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Internal Assessment Test 3 – Nov. 2018

| Sub: | Fluid Mechanics | | | | | Sub Code: | 15CV33 | Branch: | Civil |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 22/11/2018 | Duration: | 90 mins | Max Marks: | 50 | Sem/Sec: | III A and B | | OBE |

Answer any FIVE FULL Questions

| | | MARKS | CO | RBT |
|---|---|---|---|---|
| 1 (a) | Define Hydraulic Gradient Line and Total Energy Line. Explain with a neat sketch. | [05] | CO5 | L2 |
| (b) | Water flowing through a rigid pipe of diameter 500 mm with 1.5 m/s is suddenly brought to rest. Find the instantaneous pressure rise if $K_{water}$ = 2 GPa. | [05] | CO5 | L2 |
| 2 | Derive an expression for pressure rise due to sudden closure of valve when the pipe is elastic. | [10] | CO3 | L2 |
| 3 (a) | Derive an expression for head loss due to sudden enlargement in a pipe flow. | [05] | CO4 | L2 |
| (b) | Write a note on cippolletti weir. | [05] | CO5 | L2 |
| 4 | Derive the expression for discharge through a trapezoidal notch. | [10] | CO5 | L2 |

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|---|---|---|---|---|
| 5 | Two tanks are connected with help of two pipes in series. The lengths of pipes are 1000m and 800m respectively. The coefficient of friction for both the pipes is 0.008. The difference of water level in two tanks is 15m. Find the rate of flow through pipes, considering all losses. | [10] | CO5 | L4 |
| 6 (a) | A rectangular notch 40 cm long is used for measuring a discharge of 30 lps. An error of 1.5 mm was made while measuring the head over the notch. Calculate the percent error in the discharge. Take Cd = 0.6. | [05] | CO5 | L4 |
| (b) | Derive the expression for discharge through a small orifice of area '*a*' under a head '*h*' measured above the centre of the orifice. | [05] | CO4 | L2 |

CI CCI HOD


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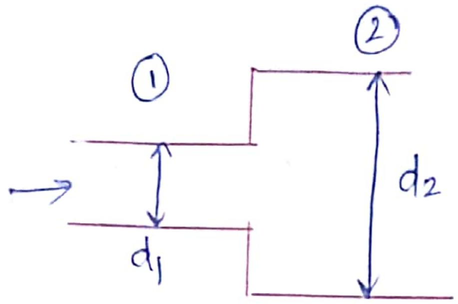
CI CCI HOD

9(c) (8)




$Q = 0.025 m^3/s$

$d_1 = 0.2 m$ $\quad a_1 = \frac{\pi}{4} \times 0.2^2 = 0.0314 m^2$

$d_2 = 0.4 m$ , $a_2 = \frac{\pi}{4} \times 0.4^2 = 0.125 m^2$

$p_1 = 11.772 N/cm^2 = 11.772 \times 10^4 N/m^2$

$$V_1 = \frac{Q}{a_1} = \frac{0.025 m^2}{0.0314} = 0.796 m/s$$

$$V_2 = \frac{Q}{a_2} = \frac{0.025}{0.125} = 0.199 m/s.$$

(i) Loss of head due to sudden enlargement, he

$$h_e = \frac{(V_1 - V_2)^2}{2g} = \frac{(0.796 - 0.199)^2}{2 \times 9.81} = \boxed{0.01816 m}$$

(ii) Pressure intensity at larger pipe, $p_2$

Applying Bernoulli's eqn at (1) & (2)

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_e \quad (z_1 = z_2, \text{ horizontal pipe})$$

$$\left(\frac{p_1}{\rho g} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_e\right) \rho g = p_2$$

$$p_2 = \left(\frac{11.772 \times 10^4}{10^3 \times 9.81} + \frac{0.796^2}{2 \times 9.81} - \frac{0.199^2}{2 \times 9.81} - 0.01816\right) \times 10^3 \times 9.81$$

$p_2 = 117338 N/m^2$

$= 11.73 N/cm^2$

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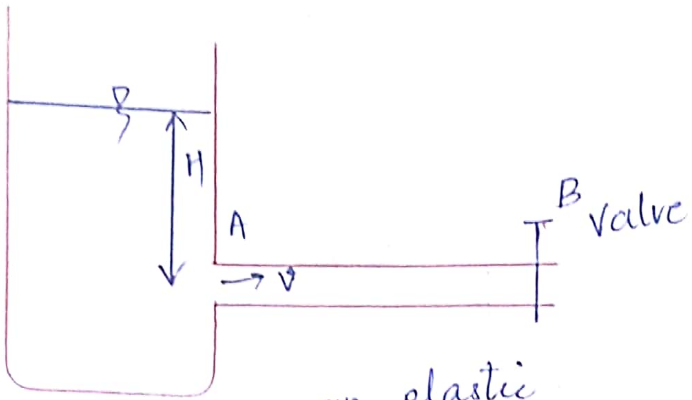
10 (a) (4)

(i) Hydraulic gradient line (HGL) – It is defined as the line which gives the sum of pressure head $\left(\frac{P}{\rho g}\right)$ and datum head (z) of a flowing fluid in a pipe with respect to some reference line.
It is the line which is obtained by joining the top of all vertical ordinates, showing the pressure head $\left(\frac{P}{\rho g}\right)$ of a flowing fluid in a pipe from the centre of the pipe.

(ii) Total Energy line (TEL) - It is defined as the line which gives the sum of pressure head $\left(\frac{P}{\rho g}\right)$, kinetic head or velocity head $\left(\frac{V^2}{2g}\right)$ and datum head (z) ~~be~~ of a flowing fluid in a pipe with respect to some reference line.

It is the line which is obtained by joining the Top of all vertical ordinates showing the pressure head $\left(\frac{P}{\rho g}\right)$ and kinetic head $\left(\frac{V^2}{2g}\right)$ from the centre of pipe.

10(b) Pressure loss due to sudden closure of valve when the pipe is elastic (8)




Consider ~~the~~ an elastic pipe AB in which water is flowing as shown in figure.

The loss of kinetic energy, $E_1$ = gain of strain energy of water, $E_2$ + ~~gain~~ strain energy stored in pipe material $E_3$.

$$E_1 = E_2 + E_3 \qquad (1)$$

Let

ρ - density of water

d - diameter of flow (pipe)

A → Area of flow

L → length of pipe

t → thickness of pipe wall

V → velocity of flow

p → Increase of pressure due to water hammer

K — Bulk modulus of water

E - Modulus of elasticity of pipe material

1/m - 1/4 Poisson's ratio

Calculation of Energy
(Kinetic heo energy)

1) Loss of K.E, $E_1$

$$E_1 = \frac{1}{2} m v^2 = \frac{1}{2} \rho A L V^2 \quad -(1)$$

2) Gain of strain energy of water, $E_2$

$$E_2 = \frac{1}{2}\left(\frac{p^2}{K}\right) \times vol$$

$$= \frac{1}{2}\left(\frac{p^2}{K}\right) AL \quad -(2)$$

3) Strain energy stored in pipe material, $E_3$

$$E_3 = \frac{1}{2E}\left[f_l^2 + f_c^2 - \frac{2 f_l f_c}{m}\right] \times vol \quad (3)$$

where

$f_l$ - longitudinal stress in pipe $= \frac{pd}{4t}$

$f_c$ - circumferential stress in pipe $= \frac{pd}{2t}$

$\frac{1}{m} = \frac{1}{4}$, ~~vol = πDLt~~ ~~vol = πdLt~~

vol = πdLt

Sub $f_l$, $f_c$ and $1/m$ in (3)

$$E_3 = \frac{1}{2E}\left[\frac{p^2 d^2}{16t^2} + \frac{p^2 d^2}{4t^2} - \frac{2 p^2 d^2}{4 \times 4 \times 2 t^2}\right] \pi d L t$$

$$= \frac{p^2 d^2}{E t^2} \frac{1}{2}\left[\frac{1}{16} + \frac{1}{4} - \frac{1}{816}\right] \pi d L t$$

$$= \frac{p^2 d^3 \pi L}{8Et} \quad \text{sub } A = \frac{\pi}{4} d^2$$

$$= \frac{p^2 d A L}{2Et} \quad \text{——— (4)}$$

Sub (1), (2) and (4) in eqn

$$E_1 = E_2 + E_3$$

$$\frac{1}{2} \rho A L V^2 = \frac{1}{2} \left( \frac{p^2}{K} \right) A L + \frac{1}{2} \frac{p^2 d A L}{Et}$$

dividing by $\frac{AL}{2}$

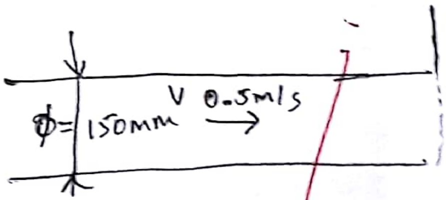
$$\rho V^2 = \frac{p^2}{K} + \frac{p^2 d}{Et}$$

$$\rho V^2 = p^2 \left( \frac{1}{K} + \frac{d}{Et} \right)$$

$$p^2 = \frac{\rho V^2}{\left( \frac{1}{K} + \frac{d}{Et} \right)}$$

$$\boxed{p = \frac{V \sqrt{\rho}}{\sqrt{\left( \frac{1}{K} + \frac{d}{Et} \right)}}}$$

6) Water is flowing in a pipe of 150mm dia with a velocity of 0.5m/s when it is suddenly brought to rest by closing valve. Find the pressure rise assuming the pipe is elastic E = 206 GN/m². Poisson ratio = 0.25 ~~K for~~ K for water GN/m²




→ Given $E = 206 \times 10^3 N/m^2$

$\mu = 0.25$

$K = 2.06 \times 10^3 N/m^2$

$D_1 = 150 \times 10^{-3}$

$$P = \frac{V\sqrt{\rho}}{\sqrt{1/K + D/ET}} = \frac{2.5\sqrt{1000}}{\sqrt{\frac{1}{2.06 \times 10^9} + \frac{150 \times 10^{-3}}{206 \times 10^9}}}$$

$$\boxed{P = 35.85 \times 10^3 N/m^2}$$

... 1200m of 0.4 and 600

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At sec 1 ⇒ $\frac{P_1}{\rho g} + z_1 = 30.67 + 0 = 30.67 m$

At sec 2 ⇒ $\frac{P_2}{\rho g} + z_2 = 0 + 15 = 15 m$

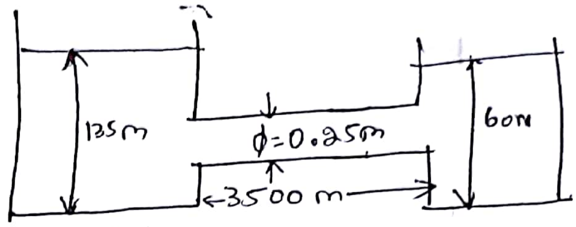
a) A 250mm diameter, 3km long straight pipe runs b/w two reservoir of surface Elevation 135m & 60m. A 1.5 Km long 300mm diameter is laid parallel to 250mm diameter pipe from its mid point to lower reservoir. Find the increase in discharge caused by addition of 300mm diameter pipe.

Ans) $H = 135 - 60 = 75 m$

$Q_B = AV = \frac{\pi}{4} 0.25^2 = 0.49 m^2$

$h_f = \frac{f l V^2}{2gD}$

$h_f = H = 135 - 60 = 75 m$

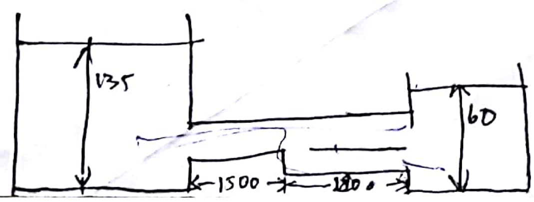



$75 = \frac{0.02 \times 3000 \times V^2}{2 \times 9.81 \times 0.25}$

$V_B = 2.47 m/s$

$Q_B = A_1 V = 0.049 \times 2.47 = 0.121 m^3/s$

$Q_A = Q_{A1} + Q_{A2}$



$$V. = \frac{4fL_{A1}V_{A1}^2}{2g D_{A1}} = \frac{V_{A2}^2 4fL_{A1}}{2g D_{A2}}$$

$$\frac{V_A^2}{0.25} = \frac{V_{A2}^2}{0.3}$$

$$V_{A2}^2 = \sqrt{\frac{0.3}{0.25}} V_{A1} \quad \text{--- (1)}$$

$$Q = Q_{A1} + Q_{A2}$$

$$\frac{\pi}{4} \times 0.25^2 V_A = \frac{\pi}{4} \times 0.25^2 V_{A1} + \frac{\pi}{4} \times 0.3^2 V_{A2} \quad \text{--- (2)}$$

sub (1) in (2)

we have $0.25^2 V_A = 0.25^2 V_{A1} + 0.3^2 \sqrt{\frac{0.3}{0.25}} V_A$

$$\Rightarrow V_A = 2.57 V_{A1}$$

$$V_{A1} = 0.389 V_A$$

considering pipe XYZ $H = h_{fA} + h_{fA1}$

$$H = \frac{fL_A V_A^2}{2g D_A} + \frac{fL_1 V_{A1}^2}{2g D_1} \Rightarrow 75 = \frac{0.02 \times 1500 V_{A1}^2}{2 \times 9.81 \times 0.25} + \frac{0.02 \times 1500 (0.389) V_A^2}{2 \times 9.81 \times 0.25}$$

$$75 = \frac{0.02 \times 1500}{2 \times 9.81} \left[ \frac{V_{A1}^2 + V_A^2 0.389}{0.25} \right]$$

$$V_{A1}^2 + 0.389 V_{A1}^2 = \frac{75}{6.162}$$

$$V_A = \sqrt{\frac{1.2262}{1.389}} = 3.26 \text{ m/s}$$

$$Q_A = \frac{\pi}{4} \times 0.25^2 \times 3.26$$

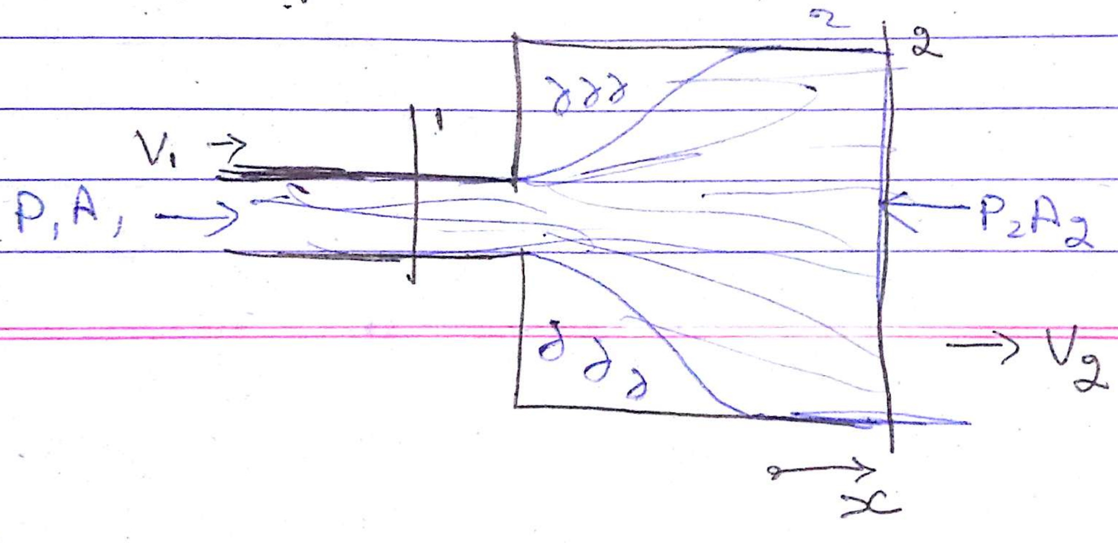
$$= 0.16 \text{ m}^3/\text{s}$$

$$\% \text{ in increase} = \frac{Q_A - Q_B}{Q_B} \times 100 = \frac{0.16 - 0.21}{0.12} \times 100$$

$$= 32.26\%$$

Minor loss

## Loss of head due to sudden Expansion



Consider a liquid flowing through a pipe which has a sudden Enlargement of diameter as shown in figure. Consider two section 1 & 2 before and after the Enlargement. Let $P_1$ and $P_2$ be the pressure (Pr Area) section at ① & ②. $V_1$ & $V_2$ be the velocity at ① & ②, $A_1$ & $A_2$ be the area of pipe at ① & ②

Due to sudden change in area from $A_1$ to $A_2$ the liquid flowing from the smaller pipe is not able to follow the abrupt change of the boundary of the pipe. Let the flow seperate from the boundary and turbulent Eddies are formed as shown in figure. The loss of Energy or head takes place due to the formation of Eddies.

Let $P'$ = The pressure intensity of the liquid eddies in the ~~liquid~~ area $(A_2 - A_1)$

force due to this pressure is given by $P' = P(A_2 - A_1)$
from alots of Experiment it is given that $P' \approx P_1$

Let $h_e$ be the loss of head due to sudden Expansion.
Applying bernollis Equation at ① & ② we get

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_e$$

since pipe is horizontal $Z_1 = Z_2$

$$h_e = \left(\frac{P_1 - P_2}{\rho g}\right) + \left(\frac{V_1^2 - V_2^2}{2g}\right) \quad \text{——①}$$

Consider a control volume b/w section ① & ② applying law of motion we have $\Sigma F_x = M a_x = M \frac{dv_x}{dt}$ = change in moment per sec

(dt/sec)

$\Sigma F_x =$ Change in momentum / sec ——(2)

$\Sigma F_x = P_1 A_1 + P'(A_2 - A_1) \mp P_2 A_2$          $P' \approx P_1$

$= P_1 A_1 + P_1 A_2 - P_1 A_1 \mp P_2 A_2$

$= A_2 (P_1 \mp P_2)$

$\Sigma F_x = A(P_1 - P_2)$ ——(3)

$\frac{\text{change in momentum}}{t} = \frac{\text{moment at section 2}}{t} - \frac{\text{moment at section 1}}{t}$

$\frac{\text{Momentum at sec 2}}{t} = \frac{MV}{} = \rho A_2 V_2 V_2 = \rho A_2 V_2^2$

$\left(\frac{\rho ALV}{T}\right)$

$\rho A_1 V_1^2$

$\rho A_2 V_2^2 - \rho A_1 V_1^2$

Equating (3) & (4)

$(P_1 - P_2) A_2 = \rho A_2 V_2^2 - \rho A_1 V_1^2$

$Q = A_1 V_1 = A_2 V_2 \Rightarrow A_1 = \frac{A_2 V}{V_1}$

$(P_1 - P_2) A_2 = \rho A_2 V_2^2 - \rho \frac{A_2 V_2 V_1^2}{V_1}$

$(P_1 - P_2) = \rho (V_2^2 - V_2 V_1)$

$\frac{P_1 - P_2}{\rho g} = \frac{V_2^2}{g} - \frac{V_2 V_1}{g}$ ——(5)

sub (5) in (1)

$\frac{V_2^2}{2g} - \frac{V_2 V_1}{g} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g}$

$= \frac{2V_2^2 - 2V_2 V_1 + V_1^2 - V_2^2}{2g} = \frac{(V_1 - V_2)^2}{2g}$ //