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Pipe Flow

Examination Questions: [1993] Q9(a) Show that maximum power transmitted through a water pipe under pressure when the frictional loss of head is one third of total head. [5] Q9(b) Determine the loss of head for flow through a circular pipe, 500mm in dia, 3000m long, if velocity of flow is 0.5 m/s. Use f = 0.025. Would the friction coefficient change if velocity of flow were increased? [5] [1992] Q7. A smooth pipe carries a water discharge of 0.3 m^3/s with a head loss of 3m/100m length of the pipe. Determine the diameter of the pipe. The kinematic viscosity of water at 20°C is 10^{-6} m^2/s. For initial calculations assume a friction factor f = 0.02. [15] [1981] Water is being taken from a reservoir having water surface elevation 100.00m through a pipe 4km long and 50cm diameter to another reservoir whose water level is 87.50m. It is required to feed a third reservoir whose water level is 85.00m through a pipe 1.5km long to be connected to the 50cm dia pipe at a distance of 1.0km from its entrance. Find the diameter of this new pipe so that the flow into both the reservoirs may be the same. Assume friction factor as 0.01 for all the pipes in Darcy's equation [9] [1999] 4(b) Three pipes - 250m long 25cm in dia; 150m long ~~& 150m long~~ & 15 cm dia; 200m long 20cm dia, are connected in series between two reservoirs. The friction factor values for the three pipes are 0.018, 0.020 and 0.019 respectively. Determine the rate of flow if the difference in elevation of water levels between two reservoirs is 15m. Use $h_f = fLV^2/2gD$ for frictional loss and account for all losses. [10] 4 [1996] Q4(b) Two reservoirs A and B are connected by 35cm ϕ, 1000m long horizontal pipe. In reservoir 'A' water stands 18m above the pipe & 2m above the pipe in reservoir 'B.' If the friction factor of the pipe is 0.08 find the discharge in the system. If the pipe bursts open at the distance of 600m from reservoir 'A' find discharge through pipes. [10]

0.056 m^3/s

Answers. ① 1.91m ② D = 2.89 ③ D_3 = 0.429m ④ Q = 0.056 m^3/s. ⑤ Q = 0.188 m^3/s, Q = 0.256 m^3/s

Exercise

1) A pipe line, 16 km long, supplies, 40 million litres of water per day to city. The first 5km length of the pipe is of 1m dia. and the remaining part is 0.8m dia pipe. If the water to the city is to be supplied at a residual head of 15m of water, Calculate the supply head at the inlet end. Neglect minor losses and assume f = 0.03 for the entire pipeline. Sketch the hydraulic gradient for the pipeline. [35.53 m]

2) A pipe 0.15m dia taking off from a reservoir suddenly expands to 0.3m at the end of 16m and continues for another 15m. If the head above the inlet of the pipe is 4.88m, determine the actual velocity at the exit, taking into consideration all the losses. Assume f = 0.04 for the complete pipeline. [1.07 m/s]

3) A pipe 0.2m dia and 1800m long connects two reservoirs one being 30m below the other. The pipeline crosses a ridge whose summit is 7.5m above the upper reservoir. What may be the minimum depth of the pipe below the summit of the ridge in order that the pressure at the apex does not fall below 7.5m vacuum? The length of the pipe from the upper reservoir to the apex is 300m. Taking f = 0.032, determine the rate of flow to the lower reservoir in litres per minute. [2.37m; 2688 lpm]

4) The water levels in the two reservoirs A and B are respectively 66m and 61.5m above datum. A pipe joins each to a common point D where the pressure is 108 kN/m^2 gauge and height is 45m above datum. Another pipe connects D to another tank C. What will be the height of water level in C assuming the same value of friction factor for all pipes?

Pipe	Length	Diameter
AD	2400 m	0.30 m
BD	2700 m	0.45 m
CD	3000 m	0.60 m

[51.90 m above datum]

* Bernoulli's Eq^n
* Darcy-Weisbach Eq^n
* Continuity eq^n in 1-D

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Def^n: A pipe is a closed conduit which is used for carrying fluids under pressure.

Reynolds No = $\frac{\text{Inertia force}}{\text{Viscous Force}} = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$

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Energy loss in pipes :- 1> Major loss : Friction
2> Minor loss : Loss due to various fitting i.e. change in velocity.

1> Major loss: Loss Due to friction : (Darcy Weisbach eq^n) ⇒ $h_f = \frac{f \cdot L V^2}{2gD}$
where f = friction factor.

2> Minor loss: a> Energy loss due to sudden enlargement ⇒ $h_L = \frac{(V_1 - V_2)^2}{2g}$

b> Loss due to sudden contraction ⇒ $h_L = \frac{0.5 V^2}{2g}$

c> Loss due to entry in the pipe ⇒ $h_L = \frac{0.5 V^2}{2g}$

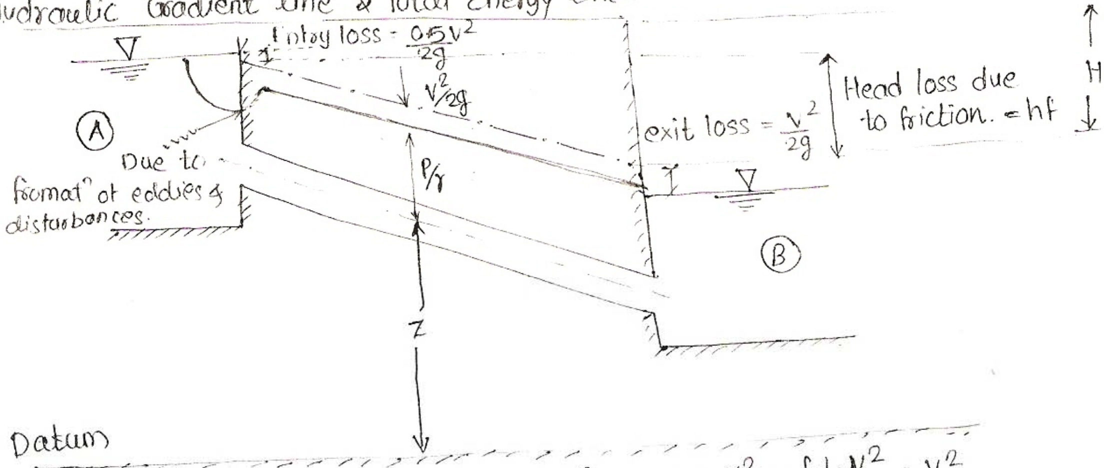
d> Loss due to exit from the pipe ⇒ $h_L = \frac{V^2}{2g}$

e> Loss due to gradual contract^n/Enlargement: $h_L = \frac{k \cdot (V_1 - V_2)^2}{2g}$

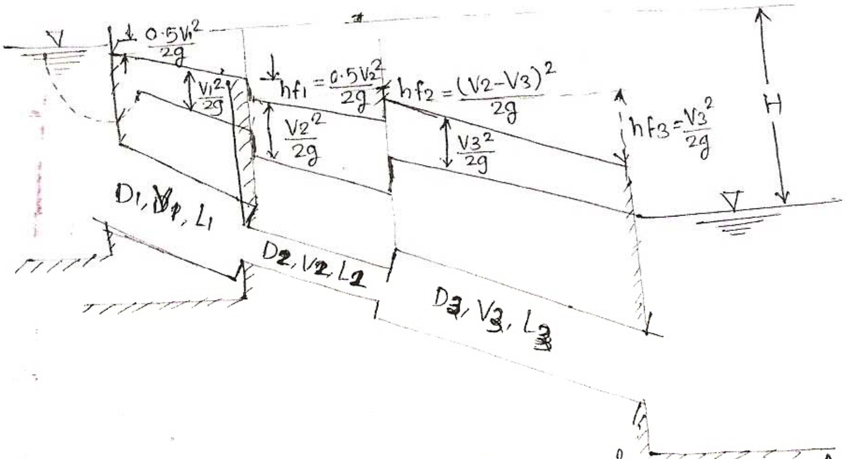
f> Loss due to bends ⇒ $h_L = \frac{K \cdot V^2}{2g}$

g> Loss due to various pipe fittings. ⇒ $h_L = \frac{K \cdot V^2}{2g}$

Hydraulic Gradient line & Total Energy line :-



$\therefore H = 0.5\frac{V^2}{2g} + h_f + \frac{V^2}{2g} = 0.5\frac{V^2}{2g} + \frac{f \cdot L \cdot V^2}{2gD} + \frac{V^2}{2g}$



$H = 0.5\frac{V_1^2}{2g} + \frac{f_1 L_1 V_1^2}{2g D_1} + 0.5\frac{V_2^2}{2g} + \frac{f_2 \cdot L_2 \cdot V_2^2}{2g D_2} + \frac{(V_2 - V_3)^2}{2g} + \frac{f_3 \cdot L_3 \cdot V_3^2}{2g \cdot D_3} + \frac{V_3^2}{2g}$

* **Flow through long Pipes:-**

$$H = \frac{V^2}{2g}\left[1 + \frac{fL}{D}\right]$$

If pipes are very long, minor losses are neglected.

* **Pipes in Series / Compound pipe:-**

$$H = 0.5\frac{V_1^2}{2g} + h_{f1} + 0.5\frac{V_2^2}{2g} + h_{f2} + \frac{(V_2 - V_3)^2}{2g} + h_{f3} + \frac{V_3^2}{2g}$$

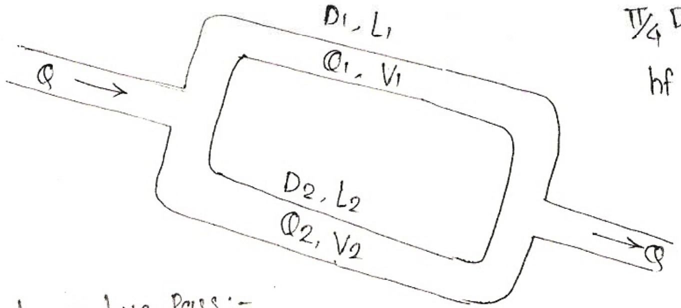
$$\Rightarrow H = h_{f1} + h_{f2} + h_{f3}.$$

$$A_1V_1 = A_2V_2 = \cdots = Q$$

* **Equivalent Pipe:-** Pipe which replaces compound pipe of varying dia. & lengths is called as equivalent pipes.

Dupuits eq^n $\Rightarrow$ $\frac{L}{D^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} + \frac{L_3}{D_3^5} + \cdots$

* **Pipes in parallel:-**

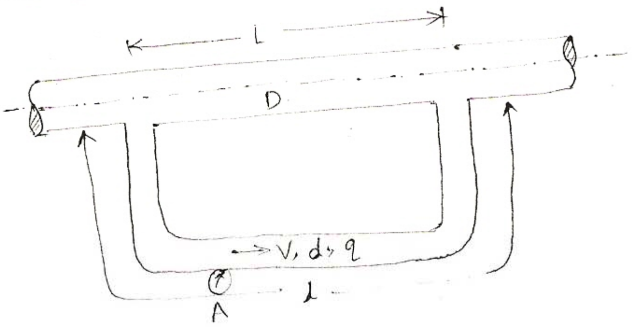


$$Q = Q_1 + Q_2$$

$$\frac{\pi}{4} D^2 \cdot V = \frac{\pi}{4} \cdot D_1^2 \cdot V_1 + \frac{\pi}{4} \cdot D_2^2 \cdot V_2$$

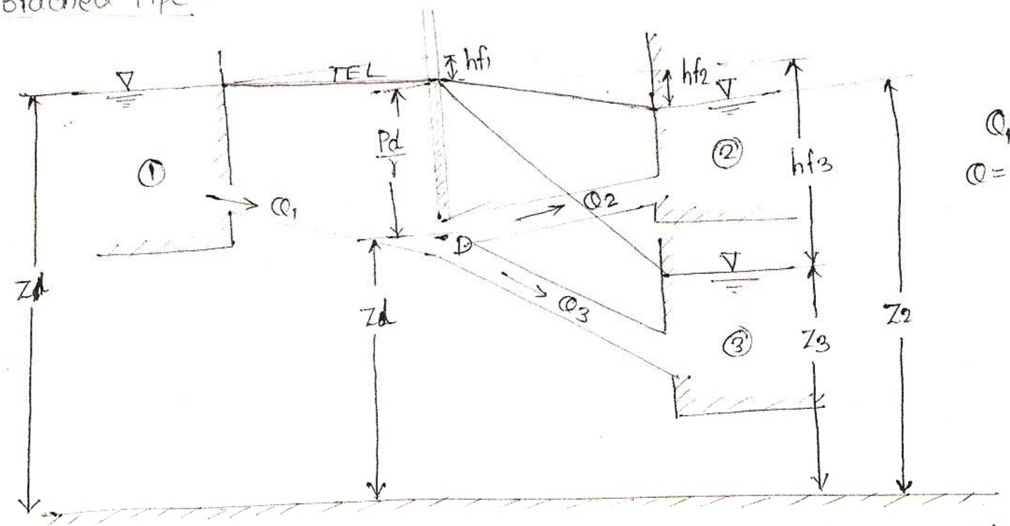
$$h_f = \frac{f L_1 V_1^2}{2g D_1} = \frac{f \cdot L_2 \cdot V_2^2}{2g D_2}$$

* **Flow through a bye Pass:-**



$$q = \frac{Q + q}{1 + \left(\frac{D}{d}\right)^5 \left(\frac{l + kd}{L}\right)}$$

* **Brached Pipe:-**



$$Q_1 = Q_2 = Q_3$$

$$Q = AV$$

$$Z_1 = Z_d + \frac{P_d}{\gamma} + h_{f1}$$

$$Z_2 = Z_d + \frac{P_d}{\gamma} - h_{f2}$$

$$Z_3 = Z_d + \frac{P_d}{\gamma} - h_{f3}$$

$$\left(Z_d + \frac{P_d}{\gamma}\right) = (Z_1 - h_{f1}) = (Z_2 + h_{f2}) = (Z_3 + h_{f3})$$

* Syphon:-

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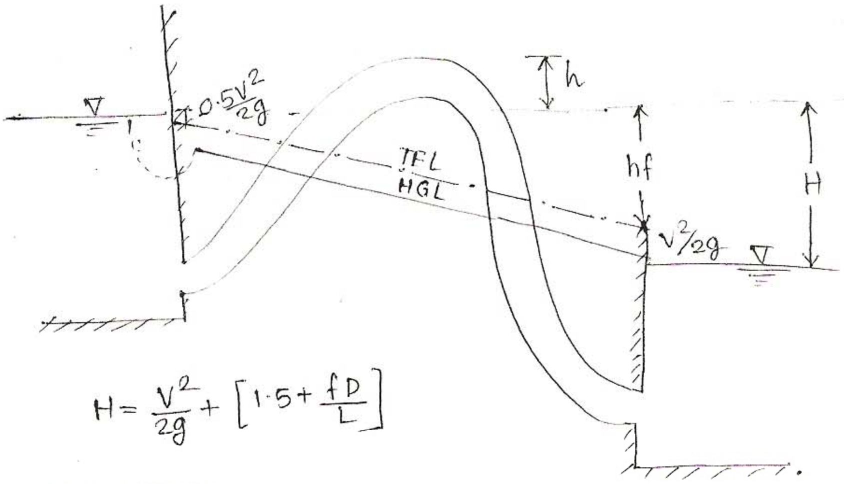


$$H = \frac{V^2}{2g} + \left[1.5 + \frac{fD}{L}\right]$$

* Tapering pipe:-

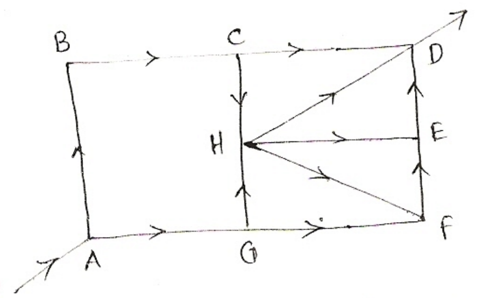
$$h_f = \frac{4f \cdot Q^2 L^5}{2g\pi^2 D_2^5}\left[\frac{1}{l^4} - \frac{1}{(L-l)^4}\right]$$

* Loss of head due to friction with side tapping:-

$$h_f = \frac{f}{D} \cdot \frac{V^2}{2g} \cdot \frac{L}{3}$$

* Transmission of power th' pipes:- $P = \gamma Q(H - h_f)$
  * Condition for max. power transmission, $H = 3h_f$
  * Efficiency = $\frac{H - h_f}{H}$
  * Efficiency corresponding to max. power transmission = 66.67 %

* Pipes Network:- A group of interconnected pipes forming several loops or circuits is called as pipe network.



* Conditions to be satisfied for distribut^n of flow:-
  1) Flow in to each junction must be equal to the flow out out Junction.
     i.e. Inflow = Outflow @ junct^n
  2) For each loop, loss of head due to flow in clockwise direct^n must be equal to the loss of head due to flow in anticlockwise direct^n
  3) Darcy-weisbach eq^n must be satisfied in each pipe. i.e. $h_f = r \cdot Q^n$
  4) Minor losses may be neglected if pipes are long.

* Procedure for Hardy-Cross Method:-
  1) Assume a most suitable distribution of flow that satisfies continuity at each junction.
  2) With the assumed values of 'Q' compute head loss due to friction by $h_f = r \cdot Q^n$
  3) Consider different loops or circuits & compute the net head loss around each circuit.
  4) hf in clockwise direct^n is +ve & hf in anticlockwise direct^n is -ve.
     i.e. Net head loss around the circuit = 0
  5) If it is not zero correction ΔQ is applied as $\Delta Q = \frac{\Sigma r \cdot Q_0^n}{\Sigma r \cdot n \cdot Q^{n-1}}$