{4}(0.15)^2 \times 2.61$$

$$Q = 0.785 \times (0.15)^2 \times 2.61$$

$$\boxed{Q = 0.046\ m^3/sec}$$

## Loss of head at the inlet of a pipe

$$h_i = 0.5 \times \frac{V_i^2}{2g}$$

## Loss of head at the outlet of pipe

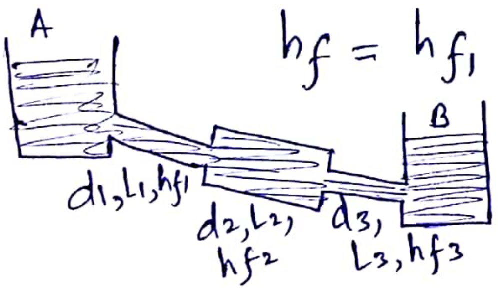
$$h_o = \frac{V^2}{2g}$$

## Pipe in Series:-

If a pipe line is joined to one or more pipe line in Continuation directly or indirectly these are Said to constitute pipes in Series.

$$Q = Q_1 = Q_2 = Q_3 \ldots\ldots$$

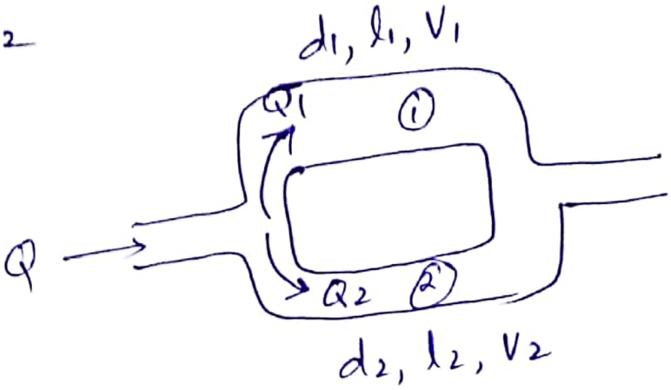
$$h_f = h_{f_1} + h_{f_2} + h_{f_3} \ldots\ldots$$



# Pipes in parallel :-

The rate of discharge in the main pipe is equal to the sum of discharges in each of the parallel pipes.

$$Q = Q_1 + Q_2$$




The loss of head in each pipe.

$$h_{f_1} = h_{f_2}$$

$$\frac{4 f_1 l_1 V_1^2}{2 g d_1} = \frac{4 f_2 l_2 V_2^2}{2 g d_2}$$

# Flow through Nozzle at the end of a pipe

A nozzle is tapering mouth piece which is fitted to the end of a water pipe line to discharge water at a high velocity.

The diameter of nozzle (d) for maximum transmission of power is given by.

$$d = \left[\frac{D^5}{8 f l}\right]^{1/4}$$

D = Diameter of pipe

f = Darcy's Coefficient of friction of pipe

l = length of pipe.