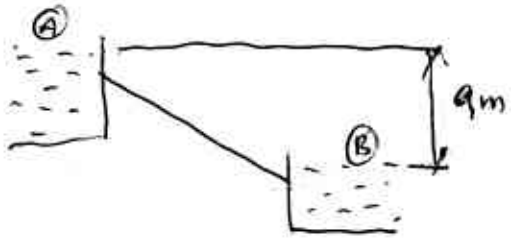
Tutorial



1) given:- $d = 400mm$
$l = 1.7km$
$elt = 9m$
$\mu = 1.141 \times 10^{-6}\ m^2/s$

a) Commercial steel

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \sum \text{losses}_{(A-B)}$$

$$z_A - z_B = \sum \text{losses}_{(A-B)}$$

$$9m = \left(\frac{fl}{d}\right)\frac{V^2}{2g} \quad -(1)$$

$$9 = \left(\frac{16fl}{2g\pi^2 d^5}\right) Q^2$$

$\therefore Q = AV$

$$R_e = \frac{lVd}{\mu}$$

$$Q = \frac{\pi d^2}{4}(V)$$

$$Q = 0.126V \ m^3/s$$

$$Q = 0.126V$$

$f = 0.$

used (1)

$$\frac{9(2g)}{V^2} = \frac{fl}{d}.$$

$$\frac{(9)d\,2g}{V^2} = 0.$$

$$\frac{(9)(2g)(d)}{V^2 l} = f$$

$$9 = \frac{16fl}{2g\pi^2 d^5}(0.618$$

$$= $$

$$9_{min} = \left(\frac{9(2g)(d)}{V^2 l}\right) l \cdot \left(\frac{V^2}{2g}\right) \Big/ d$$

$$V = \frac{4Q}{\pi d^2}$$

$$V = 7.96Q\ m^3/s$$

Guess f = 1

$$q = \frac{fl}{d}\left(\frac{V^2}{2g}\right) - (1).$$

$$q_m = \frac{(1)(1700)}{0.4}\cdot\frac{V^2}{2g}$$

$$V^2 = 0.042$$

$$V = 0.204 \text{ m/s}$$

$$Re = \frac{\rho V d}{\mu}.$$

$$Re = \frac{(1000)(0.204)(0.4)}{1.141\times10^{-6}}$$

$$Re = 7.15\times10^{7}$$

(f actual for commercial steel.

$$\varepsilon/d = \frac{0.152\times10^{-3}}{} = 0.00005$$

$$Re = 7.15\times10^{7}$$

$$f = 0.011$$

$$\therefore V^2 = \frac{(9)(0.4)(2g)}{0.011\cdot(1700)}$$

$$V^2 = 3.78$$

$$V = 1.943 \text{ m/s}.$$

$$\therefore Q = AV.$$

$$= \frac{\pi d^2}{4}(1.943)$$

$$Q = 0.244 \text{ m}^3/\text{s}$$

f actual for Cast iron.

$Re = 7.15 \times 10^7$

$f = 0.0135$

$$V^2 = \frac{(9)(0.4)(29)}{0.0135\,(1700)}$$

$V = 1.754$ m/s

$Q = AV$

$Q = \left(\frac{\pi d^2}{4}\right)(1.754)$

$Q = 0.22\ m^3/s$

f actual for Smooth concreate.

$\varepsilon/d = 0.002$

$Re = 7.15 \times 10^7$

$f = 0.023$

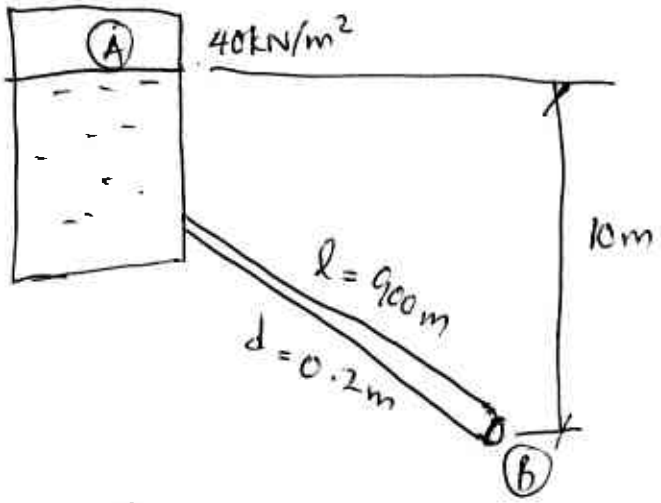
$$V^2 = \frac{9(0.4)(29)}{(0.023)(1700)}$$

$V^2 = 1.806$

$V = 1.344$ m/s

$Q = \frac{\pi d^2}{4}(1.344)$

$Q = 0.169\ m^3/s$



Condition ①

$Q_B = 49\ l/s = 0.049\ m^3/s.$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + \Sigma losses.$$

$$\frac{P_A}{\rho g} = (Z_B - Z_A) + \Sigma loss_{A-B}$$

$$= (0 + 10) + \Sigma loss(A-B)$$

$$\left(\frac{40 \times 10^3}{9810}\right) + 10 = \Sigma loss.$$

$$14.08 = \Sigma loss.$$

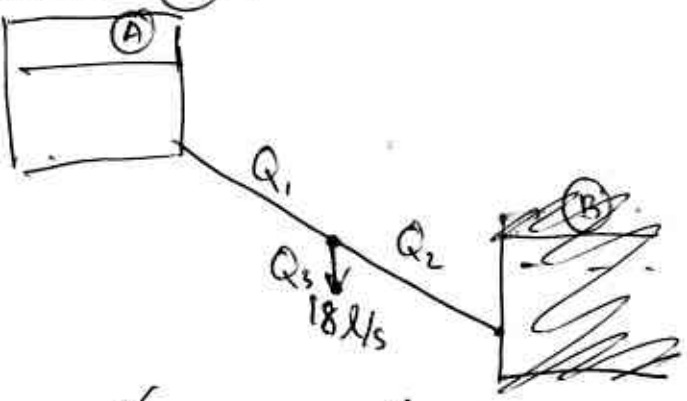
$$14.08 = \left(\frac{fl}{d}\right)\left(\frac{V^2}{2g}\right)$$

$$14.08 = \left(\frac{fl}{2g\pi^2 d^5}\right) Q^2.$$

$$f = \frac{(14.08)(2g\pi^2 d^5)}{Q^2(l)}.$$

$$f = 0.0198$$

dition (2).



$Q_1 = 0.049\ m^3/s$

$Q_2 =$

$Q_3 = 0.018\ m^3/s$.

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \Sigma \text{losses}_{(A-B)}$$

$Q_2 = 0.049 - 0.018$

$= 0.031$

$$\frac{P_A}{\rho g} + (z_A - z_B) = \Sigma \text{losses}_{(A-B)}$$

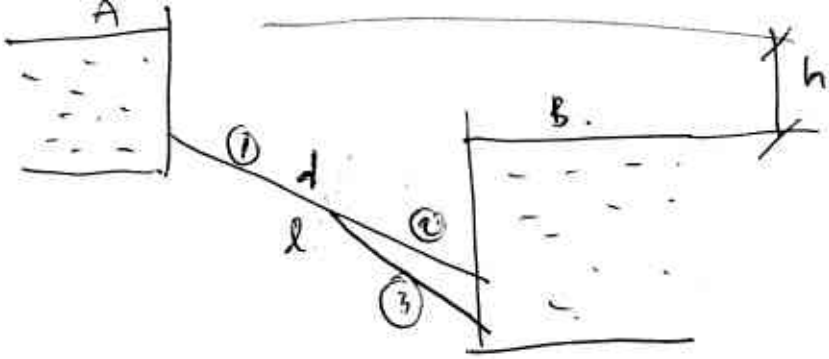
$$\frac{P_A}{\rho g} + 10 = \left(\frac{16 f l}{2g \pi^2 d^5}\right) Q^2$$

$$\frac{P_A}{\rho g} = \frac{16 (0.0198)(900)}{2g (\pi^2)(0.2)^5} Q^2$$

$$P_A = 1.4\ mN/m^2$$

#

5)



$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \Sigma \text{Loss}$$

$$\Sigma \text{Loss}_{A-B} = (z_A - z_B)$$

$$\Sigma \text{loss}_{(A-B)} = (\Delta h)$$

$$\left(\frac{16 f l}{2g\pi^2 d^5}\right) Q^2 = \Delta h$$

$$Q = \sqrt{\frac{h\, 2g\pi^2 d^5}{16 f l}}.$$

$l_{②} = l/2$.

$Q_1 = Q_2 + Q_3$.

$Q_1 = 2Q_2 \quad = Q_2 = \frac{1}{2} Q_1$

$h_{\text{Losse}②} = h_{\text{Losse}③} = \left(\frac{16 f l}{2g\pi^2 d^5}\right) Q^2$

$$\Sigma \text{Loss}_{(A-B)} = kQ_1^2 + kQ_2^2 = \left(\frac{16 f l}{4g\pi^2 d^5}\right) Q^2$$

$$\therefore \quad \Sigma \text{Loss}_{A-B} = (z_A - z_B)$$

$$\Sigma \text{Loss} = \left(\frac{16 f l/2}{2g\pi^2 d^5}\right) Q_1^2 + \left(\frac{16 f l/2}{2g\pi^2 d^5}\right) Q_2^2$$

$$\Delta h = \left(\frac{16 f l/2}{2g\pi^2 d^5}\right) \left(Q_1^2 + Q_2^2\right)$$

$$= \frac{16 f l/2}{2g\pi^2 d^5} \left(Q_1 + \tfrac{1}{2} Q_1^2\right)$$

$$\Delta h = \left(\frac{16 f l/2}{2g\pi^2 d^5}\right)\left(\frac{3}{2}Q_1\right)^2$$

$$Q_1^2 = \frac{(2g\pi^2 d^5)(\Delta h)}{16 f l/2}\left(\frac{2}{3}\right)$$

∴ increase discharge.

$$= \frac{Q_1^2 \text{ condition ①}}{Q_1^2 \text{ condition ②}} \times 100$$

$$\frac{\left(\frac{2g\pi^2 d^5}{16 f l}\right)(\Delta h)}{\left(\frac{4g\pi^2 d^5}{16 f l}\right)(\Delta h)^{\frac{2}{3}}} = \frac{\left(\frac{2g\pi^2 d^5}{16 f l}\right)(\Delta h)}{\frac{4g\pi^2 d^5}{16 f l}\cdot(\Delta h)^{\frac{2}{3}}}$$

$$\frac{1}{2} \times \frac{3}{2} =$$

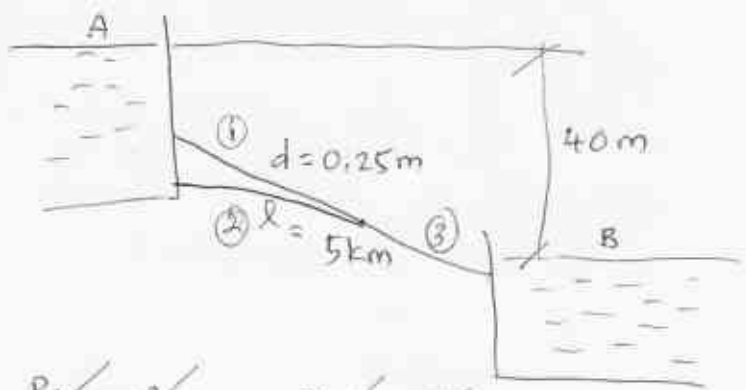
$$= \frac{3}{4} \times 100$$

Q_1 condition ①

$= 75\%$ increase.

75% of Q_1 condition ②

∴ Increase 25%



$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \sum \text{losses}_{(A-B)}$$

$$z_A - z_B = \sum \text{losses}_{(A-B)}$$

$$40 = \sum \text{loss}_{(A-B)}$$

$$40 = KQ^2 \Rightarrow 40 = \left(\frac{16 f \ell}{2g\pi^2 d^5}\right) Q^2$$

$$40 = \left(\frac{f\ell}{d}\right)\frac{V^2}{2g}$$

assume $f = 1$ =

$$40 = \left(\frac{5000}{0.25}\right)\frac{V^2}{19.62}$$

$$V = 0.198 \text{ m/s}$$

$Re = \rho V d/\mu$ $\quad \mu = 1.141 \times 10^{-6}$

$Re = 4.35 \times 10^4$

assume smooth pipe.

$f = 0.0095$

$\therefore V_{actual} =$

$$40 = \frac{(0.0095)(5000)}{0.25}\left(\frac{V^2}{2g}\right)$$

$$V = 2.032 \text{ m/s}$$

$$Q = (\pi d^2/4) V$$

$$Q_1 = 0.0998 \text{ m}^3/\text{s}$$ #

a) $Q_1 + Q_2 = Q_3$

$Q_3 = Q_1 + Q_2$

$Q_3 = 2Q_1$

$\therefore 40 = KQ_1^2 + KQ_3^2$

$$40 = \left(\frac{16 f_1 \ell_1}{2g\pi^2 d^5}\right) Q_1^2 + \left(\frac{16 f_2 \ell_2}{2g\pi^2 d^5}\right) Q_3^2$$

$40 = 2009.5 Q_1^2 + 2009.5 Q_3^2$

$40 = 2009.5 Q_1^2 + 2009.5 (2Q_1)^2$

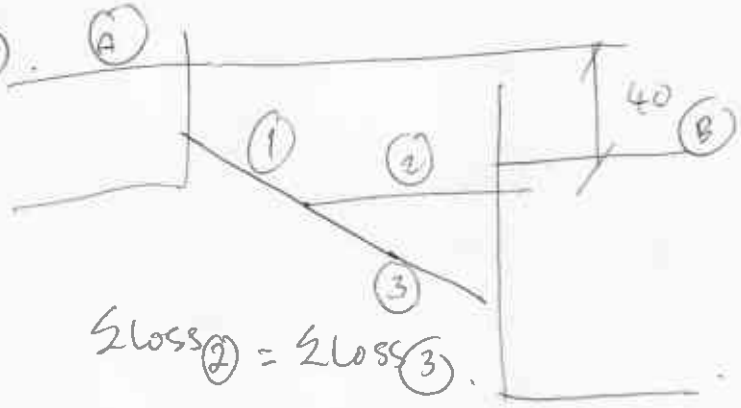
$40 = 6028.47 Q_1^2$

$Q_1 = 0.0815 \text{ m}^3/\text{s}$

$Q_3 = 2Q_1$

$Q_3 = 0.163\ m^3/s$

b).



$\Sigma loss_{②} = \Sigma loss_{③}$

$\Sigma loss = KQ_2^2$

$\Sigma loss = \left(\frac{16 f_2 l_2}{2g\pi^2 d^5}\right) Q_2^2$

$f = 0.0095$

$\Sigma loss_{②} = \left(\frac{16(0.0098)(2500)}{2g\pi^2 d^5}\right) Q_1^2$

$\Sigma loss_{②} = 2072.94 Q_2^2$

$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \Sigma losses_{(A-B)}$

$(z_A - z_B) = \Sigma loss_{(A-B)}$

$40 = kQ_1^2 + kQ_2^2$

$Q_1 = Q_2 + Q_3$

$Q_1 = 2Q_2$

$40 = 2072.94 Q_1^2 + 2072.94 Q_2^2$

$40 = 2072.94 Q_1^2 + 2072.94 \frac{Q_1^2}{2}$

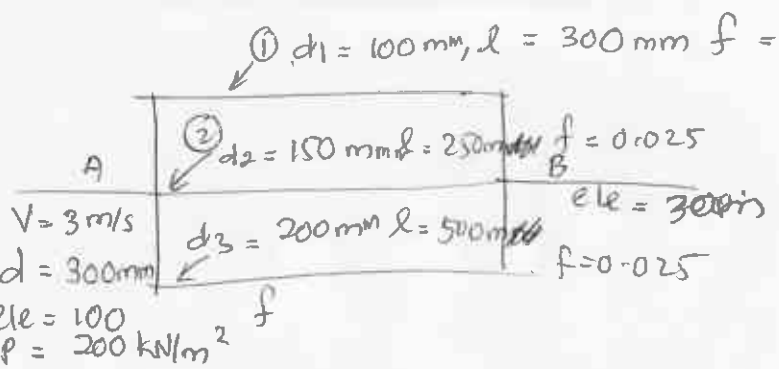
$40 = 2072.94 Q_1^2 + 1036.47 Q_1^2$

$40 = 3109.41 Q_1^2$

$Q_1^2 = 0.0129$

$Q_1 = 0.1134\ m^3/s$

9)



$$Q_A = \left(\frac{\pi d^2}{4}\right) V$$

$$Q_A = 0.212\ m^3/s.$$

$$Q_A = Q_1 + Q_2 + Q_3$$

$$\Sigma H_{L①} = \Sigma H_{L②} = \Sigma H_{L③}$$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \Sigma Losses_{(A①B)}$$

Guess discharge through pipe ①.

$Q_1' = 0.06\ m^3/s$. $\quad V = \frac{4Q}{\pi d^2}$

$V = 7.64\ m/s$

$$\Sigma loss_{A①B} = \left(\frac{16 f l}{2g\pi^2 d^5}\right) Q_①^2$$

$$= \frac{16(0.025)(300)}{2g\pi^2(0.1)^5}(0.06)^2$$

$$\Sigma loss_{A①B} = 223.093$$

$$\Sigma loss_{A①B} = \left(\frac{fl}{d}\right)\frac{V^2}{2g}$$

$$= \frac{(0.025)(300)}{(0.1)(19.62)}(7.64)^2$$

$$\Sigma loss_{A①B} = 223.09$$

Pipe ②

$$223.09 = \frac{fl}{d}\frac{V^2}{2g}$$

$$223.09 = \frac{(0.025)(250)\,V^2}{(0.15)(19.62)}$$

$$V_2' = 10.25\ m/s.$$

$$Q_2' = \left(\frac{\pi d^2}{4}\right) 10.25 = 0.181\ m^3/s.$$

Pipe ③ :

$$223.09 = \left(\frac{fl}{d}\right)\frac{V^2}{2g}$$

$$223.09 = \frac{0.025\left(\frac{500}{0.025}\right)\cdot V^2}{(0.2)(19.62}$$

$$V_3 = 8.37 \text{ m/s}.$$

$$Q_3' = \left(\frac{\pi d^2}{4}\right)V$$

$$Q_3' = 0.263 \text{ m}^3/\text{s}.$$

get a ratio Q_1'/Q_2'

$$Q_1 = \left(\frac{Q_1'}{Q_1' + Q_2' + Q_3'}\right) Q_A$$

$$Q_1 = \left(\frac{0.06}{0.504}\right)(0.212)$$

$$Q_1 = 0.0252 \text{ m}^3/\text{s}.$$

$$Q_2 = \left(\frac{0.181}{0.504}\right) 0.212$$

$$= 0.0761 \text{ m}^3/\text{s}.$$

$$Q_3 = \left(\frac{0.263}{0.504}\right) 0.212$$

$$Q_3 = 0.111 \text{ m}^3/\text{s}.$$

$$V_1 = \frac{4Q}{\pi d^2} = 3.21 \text{ m/s}.$$

$$V_2 = \frac{4Q}{\pi d^2} = 4.31 \text{ m/s}.$$

$$V_3 = \frac{4Q}{\pi d^2} = 3.53 \text{ m/s}.$$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + \Sigma \text{loss}$$

$$\frac{P_A - P_B}{\rho g} = (Z_B - Z_A) + \Sigma \text{loss}_{A①B}.$$

$$Q_1 = 0.0252 \text{ m}^3/\text{s}.$$

$$\Sigma \text{loss}_{A①B} = KQ^2$$

$$= \left(\frac{16 f_1 l_1}{2g\pi^2 d^5}\right) Q_1^2$$

$$= 386.058$$

$$\therefore \frac{P_A - P_B}{\rho g} = -70 + 386.058.$$

$$\frac{P_A - P_B}{\rho g} = 316.06$$

Use $\Sigma \text{Loss} = \frac{fl}{d}\left(\frac{V^2}{2g}\right)$

Pipe ① :

$$\frac{P_A - P_B}{\rho g} = (Z_B - Z_A) + \Sigma \text{Losses}_{A①B}.$$

$$\frac{P_A - P_B}{\rho g} = (30 - 100) + \frac{fl}{d}\left(\frac{V^2}{2g}\right)$$

$$\frac{P_A - P_B}{\rho g} = -70 + 39.4$$

$$\frac{P_A - P_B}{\rho g} = -30.61$$

check for Pipe ② .

$$\frac{P_A - P_B}{\rho g} = (30 - 100) + \frac{fl}{d}\left(\frac{V_2^2}{2g}\right)$$

$$\frac{P_A - P_B}{\rho g} = -70 + 39.4$$

Thus,

$$\frac{P_A - P_B}{\rho g} = -70 + 39.4$$

$$P_A - P_B = (-30.61)\,9810$$

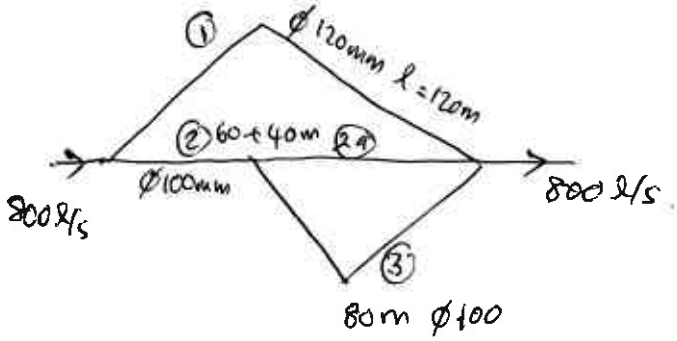
$$P_A - P_B = -300.2841$$

$$-P_B = -300.28 - 200$$

$$-P_B = -500.28 \text{ kN/m}^2$$

$$P_B = 500.28 \text{ kN/m}^2$$

#



f = from moody Chart.

Pipe 1 = f = 0.0135 for Cast iron.

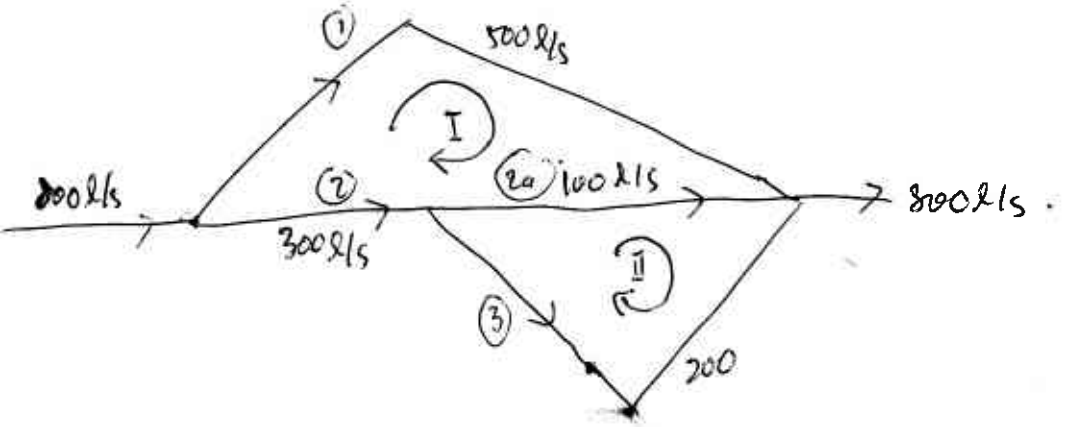
$k_1 = \frac{16 f \ell_1}{2g H^2 d^5} = \frac{16(0.0135)(120)}{2g H^2 d^5} =$ ~~13385.55~~ 5379.35

$k_2 = \frac{16 f \ell}{2g H d^5} = \frac{16(0.0135)(60)}{2g H^2 (0.1)^5} =$ 6693

$k_{2a} = \frac{16 f \ell}{2g H^2 d^5} = \frac{16(0.0135)(40)}{2g H^2 (0.1)^5} =$ 4462

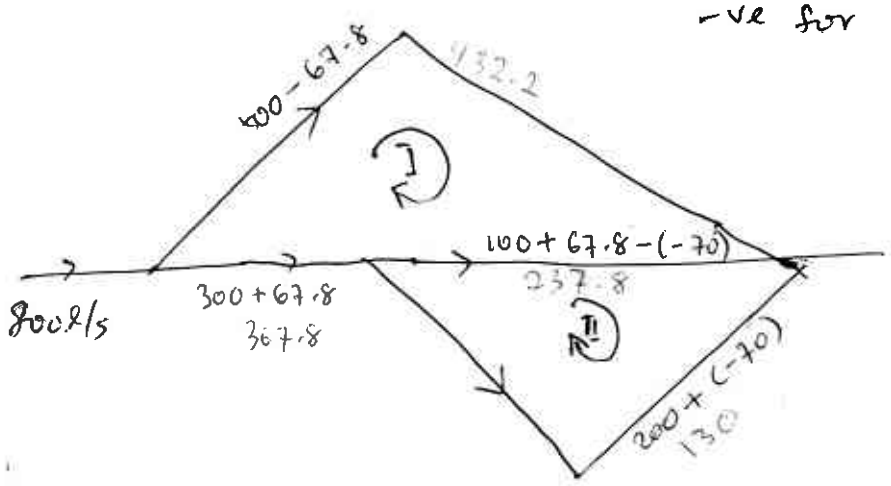
$k_3 = \frac{16 f \ell}{2g H^2 d^5} = \frac{16(0.0135)(80)}{2g H^2 (0.1)^5} =$ 8923.7

$$\delta Q = \frac{\Sigma k_c Q_c^2 - \Sigma k_{cc} Q_{cc}}{2(\Sigma k_c Q_c + \Sigma k_{cc} Q_{cc})}$$



loop	Pipe	$\sum k_c Q_c^2 - \sum k_{cc} Q_{cc}^2$	$2\sum k_c Q_c + \sum k_{cc} Q_{cc}$
I	①	$(5379.4)(\frac{500}{1000})^2 = 1344.85$	$2(5379.4)(0.5) = 5379.4$
	②	$-(6693)(\frac{300}{1000})^2 = -602.37$	$2(6693)(0.3) = 4015.8$
	2a	$-(4462)(0.1)^2 = -44.62$	$2(4462)(0.1) = 892.4$
		697.86	10287.6
		$\delta Q = \frac{697.86}{10287.6}$	
		$\delta Q = 0.0678\ m^3/s$ @ $67.8\ \ell/s$.	
II	2a	$(4462)(0.1)^2 = 44.62$	$2(4462)(0.1) = 892.4$
	3	$-(8923.7)(0.2)^2 = -356.95$	$2(8923.7)(0.2) = 3569.48$.
		-312.33	4461.88
		$\delta Q = \frac{-312.33}{4461.88} = -0.07\ m^3/s$ @ $-70\ \ell/s$.	

+ve for counterclockwise
-ve for clockwise.



Correction

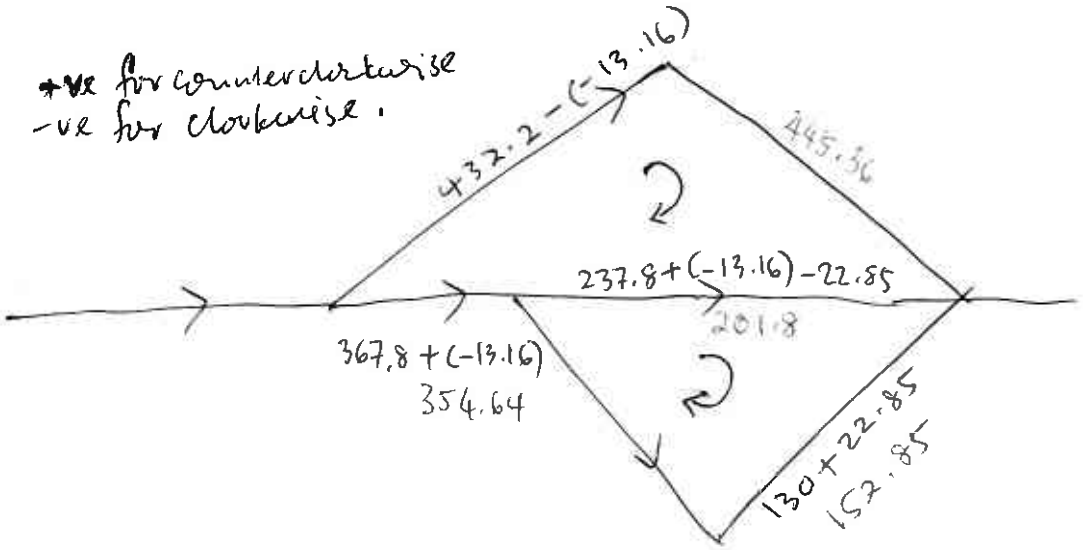
loop	Pipe	$\sum k_c Q_c^2 - \sum k_{cc} Q_{cc}^2$	$2\sum k_c Q_c^2 + \sum k_{cc} Q_{cc}^2$
I	①	$(5374)(\frac{432.2}{1000})^2 = 1003.93$	$2(5374)(0.432) = 4643.14$
	②	$-(6693)(\frac{367.8}{1000})^2 = -905.41$	$2(6693)(0.3678) = 4923.4$
	24	$-4462(0.2378)^2 = -252.32$	$2(4462)(0.2378) = 2122.13$
		-153.8	11688.67

$$\delta Q = \frac{153.8}{11688.67} = -0.0132\ m^3/s \quad @ \quad -13.16\ l/s.$$

II	24	$+4462(0.2378)^2 = 252.32$	$2(4462)(0.2378) = 2122.13$
	3	$-(8923)(0.13)^2 = -1508$	$2(8923)(0.13) = 2319.98$
		101.52	4442.11

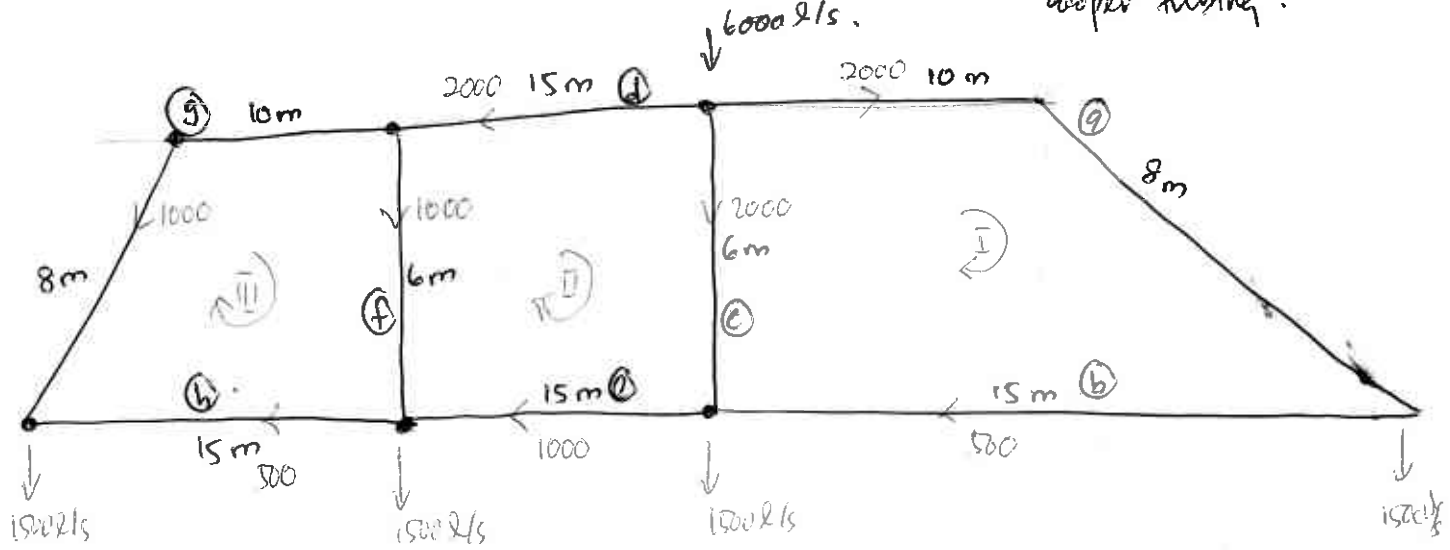
$$\delta Q = \frac{101.52}{4442.11} = 0.0229\ m^3/s \quad @ \quad 22.85\ l/s$$

+ve for counterclockwise
-ve for clockwise.



3.

copper tubing.



from moody chart

f for copper is 0.008

K value for each branch.

$$k_g, K_a = \frac{16 f \ell}{2g\pi^2 d^5} = \frac{16(0.008)(18)}{2g\,\pi^2(0.075)^5} = 5014$$

$$k_b, = \frac{16 f \ell}{2g\pi^2 d^5} = \frac{16(0.008)(15)}{2g\,\pi^2(0.075)^5} = \frac{1.92}{4.595\times10^{-4}} = 4178.5$$

, k_d, k_h

$$k_c = k_f = \frac{16 f \ell}{2g\pi^2 d^5} = \frac{16(0.008)(6)}{4.595\times10^{-4}} = 1671.38$$

$\therefore$ $k_a, k_g = 5014$

$k_b, k_e, k_d, k_h = 4178.5$

$k_c, k_f = 1671.38$.

loop	Pipe	$\sum k_c Q_c^2 - \sum k_{cc} Q_{cc}^2$	$2\sum k_c Q_c + \sum k_{cc} Q_{cc}$
I	ⓐ	$(5014)(2)^2 = 20056$	$2(5014)(2) = 20056$
	ⓑ	$(4178.5)(0.5)^2 = 1044.5$	$2(4178.5)(0.5) = 4178.5$
	ⓒ	$-(1671.38)(2)^2 = -6685.52$	$2(1671.38)2 = 6685.52$
		14414.98	30920.02

$$\delta Q = \frac{14414.98}{30920.02} = 0.466\ m^3/s$$
$$466\ l/s.$$

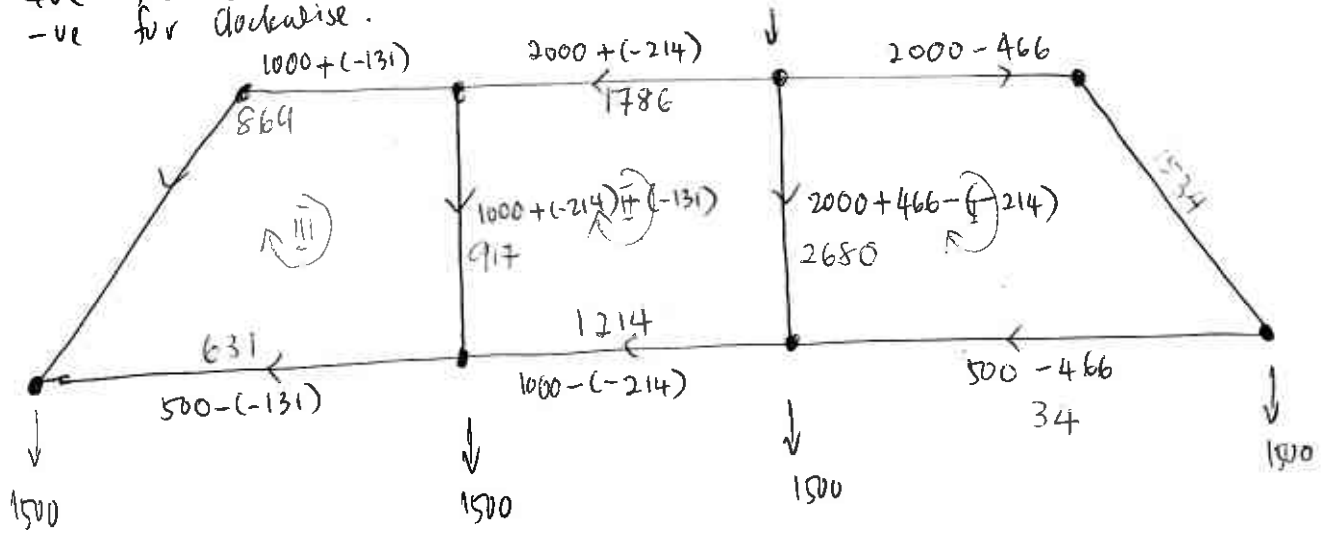
II	ⓒ	$(1671.38)(2)^2 = 6685.52$	$2(1671.38)2 = 6685.52$
	ⓓ	$-(4178.5)(2)^2 = -16714$	$2(4178.5)2 = 16714.$
	ⓔ	$(4178.5)1^2 = 4178.5$	$2(4178.5)(1) = 8357$
	ⓕ	$-(1671.38)(1)^2 = -1671.38$	$2(1671.38)(1) = 3342.76$
		-7521.36	35099.28

$$\delta Q = \frac{-7521.36}{35099.28} = -0.214\ m^3/s\ @ -214\ l/s$$

III	ⓕ	$1671.38(1)^2 = 1671.38$	$2(1671.38)(1) = 3342.76$
	ⓖ	$-5014(1)^2 = -5014$	$2(5014)(1) = 10028$
	h	$4178(0.5)^2 = 1044.5$	$2(4178)(0.5) = 4178$
		-2298.12	17548.76

$$\delta Q = \frac{-2298.12}{17548.76} = -0.131\ m^3/s\ @ 131\ l/s.$$

+ve for Counterclockwise
−ve for clockwise.



loop	Pipe	$\Sigma k_c Q_c^2 - \Sigma k_{cc} Q_{cc}^2$	$2\Sigma k_c Q + k_{cc} Q_{cc}^2$
I	ⓐ	$(5014)(1.534)^2 = 11798.7$	$2(5014)(1.534) = 15382.95$
	ⓑ	$(4178.5)(0.034)^2 = 4.83$	$2(4178)(0.034) = 284.104$
	ⓒ	$-(1671.38)(2.68)^2 = -12004.5$	$2(1671.38)(2.68) = 8958.59$
		-200.99	24624.7

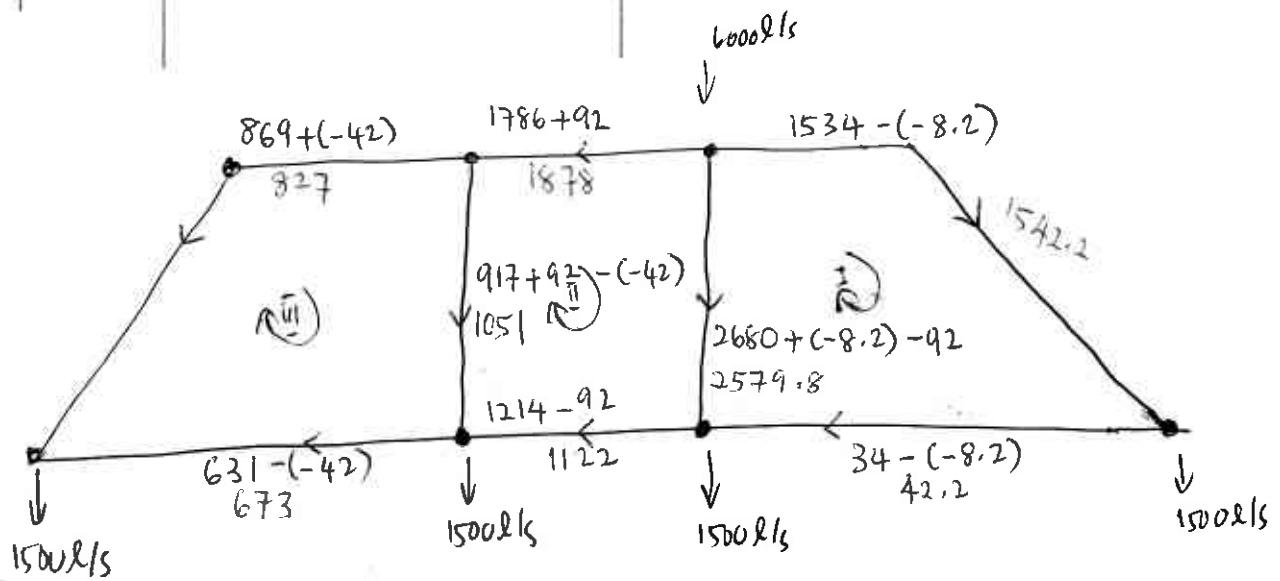
$$\delta Q = \frac{-201}{24624.7} = -8.163 \times 10^{-3}\ m^3/s \quad @ -8.2\ l/s.$$

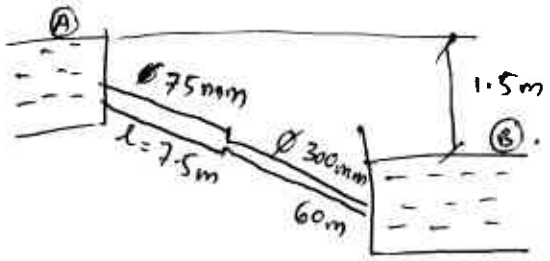
II	ⓒ	$1671.38(2.68)^2 = 12004.5$	$2(1671.38)(2.68) = 8958.59.$
	ⓓ	$-(4178.5)(1.786)^2 = -13328.6$	$2(4178.5)(1.786) = 14925.6$
	ⓔ	$(4178.5)(1.214)^2 = 6158.3$	$2(4178.5)(1.214) = 10145.4$
	ⓕ	$-(1671.38)(0.917)^2 = -1405.4$	$2(1671.38)(0.997) = 3065.3$
		3428.8	37094.5

$$\delta Q = \frac{3428.8}{37094.5} = 0.092\ m^3/s \quad @ 92\ l/s.$$

III	ⓕ	$1671.38(0.917)^2 = 1405.4$	$2(1671.38)(0.917) = 3065.3$
	ⓖ	$-5014(0.869)^2 = -3786.4$	$2(5014)(0.869) = 8714.3$
	ⓗ	$4178(0.631)^2 = 1663.5$	$2(4178)(0.631) = 5272.6$
		-717.5	17052.2

$$\delta Q = \frac{-717.5}{17052.2} = -0.042\ m^3/s \quad @ -42\ l/s.$$





$$f = 0.002(1 + 25/d)$$
$$= 0.002 + 0.05/d$$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + z_B + \frac{V_B^2}{2g} + \sum \text{losses}_{(AB)}$$

$$z_A - z_B = \sum \text{losses}_{(AB)}$$
$$(1.5 - 0) = \sum \text{losses}_{(AB)}.$$

$$\sum \text{losses}_{AB} = KQ^2 + KQ^2$$

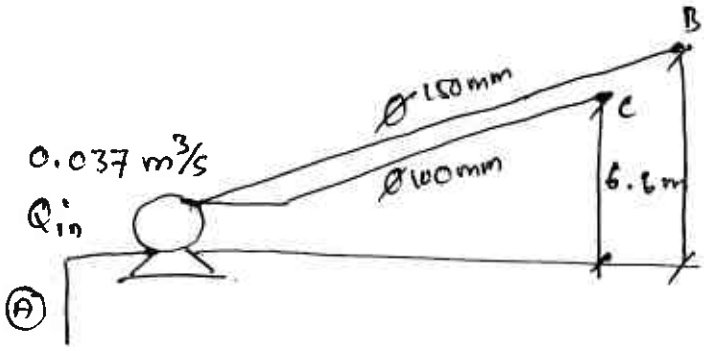
$$\sum \text{losses} = \frac{16 f_1 l_1}{2g\pi^2 d^5} Q^2 + \left(\frac{16 f_2 l_2}{2g\pi^2 d^5}\right) Q^2$$

$$\sum \text{losses} = \frac{16(0.002 + 0.05/d)(7.5)}{2g\pi^2 d^5} Q^2 + \frac{16(0.002 + 0.05/d)60}{2g\pi^2 d^5} Q^2$$

$$\sum \text{losses} = 11.403 \times 10^3 Q^2 + 25.332 Q^2$$

$$1.5 = 11428.52 Q^2$$

$$Q = 0.0115 \text{ m}^3/\text{s}.$$



$f = 0.032$

$Q_A = Q_B + Q_C.$

$\Sigma loss_B = \Sigma loss_C$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A + H_p = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + \Sigma loss_{(AB)}$$

guess Q_B. as $0.017\ m^3/s$.

$Q = AV$

$V = \frac{4Q}{\pi d^2}$

$V = 0.962\ m/s.$

$$\Sigma loss_B = \left(\frac{fl}{d}\right)\frac{V^2}{2g}$$

$$= \frac{(0.032)(60)}{0.15}\left(\frac{0.962^2}{2g}\right)$$

$\Sigma loss_B = 0.604$

$$\Sigma loss_B = \frac{f_c l_c}{d_c}\left(\frac{V_c^2}{2g}\right)$$

$$0.604 = \frac{(0.032)(45)}{0.1}\frac{V_c^2}{2g}$$

$V_c = 0.91\ m/s.$

$$Q_c = \frac{\pi d^2}{4} V$$

$= 0.00712\ m^3/s.$

Take a ratio Q_B/Q_C.

$$Q_B = \left(\frac{Q_B'}{(Q_B' + Q_C')}\right) Q_A = 0.0261\ m^3/s.$$

$$Q_C = \left(\frac{Q_C'}{(Q_B' + Q_C')}\right) 0.037 = 0.0109\ m^3/s.$$

$$\frac{P_A}{e_1} + \frac{V_A^2}{2_1} + Z_A + Hp = \frac{P_B}{e_1} + \frac{Z_B^2}{2_1} + Z_B + \Sigma loss_{AB}$$

$$Hp = (Z_B - Z_A) + \Sigma loss.$$

$$Hp = 8.5 + 0.604$$

$$Hp = 9.204\ watt.$$