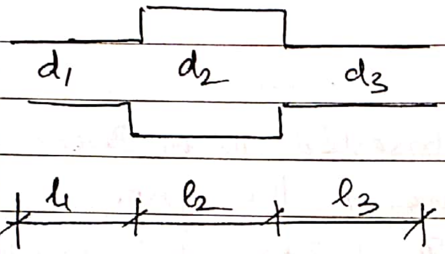
IAT-3. Solutions 18CV33.

Part A

1(a) Distinguish between
(i) Pipes in parallel and pipes in series
(ii) Hydraulic gradient line and total energy line (06)

(i) Pipes in Series



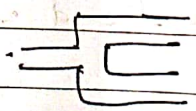
* The discharge remains same
* $Q_1 = Q_2 = Q_3 = Q$.
* Total head loss = Sum of head losses in different sections

$$h = \frac{4fl_1V_1^2}{2gd_1} + \frac{4fl_2V_2^2}{2gd_2} + \frac{4fl_3V_3^2}{2gd_3}$$

$$= \frac{4fl_1Q^2}{2g\times\left(\frac{\pi}{4}\right)^2\times d_1^5} + \frac{4fl_2Q^2}{2g\times\left(\frac{\pi}{4}\right)^2\times d_2^5} + \frac{4fl_3Q^2}{2g\times\left(\frac{\pi}{4}\right)^2\times d_3^5}.$$

$$h = \frac{4fQ^2}{2g\times(\pi/4)^2}\left[\frac{l_1}{d_1^5} + \frac{l_2}{d_2^5} + \frac{l_3}{d_3^5}\right].$$

(ii) Pipes in parallel.



* $Q = Q_1 + Q_2$
$h_1 = h_2 = h$.

(ii) HGL and TEL.

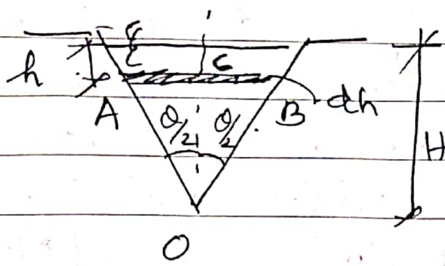
$$TEL - \frac{P}{\rho g} + \frac{V^2}{2g} + Z.$$

$$HGL = \frac{P}{\rho g} + Z.$$

or $HGL = TEL - \frac{V^2}{2g}$.

Scheme:-
(i) 2 differences — 3
(ii) both differences — 3

(b). Prove that the discharge over triangular notch is $Q = \frac{8}{15} C_d \sqrt{2g} \cdot \tan(\theta/2) \cdot H^{5/2}$. (07)



$\tan\theta/2 = \frac{AC}{OC}$

or $AC = OC \cdot \tan\theta/2 = (H-h)\tan\frac{\theta}{2}$ — ①

Area of the element strip = $AB \times dh = 2(H-h) \cdot \tan\frac{\theta}{2} \times dh$.

$dQ = C_d \times$ area of strip $\times$ theoretical velocity

$= C_d \times 2(H-h) \cdot \tan\theta/2 \times dh \times \sqrt{2gh}$. — ②

$Q = \int C_d \times \tan\theta/2 \cdot \times 2(H-h)\sqrt{2g}\, h^{1/2}$.

$= C_d \times \sqrt{2g} \cdot \tan\theta/2 \times 2 \cdot \int H h^{1/2} - h^{3/2}\, dh$. — ③

$= C_d \times \sqrt{2g} \cdot \tan\theta/2 \times 2 \cdot \left[\frac{H \cdot h^{3/2}}{3/2} - \frac{h^{5/2}}{5/2} \right]_0^H$.

$= C_d \times \sqrt{2g} \times \tan\theta/2 \times 2 \times H^{5/2} \left[\frac{2}{3} - \frac{2}{5} \right]$.

$= C_d \times \sqrt{2g} \times \tan\theta/2 \times 2 \times H^{5/2} \times \left(\frac{10-6}{15} \right)$ — ④

$= C_d \times \sqrt{2g} \times \tan\theta/2 \times H^{5/2} \times 2 \times \frac{4}{15}$.

$Q = \frac{8}{15} \times C_d \times \sqrt{2g} \times \tan\theta/2 \times H^{5/2}$. — ⑤.

Scheme:-
Fig :- 1.
Eqn ① - 2
Eqn ② - 1
Eqn ④ - 2
Eqn ⑤ - 1

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(c) The head of water over an orifice of diameter 10cm is 10m. The water coming out from the orifice is collected in a circular tank of diameter 1.5m. The rise of water level in the pipe is 1m in 25 seconds. The coordinates of a point on the jet, measured from vena contracta are 4.3m horizontal and 0.5 vertical. Find the coefficient of Cd, Cc and Cv?. (07)

$$C_v = \frac{x}{\sqrt{4yh}} = \frac{4.3}{\sqrt{4\times0.5\times10}}$$

$x = 4.3m$
$y = 0.5$
$h = 10m$.

$= \underline{\underline{0.962}}$

$$Q_{act} = \frac{\frac{\pi}{4}(1.5)^2 \times 1}{25} = \underline{\underline{0.07 m^3/s}}$$

$$V_{th} = \sqrt{2gh} = \sqrt{19.62\times10} = \underline{\underline{14 m/s}}$$

$$Q_{th} = area \times v_{th} = \frac{\pi}{4}\times0.1^2\times14 = \underline{\underline{0.1099 m^3/s}}$$

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{0.07}{0.1099} = \underline{\underline{0.64}}$$

$C_d = C_v \times C_e$.

$$\text{or } C_e = \frac{0.64}{0.962} = \underline{\underline{0.~~728~~}}\ \underline{\underline{0.67}}$$

Scheme:-

V_{th} ; Q_{act} ; Q_{th} ; C_d - 4

C_v - 2

C_c - 1

Part B.

2(a) Explain the advantages of triangular notch over rectangular notch. (03)

* Expression for a right angled triangular notch is easy.
* Ventilation of triangular notch is not necessary unlike rectangular notch
* Suitable for low discharges unlike rectangular notches
* Only H is required to compute discharge.

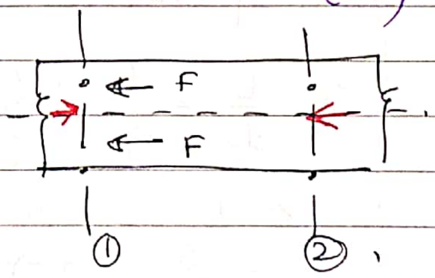
Scheme
Any 3 → 3 marks.

(b) Derive an expression for pressure rise due to sudden closure of valve when the pipe material is elastic (06)

Darcy's Eqn

Answer for 3(b)

Consider uniform horizontal pipe of area (A).
Let ① and ② be the ends of the controlled volume.



$P_1 ; V_1 ; Z_1 = Z_2 = 0$
→ Section 1-1

Applying Bernoulli's principle between ends ① and ②

$P_2 ; V_2$ → Section 2-2.

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

$V_1 = V_2$

$$\frac{(P_1 - P_2)}{\rho g} = h_f$$

$P_1 - P_2 = h_f \times \rho g$. — ①.

According to Froude

frictional force = frictional resistance × wetted area × V^2

$= f' \times \pi d L \times V^2$.

Consider equilibrium of forces.

* pressure force at 1-1
* pressure force at 2-2
* frictional force, F.

$p_1 a_1 - p_2 a_2 = F$

$p_1 - p_2 = \frac{F}{a}$ ($\because a_1 = a_2$) — (2)

Equating (1) and (2).

$$h_f \times \rho g = \frac{f' \times \pi d L \times V^2}{a} = \frac{f' \times \pi d l \times V^2}{\frac{\pi}{4} \times d^2}$$

$$h_f = \frac{4f'}{\rho g} \times \frac{lV^2}{d} \rightarrow \text{Darcy Weishbach Equation (3)}$$

Putting $\frac{f'}{\rho} = \frac{f}{2}$.

$$h_f = \frac{f}{2} \times \frac{4lv^2}{gd}.$$

Scheme.	
Fig + Boundary Condition	2
Bernoulli's → Eqn (1).	2
Force resolution upto (3)	2

(c). A compound piping system consists of 1800 m of 0.5 m; 1200 m of 0.4 m and 600 m of 0.3 m new cast iron pipes connected in series. Convert the system to (i) Equivalent length of 0.4 m pipe (ii) Equivalent size pipe 3600 m long. (06)

(i) $$\frac{L}{d^5} = \frac{l_1}{d_1^5} + \frac{l_2}{d_2^5} + \frac{l_3}{d_3^5}.$$

$$\frac{L}{(0.4)^5} = \frac{1800}{(0.5)^5} + \frac{1200}{(0.4)^5} + \frac{600}{(0.3)^5}.$$

$$\frac{L}{(0.4)^5} = 57600 + 1171875 + 246913.58$$

or $L = 4318.22\,m$

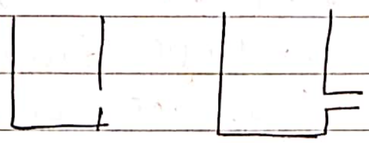
(ii) $$\frac{3600}{d^5} = 421701.08$$

$d = 0.386\,m$

Scheme	
$\frac{L_1}{d_1^5}$; $\frac{L_2}{d_2^5}$; $\frac{L_3}{d_3^5}$	3
Estimation of L	1.5
Estimation of d	1.5

3(a) Compare Orifice and mouthpiece. (03)

Both are used to measure the discharge.
Orifice is a small opening located at the top or bottom or on the sides of the tanks.
Mouthpiece is small tube that can be fitted to tank and the tube is usually projected



Scheme:-
Fig – 1.
Difference – 2.

(b) Derive an expression for the loss of energy (head) due to friction in pipes. (06)

pressure rise due to sudden gate closure

Answer for 2(b)

Let $1/m$ be the Poisson's ratio, E, modulus of elasticity of pipe; f_t – longitudinal stress $= \frac{pd}{4t}$

Circumferential stress, $f_c = \frac{pd}{2t}$

loss in KE = Strain energy stored in pipe + strain energy stored in H_2O

$$\frac{1}{2}\rho \times \frac{\pi}{4} \times d^2 \times L \times V^2 = \text{energy in pipe} + \frac{p^2}{2k} \times \frac{\pi}{4} \times d^2 \times L$$

$$\text{energy in pipe} = \frac{1}{2E}\left[f_t^2 + f_c^2 - 2 f_c \times f_t \times \frac{1}{m}\right] \quad (1)$$

$$= \frac{1}{2E}\left[\frac{p^2d^2}{16t^2} + \frac{p^2d^2}{4t^2} - \frac{2 \times p^2d^2}{8t^2} \times \frac{1}{4}\right]$$

$$= \frac{p^2d^2}{16t^2E}\left[\frac{1}{2} + 2 - \frac{1}{2}\right] = \frac{p^2d^2}{8t^2E} \quad -(2)$$

Substituting (2) in (1).

$$\frac{1}{2} \times \rho \times \frac{\pi}{4} \times d^2 \times L \times V^2 = \frac{p^2d^2}{8t^2E} \times \pi d t L + \frac{p^2}{2k} \times \frac{\pi}{4} d^2 L$$

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$$\frac{f}{8} \times l \times v^2 = \frac{p^2 \times dl}{8tE} + \frac{p^2 \times l}{8K}$$

$$f v^2 = p^2\left[\frac{d}{tE} + \frac{1}{K}\right]$$

$$\text{or } p = v \times \sqrt{\frac{f}{\frac{d}{tE} + \frac{1}{K}}}$$

Scheme :-
Strain energy in pipe - ③
Strain energy in H_2O - ①
Final - ②

(c). The water flowing in a rectangular channel of 1.2m width and 0.8m depth. Find the discharge over the rectangular weir of crest length 70cm. If the head of water over the crest of weir is 25cm and water from channel flows over the weir. Take $C_d = 0.6$. Neglect end contractions but consider velocity of approach. (06)

$$Q \text{ without end contraction} = \frac{2}{3} \times 0.6 \times 0.7 \times \sqrt{19.62} \times (0.25)^{1.5}$$
$$= \underline{\underline{0.156\ m^3/s}}$$

$$V_a = \frac{0.155}{(1.2 \times 0.8)} = \underline{\underline{0.16\ m/s}}$$

$$\frac{V_a^2}{2g} = \frac{0.16^2}{19.62} = \underline{1.32 \times 10^{-3}\ m}$$

$$Q = \frac{2}{3} \times 0.6 \times 0.7 \times \sqrt{19.62}\left[(0.25 + 0.00132)^{1.5} - (0.00132)^{1.5}\right]$$

$$= 1.24 \times (0.126 - 4.796 \times 10^{-5})$$

$$\times\ 0.126$$

$$Q = \underline{\underline{1.24\ m^3/s}} \quad 0.156\ m^3/s$$

Scheme :-
V_a - 3. $\quad$ V_a - 2, $\frac{V_a^2}{2g}$ - ①
Q - 3 $\quad$ Q eqn. ... - 2.
- q ...
Q with Q_2

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4(a) Differentiate between Cipolletti weir over trapezoidal weir. (03)

Rectangular weir will have end contractions. To counteract the same, the top side is widened to form a trapezoidal notch. In cipolletti weir, the slope is 1 ~~vert~~ horizontal to 4 vertical

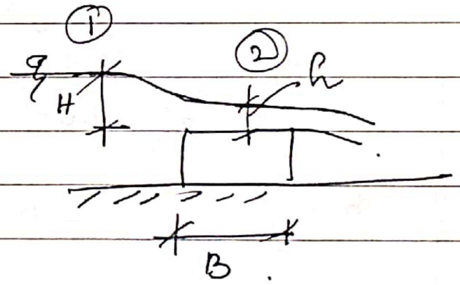
$\tan \theta/2 = 1/4$

$\theta/2 = 14^\circ 2'$

Scheme:-
Value of $\theta/2$ - 1
Compare $\theta/2$ for both - 1
Cipolletti - rectangular without end contraction - 1

(b) What is broad crested weir? Show that under maximum discharge conditions $h = \frac{2}{3}H$ with usual notations for a broad crested weir. (06)

If the width of the crest is $\geq 2.5H$ and $\leq 10H$, it is called as broad crested weir



thin plate ← $B < 0.625H$

Narrow ← $B \geq 0.625H$ and $2.5H$

Broad crested weir ← $B \geq 2.5H \leq 10H$

Section 1 - top surface
2

Applying Bernoulli's principle between Sections 1 and 2.

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\frac{V_1^2}{2g} = 0 + H = \frac{V_2^2}{2g} + h.$$

or $V_2 = \sqrt{2g(H-h)}$ — 3

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Actual discharge = Cd × Area × velocity

$$Q_{act} = Cd \times (L \times H) \sqrt{2g(H-h)} \quad -(1)$$

Scheme :- Broad crested weir (3)
Theoretical velocity (3); Qact - (1)

(c) The rate of flow of water through a horizontal pipe is $0.025\ m^3/s$. The diameter of the pipe, which is 200 mm, is suddenly enlarged to 400 mm. The pressure intensity in the smaller pipe is $11.772\ N/cm^2$. Compute
(i) loss of head due to sudden enlargement
(ii) Pressure intensity in the large pipe. (06)

(i) $V_1 = \cancel{\pi/4 \times} \dfrac{0.025}{\pi/4 \times 0.2^2} = 0.796\ m/s$

$V_2 = \dfrac{0.025}{\pi/4 \times 0.4^2} = \cancel{0.796\ m}/s\ .\ \underline{\underline{0.199\ m/s}}$

$h = \dfrac{(V_1 - V_2)^2}{2g} = \dfrac{(0.796 - 0.199)^2}{19.62} = \underline{\underline{0.0182\ m}}$

(ii) $\dfrac{11.772 \times 10^4}{1000 \times 9.81} + \dfrac{0.796^2}{19.62} = \dfrac{P_2}{9810} + \dfrac{0.199^2}{19.62} + 0.0182$

$P_2 = \underline{\underline{\cancel{12.01\ N/m^2}}}$ 117.84 kPa

$\dfrac{P_2}{9810} = 12 + 0.03028 - 0.0182$

Scheme.
(i) - 3
(ii) - 3.

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