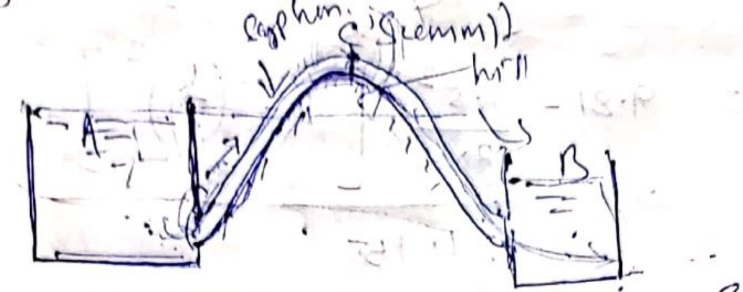
Syphon

Syphon is a long bend pipe which is used to transfer liquid from a reservoir at a higher level ground



The ~~point~~ highest point of the Syphon is called as Summit. As the pt. summit 'C' is above the free surface of the water in the tank A, the pressure at 'C' will be less than atmospheric pressure. ~~Thus~~

Theoretically the pressure is reduced -10.3 m of water, but in actual practice the pressure is only -7.6 m of water or

$10.3 - 7.6 = 2.7$ meter of water absolute.

If the pressure at 'C' becomes less than 2.7 m of water absolute, the dissolved air and other gases would come out from water and collect at the summit, the flow of the water will be ~~ob~~ be obstructed.

Use of Syphon in following cases

i) To carry water from one reservoir to another reservoir separated by hill or ridge

ii) To take the ~~water~~ liquid of the tank which is not having outlet.

iii) To empty a channel not provided with outlet sluice.

Scanned with CamScanner

module III Flow through pipes

A pipe is a closed conduit (circular section) which is used for carrying fluid under pressure. The flow in a pipe is termed pipe flow only when the fluid completely fill the crossection and there is no free surface of fluid.

Loss of energy in pipes

When a fluid flowing through a pipe, the fluid experiences some resistance due to which some of energy of the fluid is lost. The loss of energy is classified as

Energy losses

Major Energy losses
This is due to Friction & calculated by following formula
1) Darcy-weisbatch formula
2) chezy's formula

Minor energy losses
This is due to
1) sudden enlargement of pipe
2) Sudden contraction of pipe
3) Bend in pipe
4) pipe fittings.
5) An obstruction of pipe.

Scanned with CamScanner

Loss of energy (OR Head) due to friction

(a) Darcy-weisbach formula :- The loss of head (or energy) in pipes due to friction is calculated form Darcy-weisbach equation

$$\boxed{h_f = \frac{4 f L v^2}{d \times 2g}}$$

where h_f = loss of head due to friction.

$$f = \frac{16}{Re} \text{ for } Re < 2000 \text{ (viscous flow)}$$

$$= \frac{0.079}{Re^{1/4}} \text{ for } Re \text{ varying from } 4000 \text{ to } 10^6$$

L = Length of pipe

V = mean velocity of flow

d = diameter of pipe.

(*) Reynold's no :- It is the ratio of inertia force of flowing fluid and viscous force of the fluid.

$$Re = \frac{\text{inertia force}}{\text{viscous force}} = \frac{f_i}{f_v} = \boxed{\frac{Vd}{\nu} \text{ or } \frac{\rho V d}{\mu}}$$

(b) chezy's formula for loss of head due to friction in pipe.

V = Mean velocity of flow =

$$\boxed{V = C\sqrt{mi}}$$

where C = chezy's const = $\frac{8g}{f}$

Hydraulic mean depth = $m = \frac{A}{P} = \frac{\text{Area of flow}}{\text{Perimeter}} = \frac{d}{4}$

Loss of head / unit length (slope) $\leftarrow$ $\boxed{i = \frac{h_f}{L}}$ = head loss due to fri where h_f = head loss due to friction.

L = Length of pipe

The value of $m = d/4$, d = dia of pipe.

Problem:-

In a pipe of diameter 350m and length 75 mm water is flowing at a velocity of 2.8 m/s. Find the head loss due to friction using i) Darcy - weisbach formula ii) chezy's formula, C = 55.

Assume kinematic viscosity of water as 0.012 stokes

Sol^n. Given Dia of pipe - $D = 350mm = 0.35m$.

Length of pipe $L = 75$ m.

vel. = $V = 2.8$ m/s

Chezy's constant $C = 55$

Kinematic viscosity of water = $\nu = 0.012$ stokes

$= 0.012 \times 10^{-4}$ m²/s

Head loss due to friction

i) Darcy - weisbach formula

$$h_f = \frac{4fLV^2}{d2g}$$

$$Re = \frac{V \times D}{\nu} = \frac{2.8 \times 0.35}{0.012 \times 10^{-4}} = 8.167 \times 10^5$$

$$f = \frac{0.0791}{(Re)^{1/4}} = \frac{0.0791}{(8.167 \times 10^5)^{1/4}} = 0.00263$$

Head lost

$$h_f = \frac{4 \times 0.00263 \times 75 \times (2.8)^2}{0.35 \times 2 \times 9.81} = 0.9 \text{ m.}$$

(11) Chezy's formula

$$V = C\sqrt{mi} \quad , \quad C = 55$$

$$m = A/P = \frac{\pi/4\, d^2}{\pi d} = d/4 = \frac{0.35}{4} = 0.0875\,m.$$

$$2.8 = 55\sqrt{0.0875 \times i}$$

$$0.0875 \times i = \left(\frac{2.8}{55}\right)^2 = 0.00259$$

or $i = 0.0296$

But $i = \frac{h_f}{L} = 0.0296$

$$\frac{h_f}{75} = 0.0296$$

or $\boxed{h_f = 75 \times 0.0296 = 2.22\ m}$

Q-4 - An oil of sp. gravity 0.7 is flowing through a pipe of diameter 300 mm at a rate of 500 lit/s. find the head lost due to friction and power required to maintain the flow for the length of 1000m, take $\nu = 0.29$ stokes.

Sol^n Given - Sp. gravity of oil $S = 0.7$

Dia of pipe $= d = 300mm = 0.3m$

Discharge $Q = 500 lit/s = 0.5\, m^3/s$

Pipe length $L = 1000\,m$.

velocity $V = \frac{Q}{Area} = \frac{0.5}{\pi/4\, d^2} = \frac{0.5 \times 4}{\pi \times 0.3^2} = 7.073$ m/s

$\therefore$ Reynolds no, $Re = \frac{Vd}{\nu} = \frac{7.073 \times 0.3}{0.29 \times 10^{-4}} = 7.316 \times 10^4$

coefficient of friction

$$f = \frac{0.079}{Re^{1/4}} = \frac{0.79}{(7.316\times10^4)^{1/4}} = 0.0048$$

Head lost due to friction

$$h_f = \frac{4\times0.0048\times1000\times7.073^2}{0.3\times2\times9.81} = 163.18\,m$$

$$\boxed{\text{Power} = \frac{\rho g Q h_f}{1000}\ kW}$$

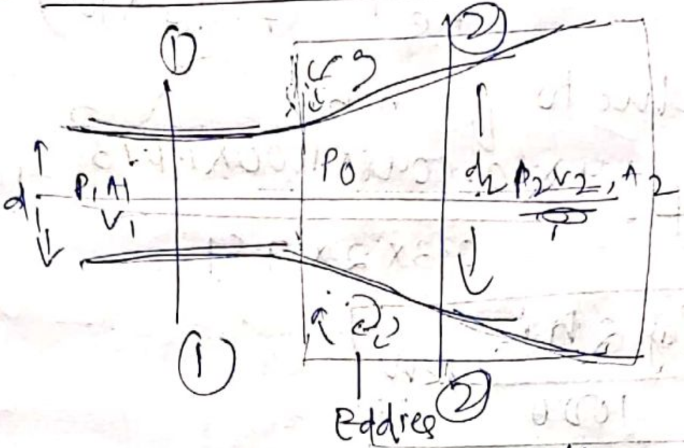
ρ = density of the oil = 0.7×1000 = 700 kg/m3
($\cancel{5}\times1000$)

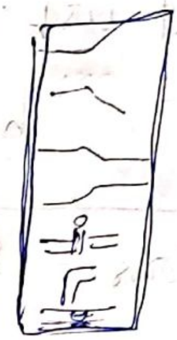
$\therefore$ power required $= \frac{700\times9.81\times0.5\times163.18}{1000}$

$= 560.28$ kWatt.

Minor energy losses

1) Loss of head due to sudden Enlargement





The fig shows a liquid flowing through a pipe which has suddenly enlargement. Due to sudden enlargement, the flow is decelerated abruptly and eddies are developed resulting in loss of energy.

Applying Bernoulli's eqn to sec^n 1-1 & 2-2

we have

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \text{head loss due to enlargement } (h_e)$$

But, $z_1 = z_2$, as horizontal.

hence the above eqn reduces to

$$h_e = \left(\frac{P_1}{\rho g} - \frac{P_2}{\rho g}\right) + \frac{v_1^2}{2g} - \frac{v_2^2}{2g} \quad \text{——— (1)}$$

Now, the force acting on liquid in the control volume in the sec^n 1-1 & 2-2 in the flow direction given by

$$F_x = P_1 A_1 + P_0 (A_2 - A_1) - P_2 A_2$$

Assuming $P_0 = P_1$, we have

$$F_x = (P_1 - P_2) A_2 \quad \text{——— (2)}$$

Consider momentum of liquid at section 1-1 and 2-2.

are ~~mass & velocity~~ i.e $\rho A_1 v_1$ & $\rho A_2 v_2$ respectively.

consider momentum of liquid/ ~~~~ sech

$\rho a v \times v$
mass $\times$ velocity $= \rho A_2 v_2^2 - \rho A_1 v_1^2$.

But from continuity equation, we have

$$A_1 v_1 = A_2 v_2$$

or $$\boxed{A_1 = \frac{A_2 v_2}{v_1}}$$

$\therefore$ change of momentum/sec.

$$= \rho A_2 v_2^2 - \rho \frac{A_2 v_2}{v_1} \times v_1^2$$

$$= \rho A_2 (v_2^2 - v_1 v_2) \quad \text{--- (3)}$$

Now net force = change in momentum.

$$(P_1 - P_2) A_2 = \rho A_2 (v_2^2 - v_1 v_2)$$

or $$\frac{P_1 - P_2}{\rho} = v_2^2 - v_1 v_2$$

Dividing both side by g, we get

$$\frac{P_1 - P_2}{\rho g} = \frac{v_2^2 - v_1 v_2}{g}$$

or $$\boxed{\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{v_2^2 - v_1 v_2}{g}}$$

Substituting the value of $\frac{P_1}{\rho g} - \frac{P_2}{\rho g}$ in eqn (1)

we get

$$h_e = \frac{v_2^2 - v_2 v_1}{g} + \frac{v_1^2}{2g} - \frac{v_2^2}{2g}.$$

Rearranging we get

$$\boxed{h_e = \frac{(v_1 - v_2)^2}{2g}}$$

Q:- At a sudden enlargement of a water main from 240mm and 480mm diameter the hydraulic gradient line rise by 10 mm. Calculate the rate of flow. (Q)

Sol Dia smaller side $D_1 = 240mm = 0.24m$.

" Large side $D_2 = 480mm = 0.48M$

Rise of hydraulic gradient line i.e

$$\boxed{\left(\frac{P_2}{\rho g} + z_2\right) - \left(\frac{P_1}{\rho g} + z_1\right)} = 10mm = 0.01m.$$

Rate of flow

Applying Bernoulli's eqn to small & large pipe sec^n 1-1 & 2-2

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + he \quad \text{--- (1)}$$

$$\text{But } \boxed{he = \frac{(V_1 - V_2)^2}{2g}} \quad \text{--- (2)}$$

From continuity eqn.

$$A_1 V_1 = A_2 V_2$$

$$V_1 = \frac{A_2 V_2}{A_1} = \frac{\pi/4\, D_2^2}{\pi/4\, D_1^2} \times V_2 = \left(\frac{D_2}{D_1}\right)^2 V_2$$

$$V_1 = \left(\frac{0.48}{0.24}\right)^2 \times V_2 = 4V_2$$

Substituting this value of V_1 in eqn (11), we get

$$he = \frac{(4V_2 - V_2)^2}{2g} = \frac{9V_2^2}{2g}$$

Now substituting the values of he and V_1 in eqn (1), we get

$$\frac{P_1}{\rho g} + \left(\frac{4V_2^2}{2g}\right) + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \frac{9V_2^2}{2g}\ (h_e)$$

$$\text{or}\ \left(\frac{P_2}{\rho g} + z_2\right) - \left(\frac{P_1}{\rho g} + z_1\right) = \frac{16V_2^2}{2g} - \frac{V_2^2}{2g} - \frac{9V_2^2}{2g}$$

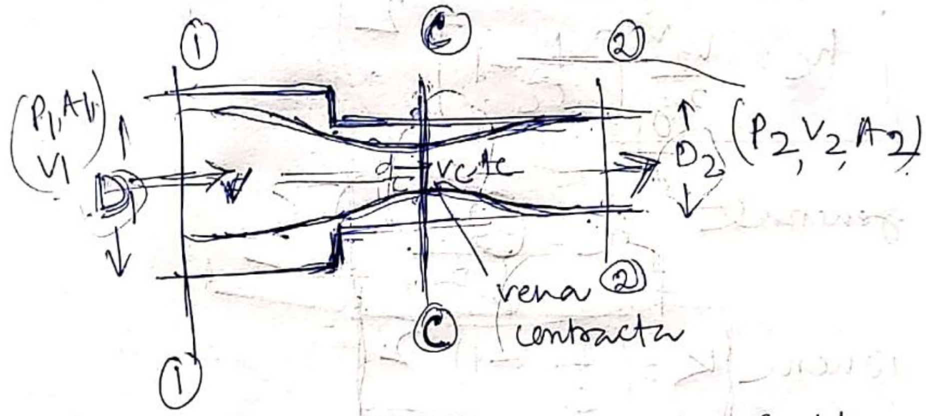
$$= \quad 0.01 = \frac{6V_2^2}{2g}$$

$$\text{or}\ V_2 = \left(\frac{0.01 \times 2 \times 9.8}{6}\right)^{1/2} = 0.181\ m/s.$$

Rate of flow $Q = A_2V_2 = \frac{\pi}{4} \times 0.48^2 \times 0.181$

$= 0.03275\ m^3/s$

Head loss due to sudden contraction



In above figure due to sudden contraction the streamline converge to minimum cross-section called the vena-contracta and then expand to fill the downstream pipe.

Here the loss of head due to sudden contraction = ~~loss of head~~ Loss up to vena contracta + Loss due to sudden enlargement due to vena contracta.

$$\text{or}\ h_c = \text{negligible due to small} + \frac{(V_c^2 - V_2^2)}{2g} \quad (1)$$

From continuity equation we have

$$A_c v_c = A_2 v_2$$

$$\frac{v_c}{v_2} = \frac{A_2}{A_c} = \frac{1}{(A_c/A_2)} = \frac{1}{C_c} \qquad \left(\because C_c = \frac{A_c}{A_2}\right)$$

Asm

or $\boxed{v_c = \frac{v_2}{C_c}}$ also $\boxed{\frac{A_c}{A_2} = C_c}$

Substituting the value of v_c in eqn (1) we get

$$h_e = \frac{\left(\frac{v_2}{C_c} - v_2\right)^2}{2g} = \frac{v_2^2}{2g}\left(\frac{1}{C_c} - 1\right)^2$$

ie $\boxed{h_e = \frac{v_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2}$

In general $\boxed{h_c = K\frac{v_2^2}{2g}}$ — 1

where $\boxed{K = \left(\frac{1}{C_c} - 1\right)^2}$

From experiment $C_c = 0.62 + 0.38\left(\frac{A_2}{A_1}\right)^2$

and thus is due to loss coefficient K is a function of ratio

$$\frac{A_1}{A_2} \text{ or } \frac{D_1}{A_2}$$

and $K = 0.375$ & $C_c = 0.62$

For gradual contraction (conical reducers)

K is a function of cone angle & $\simeq 0.1$

Note: If the value C_c is not given the loss of head due to contraction may be taken as

$\boxed{h_c = 0.5\frac{v_2^2}{2g}}$ Ч

Q = A horizontal pipe carries water at the rate 0.04 m^3/s. Its diameter, which is 300 mm reduces abruptly to 150 mm. Calculate the pressure across the contraction. Take co-efficient of contraction = 0.62.

Soln Given $Q = 0.04\, m^3/s$

$D_1 = 300mm = 0.3m$, $A_1 = \frac{\pi}{4}(0.3)^2 = 0.0707\, m^2$

$D_2 = 150mm = 0.15m$, $A_2 = \frac{\pi}{4} \times 0.15^2 = 0.01767\, m^2$

$C_c = 0.62$

Press loss across the contraction $(P_1 - P_2)$

From continuity equation, we have

$$A_1 v_1 = A_2 v_2 = Q$$

$$v_1 = \frac{Q}{A_1} = \frac{0.04}{0.0707} = 0.566\, m/s$$

& $$v_2 = \frac{Q}{A_2} = \frac{0.04}{0.01767} = 2.26\, m/s$$

Applying Bernoulli's eqn before and after contraction we get

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_c \quad (\text{as } z_1 = z_2) \quad (1)$$

$$h_c = \left(\frac{1}{C_c} - 1\right)^2 \frac{v_2^2}{2g} = \left[\frac{1}{0.62} - 1\right]^2 \times \frac{2.26^2}{2 \cdot 9.8} = 0.0978$$

Substituting these values in equation (1) we get

$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{2.26^2}{2 \times 9.81} + 0.0928 - \frac{0.566^2}{2 \times 9.81}$$

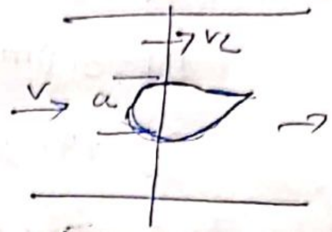
(1000 kg/m²)

$$= 0.348.$$

Hence $P_1 - P_2 = \rho g (0.3418) = 9.81 \times 0.3418 = 3.35 \text{ kN/m}^2$

Loss of head due to Obstruction in pipe

$$h_{obs} = \left[\frac{A}{C_c (A-a)}\right]^2$$



where A = Area of pipe
a = Area of Obstruction
v_2 velocity of liquid in pipe

Loss of head at the entrance to pipe:-

Loss of head at the entrance to pipe h_i' given by:

$$h_i' = 0.5 \frac{v^2}{2g},$$ where v = vel. of liquid in pipe

Loss of head at the exit of pipe (h_o)

$$h_o = \frac{v^2}{2g}$$, v = velocity at outlet of the pipe

Loss of head due to bend in pipe - (h_b)

$$h_b = K \frac{v^2}{2g}$$, where v = mean velocity of flow of fluid

K = coefficient of bend, it depends radius of curvature of bend and dia of pipe.

Loss of head in varying pipe fitting

The loss of head in the varying pipe fittings (such as valve, coupling etc) may also be represented as.

$$h_{fittings} = k\frac{v^2}{2g}$$

where V = mean velocity flow in the pipe.
& k = value of coefficient depend on pipe fitting.

Hydraulic Gradient Line and total energy lines (HGL) (TEL)

Total energy line (TEL or EGL)

The total head (total energy per unit weight) w.r.t any arbitary datum is

$$\text{Total head} = \frac{p}{\rho g} + z + \frac{v^2}{2g}$$ i.e

the sum of pressure head, datum head & velocity head.

TEL:- If the total energy at various points along the axis of the pipe is plotted and joined by a line, the line so obtained is called the Total energy line. or Energy gradient line. (EGL)

Hydraulic Gradient line (HGL)

The sum of potential head and Pressure head $\left(\frac{p}{\rho g} + z\right)$ at any point is called the piezometric head.

If a line is drawn joining the piezometer levels at various points, the line so obtained is called Hydraulic gradient line. (HGL)

Pts. to ~~remember~~ Remember

1. TEL always drops in the dirn of flow becoz of loss of head.

2. HGL may rise ~~rise~~ or fall depending on the pressure change.

3. HGL - always below ~~energy line~~ TEL and the vertical intercept betn the two ~~eqn~~ is equal to the velocity head $\left(\frac{V^2}{2g}\right)$

4. For a pipe uniform cross-secn the slope of HGL is equal to TEL

Q:- A horizontal pipeline 40m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end. For 1st 25 m of its length from the tank, the pipe is 150mm diameter and its diameter is suddenly enlarged to 300mm. The height of water level in the tank is 8 m above the centre of the pipe. Considering all losses of head which occur.

(i) Determine the rate of flow.

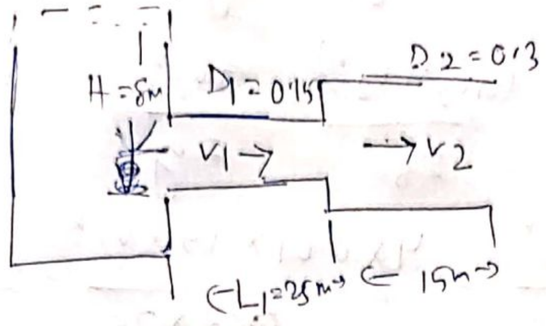
(2) Draw the HGL & TEL. Take $f = 0.01$ for both secn of pipe

$\underline{\underline{Sol^n}}$ $\underline{\text{given}}$ $L = 40\,m = L_1 + L_2$

$L_1 = 25\,m \quad D_1 = 150\,mm = 0.15\,m$

$L_2 = 15\,M \quad D_2 = 300\,mm = 0.3\,M$

$H = 8\,M \quad f = 0.01$



(1) Rate of flow

Applying Bernoulli's eqn to free surface of water in the tank and outlet of the pipe

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \text{All losses}$$

$$0 + 0 + 8 = 0 + \frac{v_2^2}{2g} + 0 + \underset{\text{Entrance}}{h_i} + \underset{\text{fr}^n}{h_{f_1}} + \underset{\text{enlgn}}{h_e} + h_{f_2} \quad \text{---(1)}$$

Where - h_i = loss of head at entrance $= 0.5\frac{v_1^2}{2g}$

h_{f_1} = Head loss due to fr^n $= \frac{4fL_1v_1^2}{D_1 \times 2g}$ (Pipe -1)

h_{f_2} = Head loss due to friction in pipe-2 $= \frac{4fL_2v_2^2}{D_2 \times 2g}$

h_e = head loss due to sudden enlargement.

$$= \frac{(v_1 - v_2)^2}{2g}$$

Again from continuity equation, we have

$$A_1 v_1 = A_2 v_2$$

$$v_1 = \frac{A_2}{A_1} v_2 = \left(\frac{D_2}{D_1}\right)^2 v_2 = \left(\frac{0.3}{0.15}\right)^2 \times v_2 = 4v_2$$

Substituting the value of v_1 (interms of v_2) in different head losses, we have

Scanned with CamScanner

$$h_i = \frac{0.5\,V_1^2}{2g} = \frac{0.5 \times 4\,V_2^2}{2g} = \frac{8\,V_2^2}{2g}$$

$$h_{f_1} = \frac{4fL_1V_1^2}{D_1 \times 2g} = \frac{4 \times 0.01 \times 25 \times (4 \times V_2)^2}{0.15 \times 2g} = 106.6\frac{V_2^2}{2g}$$

$$h_e = \frac{(V_1 - V_2)^2}{2g} = \frac{(4V_2 - V_2)^2}{2g} = \frac{9V_2^2}{2g}$$

$$h_{f_2} = \frac{4fL_2V_2^2}{D_2 \times 2g} = \frac{4 \times 0.01 \times 15 \times V_2^2}{0.3 \times 2g} = \frac{2V_2^2}{2g}$$

Substituting these values in bernoulli's eqn-(i)

$$8 = \frac{V_2^2}{2g} + \frac{8V_2^2}{2g} + \frac{106.6V_2^2}{2g} + \frac{9V_2^2}{2g} + \frac{2V_2^2}{2g}$$

$$= 126.6\frac{V_2^2}{2g}$$

$$\text{or } V_2 = \sqrt{\frac{8 \times 2 \times g}{126.6}} = 1.11\ \text{m/s}$$

Hence Q = Rate of flow $= A_2V_2 = \frac{\pi}{4}(0.3)^2 \times 1.11 = 0.078\ \text{m}^3/\text{s}$

(ii) TEL & HGL

The corresponding losses

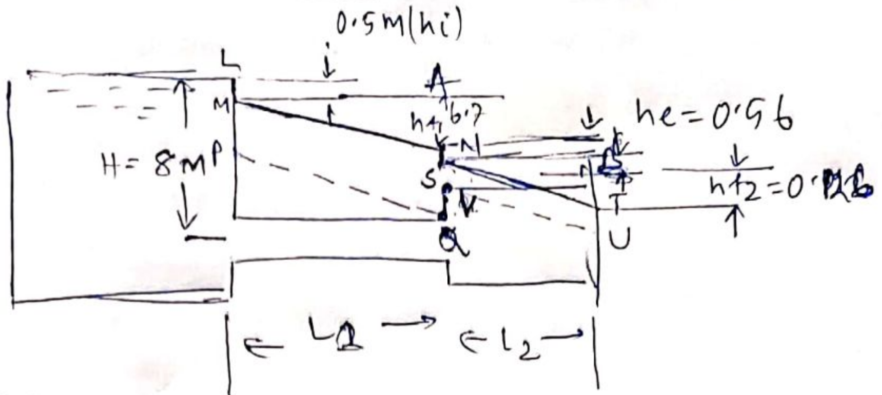
$$h_i = \frac{8V_2^2}{2g} = \frac{8 \times (1.11)^2}{2 \times 9.81} = 0.5\,\text{m}$$

$$h_{f_1} = 106.6\frac{V_2^2}{2g} = \frac{106.6 \times (1.11)^2}{2 \times 9.81} = 6.7\,\text{m}$$

$$h_e = \frac{9V_2^2}{2g} = \frac{9 \times (1.11)^2}{2 \times 9.81} = 0.56\,\text{m}$$

$$h_{f_2} = \frac{2V_2^2}{2g} = \frac{2 \times (1.11)^2}{2 \times 9.81} = 0.12\,\text{m}$$

To draw TEL & HGL



TEL L = free surface.

→ $\boxed{LM = h_i = 0.5m}$

→ From M draw horizontal line. Taking MA horizontal line equal to length of pipe L_1. Draw vertical line down word from point A. $\boxed{\text{cut } AN = h_{f_1} = 6.7m}$

→ Join MN

→ From N, draw line NS vertically down word

$\boxed{he = 0.56m.}$

→ from S, draw SB horizontal line from point and from point U draw vertical line in upward direction, meeting at B.

from $\boxed{BT = h_{f_2} = 0.126}$

→ Join ST.

→ The line LMNST represents the TEL.

HGL (Hydraulic gradient line).

③ cont'd From M, take $MP = \frac{V_1^2}{2g} = \frac{(4 \times 1.11)^2}{2 \times 9.81} = 1\,M.$

→ Draw the line PQ ||^{l} to MN

→ From the point U, draw line UV ||^{l} to TS

→ Join QV.

→ The line PQVU represents the (HGL)