مراجعه هيدروليكا
ثانيه

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ثانية مدني
هيدروليكا
يناير ٢٠١٠

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
IRRIGATION & HYDRAULICS DEPARTMENT
2nd YEAR CIVIL

Time : 3.00 Hrs

Hydraulics

The Exam Consists of four Questions in Three Pages.

Answer All Questions

Question One (25%)

a. A trapezoidal channel of side slopes 1:1, bed width $b = 5.0$ m and roughness coefficient $n = 0.02$ was used to convey water at a depth of 1.5 m until it's decided to decrease the side slopes of the channel to be 2: 1 due to slope stability problems. What is the new bed width if the discharge, water depth and the bed slope are to be kept the same?

b. A rectangular channel is 4.0m wide and carries a discharge of 20m^3/sec at a depth of 2.0m. At a certain section it is proposed to build a hump with 0.4m height.
   i. Find the type of flow.
   ii. Calculate the water depth upstream and over the hump.
   iii. Calculate the minimum width required to produce critical conditions.

Explain your answer using neat sketches.

Question Two (25%)

a. Derive the expression for the hydraulic jump sequent depths in rectangular section. (Starting from the first principle).

b. Sketch the water surface profiles for the following cases.
   i. Reservoir – mild – gate – mild – waterfall.
   ii. Mild – steep – gate – steep – Mild.

c. Water flowing under a sluice gate enters a concrete lined rectangular channel having a width of 7.0m and Manning's coefficient n= 0.0 18 and a slope of 1 in 1000. The sluice gate is regulated to discharge 12.0 m^3/s at a depth of 0.20 m at the vena-contracta.
   i. Determine the length of the channel through which the flow is non-uniform .Use direct step method (two steps only).
   ii. Determine the power lost through the jump.
   iii. Draw the T.E.L and H.G.L through the channel.

Question Three (20%)

a. A horizontal steel pipe is supplied from a reservoir with a head (H) of 120 m. The pipe has a diameter of 30 cm, a length of 1000 m, and a wall thickness of 0.20 cm. There is a valve at the downstream end and the pipe is anchored at both ends (K = 0.9375). If the valve is initially wide opened,

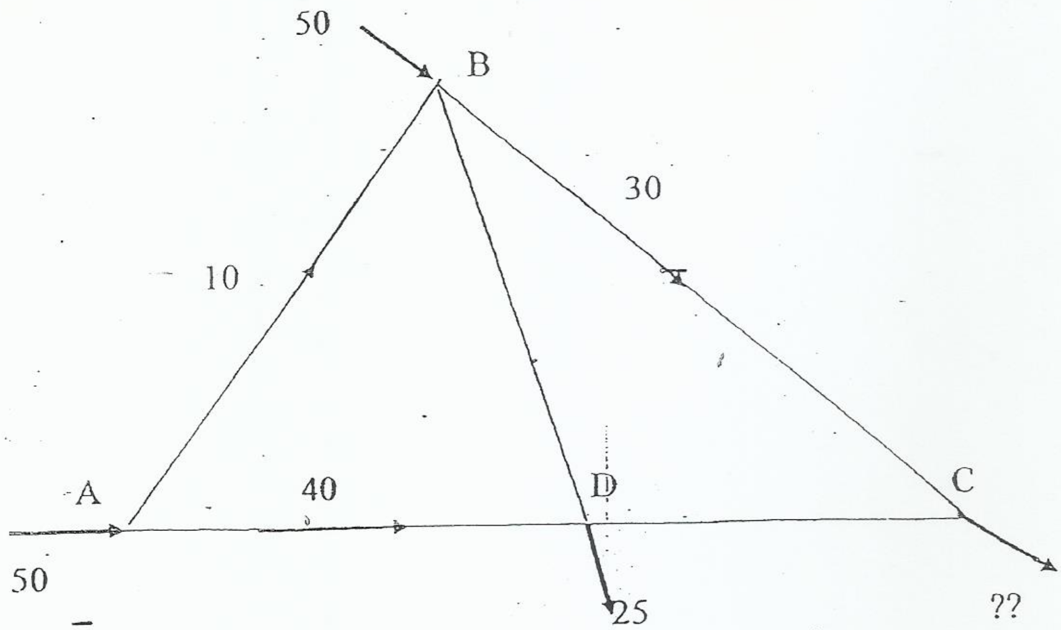
   i. Calculate the pressure rise at the valve if the time of closure is 1.0 sec.

      [$E_p = 1.9 \times 10^{11} N/m^2$, $E_w = 2.0 \times 10^9 N/m^2$ and F = 0.013].

      Neglect secondary losses

   ii. Sketch the wave celerity through the pipe for a complete cycle.

b. Use Hardy Cross method to determine the flow through the pipes for the shown network. The discharge is in lit/sec. (Two iteration only).



Pipe	AB	BC	CD	DB	DA
K	5	4	3	1	2

Question Four (30%)

This table represents the characteristic curve for a single pump:

Discharge (l/sec)	0.0	20	40	60	80	100	120
Head (m)	50	49.2	46.8	42.8	37.2	30	21.2
ηt %	0	30	50	55	53	48	40

It is required to pump 555 m^3/hr through a pipeline system as follows:

- Suction side; L = 9.0 m, F = 0.0318, d = 20.32 cm
- Delivery side; L = 54.656 m, F = 0.0318, d = 15.24 cm
- Static head = 5.0 m, and the pump is 2.0 m above the sump level
- The daily working hours are 15 hrs.

Neglect all the minor losses.

a) Determine the total head (m), and discharge (m^3/hr). if:
   i. One pump is utilized.
   ii. Two pumps in series are utilized.
   iii. Two pumps in parallel are utilized.

b) Select one case from above to satisfy the flow demand and give reasons.

c) For the selected case above

   i) Check the system against cavitation.

   Req. NPSH = 3.0 m, $\frac{P_{atm}}{\gamma} = 10.33\ m, \quad \frac{P_{vap}}{\gamma} = 0.25\,m\ (abs.)$

   If it is unsafe, what do you suggest?

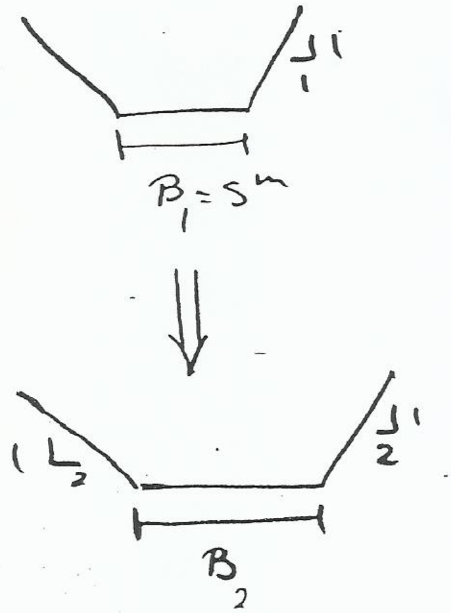
   ii) Calculate the annual cost of working power if the cost of 1 kw-hr = 0.30L.E

d) In the design problems, why do you need to calculate the total annual cost? State the methodology to calculate it.

Jan 2010

Question one:

(a)



$n = 0.02$

$y_N = 1.5^m$

$Q_1 = Q_2$

$y_{N_1} = y_{N_2}$

$S'_{o_1} = S'_{o_2}$

$\therefore \; Q_1 = Q_2$

$$\cancel{\frac{1}{n}} R_1^{2/3} \cancel{\sqrt{S_o}} \, A_1 = \cancel{\frac{1}{n}} R_2^{2/3} \cancel{\sqrt{S_o}} \, A_2$$

$$\frac{A_1^{5/3}}{P_1^{2/3}} = \frac{A_2^{5/3}}{P_2^{2/3}}$$

$$A_1 = B_1 y_1 + Z_1 y_1^2 = 5 \times 1.5 + 1 \times 1.5^2 = 9.75 \, m^2$$

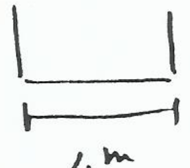
$$P_1 = B_1 + 2y_1\sqrt{1+Z_1^2} = 5 + 2 \times 1.5 \times \sqrt{1+1^2} = 9.243 \, m$$

$$\therefore \; \frac{A_2^{5/3}}{P_{2o}^{2/3}} = 10.1034$$

$$\therefore \; \frac{(B_2 * 1.5 + 2 * 1.5^2)^{5/3}}{(B_2 + 2 \times 1.5 * \sqrt{1+1.5^2})^{2/3}} = 10.1034$$

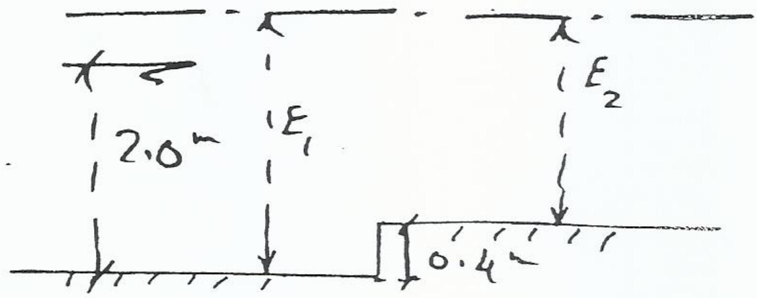
By trial & Error $\quad B_2 = 3.366^m \simeq 3.40^m$

(b)



$Q = 20\ m^3/sec$

$y = 2.0^m$



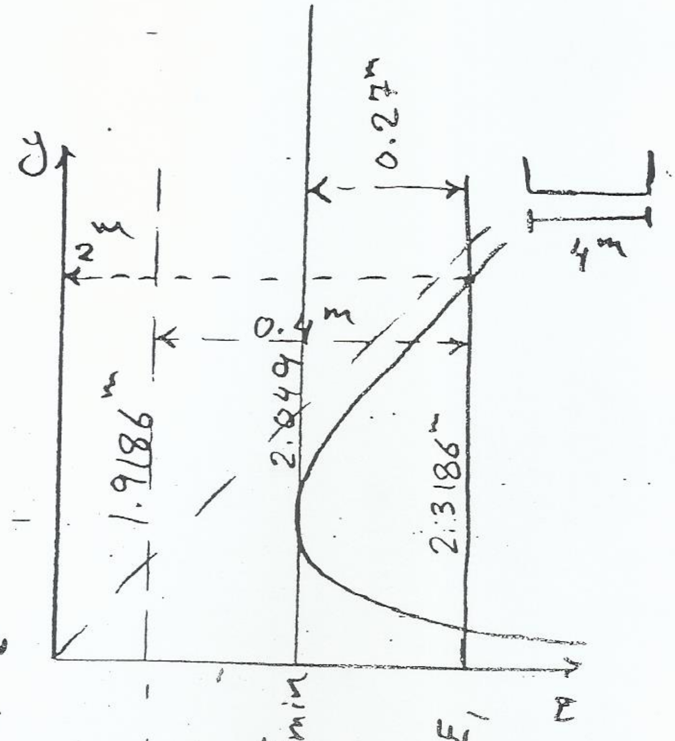
(i) $y_c = \sqrt[3]{q^2/g}$

$q = Q/B = 20/4 = 5\ m^3/s/m$

$\therefore y_c = 1.366^m$

$\because y_N = 2.0^m > y_c$

subcritical flow



(ii) $E_1 = y_1 + \frac{Q^2}{2gA_1^2} = 2 + \frac{20^2}{2 \times 9.81 \times (4 \times 2)^2}$

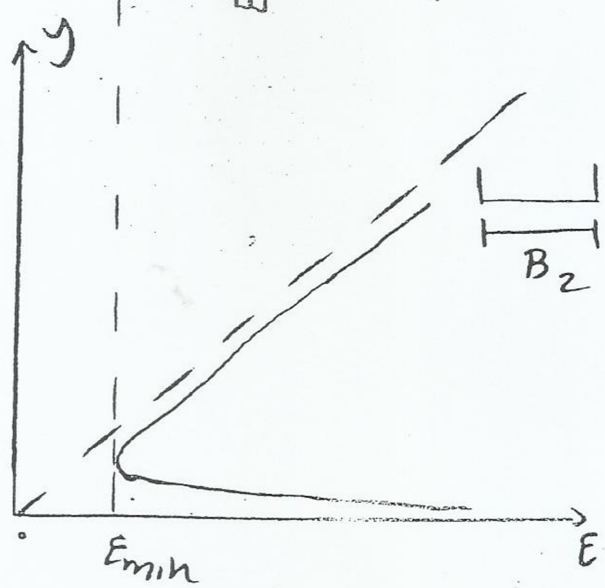
$= 2.3186^m$

$E_{min} = 1.5 y_c = 1.5 \times 1.366$

$= 2.049^m$

$\Delta Z_{max} = 0.27^m$

$\therefore E_1' = 2.049 + 0.4 = 2.449^m$

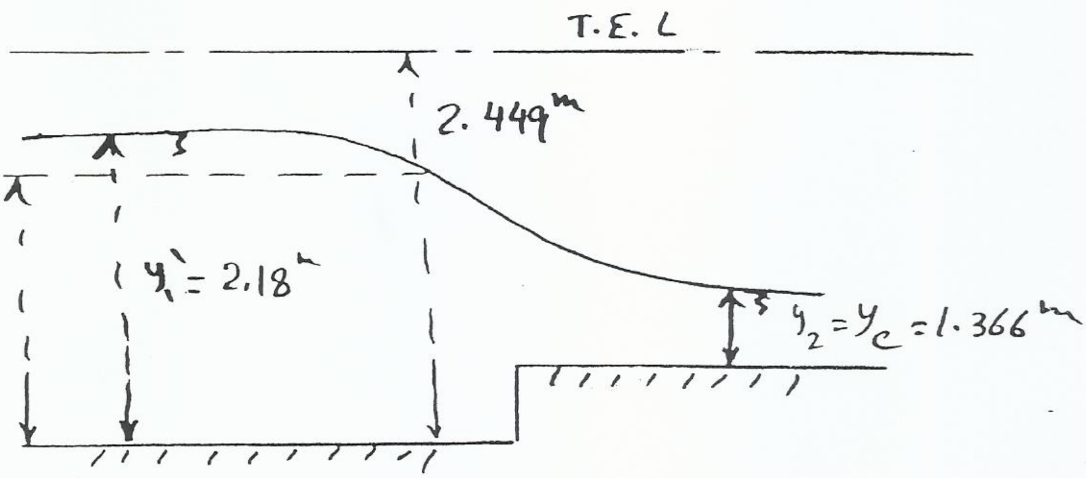


$\because E_1' = y_1' + \frac{Q^2}{2gA_1^2}$

$2.449 = y_1' + \frac{20^2}{2 \times 9.81 \times 4^2 \times y_1'^2}$

$(y_1')^3 - 2.449(y_1')^2 + 1.274 = 0$

$y_1' = 2.10^m$



(iii) A new section is required were

$$\therefore E_{min_{(2)}} = 1.9186^m$$

$$\therefore 1.5\, y_{c_{(2)}} = 1.9186^m$$

$$y_{c_{(2)}} = 1.28^m$$

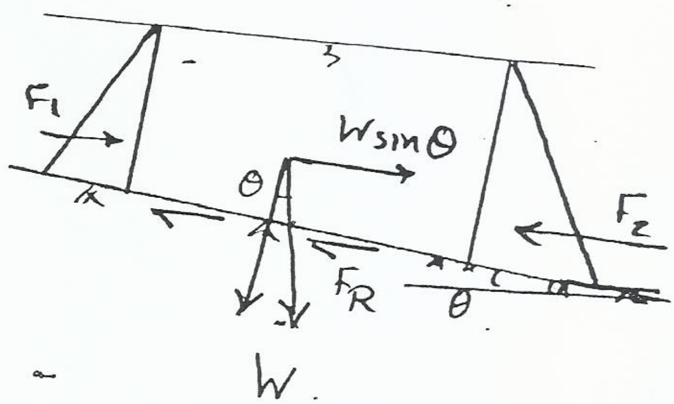
$$y_{c_{(2)}} = \sqrt[3]{q^2/g} = 1.28$$

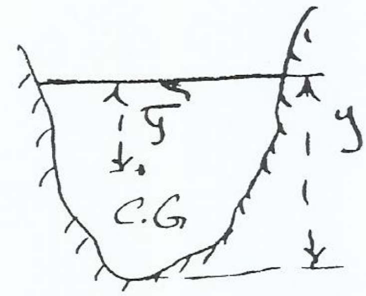
$$\therefore \frac{(20/B_2)^2}{9.81} = (1.28)^3$$

$$\boxed{\therefore B_2 = 4.40^m}$$

Question Two:

(a)





$\Sigma F = ma$

$\therefore F_1 + \cancel{W\sin\theta} - F_2 - \cancel{F_R} = \rho Q(V_2 - V_1)$

Assuming frictionless Horizontal Bed

$\gamma A\bar{y}_1 - \gamma A\bar{y}_2 = \rho Q(V_2 - V_1)$

$\because$ x-section is Rec.

$A = By \qquad \bar{y} = \frac{y}{2}$

$\therefore \gamma B y_1 * \frac{1}{2} y_1 - \gamma B y_2 * \frac{1}{2} y_2 = \rho Q(V_2 - V_1)$

$(\div B) \quad \therefore \frac{\gamma}{2}(y_1^2 - y_2^2) = \rho q (V_2 - V_1)$

$y_1^2 - y_2^2 = \frac{2q}{g}(V_2 - V_1)$

$= \frac{2q}{g}\left(\frac{Q}{A_2} - \frac{Q}{A_1}\right) = \frac{2q^2}{g}\left(\frac{1}{y_2} - \frac{1}{y_1}\right)$

$\therefore \cancel{(y_1 - y_2)}(y_1 + y_2) = \frac{2q^2}{g} * \frac{\cancel{(y_1 - y_2)}}{y_1 y_2}$

$(\div y_1^3) \qquad y_1 y_2 (y_1 + y_2) = \frac{2q^2}{g}$

$$\frac{y_2}{y_1}\left(1+\frac{y_2}{y_1}\right) = \frac{2q^2}{g y_1^3}$$

$$\because Fr_1 = \frac{V}{\sqrt{g y_1}} = \frac{q}{y_1\sqrt{g y_1}}$$

$$\therefore Fr_1^2 = \frac{q^2}{g y_1^3}$$

$$\therefore \frac{y_2}{y_1}\left(1+\frac{y_2}{y_1}\right) = 2 Fr_1^2$$

Assume $x = \frac{y_2}{y_1}$

$$\therefore x + x^2 - 2 Fr_1^2 = 0$$

Quadratic eq

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

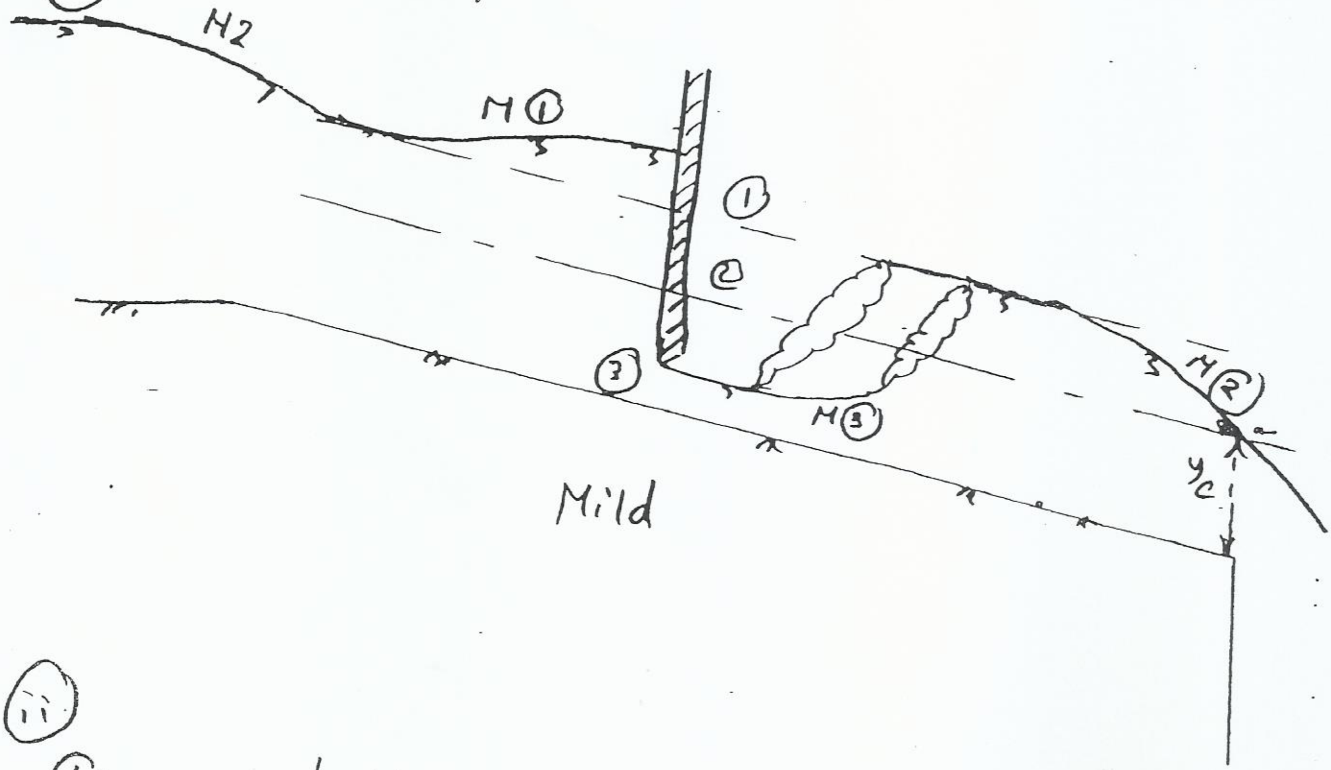
$b = 1$, $a = 1$; $c = -2 Fr_1^2$

$$\therefore x = \frac{-1 + \sqrt{1 + 8 Fr_1^2}}{2}$$

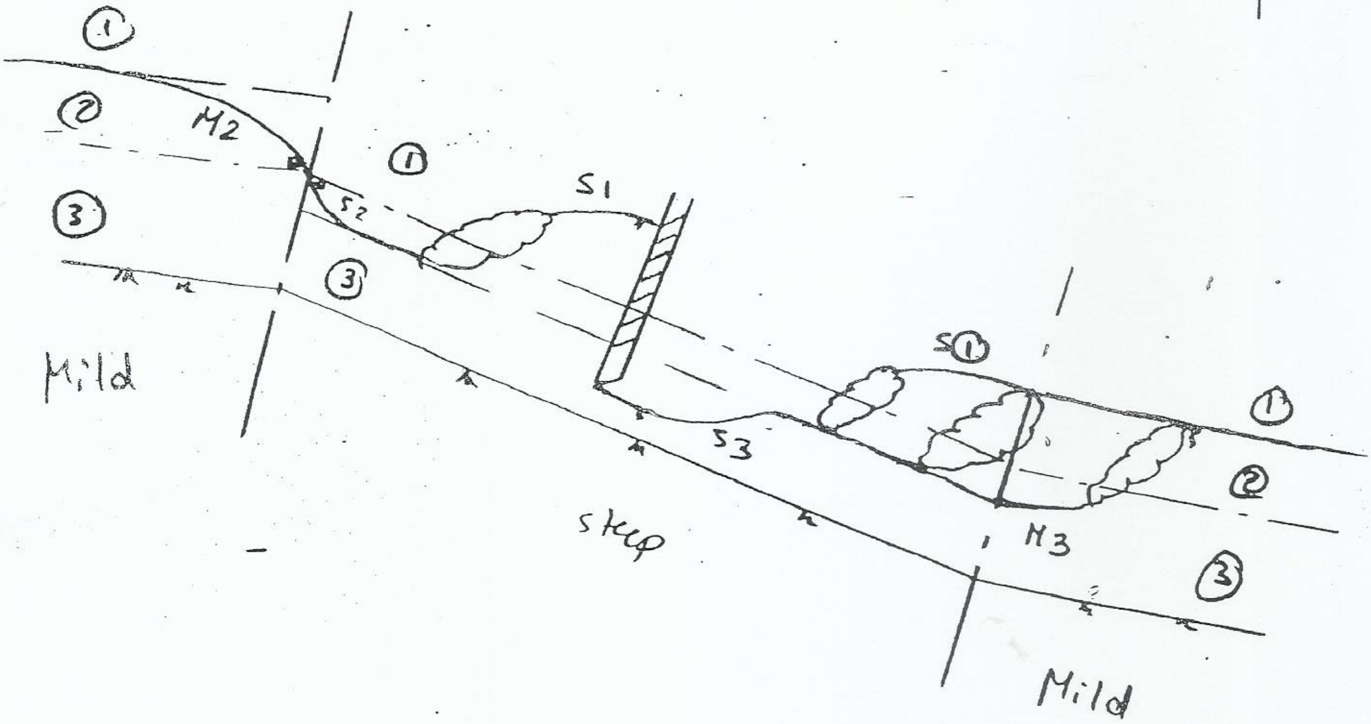
$$\boxed{\therefore \frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{1+8Fr_1^2}\right]}$$

(b)

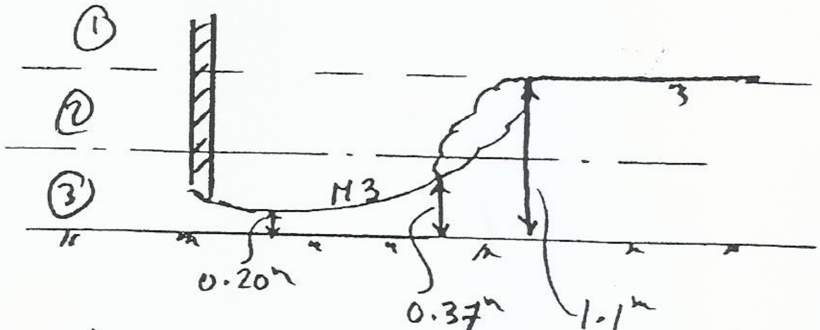
(i)

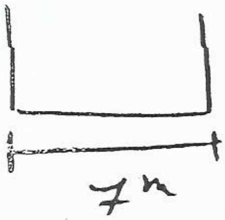

M2
M1
1
2
3
M3
M2
y_c
Mild

(ii)


1
2
3
M2
1
S2
S1
3
Mild
S1
1
S3
2
steep
M3
3
Mild

(c)





$n = 0.018^{m}$

$S = 1/1000$

$Q = 12\ m^3/sec$

$y_v = 0.20^{m}$

$$Q = \frac{1}{n} R^{2/3} \sqrt{S_o}\ A$$

$$\frac{Qn}{\sqrt{S_o}} = \frac{A^{5/3}}{P^{2/3}}$$

$$\frac{12 \times 0.018}{\sqrt{1/1000}} = \frac{(7y)^{5/3}}{(7+2y)^{2/3}}$$

By trial & Error

$y_n = 1.1^{m}$

to Jump to occur

$$\frac{y_2}{y_v} = \frac{1}{2}\left[-1+\sqrt{1+8Fr_v^2}\right]$$

$$\therefore \frac{y_2}{0.20} = \frac{1}{2}\left[-1+\sqrt{1+8\times 6.12^2}\right]$$

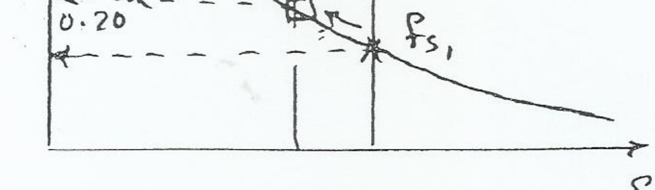
$$Fr_v = \frac{Q}{By_v\sqrt{gy_v}} = 6.12$$

$$\boxed{y_2 = 1.633^{m}}$$

$$y_c = \sqrt[3]{q^2/g}$$

$$= \sqrt[3]{\frac{(12/7)^2}{9.81}} = 0.67^{m}$$

$y_n > y_c$ (Mild slope)



$$\frac{y_1}{y_2} = \frac{1}{2}\left[-1+\sqrt{1+8Fr_2^2}\right]$$

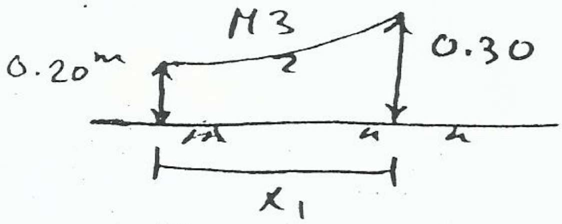
$$Fr_2 = \frac{Q}{By_2\sqrt{gy_2}} = 0.474$$

$$\boxed{\therefore y_1 = 0.37^{m}}$$

For the jump length

$$L_J = 6y_2 = 6 \times 1.1 = 6.6^m$$

For Curve M3 :



$$x_1 = \frac{E_2 - E_1}{S_o - \bar{S}_f}$$

For sec 1 :

$$E_1 = y_1 + \frac{Q^2}{2gA_1^2}$$

$$= 0.20 + \frac{(12)^2}{2 \times 9.81 \times 7^2 \times 0.20^2}$$

$$= 3.945^m$$

$$P_1 = 7 + 2 \times 0.2 = 7.4^m$$

$$A_1 = 7 \times 0.2 = 1.4\ m^2$$

$$R_1 = 0.1892\ m$$

$$\therefore S_{f_1} = \left(\frac{Qn}{R_1^{2/3} A_1}\right)^2 = 0.219\ m/m$$

For sec 2 :

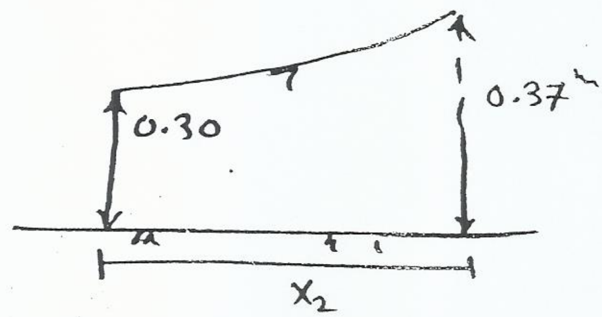
$$E_2 = 0.30 + \frac{12^2}{2 \times 9.81 \times (7 \times 0.30)^2}$$

$$= 1.964^m$$

$$P_2 = 7 + 2 \times 0.3 = 7.6^m$$

$$A_2 = 7 \times 0.3 = 2.1\ m^2$$

$$R_2 = 0.276^m$$



For sec 1 :

$$E_1 = 1.964^m$$

$$S_{f_1} = 0.059\ m/m$$

For sec 2 :

$$E_2 = 0.37 + \frac{12^2}{2 \times 9.81 \times (0.37 \times 7)^2}$$

$$= 1.464^m$$

$$P_2 = 7 + 2 \times 0.37 = 7.74^m$$

$$A_2 = 0.37 \times 7 = 2.59\ m^2$$

$$R_2 = 0.335\ m$$

$$S_{f_2} = \left(\frac{Qn}{R_2^{2/3} A_2}\right)^2$$

$$= 0.0299\ m/m$$

$$\therefore X_1 = \frac{1.964 - 3.945}{\frac{1}{1000} - \left(\frac{0.219+0.059}{2}\right)} = 14.4^m$$

$$X_2 = \frac{1.464 - 1.964}{\frac{1}{1000} - \left(\frac{0.059+0.0299}{2}\right)} = 11.51^m$$

$$X = 25.91^m$$

Total Length $= 6.6 + 25.91 = 32.50^m$

(ii) $$\text{Power Lost} = \frac{\gamma Q H_{Lost}}{0.75}$$

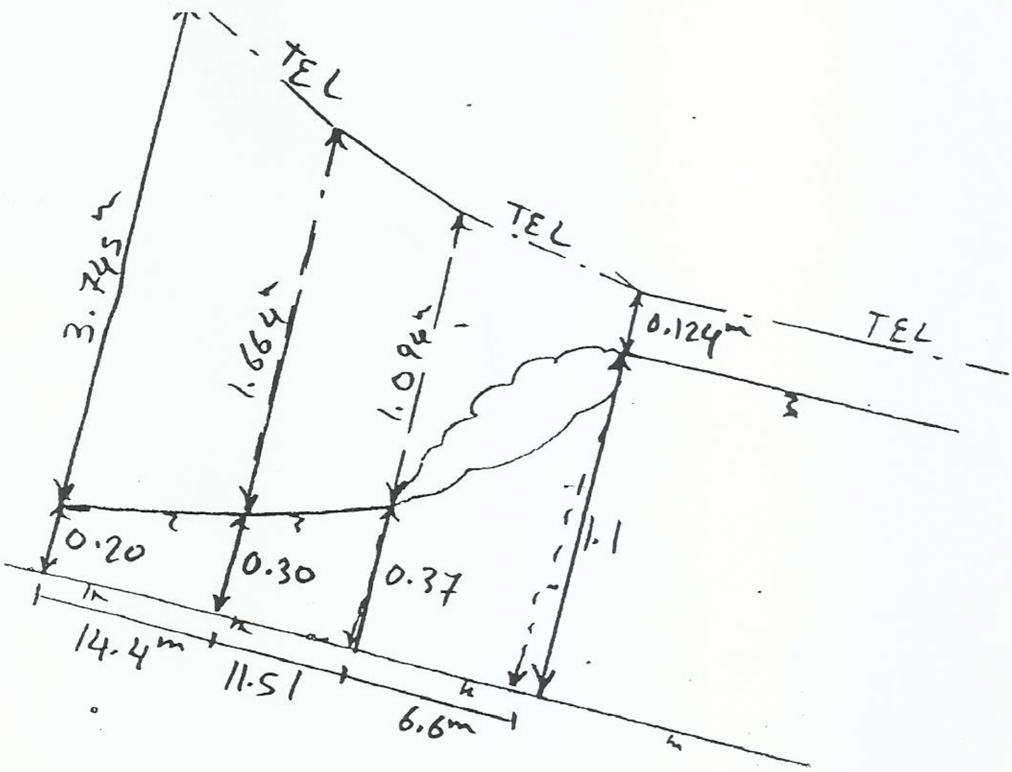
$$H_{Lost} = E_{\substack{\text{after}\\ \text{Jump}}} - E_{\substack{\text{before}\\ \text{Jump}}}$$

$$E_{after} = 1.1 + \frac{12^2}{2 \times 9.81 \times (7 \times 1.1)^2} = 1.224^m$$

$$E_{before} = 1.464^m$$

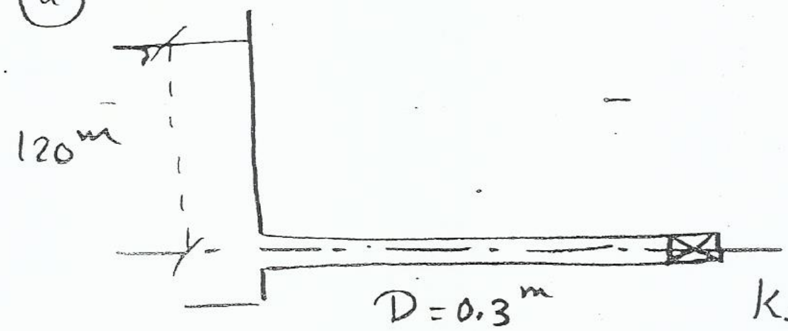
$$H_{Lost} = 0.24^m$$

$$\text{Power Lost} = \frac{9810 \times 12 \times 0.24}{0.75} = 37670 \text{ HP}$$



Question three:

(a)



$D = 0.3^{m}$

$L = 1000^{m}$

$t = 0.2 \times 10^{-2} m$

$K = 0.9375$

i) $\because C = \sqrt{\frac{K_e}{\rho}}$

$$\frac{1}{K_e} = \frac{1}{K} + \frac{KD}{Et} = \frac{1}{2\times10^{9}} + \frac{0.9375 \times 0.3}{1.9\times10^{11} \times 0.2\times10^{-2}}$$

$$= 1.24 \times 10^{-9}$$

$$K_e = 806.4 \times 10^{6}\ Pa$$

$$\therefore C = \sqrt{\frac{806.4 \times 10^{6}}{1000}} = 898\ m/s$$

$\therefore t_r = \dfrac{2L}{c} = \dfrac{2 \times 1000}{898} = 2.28 \text{ sec}$

$t_r > t_c$ [closure time]

$\therefore$ Closure is instantaneous

$\therefore \Delta H = \dfrac{-c}{g} \Delta V$

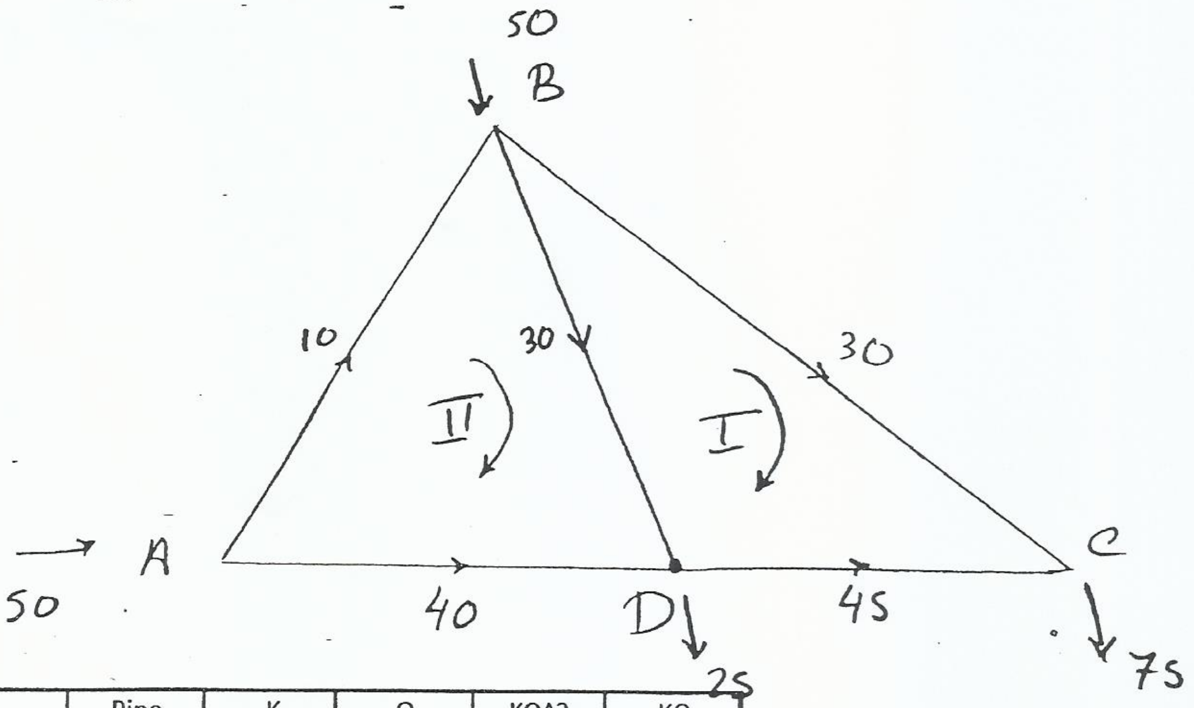
$\because \Delta V = V_f - V_i = 0 - V_o$

$\because 120 = \dfrac{f L V_o^2}{2 g d}$

$\therefore 120 = \dfrac{0.013 \times 1000 \times V_o^2}{2 \times 9.81 \times 0.3} \longrightarrow V_o = 7.4 \text{ m/sec}$

$\therefore \Delta H = \dfrac{-898}{9.81} * (0 - 7.4) = 677.4^{m}$

(b)

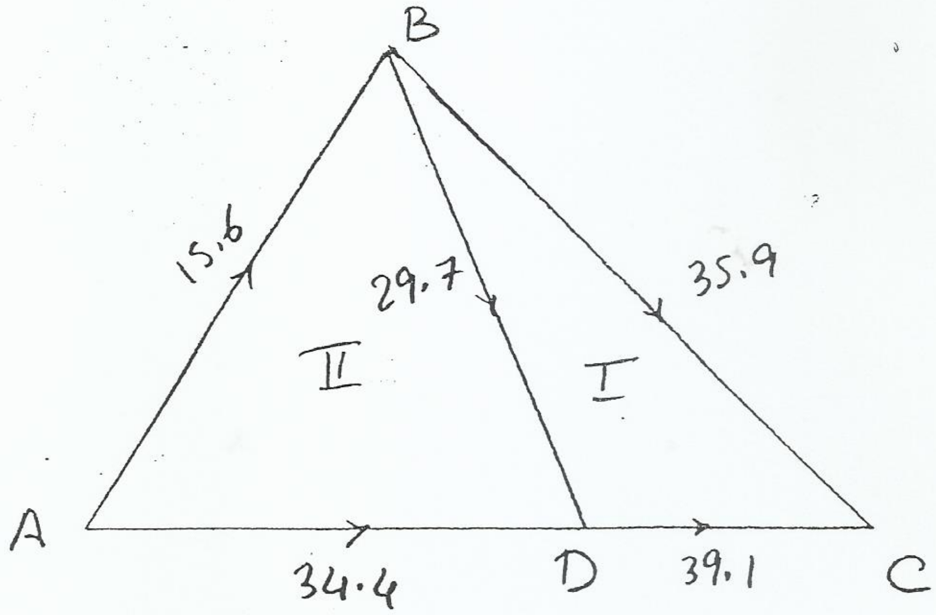


	Pipe	K	Q	KQ^2	KQ
Loop I	BC	4	0.03	0.0036	0.1200
	DC	3	0.045	-0.0061	0.1350
	BD	1	0.03	-0.0009	0.0300
				-0.0034	0.2850

ΔQ = 0.0059 = 5.9 L/s

	Pipe	K	Q	KQ^2	KQ
Loop II	BD	1	0.03	0.0009	0.0300
	AD	2	0.04	-0.0032	0.0800
	AB	5	0.01	0.0005	0.0500
				-0.0018	0.1600

ΔQ = 0.0056 = 5.6 L/s

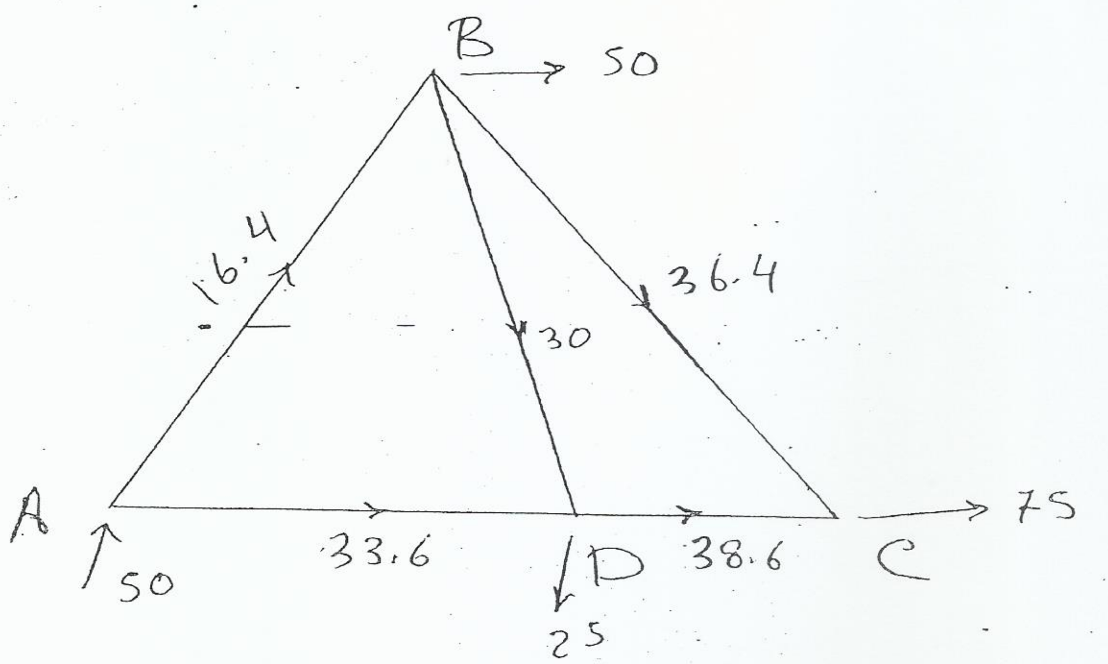


	Pipe	K	Q	KQ^2	KQ
Loop I	BC	4	0.0359	0.0052	0.1436
	DC	3	0.0391	-0.0046	0.1173
	BD	1	0.0297	-0.0009	0.0297
				-0.0003	0.2906

$\Delta Q =$ 0.0005 $= 0.5\ L/s$

	Pipe	K	Q	KQ^2	KQ
Loop II	BD	1	0.0297	0.0009	0.0297
	AD	2	0.0344	-0.0024	0.0688
	AB	5	0.0156	0.0012	0.0780
				-0.0003	0.1765

$\Delta Q =$ 0.0008 $= 0.8\ L/s$



(a) (i) 1 pump is utilized

G (m^3/hr)	0	72	144	216	288	360	432	
Total Head (m)	50	49.2	46.8	42.8	37.2	30	21.2	single pump
Total Head (m)	100	98.4	93.6	85.6	74.4	60	42.4	2 pump in serie

For 2 pumps in parallel:-

G (m^3/hr)	0	144	288	432	576	720	864
Total head (m)	50	49.2	46.8	42.8	37.2	30	21.2

For system Curve

$$h_f = H_{static} + KG^2$$

$$K = \frac{8fL}{\pi^2 g d^5}_{suction} + \frac{8fL}{\pi^2 g d^5}_{Delivery}$$

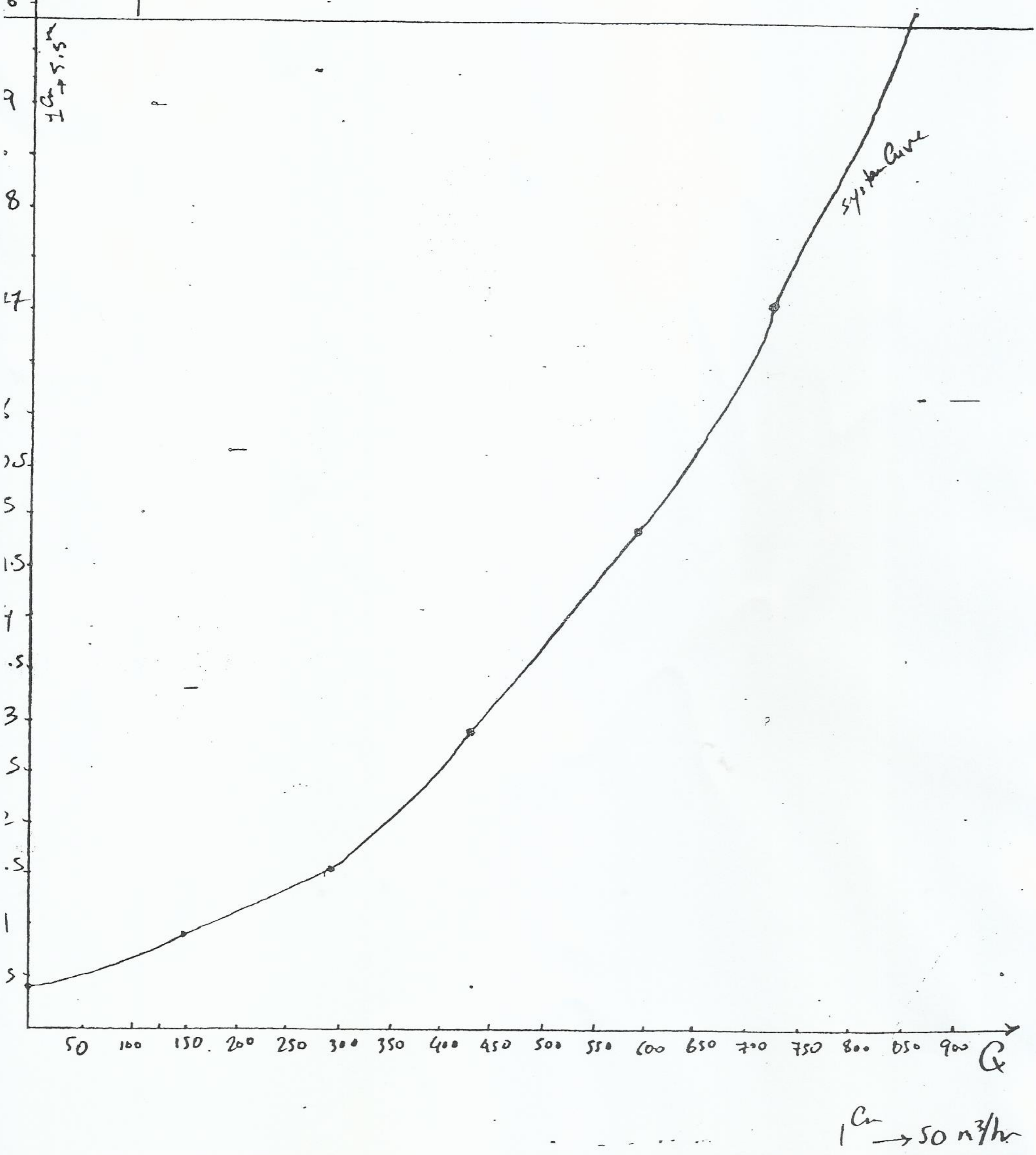
$$= \frac{8 \times 0.0318 \times 9}{\pi^2 \times 9.81 \times (0.2032)^5} + \frac{8 \times 0.0318 \times 54.656}{\pi^2 \times 9.8.1 \times (0.1524)^5}$$

$$= 1815.134$$

$$\therefore h_p = 5 + 1815.134 G^2$$

system Curve :

Q (m^3/hr)	0	144	288	432	576	720	864
H system	5	7.9	16.62	31.14	51.5	77.6	109.6



E

Final Exams

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
IRRIGATION & HYDRAULICS DEPARTMENT
2^{nd} YEAR CIVIL

2008-2009

Time : 3.00 Hrs

Hydraulics

The Exam Consists of Six Questions in Three Pages.

Question One (8 M)

a) ***Derive*** Chezy formula for the uniform steady flow in open channel.

b) A main canal is used to irrigate 125000 feddans. The water duty is 25 m^3/ feddan/ day for 40 % of the area served and 20 m^3/ feddan/ day for 60 % of the area served. Assuming Manning coefficient of 0.035, bed slope 10 cm/km and side slopes of 2:1. ***Design*** the main canal such that the maximum water velocity is equal to 0.5 m/sec.

Question Two (15 M)

a) A rectangular concrete channel 3.5 m wide carries 2.5 m^3/sec discharge. Chezy coefficient is equal to 50. ***Find*** the channel slope such that the velocity of uniform flow is double the critical velocity. ***Calculate*** the sequent depth of the hydraulic jump and the head loss.

b) A very long rectangular canal of bed width 10 m and bed slope 15 cm/ km is used to convey a discharge of 15 m^3/sec. Manning coefficient n = 0.012. A short and smooth hump of height z is introduced to the canal bed. ***Calculate*** the maximum allowable hump height such that the water level upstream the hump remains the same. Also ***calculate*** the water depth upstream the hump when its height is increased to 0.7 m. ***Sketch*** the water surface profile for both cases.

Question Three (10 M)

A wide rectangular channel has a bed slope of 1:500 Chezy's Coefficient is 40 (metric) and the discharge per unit width is 0.585 m^3/sec/m. The water enters the channel under a sluice gate. The depth just downstream the gate is 0.1 m. A weir is built at a distance of 1000 m downstream the gate to raise the water depth at its site to 1.22 m.

i) ***Sketch*** the water surface profile and

ii) ***Compute*** the length of the backwater curve. (Use **step by step method** in two steps).

Question Four (10 M)

A horizontal steel pipe is supplied from a reservoir with a head (H) of 100 m. The pipe has a diameter of 20 cm, a length of 1500 m, and a wall thickness of 0.25 cm. There is a valve at the downstream end and the pipe is anchored at both ends (K = 0.9375). If the valve was initially wide opened,

a) ***Prove*** that $\Delta P = \rho\, v\, C$.

b) ***Calculate*** the pressure rise at the valve if the time of closure is:

i) 0.5 sec ii) 5 sec

Take $E_p = 1.9 \times 10^{11}$ N/m^2 and $E_w = 2.0 \times 10^9$ N/m^2

Assume F = 0.014 and neglect secondary losses.

c) ***Calculate*** the existing stresses in the pipe ***in case (i) only.***

d) ***Sketch*** the wave celerity through the pipe ***at time equal L/C only*** in the following two cases:

i) If the valve is at the downstream of the pipe.

ii) If the valve is at the middle of the pipe.

Question Five (7 M)

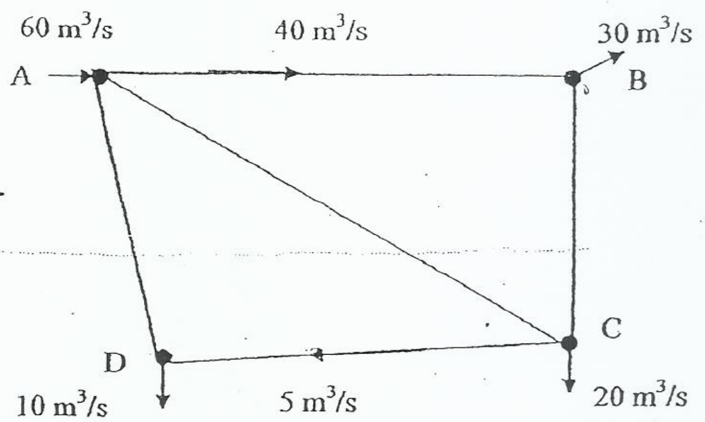
a) ***Compare*** between the different methods of the analysis techniques in the pipe networks.

b) For the pipe network shown in the following figure;

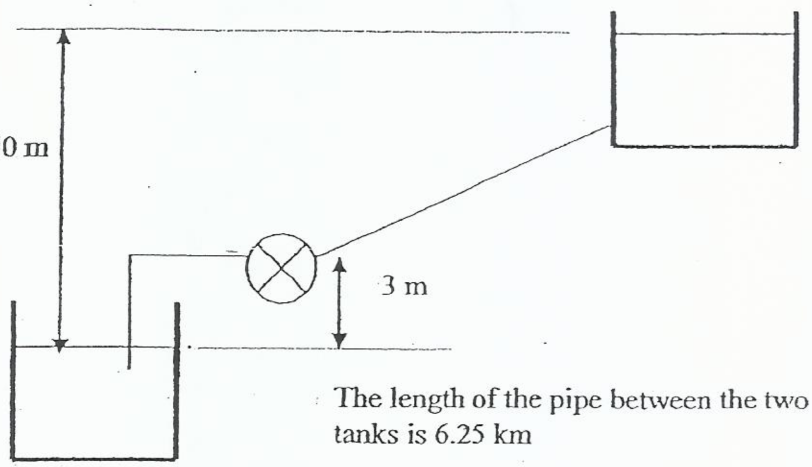
i) ***Write down*** the (ΔQ-system) equations. The solution of the equations is not required.

ii) ***Solve*** the network using the Hardy Cross Method. (*One step* only is required)

K is constant for all the pipes and equals 2.



Question Six (10 M)



The length of the pipe between the two tanks is 6.25 km

It is required to pump 1600 m^3/day for the shown system. The daily working daily hours is 12 hours. Take F = 0.016 and $\Sigma hL_{suction} = 4$ m. Neglect the minor (secondary) losses. The characteristic curve (pump curve) for a single pump is given below:

Discharge (L/sec)	0	10	20	30	40	50
Head (m)	120	118	112	102	88	70
Efficiency %	-	60	70	80	70	60

a) ***Design*** the pipe diameter. The available diameters are 50,100,150,200 mm, ...

b) ***Draw*** the system curve, then ***get*** the operating discharge and head point.

c) ***Estimate*** the W.H.P, E.H.P, and daily cost of operating if 1 kw-hour costs 0.30 L.E.

d) ***Check*** – the system against cavitaion. Req. NPSH = 3.0 m, $\frac{P_{atm}}{\gamma} = 10.33\ m$, $\frac{P_{vap}}{\gamma} = 0.25\ m$

e) ***Where*** is the point through the pipe which has the maximum positive pressure head? ***Calculate*** its value in bar.

f) ***What*** is the meaning of negative static head Hs?. ***Sketch*** the system curve in this case.

GOOD LUCK

January 2009

Question 1

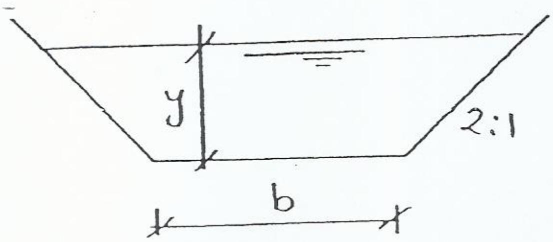
Area served $= 125\,000$ fd

water duty$_1$ $= 25\ m^3/fd/day$ for 40 % of A_{served}

water duty$_2$ $= 20\ m^3/fd/day$ for 60 % of A_{served}

$n = 0.035$ $S = 10\ cm/Km$

$V = 0.5\ m/s$ Design



Solution

$$Q = W.D_1 * 0.4\,A_s + W.D_2 * 0.6\,A_s$$

$$= (25 * 0.4 + 20 * 0.6)\,125\,000 = 2{,}750{,}000\ m^3/day$$

$$= \frac{2{,}750{,}000}{24 * 60 * 60} = 31.8\ m^3/s$$

$$A = \frac{Q}{V} = \frac{31.8}{0.5} = 63.6 = by + zy^2 = by + 2y^2 \quad \to ①$$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$0.5 = \frac{1}{0.035}\left(\frac{63.6}{P}\right)^{2/3}\left(10 * 10^{-5}\right)^{1/2} \Rightarrow P = 27.5\ m$$

$$P = b + 2y\sqrt{z^2+1}$$

$$27.5 = b + 2y\sqrt{(2)^2+1} = b + 4.47y$$

$$\therefore b = 27.5 - 4.47y \quad \to ②$$

from ①, ②

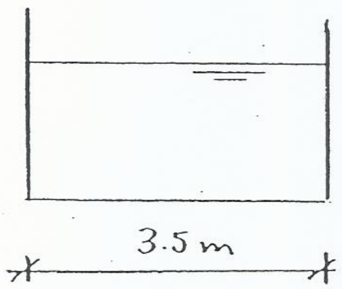
$$(27.5 - 4.47y)\,y + 2y^2 = 63.6$$

$$2.47y^2 - 27.5y + 63.6 = 0 \Rightarrow y = \underline{3.27} \quad b = \underline{12.9}$$

Question 2a

$Q = 2.5\ m^3/s \qquad C = 50$

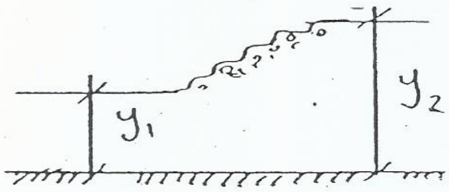
$V_n = 2V_c \qquad S = ? \quad y_2 = ? \quad h_L = ?$



Solution

$$q = \frac{Q}{b} = \frac{2.5}{3.5} = 0.714$$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{(0.714)^2}{9.81}} = 0.373\ m$$



$$V_c = \sqrt{g y_c} = \sqrt{9.81(0.373)} = 1.91\ m/s$$

$$V_n = 2V_c = 2(1.91) = 3.82\ m/s$$

$$A = b y_1 = 3.5 y_1 = \frac{Q}{V_n} = \frac{2.5}{3.82} = 0.65$$

$$\therefore y_1 = 0.187\ m$$

$$P = b + 2y_1 = 3.5 + 2(0.187) = 3.87$$

$$R = \frac{A}{P} = \frac{0.65}{3.87} = 0.168$$

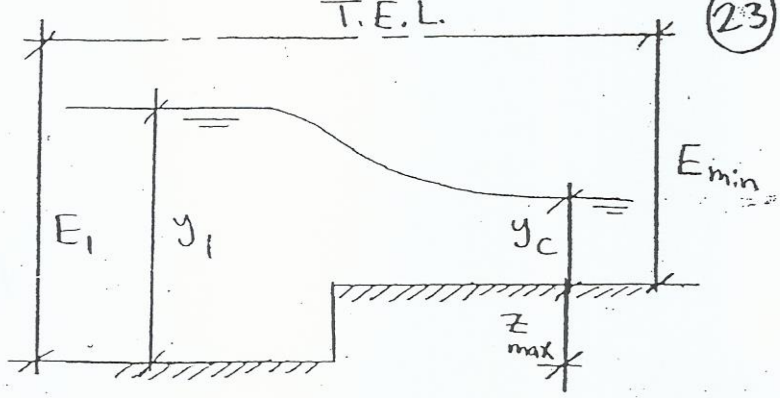
$$Q = CA\sqrt{RS}$$

$$2.5 = 50(0.65)\sqrt{0.168\ S} \Rightarrow S = 0.0352$$

$$F_1 = \frac{V}{\sqrt{g y_1}} = \frac{3.82}{\sqrt{9.81(0.187)}} = 2.82$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[\sqrt{1 + 8F_1^2} - 1\right]$$

$$y_2 = \frac{0.187}{2}\left[\sqrt{1 + 8(2.82)^2} - 1\right] = 0.658\ m$$



Question 2b

$b = 10\ m \qquad S = 15\ cm/Km$

$Q = 15\ m^3/s \qquad n = 0.012$

$Z_{max} = ?$

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

$$15 = \frac{1}{0.012}\left(\frac{10y}{10+2y}\right)^{2/3}\left(15 * 10^{-5}\right)^{1/2} 10y$$

by trial and error $\Rightarrow y_1 = 1.39$

$$q = \frac{Q}{b} = \frac{15}{10} = 1.5\ m^3/s/m'$$

$$E_1 = y_1 + \frac{q_1^2}{2gy_1^2} = 1.39 + \frac{(1.5)^2}{2(9.81)(1.39)^2} = 1.45$$

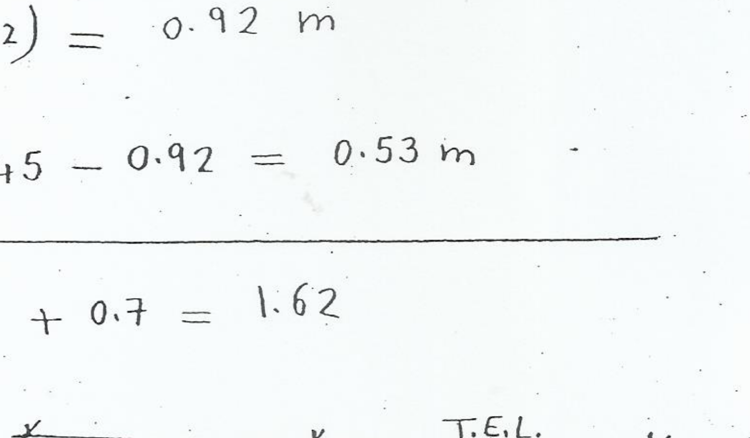
$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{(1.5)^2}{9.81}} = 0.612\ m$$

$$E_{min} = \frac{3}{2} y_c = \frac{3}{2}(0.612) = 0.92\ m$$

$$Z_{max} = E_1 - E_{min} = 1.45 - 0.92 = 0.53\ m$$

$$E_1' = E_{min} + Z = 0.92 + 0.7 = 1.62$$

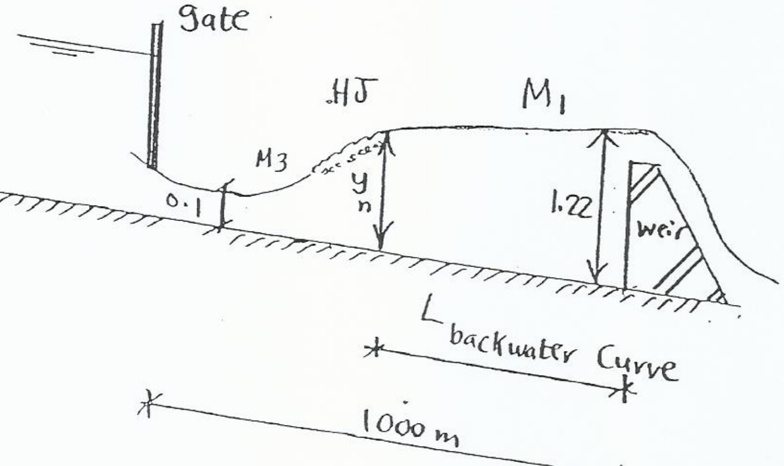
$$E_1' = y_1' + \frac{q_1^2}{2gy_1'^2}$$



$$1.62 = y_1' + \frac{(1.5)^2}{2(9.81)\,y_1'^2}$$

$$y_1' = 1.57$$

Question 3 Jan 2009



$S' = \frac{1}{500}$ $C = 40$

$q = 0.585 \ m^3/s/m'$

wide rectangular $\Rightarrow R \cong y$

Solution

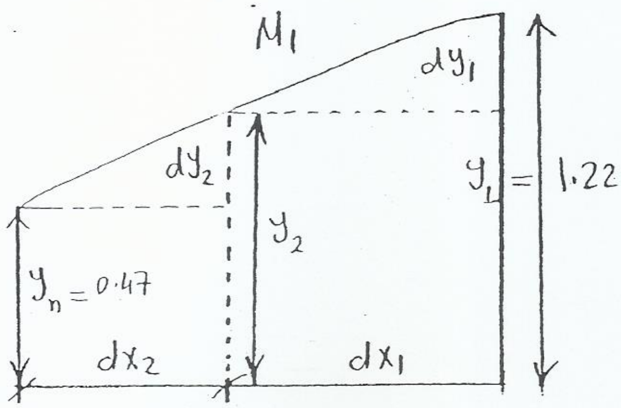
$q = C y \sqrt{R S}$

$0.585 = 40 \, y \sqrt{y \frac{1}{500}}$

$\Rightarrow y_n = 0.47 \text{ m}$

$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{(0.585)^2}{9.81}} = 0.327 \text{ m}$

$y_n > y_c$ Mild slope



$$\frac{dy}{dx} = S_o \frac{1 - \left(\frac{y_n}{y}\right)^3}{1 - \left(\frac{y_c}{y}\right)^3}$$

$dy_1 = dy_2 = \frac{y_1 - y_n}{2} = 0.375$

Step 1

$$\frac{0.375}{dx_1} = \frac{1}{500} \frac{1 - \left(\frac{0.47}{1.22}\right)^3}{1 - \left(\frac{0.327}{1.22}\right)^3}$$

$\Rightarrow dx_1 \cong 195 \text{ m}$

$y_2 = y_1 - dy_1 = 1.22 - 0.375 = 0.845$

Step 2

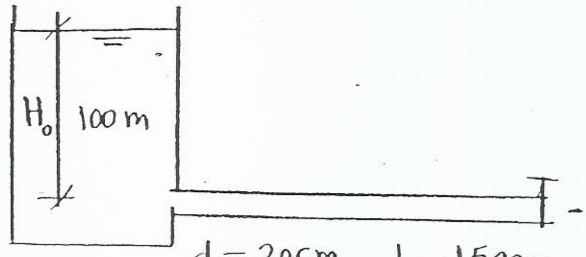
$$\frac{0.375}{dx_2} = \frac{1}{500} \frac{1 - \left(\frac{0.47}{0.845}\right)^3}{1 - \left(\frac{0.327}{0.845}\right)^3}$$

$\Rightarrow dx_2 \cong 213 \text{ m}$

$L = dx_1 + dx_2 = 195 + 213 = \underline{408 \text{ m}}$

Question 4 -

$$\Delta P_{max} = \rho V_o C$$



$d = 20cm$, $L = 1500m$

$F = 0.014$ $T = 0.25cm$ $K = 0.9375$

$E_p = 1.9 * 10^{11} \frac{N}{m^2}$, $E_w = 2 * 10^9 \frac{N}{m^2}$

to get V_o

$$h_f = \frac{F L V^2}{2 g d}$$

$$100 = \frac{0.014 (1500) V_o^2}{2 * (9.81) * 0.2} \Rightarrow V_o = 4.32 \ m/s$$

to get C

$$\frac{1}{E_c} = \frac{1}{E_w} + \frac{K D}{E_p T}$$

$$\frac{1}{E_c} = \frac{1}{2 * 10^9} + \frac{(0.9375) * (0.20)}{1.9 * 10^{11} * 0.0025} \Rightarrow E_c = 1.12 * 10^9$$

$$C = \sqrt{\frac{E_c}{\rho}} = \sqrt{\frac{1.12 * 10^9}{1000}} = 1057 \ m/s$$

$$\Delta P_{max} = \rho V_o C = 1000 (4.32) (1057) = 4.56 * 10^6 \ Pa$$

$$t_r = \frac{2L}{C} = \frac{2(1500)}{1057} = 2.84 \ sec$$

i) $t_v = 0.5$ sec $< t_r = 2.84$ sec $\Rightarrow \Delta P = \Delta P_{max} = \underline{\underline{4.56 \ MPa}}$

ii) $t_v = 5$ sec $> t_r = 2.84$ sec

$$\therefore \Delta P = \Delta P_{max} * \frac{t_r}{t_v} = 4.56 * 10^6 * \frac{2.84}{5} = \underline{\underline{2.6 \ MPa}}$$

$Mega = 10^6$

c) $$\sigma = \frac{(P_o + \Delta P)\, d}{2\, T}$$

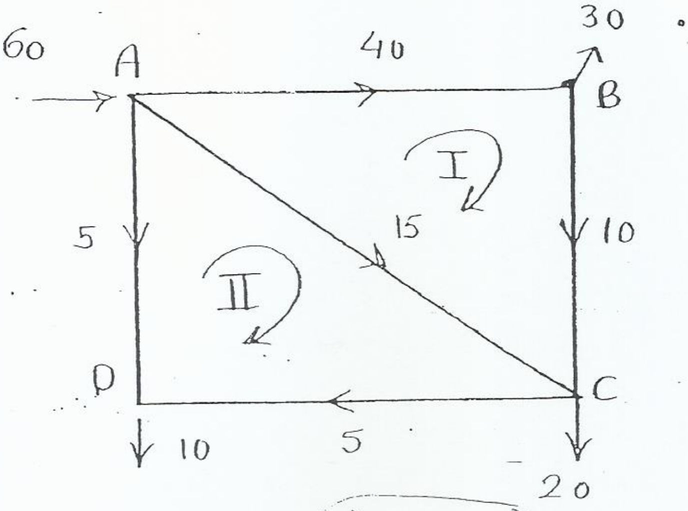
$$P_o = \gamma H_o = 9810\,(100) = 0.98 * 10^6 \text{ Pa}$$

$$\Delta P_i = 4.56 * 10^6 \text{ Pa}, \quad d = 0.2\,m, \quad T = 0.0025\,m$$

$$\therefore \sigma = \frac{(0.98 + 4.56) * 10^6 * 0.2}{2\,(0.0025)} = 221.6 * 10^6 \frac{N}{m^2}$$

Question 5

$K = 2$



loop	pipe	Q	KQ^2	$\lvert KQ \rvert$
I	AB	+ 40	+3200	+ 80
	BC	+10	+ 200	+ 20
	AC	−15	− 450	+ 30
			2950	130

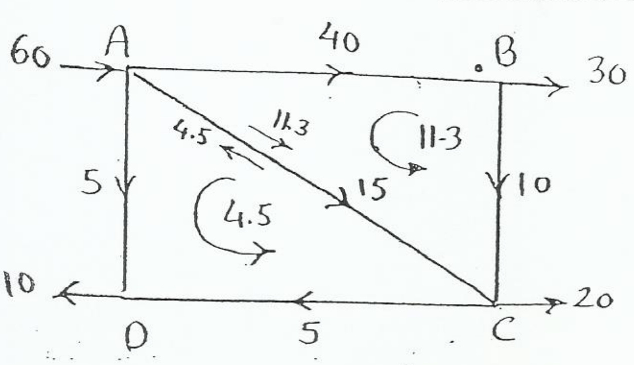
K constant = 2

$$\Delta Q_I = \frac{-\Sigma KQ^2}{2\Sigma \lvert KQ \rvert} = \frac{-\Sigma Q^2}{2\Sigma \lvert Q \rvert}$$

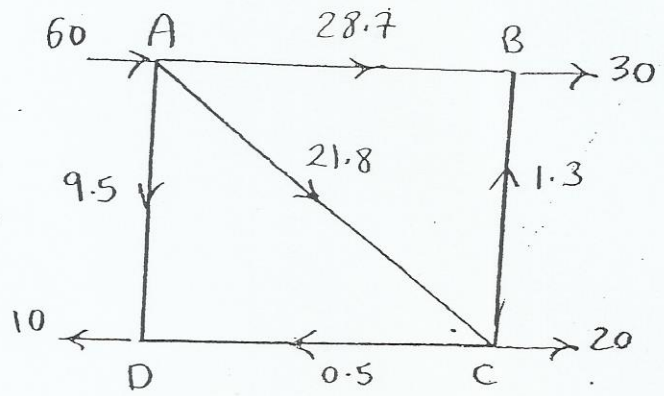
loop	pipe	Q	Q^2	$\lvert Q \rvert$
II	AC	+15	+225	+15
	CD	+ 5	+ 25	+ 5
	AD	− 5	− 25	+ 5
			+225	+25

$$\Delta Q_I = \frac{-2950}{2\,(130)} = -11.3\ m^3/s$$

$$\Sigma Q_{II} = \frac{-225}{2(25)} = -4.5$$



$\Rightarrow$



Question 6

1- Design Pipe diameter

$$Q_{design} = 1600\ \frac{m^3}{day} * \frac{1}{12\ \frac{hrs}{day} * 60 * 60} = 0.037\ m^3/s = 37\ l/s$$

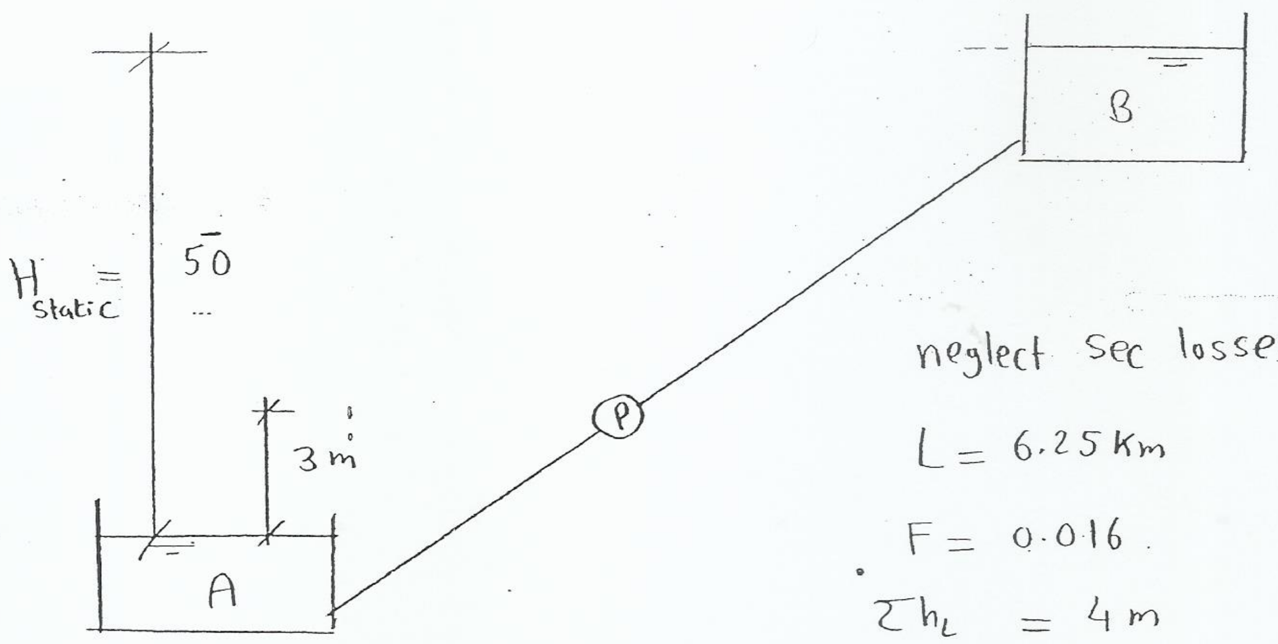
assume $\boxed{V = 1.5\ m/s}$ ** don't forget **

$$A = \frac{Q}{V}$$

$$\frac{\pi d^2}{4} = \frac{0.037}{1.5} \Rightarrow d = 0.177 \simeq 177\ mm$$

choose $d = 200\ mm$

$$V_{actual} = \frac{Q}{A} = \frac{0.037}{\frac{\pi (0.2)^2}{4}} = 1.18\ m/s < 1.5\ m/s \text{ ok}$$



neglect sec losses

$L = 6.25\ Km$

$F = 0.016$

$\sum h_{L\,suction} = 4\ m$

2 – System Curve

$$H_p = H_s + \sum \text{losses}$$

$$= 50 + \frac{8FLQ^2}{\pi^2 g d^5}$$

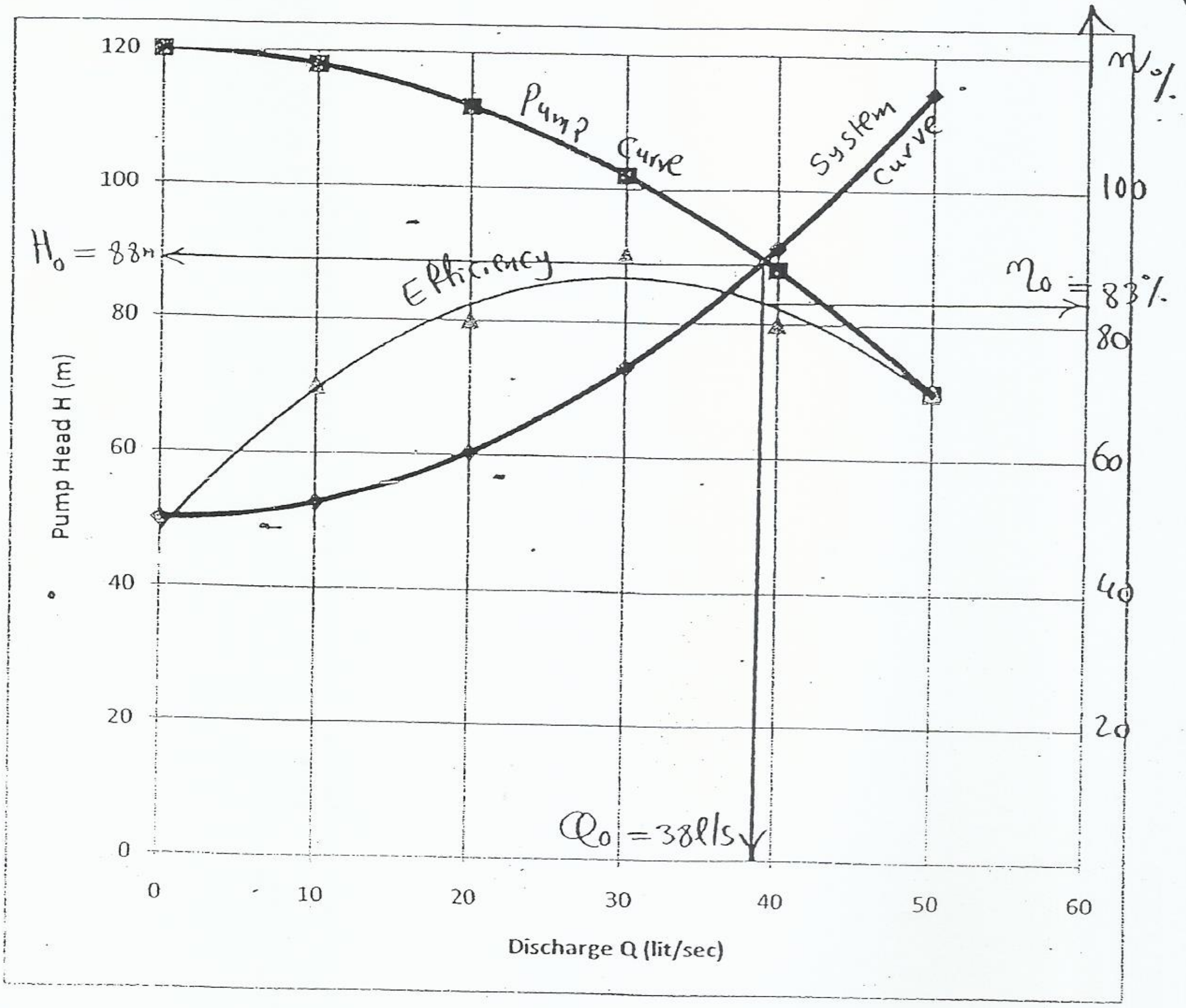
$$= 50 + \frac{8(0.016)(6250)Q^2}{\pi^2 (9.81)(0.2)^5}$$

$$H_p = 50 + 25820\,Q^2$$

Q (l/s)	0	10	20	30	40	50
Q (m³/s)	0	0.01	0.02	0.03	0.04	0.05
Hp (m)	50	52.58	60.3	73.2	91.3	114.5

3 – Pump Curve

Q (l/s)	0	10	20	30	40	50
Hp (m)	120	118	112	102	88	70
η %	---	60	70	80	70	60



4- Operating point

$\Rightarrow Q_o = 38 \ l/s \quad , \quad H_o = 88 \ m \quad , \quad \eta = 83\%$

$\because Q_{design} = 37 \ l/s$ OK

5- Actual working hours

$\forall_{constant} = Q_{design} * t_1 = Q_o * t_2$

$= 37 \ l/s * 12 \ hrs = 38 \ l/s * t_2$

$\Rightarrow t_2 = 11.68 \ hrs$

6- Power Consumption

$$W.H.P = \frac{\gamma Q_o H_o}{K} = \frac{9810\,(0.038)\,(88)}{735} = 44.6 \text{ HP}$$

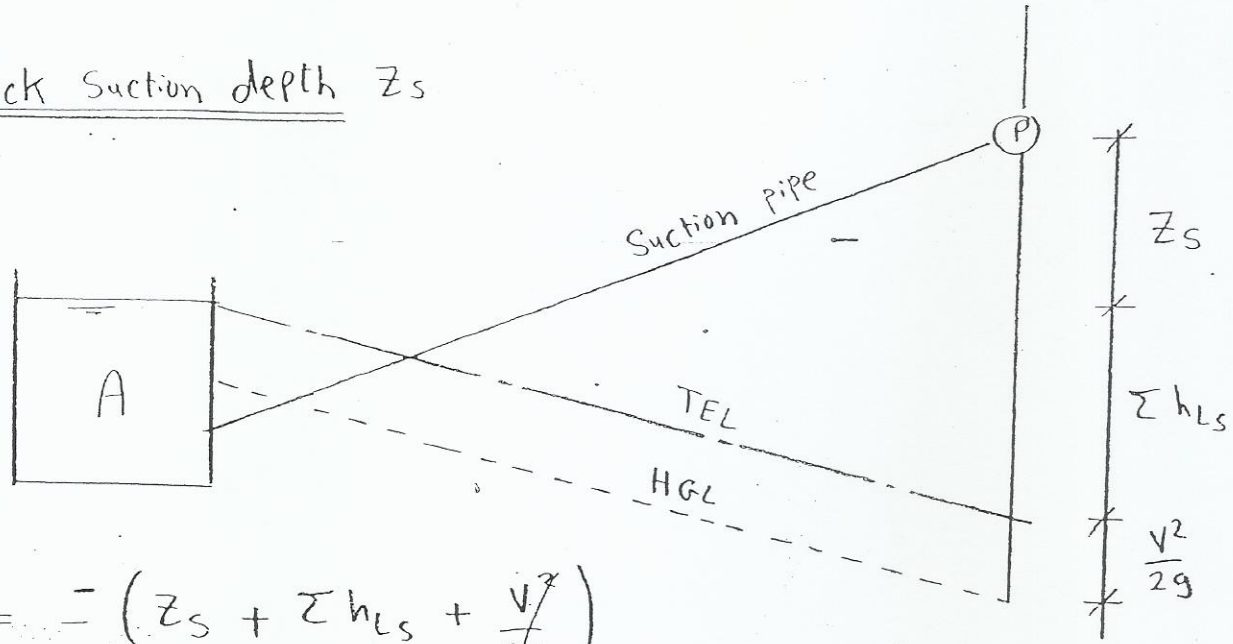
$$E.H.P = \frac{W.H.P}{\eta_o} = \frac{44.6}{0.83} = 53.7 \text{ HP}$$

7- Annual Cost

$$Cost = 0.30 \frac{L.E}{Kwatt.hr} * 11.68 \frac{hrs}{day} * \left(53.7 * \frac{735}{1000}\right) Kw * 365 \frac{days}{year}$$

$$= 50,480 \text{ LE}$$

8- Check Suction depth Zs



$$\frac{P_1}{\gamma} = -\left(Z_s + \Sigma h_{Ls} + \frac{V^2}{2g}\right)$$

$$\frac{V^2}{2g} \simeq 0$$

Given

$\Sigma h_{Ls} = 4\text{m}$

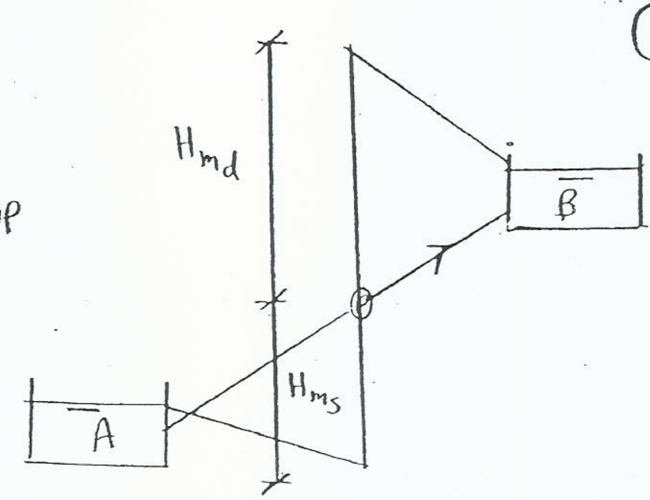
$NPSH_{req} = 3\text{m}$

$$= -(3 + 4) = -7\text{m}$$

$$NPSH_{act} = \left(\frac{P_{atm}}{\gamma} - \frac{P_{vap}}{\gamma}\right) - \left|\frac{P_1}{\gamma}\right|$$

$$= (10.33 - 0.25) - |-7| = 3.08 > 3 \text{ safe}$$

e) Max +ve Pressure head



$\left(\frac{P}{\gamma}\right)_{max}$ occurs just after the Pump

$$H_{md} = \left(\frac{P_1}{\gamma}\right)_{max}$$

$$H_{ms} = \left(\frac{P_1}{\gamma}\right)_{min}$$

$$H_m = H_{ms} + H_{md} \simeq H_o \quad (H_{Total})$$

$$= 7 + H_{md} = 88 \Rightarrow H_{md} = 81\,m$$

$$\therefore \left(\frac{P_1}{\gamma}\right)_{max} = 81\,m.$$

$$P_1 = 81 * 9810 = 7.94 * 10^5\ Pa = \underline{\underline{7.94\ bar}}$$

f) Negative static head H_s

Occurs when water is pumped from a higher reservoir to a lower one in order to increase the discharge