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ESE – 2019 MAINS
OFFLINE TEST SERIES

CIVIL ENGINEERING
TEST – 8
SOLUTIONS

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01(a).

Sol: Discharge required for crops

Discharge for sugarcane = $Q = \frac{A}{D} = \frac{850}{580}$ = 1.466 cumec

Discharge for sugarcane additional in summer = $\frac{120}{580}$ = 0.207 cumec

Discharge for wheat $= \frac{600}{1600}$ = 0.375 cumec

Discharge for Bajra = $\frac{500}{2000}$ = 0.25 cumec

Discharge for vegetables = $\frac{360}{600} = 0.60$ cumec

Discharge required in every season:

1. In Rabi season:

$= Q_{\text{sugar cane}} + Q_{\text{wheat}}$

$= 1.466 + 0.375$

$= 1.841$ cumec

2. $Q_{\text{Monsoon}} = Q_{\text{sugarcane}} + Q_{\text{Bajra}}$

$= 1.466 + 0.25$

$= 1.716$ cumec

3. $Q_{\text{Hot weather}} = Q_{\text{sugarcane}} + Q_{\text{vegetables}}$

$= 1.466 + 0.207 + 0.60$

$= 2.273$ cumec

$\Rightarrow Q_{max} = Q_{\text{Hot weather}} = 2.273\ m^3/sec$

$\therefore$ Full supply discharge at the head of the canal = $\frac{Q_{max}}{t_f} = \frac{2.273}{0.65}$

$= 3.497\ m^3/s$

$\therefore$ Design discharge = $\frac{\text{Full supply discharge}}{\text{Capacity factor}}$

$= \frac{3.497}{0.8} = 4.371\ m^3/s$

01(b).

Sol: Given data

$h = 0.05$ m, $v = 10$ cm^3, $\rho = 900$ kg/m^3, $L = 0.1$ m, $D = 1$ mm, $T = 254$s, $g = 9.81$ m/s^2

Applying Bernoulli's equation between free surface and exit

$$\underbrace{\cancel{\frac{P_1}{\rho g}}}_{0} + \underbrace{\cancel{\frac{V_1^2}{2g}}}_{\approx 0} + Z_1 = \underbrace{\cancel{\frac{P_2}{\rho g}}}_{0} + \frac{V_2^2}{2g} + Z_2 + hf$$

$$h + L = \frac{V_2^2}{2g} + \frac{32\mu V_2 L}{\rho g D^2} \quad \text{(Assuming laminar flow)} \rightarrow (1)$$

$$Q = \frac{\text{Volume}}{\text{Time}}$$

$$= \frac{10 \times 10^{-6}}{254}$$

$= 3.937 \times 10^{-8}$ m^3/s

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

$$= \frac{3.937 \times 10^{-8}}{\frac{\pi}{4} \times 0.001^2}$$

$= 0.05$ m/s

Substituting in equation (1)

$$(0.05 + 0.1) = \frac{0.05^2}{2 \times 9.81} + \frac{32 \times \mu \times 0.05 \times 0.1}{900 \times 9.81 \times 0.001^2}$$

$\mu = 8.27 \times 10^{-3}$ Pa.s

$$Re = \frac{\rho V_2 D}{\mu}$$

$$= \frac{900 \times 0.05 \times 0.001}{8.27 \times 10^{-3}}$$

$= 5.44 < 2000$

$\Rightarrow$ Assumption of laminar flow was correct

01(c).

Sol: $h = y \sin\theta$

$dF = p\, dA$

$= \gamma h\, dA$

$dF = \gamma \sin\theta.\, y.dA$

$F = \gamma \sin\theta \int_A y dA$

$\int_A y dA = \bar{y}A \Rightarrow F = \gamma \sin\theta\ \bar{y}.A$

$\because\ \bar{y}\sin\theta = \bar{h} \Rightarrow F = \gamma A\bar{h} \rightarrow (1)$

$dM_o = dFy \Rightarrow dM_o = \gamma \sin\theta\, y^2 dA$

$M_o = \gamma \sin\theta \int_A y^2 dA$

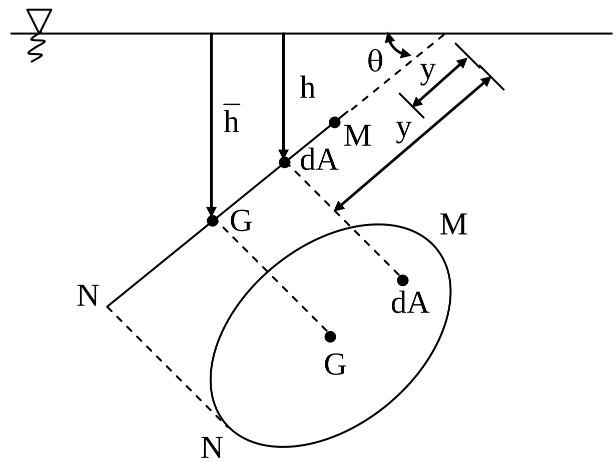
$\int y^2 dA = I_x = I_{xG} + A\bar{y}^2$

$\Rightarrow M_o = \gamma\sin\theta\,(I + A\,\bar{y}^2)\ ;\ M_o = F.y^*$

$\Rightarrow \gamma\sin\theta\ \bar{y}\,Ay^* = \gamma \sin\theta\,(I + A\bar{y}^2)$

$\Rightarrow y^*\ \bar{y} + \frac{I}{A\bar{y}} \Rightarrow \frac{h^*}{\sin\theta} = \frac{\bar{h}}{\sin\theta} + \frac{I\sin\theta}{A\bar{h}}$

$\Rightarrow\ h^* = \bar{h} + \frac{I\sin^2\theta}{A\bar{h}} \rightarrow (2)$



01(d).

Sol: Synder's approach is construction of UH with Catchment characteristics.

$L = 80$ km

$L_C = 50$ km

$A = 2100\ km^2$

$C_t = 1.85$

$C_p = 0.45$

$\rightarrow$ lag time = $t_p = C_t(LL_C)^{0.3}$

$= 1.85\,(80(50))^{0.3}$

$= 22.27$ hours

$\rightarrow$ Base period $= 72 + \dfrac{t_p}{8}$

$= 72 + \dfrac{22.27}{8}$

$= 72 + 2.78 = 75$ hours

$\rightarrow Q_{max} = \dfrac{2.778\ C_p A}{t_p}$

$= \dfrac{2.778(0.45)(2100)}{22.27}$

$= 120$ cumec

$\rightarrow$ Duration of RF

$$D = \frac{t_p}{5.5} = \frac{22.27}{5.5} = 4 \text{ hours}$$

01(e). (i)

Sol: True bearing = $348^o38'12''$

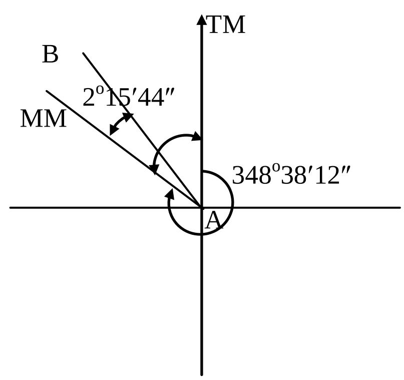
Magnetic bearing = $2^o15'44''$

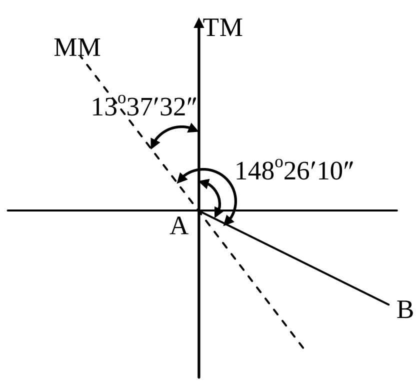
Declination = $360^o - 348^o38'12'' + 2^o15'44''$

$= 11^o21'48'' + 2^o15'44''$

$= 13^o37'32''$W

The declination is $13^o37'32''$





True bearing of the line AB = $148^o26'10'' - 13^o37'32''$

$= 134^o48'38''$

01(e). (ii)

Sol: $L = \dfrac{v^3}{\alpha R}$ $\qquad$ R = 200 m

l = 15 cm e = G tanθ = $\dfrac{G.v^2}{gR}$

v = 14 m/sec

$$L = \frac{v^3}{\alpha R} = \frac{(14)^3}{0.3 \times 200} = 46\text{m}$$

02(a).

Sol: Let Q = f(H, g, ρ, μ, σ)

Six variables namely Q, H, g, ρ, σ are given involving three fundamental units. Hence we can frame 6 – 3 = 3 dimensionless constants. Let us select H, g and ρ as repeating variables. Let the dimensionless constants be

$\pi_1 = H^{\alpha_1} g^{b_1} \rho^{c_1} Q$

$\pi_2 = H^{\alpha_2} g^{b_2} \rho^{c_2} \mu$

$\pi_3 = H^{\alpha_3} g^{b_2} \rho^{c_3} \sigma$

$$\begin{matrix} Q \\ \left.\begin{matrix} H \\ g \\ \rho \end{matrix}\right\rangle \text{Repeating variables} \\ \mu \\ \lambda \end{matrix}$$

Performing a dimensional analysis for π_1

$L^o M^o T^o = L^{a_1} \left(LT^{-1}\right)^{b_1} \left(ML^{-3}\right)^{c_1} L^3 T^{-1}$

Comparing the power of L, $0 = a_1 + b_1 - 3c_1 + 3$

Comparing the power of M, $0 = c_1$

Comparing the power of T, $0 = -2b_1 - 1$

Solving, we get $\alpha_1 = -\dfrac{5}{2}$, $b_1 = -\dfrac{1}{2}$, $c_1 = 0$

$$\pi_1 = -\frac{Q}{H^{5/2} g^{1/2}}$$

Performing a dimensional analysis for π_2

$(L^o M^o T^o) = L^{a_2} \left(LT^{-2}\right)^{b_2} \left(ML^{-3}\right)^{c_2} ML^1T^{-1}$

Comparing the power of L, $0 = a_2 + b_2 - 3c_2 - 1$

Comparing the power of M, $0 = c_2 + 1$

Comparing the power of T, $0 = -2b_2 - 1$

Solving, we get $a_2 = -\frac{3}{2}$, $b_2 = -\frac{1}{2}$, $c_2 = -1$

$$\pi_2 = -\frac{\mu}{H^{3/2} g^{1/2} \rho}$$

Performing a dimensional analysis for π_3

$$(L^o M^o T^o) = L^{a_3} \left(LT^{-2}\right)^{b_3} \left(ML^{-3}\right)^{c_3} MT^{-2}$$

Comparing the powers of L, $0 = a_3 + b_3 - 3c_3$

Comparing the powers of M, $0 = c_3 + 1$

Comparing the powers of T, $0 = -2b_3 - 2$

Solving, we get $a_2 = -2$, $b_3 = -1$, $c_3 = -1$

Solving we get $a_2 = -2$. $b_3 = -1$, $c_3 = -1$

$$\therefore \pi_3 = \frac{\sigma}{H^2 g \rho}$$

$$\pi_1 = f(\pi_2, \pi_3)$$

$$\frac{Q}{H^{5/2} g^{1/2}} = f\left(\frac{\mu}{H^{3/2} g^{1/2} \rho}, \frac{\sigma}{H^2 g \rho}\right)$$

$$\Rightarrow Q = H^{5/2} g^{1/2} f\left(\frac{\mu}{H^{3/2} g^{1/2} \rho}, \frac{\sigma}{H^2 g \rho}\right)$$

02(b). (i)

Sol: Given Data:

$H = 20$ m, S.P = 16 MW, $\eta_o = 80$, $\eta_h = 90\%$, $D_t = 42$m, $D_h = 2$m, $n_s = 3$

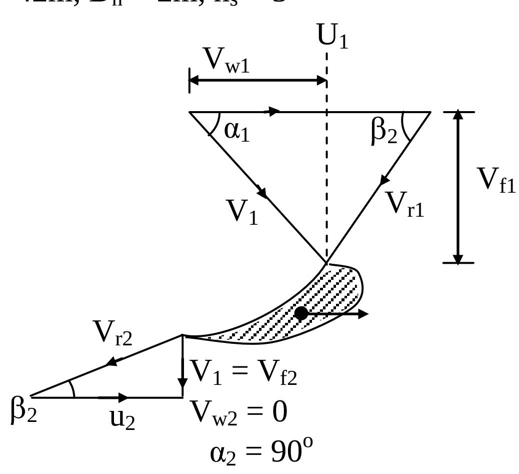
$S.P = \eta_o \rho G q h$

$16 \times 10^6 = 0.8 \times 9810 \times Q \times 20$

$\Rightarrow Q = 101.9$ m^3/s

$$n_s = \frac{w\sqrt{P/\rho}}{(gH)^{5/4}}$$

$$\therefore w = \frac{n_s \times (gH)^{5/4}}{\sqrt{P/\rho}}$$



$$= \frac{3\times(9.81\times 20)^{1.25}}{\sqrt{\frac{16\times 10^6}{1000}}} = 17.415 \text{ rad/s}$$

$$D_m = \left(\frac{D_t + D_h}{2}\right) = \left(\frac{4.2+2}{2}\right) = 3.1 \text{ m}$$

$$R_m = \frac{D_m}{2} = 1.55 \text{ m}$$

$$u_1 = u_2 = R_m \times w = 26.99 \text{ m/s}$$

$$\eta_h = \frac{V_{w_1} u_1}{gH}$$

$$\therefore\ 0.9 = \frac{V_{w_1} \times 26.99}{9.81\times 20}$$

$$V_{w1} = 6.542 \text{ m/s}$$

$$V_{f_1} = V_{f_2} = \frac{Q}{\frac{\pi}{4}\left(D_t^2 - D_h^2\right)} = \frac{101.9\times 4}{\pi\times\left(4.2^2 - 2^2\right)} = 9.511 \text{ m/s}$$

$$\tan\beta_1 = \frac{Vf_1}{u_1 - V_{w_1}} = \frac{9.511}{26.99 - 6.542}$$

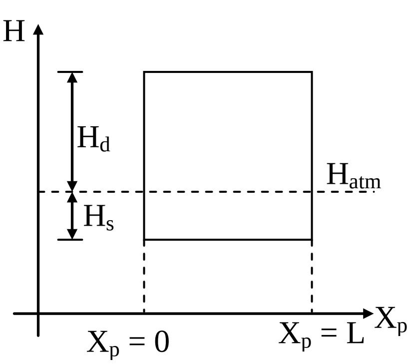
$$\Rightarrow \beta_1 = 24.95^o$$

$$\tan\beta_2 = \frac{Vf_2}{U_2} = \frac{9.511}{26.99}$$

$$\Rightarrow \beta_2 = 19.41^o$$

02(b). (ii)

Sol: Given data:



$D_p = 150$ mm

$N = 60$ rpm

$L = 250$ mm (∵ 1 rev = 2 strokes)

$H_s = 6$ m

$H_d = 15$ m

$$Q^{th} = \frac{A_p L N}{60}$$

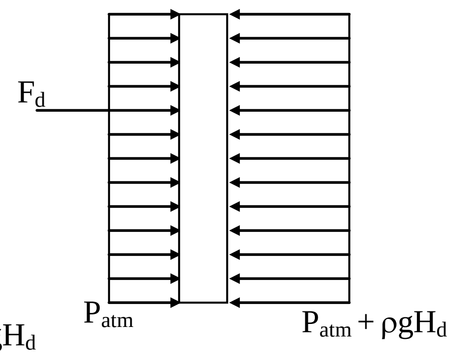
$$= \frac{\frac{\pi}{4}\times 0.15^2 \times 0.25 \times 60}{60}$$

$= 4.418 \times 10^{-3}\ m^3/s$

$P^{th} = \rho g Q^{th}\ [H_s + H_d]$

$= 9.81 \times 10^3 \times 4.418 \times 10^{-3} \times (6 + 15)$

$= 0.91$ Kw



The pressure difference across piston during delivery stroke $\rho g H_d$

$\therefore\ F_d = \rho g H_d\ A_P$

$$= 9810 \times 21 \times \frac{\pi}{4} \times 0.15^2 = 2.6\ kN$$

02(c).

Sol:

Stations	Chainage	Staff Readings (m)			H.I	R.L	Remarks
		B.S	I.S	F.S			
A		0.964			361.614	360.650	
		1.632		0.948	362.298	360.666	___ uniform gradient 1 in 40.
		1.105		1.153	362.250	361.145	
		0.850		1.984	361.116	360.266	
		0.396		1.125	360.387	359.991	
	0		0.387			360.000	
	10		0.637			359.750	
	20		0.887			359.500	
	30		1.137			359.250	
	40		1.387			359.000	
	50		1.637			358.750	
	60			1.881		358.500	
		ΣBS = 4.947		ΣFS = 7.097			

$\Sigma BS - \Sigma FS = -2.15$

Last R.L. 1st R.L = 2.15, hence checked.

03(a).

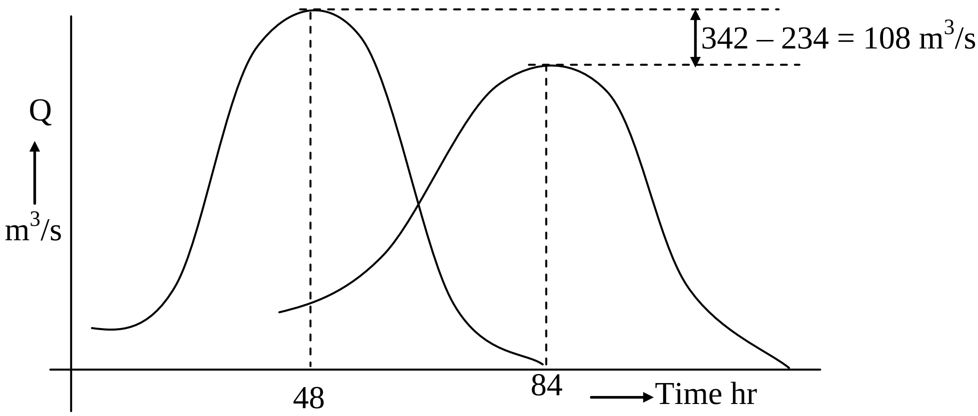
Sol: $C_o = \dfrac{-kx + 0.5\Delta t}{k - kx + 0.5\Delta t} = 0.02$

$C_1 = \dfrac{kx + 0.5\Delta t}{k - kx + 0.5\Delta t} = 0.31$

$C_2 = 1 - C_o - C_1 = 0.67$

$Q_2 = C_oI_2 + C_1 I_1 + C_2O_1$

Time	Inflow (I) cumec	Outflow $O_n = C_oI_n + C_1I_{n-1} + C_2O_{n-1} = 0.02\ I_n + 0.31\ I_{n-1} + 0.67\ O_{n-1}$	O_n
0	42		42
12	45	0.02(45) + 0.31(42) + 0.67 (42)	42.1
24	88	0.02 (88) + 0.31(45) + 0.67(42.1)	44
36	272	0.02 (272) + 0.31(88) + 0.67 (44)	62.2
48	342	0.02 (342) + 0.31 (272) + 0.67 (62.2)	132.8
60	288	0.02 (288) + 0.31(342) + 0.67 (132.8)	200.7
72	240	0.02 (240) + 0.31(288) + 0.67 (200.7)	233.00
84	198	0.02 (198) + 0.31 (240) + 0.67 (233.00)	234.00
96	162	0.02(162) + 0.31(198) + 0.67 (234.00)	221.6
108	133	0.02 (133) + 0.31(162) + 0.67 (221.6)	201.6
120	110	0.02 (110) + 0.31 (133) + 0.67 (201.0)	178.9
132	90	0.02 (90) + 0.31(110) + 0.67 (178.9)	155.7
144	79	0.02 (79) + 0.31 (90) + 0.67 (155.7)	133.5
156	68	0.02(68) + 0.31(79) + 0.67 (433.5)	115.3
163	61	0.02 (61) + 0.31(68) + 0.67(115.3)	99.7



Attenuation = Drop in peak flood

$= (Q_{max})_{IHG} - (Q_{max})_{OHG}$

$= 342 - 234$

$= 108$ Cumec

Basin lag = $t_{max\ Q\ of\ OHG} - t_{max\ Q\ of\ IHG}$

$= 84 - 48$

$= 36$ hours

03.(b)

Sol: Given Data:

$W = 1000$ N, $V_1 = 40$ m/s

$C_D = 1.3$, $\rho = 1.2$ kg/m^3

$V_2 = 4$ m/s

By Newton's second law of motion,

$\Sigma \vec{F} = m\vec{a}$

i.e $W - F_D = m\dfrac{dv}{dt} \qquad \rightarrow (1)$

When parachute comes down with steady sinking speed acceleration is zero

$\therefore W - F_D = 0$

$$1000 = \frac{C_D}{2} \times \rho A V^2$$

$$A = \frac{2\times1000}{1.2\times1.3\times4^2} = 80.13\ m^2$$

From equation (1)

$$W - \frac{C_D}{2}\rho A V^2 = m\frac{dv}{dt}$$

$$\therefore\ dt = \frac{mdv}{W - \frac{C_D}{2}\rho A V^2}$$

$$\text{i.e}\ \ dt = \frac{\frac{2m,}{C_D\rho A}dv}{\frac{2W}{C_D\rho A} - V^2}$$

$$dt = \frac{bdv}{a^2 - V^2} \rightarrow (3)$$

Where

$$b = \frac{2m}{C_b\rho A} = \frac{2\times100}{1.3\times1.2\times80.13} = 1.6$$

$$a = \sqrt{\frac{2W}{C_D\rho A}} = \sqrt{\frac{2\times1000}{1.3\times1.2\times80.13}} = 4$$

Integrating on both sides

$$\int dt = \int\frac{bdv}{d^2 - v^2} + c$$

$$t = \frac{b}{2a}\ell n\left|\frac{a+v}{a-v}\right| + c$$

At t = 0, V = 40 m/s

$$\therefore\ c = \frac{-1.6}{2\times4}\times\ell n\left|\frac{4+40}{4-40}\right| = 0.04$$

$$\therefore\ t = \frac{b}{2a}\ell n\left|\frac{1+v/a}{1-v/a}\right| - 0.04$$

Note: $a = \sqrt{\frac{2W}{C_b\rho A}} = 4m/s$ **=** Equilibrium sinking speed at 99.9% equilibrium speed v/a = 0.999

$$\therefore\ T = \frac{1.6}{2\times 4}\ell n\left|\frac{1.999}{0.001}\right| - 0.04$$

$$= 1.48 \text{ sec}$$

From equation (1)

$$W - F_D = m\frac{dv}{dy}\frac{dy}{dt}$$

$$W - \frac{C_D}{2}\rho AV^2 = mv\frac{dv}{dy}$$

$$\therefore\ dy = \frac{m}{W - \frac{C_D}{2}\rho AV^2}.vdv \rightarrow (4)$$

Comparing equation (2) (3) and (4)

$$dy = \frac{bvdv}{a^2 - V^2}$$

$$\therefore\ y = b\int\frac{vdv}{d^2 - v^2} + c$$

$$= \frac{-b}{2}\int\frac{(-2v)dv}{a^2 - v^2} + c$$

$$y = \frac{-b}{2}\ell n\left|4^2 - v^2\right| + c$$

At y = 0, v = 40 m/s

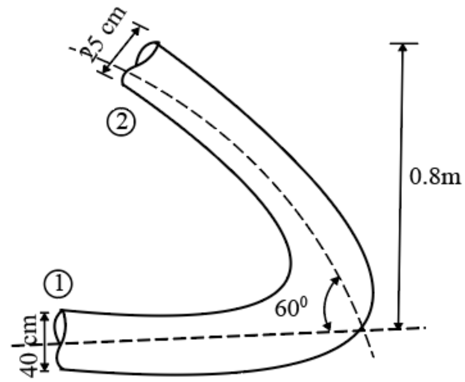
$$\Rightarrow c = \frac{1.6}{2}\ell n\ a^2\left|\left(1 - \left(\frac{V}{a}\right)^2\right)\right| + 5.89$$

$$= \frac{-1.6}{2}\ell n\left|16\left(1 - 0.999^2\right)\right| + 5.89$$

$$= 8.648 \text{ m}$$

03(c).

Sol: By continuity equation:



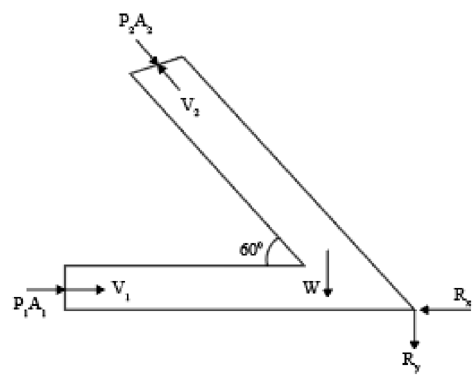
$A_1V_1 = A_2V_2$ (or) $D_1^2V_1 = D_2^2V_2$

$$\Rightarrow V_2 = V_2\left(\frac{D_2^2}{D_1^2}\right)$$

$V_1 = 5.86$ m/s $\rightarrow$ (1)

By Bernoulli equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + Z_2 + \cancel{h}$$



$$P_1 = \gamma\left(\frac{V_2^2 - V_1^2}{2g} + Z_2\right)$$

$$= 9.81\left(\frac{15^2 - 5.86^2}{2\times 9.81} + 0.8\right)$$

$P_1 = 103.178$ kPa

By Momentum Flux equation:

$\sum F_x = \dot{m}(V_2 - V_1)_x$

$\Rightarrow P_1A_1 + \cancel{P_2A_2 \cos 60^o}^{\,o} - R_x = \rho A_1V_1 (V_{2x} - V_{1x})$

$R_x = P_1A_1 - \rho A_1V_1 (V_{2x} - V_{1x})$

$$= (103.178)\frac{\pi}{4}(0.4)^2 \times 10^3 - 10^3 \times \frac{\pi}{4}(0.4)^2 \times 5.86(-15\cos 60 - 5.86)$$

$= 125.66 (103.178 + 78.29)$

$F_x = 22.803$ kN ($\leftarrow$)

$\sum F_y = \dot{m}(V_{y_2} - \cancel{V_{y_1}}^{\,o})$

$-W - \cancel{P_2 A_2 \sin 60}^{\,o} + R_y = \rho A_1V_1(V_2 \sin 60)$

$\Rightarrow R_y = W + \rho\, A_1V_1\, V_2 \sin 60^o$

$R_y = 1000 + 10^3 \times \frac{\pi}{4}(0.4)^2 \times 5.86 \times 15 \sin 60^o$

$R_y = 9.565$ kN ($\uparrow$)

$R = \sqrt{R_x^2 + R_y^2}$

$= \sqrt{22.803^2 + 9.565^2}$

$R = 24.728$ kN

Angle of action $= \tan^{-1}\left(\frac{9.565}{22.803}\right)$

$= 22.756^o$

04(a).

Sol:

Tangent length = $R \tan\frac{\Delta}{2}$ = 7.074 chains = 141.48 m

Length of the curve = $\frac{\pi R \Delta}{180}$ = 13.221 chains = 264.42 m

Change of P.I = 59 + 60 = 1192.00 m

Change of T_1 = 1192 – 141.48 = 1050.52 m

Change of T_2 = 1050.52 + 264.42 = 1314.94 m

Length of 1st sub chord = 1060 – 1050.52 = 9.48 m = C_1

Length of last sub chord = 1314.94 – 1300 = 14.94 m

C_{13} = 20 m, R = 15 × 20 = 300 m, C_{14} = 14.94 m

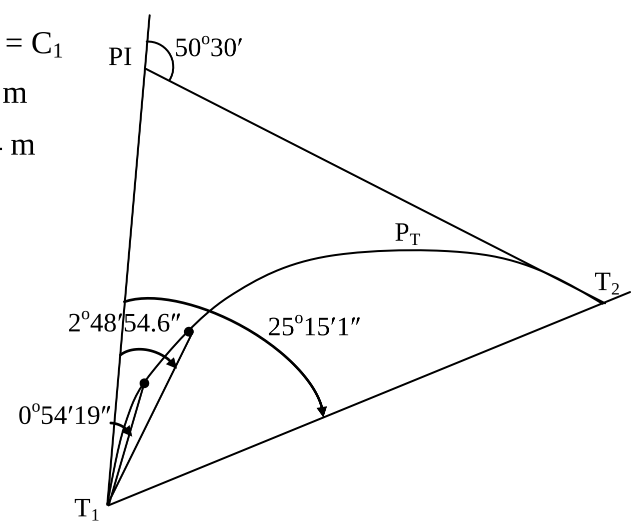
$\delta_1 = 1718.9\frac{C_1}{R} = 0^o 54' 19''$

$\delta_2 = \delta_{13} = 1718.9 \times \frac{20}{300} = 1^o 54' 35.6''$

$\delta_{14} = 1718.9 \times \frac{14.94}{300} = 1^o 25' 35''$

$\Delta_1 = \delta_1 = 0^o\, 54'\, 19''$

$\Delta_2 = \delta_1 + \delta_2 = 2^o\, 48'\, 54.6''$



$\Delta_3 = \Delta_2 + \delta_3 = 4^o\ 43'\ 30.2''$

$\Delta_4 = \Delta_3 + \delta_4 = 6^o\ 38'\ 5.8''$

$\Delta_5 = \Delta_4 + \delta_5 = 8^o\ 32'\ 41.4''$

$\Delta_6 = \Delta_5 + \delta_6 = 10^o\ 27'\ 17''$

$\Delta_7 = \Delta_6 + \delta_7 = 12^o\ 21'\ 52.6''$

$\Delta_8 = \Delta_7 + \delta_8 = 14^o\ 16'\ 28.2''$

$\Delta_9 = \Delta_8 + \delta_9 = 16^o\ 11'\ 3.8''$

$\Delta_{10} = \Delta_9 + \delta_{10} = 18^o\ 5'\ 39.4''$

$\Delta_{11} = \Delta_{10} + \delta_{11} = 20^o\ 0'\ 15''$

$\Delta_{12} = \Delta_{11} + \delta_{12} = 21^o\ 54'\ 50.6''$

$\Delta_{13} = \Delta_{12} + \delta_{13} = 23^o\ 49'\ 26.2''$

$\Delta_{14} = \Delta_{13} + \delta_{14} = 25^o\ 15'\ 1'' = \dfrac{\Delta}{2}$

04(b). (i)

Sol: Let $F_{r1} \rightarrow$ Froude no before hydraulic jump

$F_{r2} \rightarrow$ Froude no after hydraulic jump

$\therefore\ F_{r1} = \dfrac{V_1}{\sqrt{gy_1}}$; $F_{r2} = \dfrac{V_2}{\sqrt{gy_2}}$

$V_1 = F_{r1}\sqrt{gy_1}$; $V_2 = F_{r2}\sqrt{gy_2}$

From Continuity equation

$y_1V_1 = y_2V_2$

$\Rightarrow y_1\, F_{r1}\sqrt{gy_1} = y_2\, F_{r2}\sqrt{gy_2}$

$\Rightarrow \left(\dfrac{y_1}{y_2}\right)^{3/2} = \dfrac{F_{r2}}{F_{r1}}$

$\Rightarrow \dfrac{y_1}{y_2} = \left(\dfrac{F_{r2}}{F_{r1}}\right)^{2/3} \rightarrow (1)$

Also we know $\dfrac{y_1}{y_2} = \dfrac{2}{\sqrt{1+8F_{r1}^2}-1} \rightarrow (2)$

$\therefore$ From (1) & (2)

$$\left(\frac{F_{r2}}{F_{r1}}\right)^{2/3} = \frac{2}{\sqrt{1+8F_{r1}^2}-1}$$

$$\Rightarrow \frac{F_{r2}}{F_{r1}} = \left[\frac{2}{\sqrt{1+8F_{r1}^2}-1}\right]^{3/2}$$

$$F_{r2} = F_{r1}\left[\frac{2}{\sqrt{1+8F_{r1}^2}-1}\right]^{3/2}$$

04(b). (ii)

Sol: $\Delta h = h_2 - h_1 = 0.4$ m

$r_1 = 0.3$ m

$r_2 = 0.6$ m

$$\Delta h = \frac{\omega^2}{2g}\left[r_2^2 - r_1^2\right]$$

$$\Rightarrow 0.4 = \frac{\omega^2}{2\times 9.81}\left(0.6^2 - 0.3^2\right)$$

$$\Rightarrow \omega^2 = \frac{0.8\times 9.81}{0.6^2 - 0.3^2}$$

$\Rightarrow \omega = 5.39$ rad/s

$$N = \frac{60\omega}{2\pi} = \frac{60\times 5.39}{2\times 3.14}$$

N = 51.48 rpm

04(b). (iii)

Sol: When a constrained fluid is pressurized, then every point in the fluid experiences a rise in pressure by same magnitude.

Proof:

Consider a small fluid element ABC as shown:

$\sum F_x = 0$

$\Rightarrow P_x (BC) = P_2 \, AC \sin \alpha$

$\because \; AC \sin \alpha = BC$

$P_x = P_2$

similarly $\sum F_y = 0$

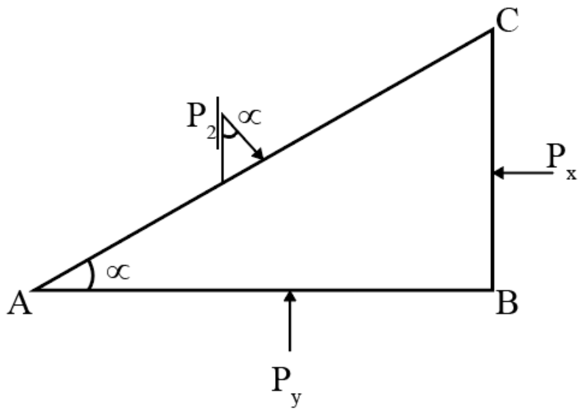
$\Rightarrow P_y (AB) = P_2 \, AC \cos \alpha$

$\because \; AC \cos \alpha = AB$

$\Rightarrow P_y = P_2$

$\Rightarrow P_x = P_y = P_2$

Hence proved

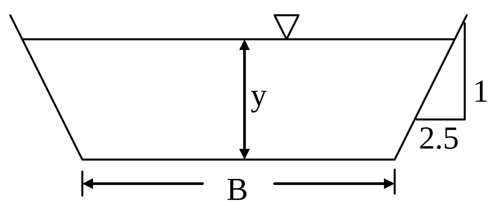


04(c). (i)

Sol: $Q = 36 \text{ m}^3/\text{s}$

For hydraulically efficiency channel

Wetted perimeter should be minimum



$$\frac{dP}{dy} = 0$$

$$P = B + 2y\sqrt{(2.5)^2 + (1)^2}$$

$A = By + 2.5\,y^2$

$$B = \frac{A}{y} - 2.5y$$

$$P = \frac{A}{y} - 2.5y + 2\sqrt{7.25}y$$

$$P = B + 2y\sqrt{2.5^2 + 1^2}$$

$$= \frac{A}{y} + 2.885\,y$$

$$\frac{dP}{dy} = \frac{-A}{y^2} + 2.885 = 0$$

$A = 2.885\,y^2$

$P = 2\,(2.885y)$

$$R = \frac{A}{P} = \frac{y}{2}$$

$$Q = \frac{A}{N} R^{2/3} S^{1/2} = \frac{2.885y^2}{N}\left(\frac{y}{2}\right)^{2/3} S^{1/2}$$

For lined canal

$$36 = \frac{2.885y^2}{0.015}\left(\frac{y}{2}\right)^{2/3}\left(\frac{1}{2500}\right)^{1/2}$$

$\Rightarrow y^{8/3} = 14.844$

$\Rightarrow y = 2.75$ m

$B = 1.06$ m

For unlined canal

$$36 = \frac{2.885y^2}{0.028}\left(\frac{y}{2}\right)^{2/3}\left(\frac{1}{2500}\right)^{1/2}$$

$\Rightarrow y = 3.48$ m $B = 1.34$ m

04(c). (ii)

Sol: Given that $V = \sqrt{\frac{2}{5} fR}$

$Af^2 = 140\ V^5$

$$\Rightarrow Af^2 = 140\left(\frac{2}{5} fR\right)^{5/2}$$

$$Af^{-1/2} = 140\left(\frac{2}{5} R\right)^{5/2}$$

$$\frac{A}{\sqrt{f}} = 140\left(\frac{V}{\sqrt{f}}\right)^5$$

Multiplying with V on both sides,

$$\frac{AV}{\sqrt{f}} = 140\frac{V^6}{f^{5/2}}$$

$$Q = 140\frac{V^6}{f^2}$$

$$V = \left(\frac{Qf^2}{140}\right)^{1/6}$$

$$V = \left(\frac{2}{5}fR\right)^{1/2}$$

$$V^2 = \frac{2}{5}f\frac{A}{P}$$

$$P = \frac{2}{5}\frac{fA}{V^2} = \frac{2}{5V^2}(Af)$$

But we know $Af^2 = 140\ V^5$

$$Af = \frac{140V^5}{f}$$

$$P = \frac{2}{5V^2}\frac{140V^5}{f} = \frac{280}{5}\frac{V^3}{f}$$

$$P = \frac{280}{5f}\left(\frac{Qf^2}{140}\right)^{3/6}$$

$$= \frac{280}{5(140)^{3/6}}\sqrt{Q}$$

$$= 4.73286\sqrt{Q}$$

$$\Rightarrow P = 4.75\sqrt{Q}$$

Hence proved

05(a).

Sol: B = 5 m

y = 2.5 m

Side slope 1.5 H : 1V $\quad S = \frac{1}{1000}$, N = 0.016

For a lined canal

$A = By + y^2 (\theta + \cot\theta)$

$P = B + 2y (\theta + \cot\theta)$

$\cot\theta = \frac{H}{V} = 1.5 \qquad \theta = \cot^{-1}(1.5) = 0.5880$

$\theta + \cot\theta = 0.5880 + 1.5 = 2.088$

$A = By + y^2 (\theta + \cot\theta)$

$= 12.5 + 6.25 (2.088) = 25.55 \text{ m}^2$

$P = B + 2y (\theta + \cot\theta)$

$= 5 + 5(2.088) = 15.44 \text{ m}$

$$R = \frac{A}{P} = \frac{25.55}{15.44} = 1.655 \text{ m}$$

$Q = AV$

$$= A\frac{1}{N}R^{2/3}S^{1/2}$$

$$= 25.55\ \frac{1}{0.016}(1.655)^{2/3}\left(\frac{1}{1000}\right)^{1/2}$$

$= 70.65 \text{ m}^3/\text{s}$

(ii) In a time of 10 days, volume of water which can be supplied by the channel

$= 70.65 \times 10 \times 24 \times 60 \times 60$

$= 61.04 \times 10^6 \text{ m}^3.$

$\forall = A (y_f)$

$$A = \frac{\forall}{y_f} = \frac{61.04 \times 10^6}{150 \times 10^{-3} \times 10^4} \text{ha}$$

$= 40,693$ ha

05(b). (i)

Sol:

Effects of tunneling on the ground:

1. The tunneling process deteriorates the physical conditions of the ground. This happens because due to heavy and repeated blasting during excavation, the rocks get shattered to a great extent and develop numerous cracks and fractures. This reduces the cohesiveness and compactness of rocks. In other words, rocks become loose and more fractured and porous. This naturally adversely affects the competence of the rocks concerned.
2. Further, as a consequence of underground tunneling, the overlying rocks are deprived of support from the bottom, which means they are rendered unstable.

3. Such unstable conditions become still more precarious if the tunneled beds are incompetent or loose or unconsolidated or saturated with ground water.
4. Unstable conditions may also result when the beds involved are many, heterogeneous, and inclined along the tunnel. It is more so if the beds are alternatingly hard and soft.
5. Fault zones and shear zones are naturally potentially weak, and tunneling through them further deteriorates them and causes stability problems.
6. Stability of the ground may be jeopardized when the tunneled ground has unfavourable ground water conditions.

05(b). (ii)

Sol:

Geological considerations in the selection of a Dam Site:

In a way, the success of a dam is not only related to its own safety and stability but also to the success of associated reservoirs. In other words, on construction, if a dam stands firmly but if its reservoir leaks profusely (as in the case of the Cedar Lake dam or Malpasset dam) then such a dam is to be treated only as a failure because the purpose for which it was constructed has not been served. In such a case, the dam may be successful structurally but virtually (i.e, indirectly) it is a failure. Therefore, utmost care is needed in palling for the success of both the dam and the reservoir. First, it shall be proper to consider the various factors responsible for the success of a dam alone and later the factors for the success of a reservoir.

1. Narrow river valley
2. Occurrence of the bedrock at a shallow depth
3. Competent rocks to offer a stable foundation
4. Proper geological structure.

05(c).

Sol:

(i) Correction for absolute length = $+\dfrac{(30.0150-30.00)}{30.00}\times 114.095$

$= +\ 0.0570$ m

(ii) Temperature correction = $L\alpha(T - T_1)$

$= 114.095 \times 1.15 \times 10^{-5} \times (12^{o} - 20^{o})$

$= -\ 0.01049674$ m

(iii) Pull correction $=\dfrac{(P-P_1)L}{AE}$

$$=\frac{(100-70)(114.095)}{(0.028)(2.1\times 10^{7})}=+.0058211\,\text{m}$$

(iv) Sag correction = $\dfrac{W^2L}{24P^2}$(negative)

$$=\left(\frac{9^2\times 30}{24\times 100^2}\right)(3)+\frac{\left(\frac{9}{30}\times 24.095\right)^2(24.09)}{24\times 100^2}$$

= 0.030375 + 0.005245 = 0.356208 (negative)

(v) Correction for slope = $-\dfrac{d^2}{2L}$

$$=-\frac{2.5\times 2.5}{2\times 100}=-0.3125\,\text{m}/100\text{m}$$

For 114.095 m, slope correction

$$=-\frac{0.3125}{100}\times 114.095=-0.356546\,\text{m}$$

Hence total correction

$= +\ 0.0570 - 0.01049 + 0.0058 - 0.0356 - 0.03565$

$= -\ 0.01894$

Corrected length = 114.076 m

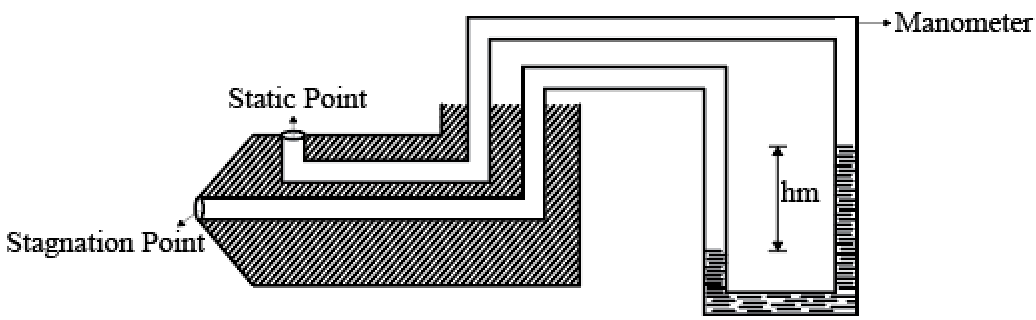
05(d). (i)

Sol:

Free Vortex Motion	Forced Vortex Motion
External torque is zero	Constant external torque acts on the fluid body
Flow is irrotational	Flow is rotational
$Vr = C \Rightarrow V \propto \frac{1}{r}$	$\omega.c \Rightarrow \frac{v}{r} = c \Rightarrow v \propto r$
$\frac{P}{\gamma} + \frac{V^2}{2g} + Z = C$	$\frac{P}{\gamma} - \frac{V^2}{2g} + Z = C$

05(d). (ii)

Sol:



$$V_{th} = \sqrt{2g\Delta h^*}$$

$$V_{ac} = C_v \ V_{th}$$

$$\Delta h^* = h_m\left(\frac{S_m}{S_w} - 1\right)$$

$$\Rightarrow V_{ac} = C_v\sqrt{2gh_m\left(\frac{S_m}{S_w} - 1\right)}$$

05(d). (iii)

Sol: W = 50 × 10^6 N

P = 75 × 10^3 N

x = 5 m

$$\tan\theta = \frac{25\times10^{-3}}{2}$$

$$GM = \frac{Px}{W\tan\theta}$$

$$\Rightarrow\ GM = \frac{75\times10^3\times5\times2}{50\times10^6\times25\times10^{-3}}$$

GM = 0.6 m

05. (e)

Sol: Given data:

$R_{e_{cr}} = 5\times10^5$, U_∞ = 45 m/s   ν = 1.5 × 10^{-5} m^2/s

x = 0.1 m, y = 2 × 10^{-4} m

$$Re_{cr} = \frac{V_o x_{cr}}{\nu}$$

$$5\times10^5\ \frac{45\times x_{cr}}{1.5\times10^{-5}}$$

x_{cr} = 0.167 m

As per Blasius solution,

$$\frac{U}{U_\infty} = f(\eta) \text{ where } \eta = y\sqrt{\frac{U_\infty}{\nu x}}$$

$$\therefore\ \eta = 2\times10^{-4}\times\sqrt{\frac{45}{1.5\times10^{-4}\times0.1}} = 0.346$$

$$\text{At } \eta = 0.3,\ \frac{U}{U_\infty} = 0.0996$$

$$\text{At } \eta = 0.4,\ \frac{U}{U_\infty} = 0.13276$$

∴ at η = 0.346

$$\frac{U}{U_\infty} = 0.0996 + \frac{0.13276 + 0.0996}{0.4 - 0.3} \times (0.346 - 0.3)$$

$= 0.11465$

$\therefore\ u = 0.11485 \times 45$

$= 5.168$ m/s

06(a).

Sol: (i) The checking for inconsistency of a record is done by the double-mass curve technique. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent.

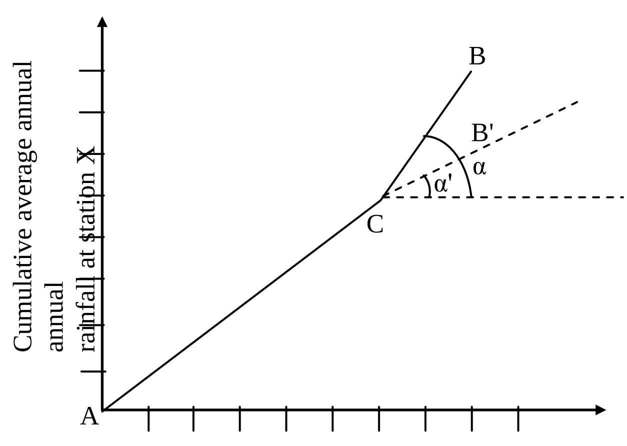
The accumulated precipitation of the station X (i.e ΣP_x) and the accumulated values of the average of the group of base stations (ΣP_{av}) are calculated starting from the latest record.

The double mass curve technique is used to test the consistency of rainfall record at any raingauge station which is suspended to contain certain discrepancies.

The data found to be inconsistent can also be adjusted by multiplying it with a correction factor which is nothing but the ratio of the slope of the adjusted mass curve to the slope of the unadjusted mass curve. Again referring to figure the data of station X is inconsistent during the period 1941 to 1953. The adjusted rainfall of station X in any year during this period, P' can be obtained as

$$P' = \frac{\tan\alpha'}{\tan\alpha} P$$

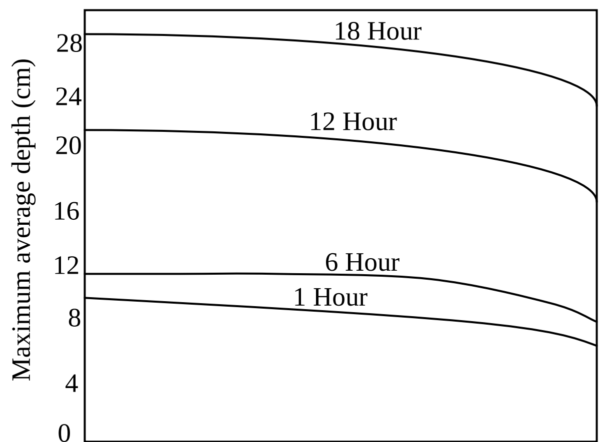
Where P is the observed rainfall at station X in the same year, $\tan\alpha'$ is the slope of the adjusted mass curve (slope of CB') and $\tan\alpha$ is the slope of the unadjusted mass curve (slope of CB).



(ii) DAD Analysis

A storm of given duration over a particular area rarely produces uniform rainfall depth over the entire area. The storm usually has a centre where the rainfall P_o, is maximum and this is always larger than the average depth of rainfall P, applicable for the area as a whole. Generally the difference between these two values, that is $(P_o - P)$, increases with increase in area and decreases with increase in the duration.

The results are then plotted on semilogarithmic paper. That is, for each duration the maximum average depth of rainfall on an ordinary scale is plotted against the area on logarithmic scale. If a storm contains more than one storm centres, the above analysis is carried out for each storm centre. An enveloping curve is drawn for each duration. Alternatively for each duration a depth-area relation of the form $P = P_o e^{-kA^n}$



It may be seen that the maximum depth for a given storm decreases with the area; for a given area the maximum depth increases with the duration.

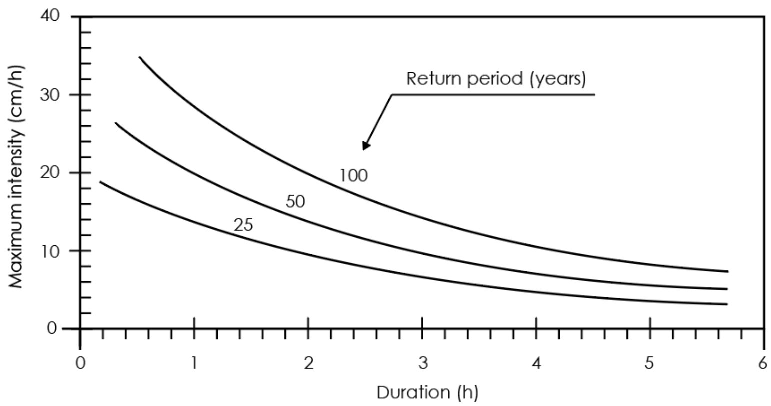
(iii) Intensity – frequency – duration curves

If the rainfall data from a recording rainguage is available for a longer period such as 40 or 50 years, the frequency of occurrence of a given maximum intensity can also be determined. Then we obtain the intensity-frequency-duration relationships.

Every storm in a year is analysed to find the maximum intensities for various durations as decreased in the previous section. Thus each storm gives one value of maximum intensity for a given duration. The largest of all such values is taken to be the maximum intensity in that year for the duration. Likewise the annual maximum intensity is obtained for all the duration.

It will then be observed that the annual maximum intensity for any given duration is not the same every year but it varies from year to year.

From the curve intensity-frequency duration graph is plotted with duration on x-axis and intensity on y-axis for different return periods.



Maximum Intensity - Duration - Frequency Curves

(iv) Raingauge Network

Since the catching area of a raingauge is very small compared to the areal extent of a storm, it is obvious that to get a representative picture of a storm over a catchment the number of raingauges should be as large as possible, i.e. the catchment area per gauge should be small. On the other hand, economic considerations to a large extent and other considerations, such as topography, accessiblilty, etc. to some extent restrict the number of gauges to be maintained. Hence one aims at an optimum density of gauges from which reasonably accurate information about the storms can be obtained from which reasonably accurate information about the storms can be obtained. Towards this the World Meteorological Organisation (WMO) recommends the following densities.

1. In flat regions of temperate, Mediterranean and tropical zones:
   Ideal - 1 station for 600 – 900 km^2
   Acceptable – 1 station for 900-3000 km^2;
2. In mountainous regions of temperate, Mediterranean and topical zones:
   Ideal – 1 station for 100 – 250 km^2
   Acceptable – 1 station for 250-1000 km^2 and
3. In arid and polar zones: 1 station for 1500-10,000 km^2 depending on the feasibility.

Ten percent of raingauge stations should be equipped with self-recording gauges to know the intensities of raingall.

From practical considerations of Indian conditions, the Indian Standard (IS: 4987-1968) recommends the following densities as sufficient.

1. In plains : 1 stations per 520 km^2
2. In regions of average elevation 1000 m : 1 station per 260-390 km^2; and
3. In predominantly hilly areas with heavy rainfall: 1 station per 130 km^2.

06(b).

(i) Radar measurement of rainfall

The meteorological radar is a powerful instrument for measuring the areal extent, location and movement of rain storms. Further, the amounts of rainfall over large areas can be determined through the radar with a good degree of accuracy.

The radar emits a regular succession of pluses of electromagnetic radiation in a narrow beam.

Meteorological radar operate with wavelengths ranging from 3 to 10 cm, the common values being 5 and 10 cm. For observing details of heavy flood producing rains, a 10-cm radar is used while for light rain and snow a 5-cm radar is used. The hydrological range of the radar is about 200 km. Thus a radar can be considered to a remote-sensing super gauge covering an areal extent of as much as 100,000 kms.

(ii) Location of raingauge

- The ground must be level and in the open and the instrument msut present a horizontal catch surface.
- The gauge must be set as near the ground as possible to reduce wind effects but it must be sufficiently high to prevent splashing, flooding etc.
- The instrument must be surrounded by an open fenced area of at least 5.5 m × 5.5 m. No object should be nearer to the instrument than 30 m or twice the height of the obstruction.

(iii) Water budget and energy balance method

(a) Water Budget Method:

- It is the simplest of the three analytical methods and is also the least reliable.
- It involves writing the hydrological continuity equation for the lake and determining the evaporation from a knowledge or estimation of other variables.

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E_L + \Delta S + T_L$$

Where,

P = Precipitation

V_{is} = surface inflow into the lake

V_{ig} = groundwater inflow

V_{os} = surface outflow from the lake

V_{og} = seepage outflow

E_L = Lake evaporation

ΔS = Increase in lake storage

T_L = Transpiration loss

(b) Energy Budget Method:

- Application of the law of conservation of energy

Evaporation rate, $E_r = \dfrac{R}{L.\rho}$

Where,

R = radiation, Watts/m^2.

L = Latent heat of vaporization (J/kg)

ρ = mass density of water (kg/m^3)

Bowen ratio $\beta = \dfrac{H_a}{H_e}$

Where,

H_a = Sensible heat transfer from water surface to air

H_e= Heat energy used up in evaporation – used in the energy balance method.

Radiation is measured by an instrument called, *Radiometer*.

(iv) Advantages & Disadvantages of weighing bucket type and tipping bucket type recording raingauges

The biggest advantage of the tipping bucket gauge is that it is the only recording raingauge which cssan be used in remote places by installing the recorder at a convenient and easily accessible location.

The main usefulness of this type of gauge is that it can record snow, hail and mixture of rain and snow. All forms of precipitation are wighed and recorded in equivalent depth automatically. The disadvantages quoted against this gauge include : (i) the effects of temperature and friction on weighing mechanism may introduce errors in the record, (ii) shrinkage and expansion of the chart paper caused by changes in humidity may distort the time and the scale of rainfall, and (iii) failure of reverse mechanism results in the loss of record.

The disadvantages of this type of gauge are as follows. If the buckets are designed to tip at a convenient frequency for a particular intensity of rainfall, they will tip either too soon or too late for other intensities. As a result both the intensity and amount of rainfall recorded will be in error except during a storm which has the same intensity for which the buckets are designed. The record obtained from this gauge is not in a convenient form. For higher intensites the bucket tips so rapidly that the jogs in the record tend to overlap and blend into one broad solid line making it jogs in the record during that period

06(c).

Sol: Three-point Problem

Fixing the plotted position of the station occupied by the plane table by means of observations to three well-defined points whose plotted positions are known, is called three - point problem.

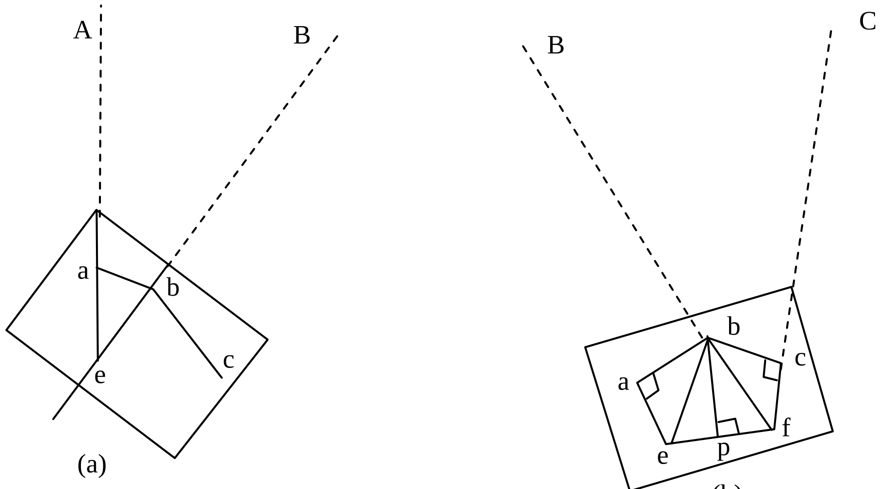
Say A, B and C are three well-defined points and their plotted positions are a, b and c, respectively. The plane table is at station P and its plotted position 'P' is to be found. Any one of the following three methods can be used to solve this problem:

1. Mechanical Method (Tracing Paper Method)
2. Graphical Method, or
3. Trial and Error Method (Lehman's Method).

Trial and Error Method

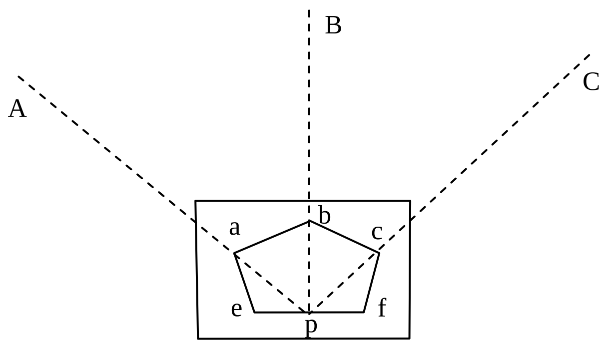
This method is also known as Lehman's method and Triangle of Errors method. The method is as given below:

1. Set the table above point P and orient approximately by looking at station A, B, C and their plotted positions a, b, and c. Clamp the table.



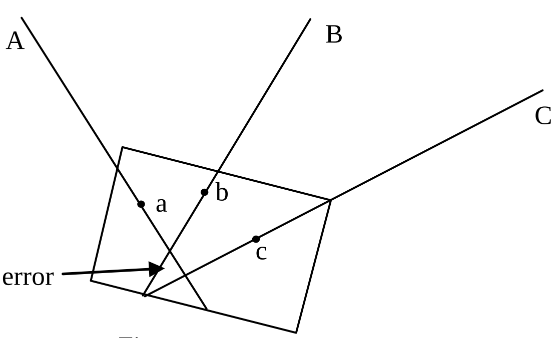
(a)

(b)



(c)

2. Draw the rays aA, bB and cC. If orientation is not correct a triangle is formed (Fig. below). This is called triangle of error.



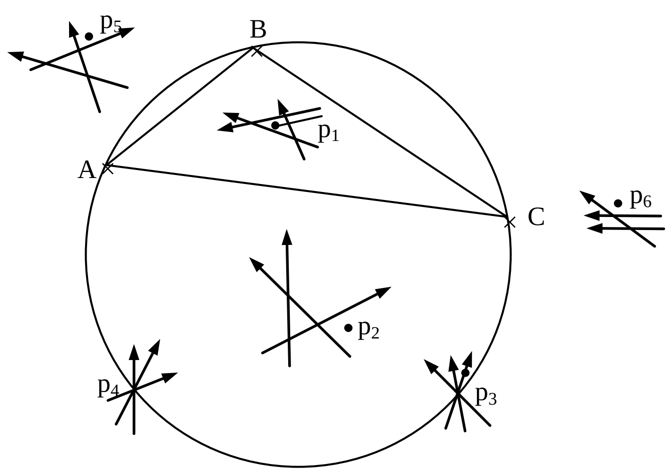
Figure

3. To eliminate the triangle of error and get a point 'P' an approximate position of p say P is selected near the triangle of error. Keeping alidade along p' a orientation of table is slightly changed to sight A. Table is clamped and resectors Bb and Cc are drawn. The size of triangle of error reduces.
4. Step 3 is repeated till triangle of error is eliminated and all the three resectors Aa, Bb, Cc pass through a point. That point is the position of station P and that orientation is the required orientation.

The following rules presented by Lehman assist in getting correct orientation quickly.

Rule 1: The distance of point sought (p) is in the same proportion from the corresponding rays as the distance of those from the plane table station.

Rule 2: The point sought 'p' is on the same side of all the three resectors (Aa, Bb and Cc). Defining the triangle ABC on the field as great triangle and the circle passing through ABC on the field as great circle [Ref. Fig. below], from the above two rules, the, following sub-rules can be derived which help in selecting trial point p' so that final position of 'p' is quickly obtained.



(a) If the plane table station P lies inside the great triangle ABC, 'p' lies inside the triangle of error (Ref. p_1)

(b) If the plane table station P lies outside the great triangle the point sought 'p' will be outside the triangle of errors (Ref. p_2)

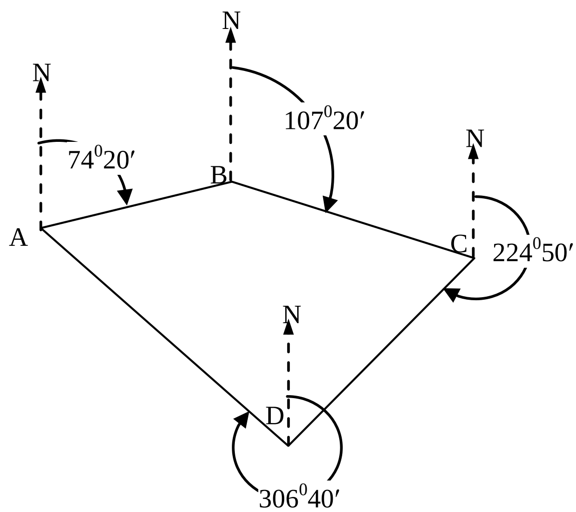
(c) If the plane table station lies on the great circle, correct solution is indeterminate since all the rays intersect at a single point irrespective of the three positions. [Ref. Points p_3 and p_4].

(d) If the station P is outside the great circle point sought is nearer to the intersection of rays to the nearest two stations [Ref. p_5].

(e) If point P is outside the great circle and the two rays drawn are parallel to each other the point sought is outside the parallel lies and on the same side of all the three rays [Ref. p_6]

07(a).

Sol:



From above figure

Interior angle at A = bearing of AD - bearing of AB

$= 126^0\ 00' - 74^0 20' = 51^0 40'$

Interior angle at B = bearing of BA - bearing of BC

$= 256^0 00' - 107^0 20' = 148^0 40'$

Interior angle at C = bearing of CB - bearing of CD

$= 286^0 20' - 224^0 50' = 61^0 30'$

Exterior angle at D = bearing of DA - bearing of DC

$= 306^0 40' - 44^0 50' = 261^0 50'$

Interior angle at D = $360^0 - 261^0 50' = 98^0 10'$

Sum of interior angles = $51^0 40' + 148^0 40' + 61^0 30' + 98^0\ 10'$

$= 360^0 00'$

Theoretical sum $= (2n-4) \times 90^0 = (2 \times 4-4) \times 90^0$

$= 360^0$

Where n is number of lines in a traverse

Therefore, no correction is required for the included angles. If the computed sum minus the theoretical sum is dA, which is the error, the correction to each included angle will be $-\frac{dA}{n}$. After applying the correction, calculate the corrected bearings as below.

As the fore bearing and back bearing of CD differ exactly by 180^0, stations C and D are free from local attractions. Hence the observed fore bearing of CD, back bearing of BC, back bearing of CD and fore bearing of DA are the correct bearings.

Correct fore bearing of DA = $306^0 40'$ (given)

Correct back bearing of DA = $306^0 40' - 180^0 = 126^0 40'$

Correct fore bearing of AB = Correct back bearing of DA - Included angle at A

$= 126^0 40' - 51^0 40' = 75^0 00'$

Correct back bearing of AB = $75^0 00' + 180^0 = 255^0 00'$

Correct fore bearing of BC = Correct back bearing of AB - included angle at B

$= 255^0 00' - 148^0 40' = 106^0 20'$

Correct back bearing of BC = $106^0 20' + 180^0 = 286^0 20'$

Check: The computed back bearing of BC is same as the observed back bearing at C which is free from local attraction.

Line	Correct fore bearing	Correct back bearing
AB	$75^0 00'$	$255^0 00'$
BC	$106^0 20'$	$286^0 20'$
CD	$224^0 50'$	$44^0 50'$
DE	$306^0 40'$	$126^0 40'$

07(b). (i)

Sol: Co-ordinate method

Station	L	P	Station	Co-ordinate	
				X	Y
			A (1)	0	0
AB	–155.5	152.5			
			B (2)	–155.5	152.5
BC	208.5	50.5			
			C (3)	53	203
CD	173.5	(–) 96.5			
			D (4)	226.5	106.5
DA	(–) 226.5	(–) 107.5		0	(–1)

	(1)	(2)	(3)	(4)	(5)
x	0	–155.5	53	226.5	0
y	0	152.5	203	106.5	(–1)

$$A = \frac{1}{2}\left(0 + (-155.5 \times 203) - (152.5 \times 53) + (53 \times 106.5) - (226.5 \times 203) - 226.5\right)$$

A = 40054.5 m^2

07(b) (ii)

Sol:

Given data,

Measured area in plane = 125.50 cm^2

Scale 1 cm = 40 m

Measured are in ground = 125.50 × 40^2

= 200.800 × 10^3 m^2

Since chain was 5 cm too long and l = 20 cm

l' = 20 + 0.05 = 20.05 m

$\therefore$ Correct area after correction of chain

$$= \left(\frac{\ell'}{\ell}\right)^2 \times \text{measured area}$$

$$= \left(\frac{20.05}{20}\right)^2 \times 200800$$

$= 201805.255\ m^2$

and plane was shrink by 19.5 cm

Correct area after shrinkage correction of plan $= \left(\frac{20}{19.5}\right)^2 \times 201805.255$

$= 212286.92\ m^2 = 21.2286$ hectares (1 hect = 10,000 m^2)

07(c). (i)

Sol: $d_w = 0.5y = 0.5$ (Sd (FC – pwp)

$$= 0.5\ 1.5(90)\frac{(22-12)}{100}$$

$= 6.75$ cm $= 67.5$ mm

$$f = \frac{d_w}{c_u} = \frac{67.5}{22} = 3.07 = 3 \text{ days}$$

depth of irrigation water

$$y_c = \frac{d_w}{n_i} = \frac{67.5}{0.6} = 112.5 \text{ mm}$$

07(c). (ii)

Sol: $H_d = 180 - 178.00 = 2.00$ m

$L_e = L - 2\ H_d\ [k_Q + (n-1)\ k_p]$

$= 160 - 2(2)\ [0.1 + 3(0.1)]$

$= 160 - 4(0.4)$

$= 158.4$ m

$$H_e = H_d + H_a = 2 + \frac{V_a^2}{2g}$$

$$= 2 + \frac{0.8^2}{2(9.81)} = 2.0326 \text{ m}$$

$Q = C\, L_e H_e^{3/2}$

$= 2.5\ 158.4\ (2.0326)^{3/2} = 1148$ cumec

$$\left.\begin{aligned} Q &= \frac{2}{3} C_d L_e H_e^{3/2} \sqrt{2g} \\ Q &= C L_e H_e^{3/2} \end{aligned}\right\} \quad C = \frac{2}{3} C_d \sqrt{2g}, \quad C_d = \frac{3C}{2\sqrt{2g}} = \frac{3 \times 2.5}{2\sqrt{2(9.81)}} = 0.85$$

07(c). (iii)

Sol: $f = 1.76\sqrt{D_{75}} = 1$

Side slope $= \frac{1}{2} H : 1V$

Q = 50 cumec

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} = 0.84 \text{ m/s}$$

$$P = 4.75\sqrt{Q} = 33.6 \text{ m}$$

$$A = \frac{Q}{V} = \frac{50}{0.84} = 59.52 \text{ m}^2$$

$$\left.\begin{aligned} P &= B + 2.236D = 33.6 \\ A &= BD + \frac{D^2}{2} = 59.52 \end{aligned}\right\}$$

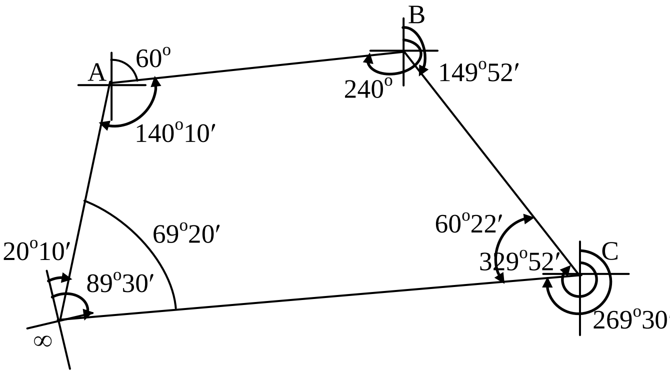
solving

$$\left.\begin{aligned} B &= 29 \text{ m} \\ D &= 2 \text{ m} \end{aligned}\right\}$$

$$S = \frac{f^{5/3}}{3340 Q^{1/6}} = \frac{1}{6400}$$

08(a). (i)

Sol: Given bearing of AB = 60^o



Bearing of BC = BB of AB – ∠B

$= 60^o + 180^o - 90^o8'$

$= 149^o52'0''$

Bearing of CD = BB of BC - ∠C

$= 149^o52' + 180^o - 60^o22'$

$= 269^o30'0''$

Bearing of OA = BB of CD - ∠D

$= 269^o30' - 180^o - 69^o20'$

$= 20^o10'0''$

08(a). (ii)

Sol: Bubble tube A

The distance of the bubble from the centre of its run

(i) $n_1 = \frac{1}{2} \times (13 - 5) = 4$ division

(ii) $n_2 = \frac{1}{2} \times (12 - 8) = 2$ division

The total number of divisions n through which bubble has moved = $n_1 + n_2 = 6$

The staff intercept s = 1.767 – 1.618 = 0.149 m

The sensitivity of the bubble tube

$$\alpha'_A = 206265 \times \frac{s}{nD} \text{seconds}$$

$$= 206265 \times \frac{0.149}{6 \times 80} \text{seconds} = 1'4''$$

Bubble tube B

The distance of the bubble from the centre of its run

(i) $n_1 = \frac{1}{2} \times (15 - 3) = 6$ division

(ii) $n_2 = \frac{1}{2} \times (14 - 6) = 4$ division

The total number of divisions n through which bubble has moved = $n_1 + n_2 = 10$

The staff intercept s = 1.788 – 1.635 = 0.153 m

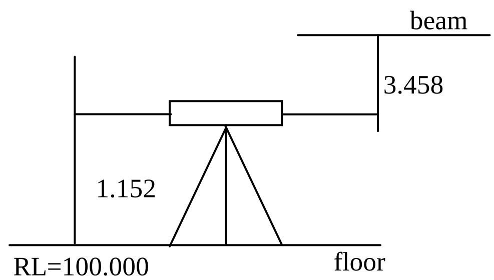
The sensitivity of the bubble tube

$$\alpha'_B = 206265 \times \frac{0.153}{10 \times 80} \text{seconds} = 40''$$

Since $\alpha'_A > \alpha'_B$, the bubble A is more sensitive than B.

08(b). (i)

Sol:



HI = RL + 1.152 = 101.152 m

RL of the beam = 100.000 + 1.152 + 3.458 = 104.610 m

$\therefore$ Height of the beam = 104.610 – 100 = 4.610 m

08(b). (ii)

Sol:

(a) Longitude of the place = $38^0\ 45'$ W

$$38^0 = \frac{38}{15} h = 2^h\ 32^m\ 0^s$$

$$45' = \frac{45}{15} m = 0^h\ 3^m\ 0^s$$

$\therefore$ $38^0\ 45' = 2^h\ 35^m\ 0^s$

Since longitude Greenwich is zero, difference in longitudes = longitude of the place.

From the relation,

LMT = GMT ± Difference M longitudes $\frac{E}{W}$, We get,

$8^h\ 12^m\ 16^s = \text{GMT} - 2^h\ 35^m\ 0^s$

$\text{GMT} = 10^h\ 47^m\ 16^s$ (AM).

(b) Longitude of the place $58^0\ 20'$ E

$$58^0 = \frac{58}{15} \text{ hours} = 3^h\ 52'\ 0^s$$

$$20' = \frac{20}{15} \text{ min} = 0^h\ 1'\ 20^s$$

$\therefore\ 58^0\ 20'\text{ E} = 3^h\ 53'\ 20^s$ E

Since longitude of Greenwich is zero, this is same as difference in longitude Since the place is to the east of Greenwich,

$$\text{LMT} = \text{GMT} + \text{Longitude}$$

$$6^h\ 8^m\ 24^s = \text{GMT} + 3^h\ 53^m\ 20^s$$

$$\text{GMT} = 2^h\ 15^m\ 4^s \text{ (AM)}$$

08(c).

Sol: Given data:

$D_1 = 400$ mm, $L_1 = 200$ m, $f = 0.02$

$D_2 = 200$ mm, $L_2 = 100$ m, $C_c = 0.6$

$D_3 = 300$ mm, $L_3 = 150$ m

Case –I: All minor losses neglected

By Bernoulli's equation

$$\cancelto{0}{\frac{P_1}{\rho g}} + \cancelto{\approx 0}{\frac{V_1^2}{2g}} + Z_1 = \cancelto{0}{\frac{P_2}{\rho g}} + \cancelto{\approx 0}{\frac{V_2^2}{2g}} + Z_2 + hf_1 + hf_2 + hf_3$$

$\therefore\ Z_1 - Z_2 = hf_1 + hf_2 + hf_3$

$$16 = \frac{fL_1Q^2}{12.1D_1^5} + \frac{fL_2Q^2}{12.1D_2^3} + \frac{fL_3Q^2}{12.1D_3^5}$$

$$16 = Q^2\left\{\frac{2\times 200}{0.4^5} + \frac{100}{0.2^5} + \frac{150}{0.3^5}\right\} \times \frac{0.02}{12.1}$$

$Q = 0.157\ m^3/s$

Case II: Considering minor as well as major losses if we consider minor losses then application of Bernoulli's equation beln reservoirs gives

$$\cancelto{0}{\frac{P_1}{\rho g}} + \cancelto{\approx 0}{\frac{V_1^2}{2g}} + Z_1 = \cancelto{0}{\frac{P_2}{\rho g}} + \cancelto{\approx 0}{\frac{V_2^2}{2g}} + Z_2 + h_{L,ent} + hf_1 + h_{L.const} + hf_2 + hf_{2,exp} + hf_3 + h_{L,exit}$$

$\therefore\ Z_1 - Z_2 = h_{L,\,ent} + h_{f1} + h_{L,const} + hf_2 + h_{L,exp} + hf_3 + h_{L,exit}$

$$h_{L,ent} = 0.5\frac{V_1^2}{2g} = \frac{0.5}{2\times 9.81}\left(\frac{Q}{\frac{\pi}{4}\times 0.4^2}\right)^2$$

$= 1.614\ Q^2$

$$hf_1 = \frac{fL_1Q^2}{12.1D_1^5} = \frac{0.02\times 200}{12.1\times 0.45}Q^2 = 32.28\ Q^2$$

$$h_{L,const} = \left(\frac{1}{C_c}-1\right)^2\frac{V_2^2}{2g} = \left(\frac{1}{0.6}-1\right)^2\times\frac{1}{2\times 9.81}\times\left(\frac{Q}{\frac{\pi}{4}\times 0.2^2}\right)^2$$

$= 22.95Q^2$

$$hf_2 = \frac{fL_2Q^2}{12.1D_2^5} = \frac{0.02\times 100\times Q^2}{12.1\times 0.2^5} = 516.5\,Q^2$$

$$h_{L,exp} = \frac{(V_2-V_3)^2}{2g} = \frac{Q^2}{2\times 9.81}\left(\frac{4}{\pi\times 0.2^2}-\frac{4}{\pi\times 0.3^2}\right)^2$$

$= 15.94\ Q^2$

$$hf_3 = \frac{fL_3Q^2}{12.1D_3^5} = \frac{0.02\times 150\times Q^2}{12.1\times 0.3^5}102Q^2$$

$$h_{L,exit} = \frac{V_3^2}{2g} = \frac{1}{2\times 9.81}\times\left(\frac{Q}{\frac{\pi}{4}\times 0.3^2}\right)^2 = 10.2Q^2$$

$16 = (1.614 + 32.28 + 22.95 + 516.5 + 15.94 + 102 + 10.2)Q^2$

$Q = 0.151\ m^3/s$