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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-11

Full Syllabus Test (Paper-II)

Name : ROHIT DHONDGE

Roll No : C E 4 M C T D L A 0 0 4

Test Centres	Student's Signature
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Hyderabad ☐	Dhondge

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	32
Q.2	47
Q.3	33
Q.4	
Section-B	
Q.5	33
Q.6	
Q.7	46
Q.8	
Total Marks Obtained	211

Signature of Evaluator NJawal

Cross Checked by .....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Remarks

- Avoid silly mistakes.

Section-A

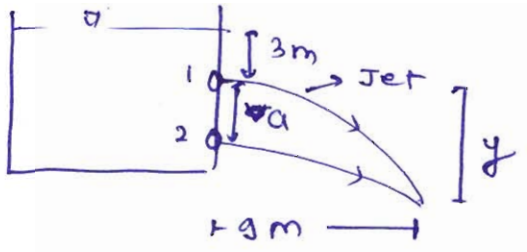
.1 (a) .Two identical orifices are mounted on one side of a vertical tank. The height of water above the upper orifice is 3 m. If the jets from two orifices intersect at a horizontal distance of 9 m from tank then estimate

(i) Vertical distance between the two orifices.

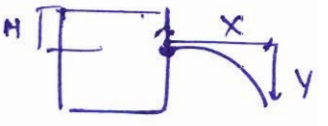
(ii) Vertical distance of point of intersection of jets from top of water level in tank.

[Assume $C_v = 1$ for both the orifices]

[12 marks]



Here we know $C_v = \frac{x}{2\sqrt{yH}}$



Here given $C_v = 1$

For 1st orifice

$$C_v\ 1 = \frac{9}{2\sqrt{(y)(3)}}$$

$$y = 6.75\text{ m}$$

12

For second orific.

$$C_v = 1 = \frac{9}{2\sqrt{(y-a)(3+a)}}$$

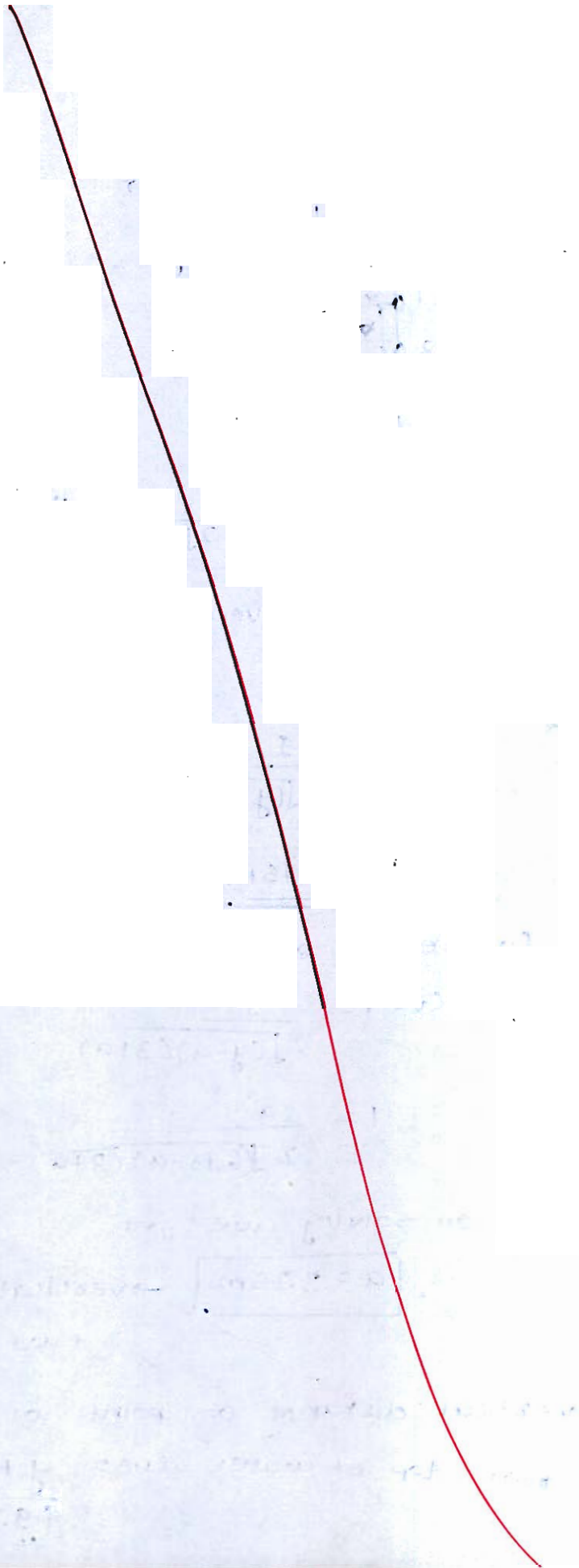
$$1 = \frac{9}{2\sqrt{(6.75-a)(3+a)}}$$

on solving we get

$$a = 3.75\text{m}$$ → vertical dist b/w two orifi.

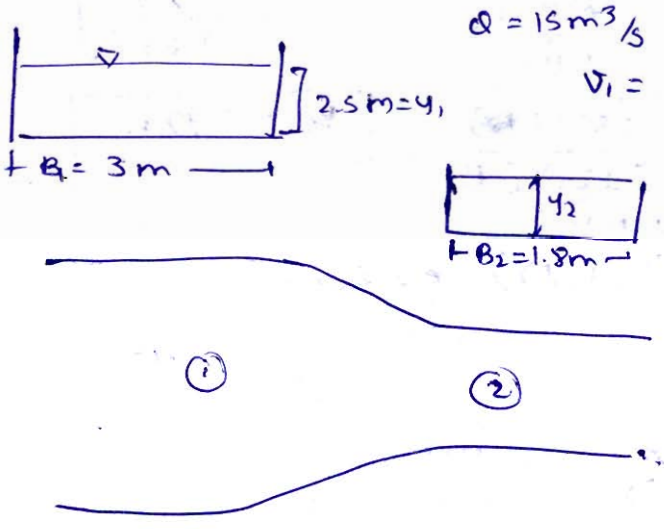
i.) vertical distance of point of intesect from top of water lve = $y + 3 = 6.75 + 3$

$= 9.75\text{m}$



.1 (b) A rectangular channel is 3 m wide and conveys a discharge of 15 m^3/sec at a depth of 2.5 m. It is proposed to reduce the width of the channel at hydraulic structure. Assuming the transition to be horizontal and the flow to be frictionless, determine the water surface elevations upstream and downstream of the constriction when the constricted width is 1.8 m.

[12 marks]



$Q = 15 m^3/s = k$

$V_1 = \frac{Q}{A} = \frac{15}{(3)(2.5)} = 2 m/s$

$q = \frac{Q}{B} = \frac{15}{3} = 5 m^3/sm$

- E → specific energy

$E_1 = E_2$

$y_1 + \frac{V_1^2}{2g y_1^2} = y_2 + \frac{V_2^2}{2g y_3^3}$

First let us find B_{min}, occur when $E_2 = E_c = \frac{3}{2} y_c$

$\therefore 2.5 + \frac{(2)^2}{(2)(9.81)(2.5)^2} = \frac{3}{2} y_c$

$\Rightarrow y_c = 1.688 m \Rightarrow B_c =$

$\Rightarrow V_c = \sqrt{g y_c} \Rightarrow B_c = \frac{Q}{(y V)} = \frac{15}{1.688 \sqrt{(9.81)(1.688}}$

$= 2.18 m$

as given $B_2 < B_c$

∴ water depth at U/s will change

at d/s water level depth = $y_c = 1.688 m$ will be equal to critical

$E_1 = E_2$ For d/s

$y_1 + \frac{q_1^2}{2g y_1^2} = E_c$ $q_2 =$

$E_2 = q_2^2$

$y_c = \left(\frac{q^2}{g}\right)^{1/3}$

$= \left(\frac{\left(\frac{15}{1.8}\right)^2}{9.81}\right)^{1/3}$

For d/s

$\frac{Q^2 T}{g A^3} = 1$

$\frac{(15)^2 (\quad)}{(9.81)(B}$

$y_c = 1.92\text{m}$

For rectangular channel

$E_2 = E_c = \frac{3}{2} y_c = \left(\frac{3}{2}\right)(1.92) = 2.88\text{m}$

$E_1 = E_c$

$\therefore y_1 + \frac{q^2}{2g y_1^2} = 2.88$

$y_1 + \frac{5^2}{(2)(9.81) y_1^2} = 2.88$

$\Rightarrow y_1 = 2.706\text{m}$

12

Final depths

.1 (c) An undisturbed saturated specimen of clay has a volume of 18.9 cm^3 and a mass specific gravity of 1.6. On oven drying, its mass specific gravity increases to 1.8 while its volume reduces to 9.9 cm^3. Determine the shrinkage limit, specific gravity, shrinkage ratio and volumetric shrinkage.

[12 marks]

$G_{m_1} = 1.6$ ⟹ oven drying ⟹ $G_{m_2} = 1.8$

$V_1 = 18.9\,cm^3$ $V_2 = 9.9\,cm^3$

$G_m = \frac{M_w + M_s}{V_T}$

$G_{M_1} = 1.6 = \frac{M_w + M_s}{18.9}$ $G_{M_2} = 1.8 = \frac{M_s}{9.9}$

$M_1 \Rightarrow M_w + M_s = 30.24\,g$ $M_2 = M_s = 17.82\,g$

$\Rightarrow M_w = 30.24 - 17.82 = 12.42\,g. \Rightarrow w_1 = \frac{M_w}{M_s} = \frac{12.42}{17.82} = 0.697$

① $w_s = \left(\frac{M_1 - M_2}{M_2}\right) - \frac{(V_1 - V_2)\rho_w}{M_2}$

$= \frac{(30.24 - 17.82)}{17.82} - \frac{(18.9 - 9.9)(1)}{17.82}$ (9)

$w_s = 0.1919$

∴ shrinkage limit = 19.19%.

② $w_s = \frac{1}{R} - \frac{1}{G}$ $\left(R = \frac{\rho_d}{\rho_w}, \frac{M_s}{V_2}(1) = \frac{17.82}{9.9} = 1.8\right)$

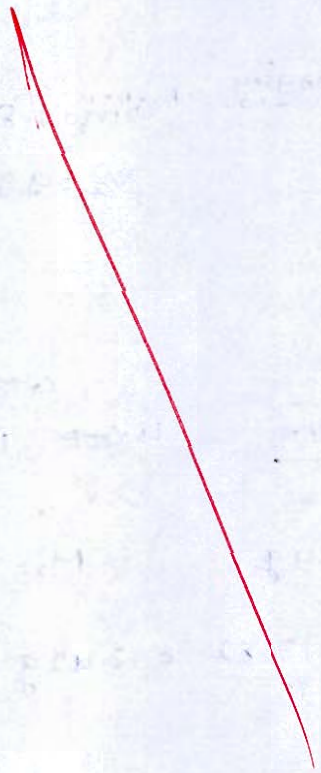
$0.1919 = \frac{1}{1.8} - \frac{1}{G}$

$\Rightarrow \boxed{G = 2.75}$

③ Shrinkage Ratio $R = 1.8$

④ Volumetric shri = $\frac{\frac{V_1 - V_d}{V_d}}{w_1 - w_s} = \frac{\frac{18.9 - 9.9}{9.9}}{0.697 - 0.1919}$

$= 1.79$



Q.1 (d) (i) Define the following terms:

1. Countour interval, 2. Horizontal equivalent, 3. Contour map.

(ii) What are the different characteristics of contours lines?

[6 + 6 = 12 marks]

Co. Contour interval

↳ difference in elevation b/w two successive contours in called as contour inte

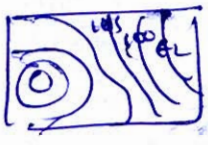
[Its choise depents on slope of terrain, steep the slope higher is contour interv kep.

Horizontal equivale.

↳ Horizontal distance b/w two successiv contours

↳ ~~For st ne~~ less the horizontal equival. steeper the slope will be

contour map → map showing contour of different elevation for particular area
↳ Helps to know about steepness of terrain, used to get rough idea about planning of Highways, alignment.



contour map

11

different characteristic of contour lines
- They always close on same contour line
- They never intersect each other except in case of escarpments
- Nearer the contour lines steeper the slope, 90° slope
- contour line with increasing elevation towards centre → Hill
  decreasing elevation towards centre → Lake → depression

1.1 (e) What do you mean by 'Governing of turbines'? Explain the working of an oil pressure governor?

[12 marks]

→ Governing of turbines refers to controlling the discharge passing to turbine
The shaft of turbine is couple with electric generator, To maintain at constant freq of electrical turbine speed is need to be maintain constant,
If load on turbine decreases, It tries to increase speed, in case of pelton turbine splinde rod is pushed into from nozzle to decrease amount of water of bowl, → Thus maintaing the constant speed
Governing controls the discharge, and inlet angle at which water passes on vanes, This also helps to increase efficiency in kaplan turbines for low discharge.

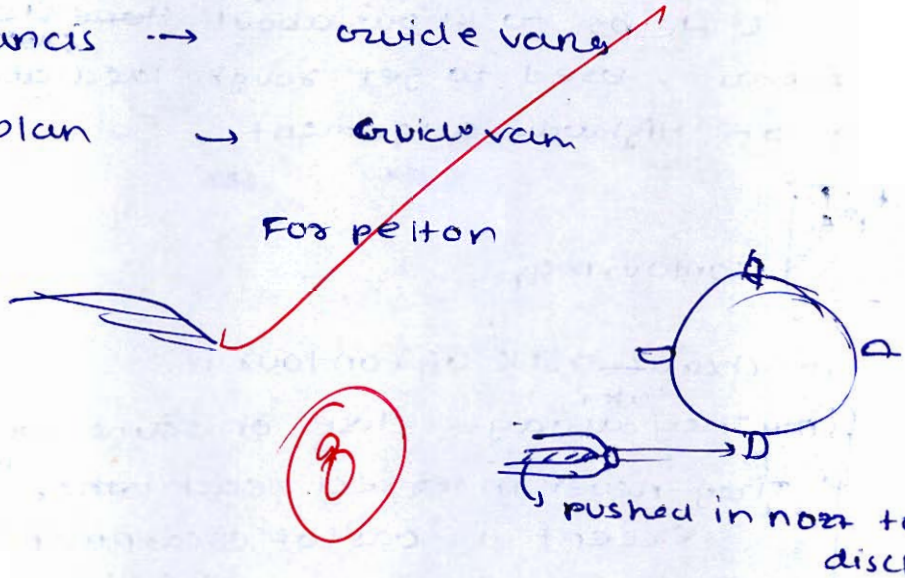
For Governing

Pelton → rod cylinder

Francis → guide vane

Kaplan → Guide vane

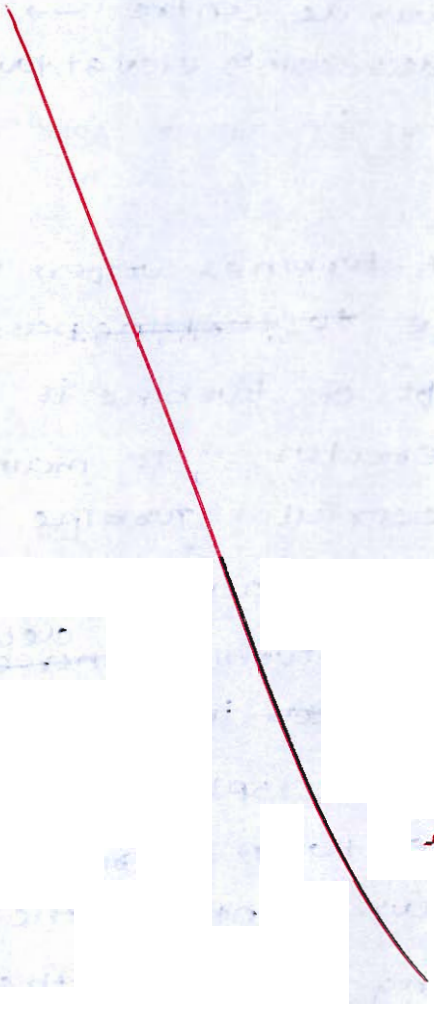
For pelton



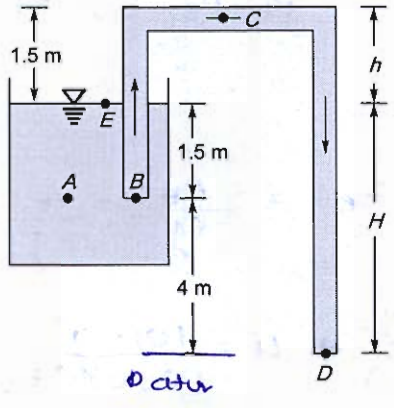
(8)

pushed in nozz to decreas discharg

and vice ves to increase dischar



.2 (a) (i) A tube is used as a siphon to discharge an oil of specific gravity 0.8 from a large open vessel into a drain at atmospheric pressure as shown in figure.



Calcualte:

1. Velocity of oil through the siphon.
2. Pressure at points *A* and *B*.
3. Pressure at highest point C.

(Take the vapour pressure of liquid at the working temperature to be 29.5 kPa and atmospheric pressure as 101 kPa. Neglect major and minor losses).

(ii) An oil having viscosity of 0.143 N-s/m^2 and specific gravity of 0.9 flows through a pipe 2.5 cm in diameter and 300 cm long, at $\frac{1}{10}$ of the critical velocity for which Reynold's number is 2500. Find the velocity of flow through the pipe, the headloss in meters of oil across the pipe length required to maintain the flow and power required for the flow.

[12 + 8 = 20 marks]

① Applying ~~Eneg~~ Bernoullis eqn b/w E & D (Neglecting losses

$$\frac{P_E}{\rho g} + \frac{V_E^2}{2g} + z_E = \frac{P_D}{\rho g} + \frac{V_D^2}{2g} + z_D$$

$P_E = P_D = P_{atm}$

$V_E \approx 0$

$$S.S = \frac{V_D^2}{(2\times 9.81)} + 0 \Rightarrow \boxed{V_D = 10.388 \text{ m/s}}$$

↳ velocity of oil through hose

② $P_A = P_E + \rho_{oil} g h_A$

$= 101\times10^3 + (800)(9.81)(1.5)$

$= 112.772 \text{ kPg}$

at pressure at B

↳ Just outside pipe

$P_A = P_B = 112.772$ kPa

at inside pipe

$$\frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B = \frac{P_E}{\rho g} + \frac{V_E^2}{2g} + z_E$$

$$\frac{P_B}{(800)(9.81)} + \frac{(10.388)^2}{(2)(9.81)} + 4 = \frac{101\times10^3}{(800)(9.81)} + 0 + 5.5$$

$$\Rightarrow P_B = 69.608 \text{ kPa}$$

Apply Bernoullis ean b/w E & C

$$\frac{P_E}{\rho g} + \frac{V_E^2}{2g} + z_E + \frac{P_C}{\rho g} + \frac{V_C^2}{2g} + z_C$$

$$\frac{101\times10^3}{(800)(9.81)} + 0 + 5.5 = \frac{P_C}{(800)(9.81)} + \frac{(10.388)^2}{(2)(9.81)} + 7$$

$$\Rightarrow P_C = 46.068 \text{ kPa}$$

11). $\mu = 0.143$ Ns/m² $G = 0.9$

D = 2.5 cm → V

L = 0.3 m

$$Re_{cr} = 2500 = \frac{VD}{(\mu/\rho)}$$

$$2500 = \frac{V_{cr}(2.5\times10^{-2})}{\left(\frac{0.143}{900}\right)}$$

$V_{cr} = 15.89$ m/s

Given $V = \frac{1}{10} V_{cr} = 1.589$ m/s ⇒ velocity of flow through pipe

⇒ Head loss by Darcy-weisbac eq

$$h_f = \frac{fLV^2}{2gD}$$

$$\left(f = \frac{64}{Re}\right.$$

$$= \frac{64}{\left(\frac{2500}{10}\right)}$$

$$= 0.256 \Big)$$

$$= \frac{(0.256)(0.3)(1.59)^2}{(2)(9.81)(2.5\times10^{-2})}$$

$$= 0.396\ m$$

⇒ power required $= \dot{m} g h_f$

$$= \rho Q g h_f$$

$$= (900)\left(\frac{\pi}{4} \times (0.025)^2 \times 1.59\right) \times 9.81 \times 0.396$$

$$= 2.73\ W$$

20

Q.2 (b) **(i)** As chaining was not possible, a traverse was conducted using tacheometry. The data is tabulated below. The line of sight was horizontal in all the cases. Find the length of sides and length and bearing of line *AC*. Also determine the gradient from *A* to *C* if the reading on a staff held at a benchmark is 2.415 m from A and 0.645 m from *C*. The instrument constants were 100 and 0.3.

Line	Bearing	Instrument at	Staff at	Cross hair recordings (m)
AB	78°40'20"	A	B	1.535, 2.214, 2.893
BC	152°31'40"		D	2.018,2.70,3.708
CD	251°18'40"		C	
DA	3°44'15"	C	B	1.033,1.733,2.432
			D	1.363,2.243,3.123
			A	

(ii) The offsets taken from a chain line to a curved boundary are given below:

Chainage	0	5	10	15	20	25	35	45	55	65
Offset (m)	2.5	3.8	8.4	7.6	10.5	9.3	5.8	7.8	6.9	8.4

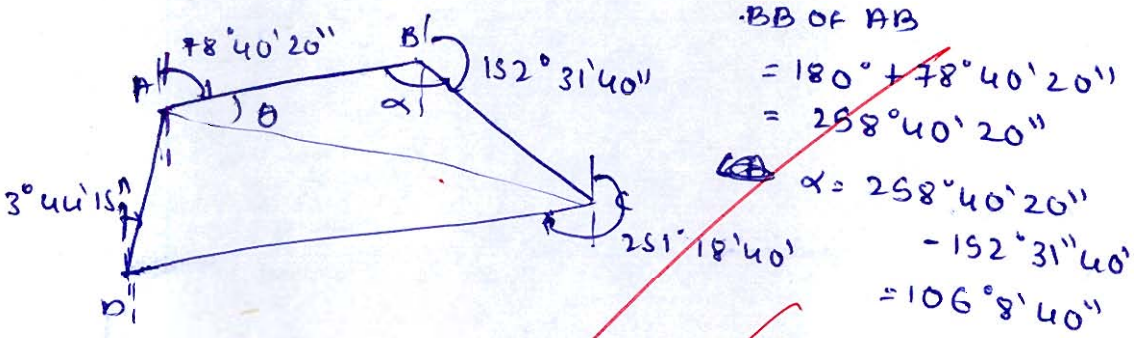
Find the area between chain line, first and last offsets and boundary by Simpson's rule.

[15 + 5 = 20 marks]

i) Here $D = KS + C$ $K = 100$, $C = 0.3$

$= 100S + 0.3$

Rough plot of station



BB of AB

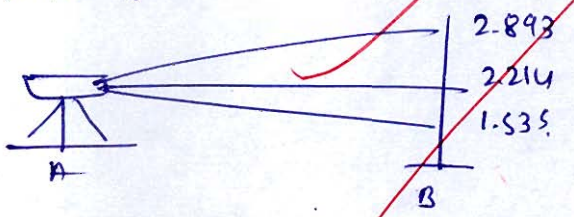
$= 180° + 78°40'20"$

$= 258°40'20"$

$\alpha = 258°40'20" - 152°31'40"$

$= 106°8'40"$

From A to B



$D = AB$ $D = (100)(2.893 - 1.535) + 0.3$

$= 136.1\ m$

similarl

AD = (100)(3.708 - 2.018) + 0.3 = 169.3m

CB = 100(2.432 - 1.033) + 0.3 = 140.2m

CD = 100(3.123 - 1.363) + 0.3 = 176.3m.

Length of AC

$= \sqrt{(AB)^2 + (BC)^2 - 2(AB)(BC)\cos\alpha}$

$= \sqrt{(136.1)^2 + (140.2)^2 - (136.1)(140.2)(2)\cos(106°8'40")}$

AC = 174.366m

$\cos\theta = \frac{(BC)^2 - }{(2)(AB)}$

$(BC)^2 = 114$ BC can be written as

$BC = (140.2) = \sqrt{(136.1)^2 + (166.05)^2 - 2(136.1)(166.05)\cos\theta}$ (174.366)

$\Rightarrow \theta = 51°55'24"$

Bearing of AC = 78°40'20" + 51°55'24"

= 130°35'44"

Gradient of AC = $\frac{EL_A - EL_C}{L_{AC}}$

$= \frac{h_A - h_C}{L_{AC}}$

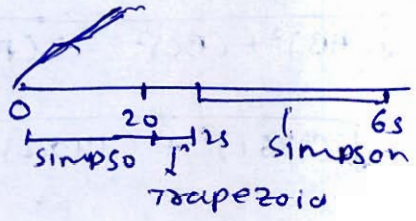
$= \frac{2.415 - 0.645}{174.366}$

Gradient of AC. $= \frac{1}{98.512}$

1)

0	5m	2.5
5	5m	3.8
10	5m	8.4
15	5m	7.6
20	5m	10.5
25	10m	9.3
35	10m	5.8
45	10m	7.8
55	10m	6.9
65		8.4

4



Using simpson 1/3rd rule.

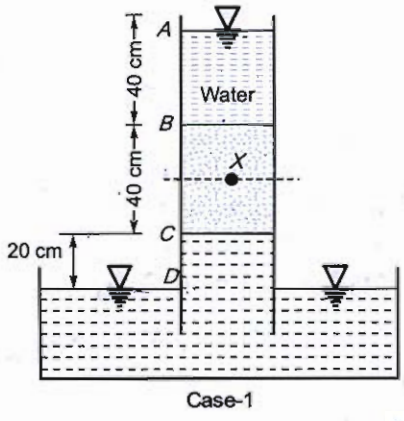
$$A = \frac{5}{3}\left[2.5 + 10.5 + 4(3.8 + 7.6) + 2(8.4)\right] + \left(\frac{10.5 + 9.3}{2}\right)(5) + \frac{10}{3}\left[9.3 + 8.4 + 4(5.8 + 6.9) + 2(7.8)\right]$$

$$= 459.5\ m^2$$

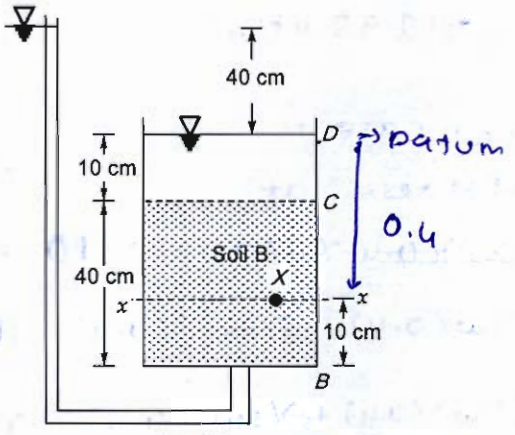
Q.2 (c) For the cases 1 and 2 shown below, determine

(i) the pressure head, datum head, total head and head loss at B, C, D and point X of the sample considering 'D' to be datum in both the cases.

(ii) total stress at B, C, D and point X if specific gravity and void ratio for both the soils are 2.65 and 0.6 respectively. [Take $\gamma_\omega = 10\ kN/m^3$]



Case-1



Case-2

[20 marks]

case 1 ⇒ $i_1 = \frac{100}{40} = 2.5$ case 2 $i_2 = \frac{40}{40} = 1$

case 1

(m)	B	C	D	X
PH	0.4	-0.2	0	TH-DH = 0.5 - 0.4 = 0.1
DH	0.6	0.2	0	0.4
TH	1m	0	0	$TH_C + iz$ = 0 + (2.5)(0.2) = 0.5

Headloss at B = 0, at C, = i(0.4) = 1m at D = 0 or (bw C/D)

case 2

cm	B	C	D	X
PH	1m	0.1	0	PH = (TH-DH) = 0.4+0.4 = 0.8
DH	-0.5	-0.1	0	-0.4
TH	0.5	0	0	$TH_X = TH_B - i(0.1)$ = 0.5 - (1)(0.1) = 0.4

PHx = 0.8 m

$$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e}$$

$$= \frac{(2.65+0.6)(9.81)}{1+0.6}$$

$$= 19.93 \text{ kN/m}^2.$$

~~Totals~~ case 1

Total stress at

$\sigma_B = (\gamma_{sat})(0.4)\ \gamma_w(0.4) = (10)(0.4) = 4 \text{ kN/m}^2$

$\sigma_C = \gamma_w(0.4) + (\gamma_{sat})(0.4) = (10)(0.4) + (9.93)(0.4)$

$= 11.972 \text{ kN/m}^2$

$\sigma_D = (\gamma_w)(0.4) + \gamma_{sat}(0.4) + \gamma_w(0.2)$

$= (10)(0.4) + 19.93(0.4) + 10(0.2) = 13.972 \text{ kN/m}^2$

$\sigma_E = \gamma_w(0.4) + \gamma_{sat}(0.2)$

$= (10)(0.4) + 19.93(0.2) =$

$= 7.986 \text{ kN/m}^2$

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1 kN/m²

case 2

Total stress at:

$A = (0)\ \gamma_w(0) = 0$

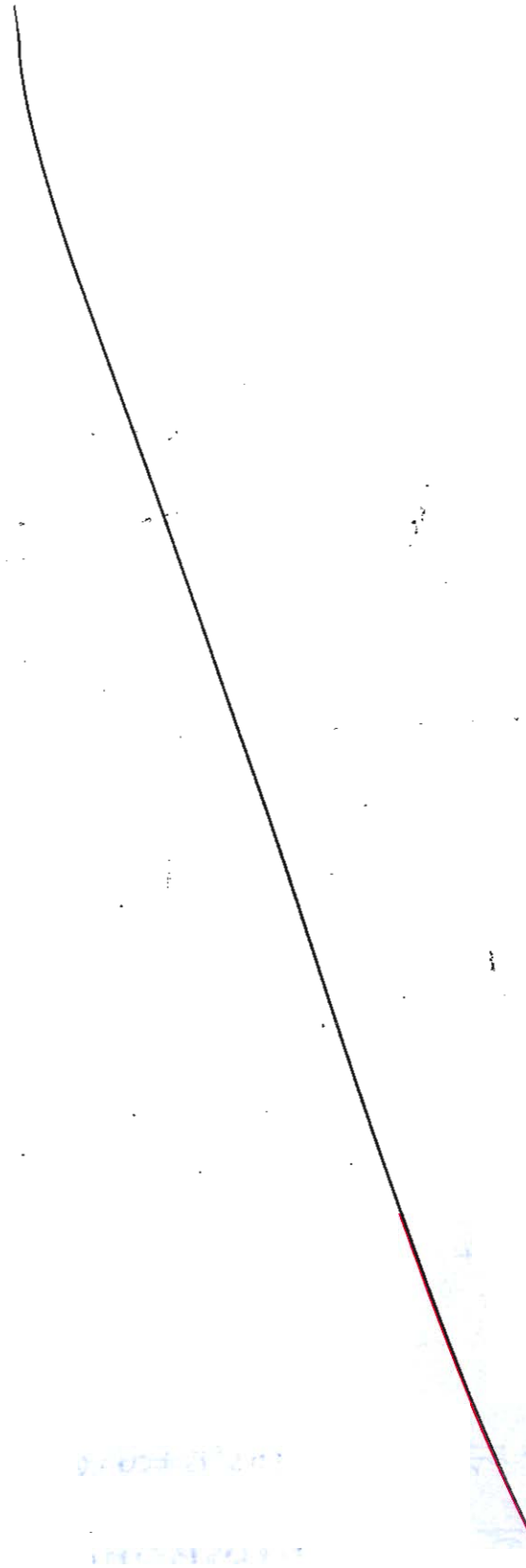
$C = \gamma_w(0.1) = 10(0.1) = 10 \text{ kN/m}^2$

$B = 0.1\gamma_w + 0.4\gamma_{sat} = 0.1(10) + 0.4(19.93) = 8.972 \text{ kN/m}^2$

$X = (0.1\gamma_w) + 0.3\gamma_{sat} = 0.1(10) + 0.3(19.93)$

$= 6.979 \text{ kN/m}^2$

Calculation



Q.3 (a) (i) An infinite slope in a C – ϕ soil is inclined at 20° to horizontal. The properties of soil are:

$C' = 15\ kN/m^2$, $\phi' = 32°$, $G = 2.66$, $e = 0.65$

A hard layer exists 5 m below and parallel to surface. What is factor of safety against slip when

1. The slope has ngeligible water in it.
2. The slope is completely submerged with seepage parallel to surface.
3. Water table level is parallel to ground surface at 2.5 m depth, seepage being parallel.

(ii) State the various assumptions used in Terzaghi's theory of one dimensional consolidation.

[14 + 6 = 20 marks]

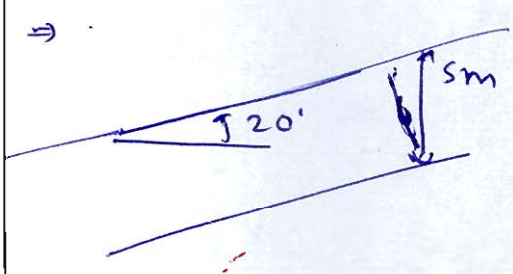
$C = 15\ kN/m^2$

$\gamma' = \left(\frac{G-1}{1+e}\right)\gamma_w = \left(\frac{2.66-1}{1+0.65}\right)9.81 = 9.87\ kN/m^3$

$\gamma_{sat} = \frac{(G+e)}{(1+e)}\gamma_w$

$= \frac{2.66+0.65}{1+0.65} \times 9.81 =$

$= 19.68\ kN/m^3$



(1) slope as Neglible wate.

$FOS = \frac{\tau}{\tau_f} = \frac{c + \bar{\sigma}_n \tan\phi}{\gamma h \cos^2\beta \sin\beta}$ $\left(\tau = c + \bar{\sigma}_n \tan\phi\right.$

$FOS = \frac{c + \gamma_d h \cos^2\beta \tan\phi}{\gamma_d h \cos\beta \sin\beta}$

$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{(2.66)(9.81)}{1+0.65}$

$= 15.81\ kN/m^3$

$= \frac{15 + (15.81)(5)\cos^2(20)\tan(32)}{(15.81)(5)\cos(20)\sin 20}$

$= 2.307$

(2) Slope i

Here $\bar{\sigma}_n = \gamma' h \cos^2\beta \tan\phi$

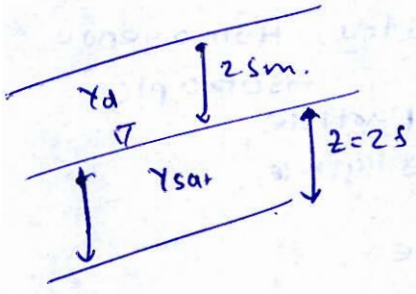
$\tau_n = \gamma_{sat} h \cos\beta \sin\beta$

$FOS = \frac{c + \bar{\sigma}_n \tan\phi}{\gamma_{sat} h \cos\beta \sin\beta}$

$$FOS = \frac{15 + (9.87)(5)\cos^2(20)\tan(32)}{(19.68)\cos(20)\sin(20)(5)}$$

$$= 1.335$$

(3)



$$\gamma_{avg} = \frac{\gamma_d(2.5) + \gamma_{sat}(2.5)}{5}$$

$$= \frac{(15.81)(2.5) + 19.68(2.5)}{5}$$

$$= 17.745 \text{ KN/m}^3$$

~~$FOS = \frac{C + \gamma' Z \cos^2\beta \tan\phi}{\gamma_{avg} \cos}$~~

(10)

~~$\sigma_n = \gamma_d(2.5) + \gamma'(2.5)$~~

$= 15.81(2.5) + 9.87(2.5) = 64.2$

$\sigma_n = (\gamma_{avg} \cos^2\beta) - (\gamma_w)(Z)\cos^2\beta$

$= (17.745)(5)\cos^2(20) - (9.81)(2.5)\cos^2(20)$

$= 56.69 \text{ KN/m}^2$

$$FOS = \frac{15 + 56.69\tan(32)}{\gamma_{avg} \cos\beta \sin\beta}$$

$$= \frac{15 + 56.69\tan(32)}{(17.745)(5)\cos(20)\sin 20}$$

$$FOS = 1.96$$

~~TCST~~

ii)

~~ΔV=~~ ① ~~change in volume~~ of
change in ✓ area of soil = ①

$$\therefore \frac{\Delta V}{V} = \frac{\Delta H}{H}$$

② soil is completely saturated, Homogenous isotropic

③ ~~&~~ compression of soil particle and water is negligible.

④ soil is elastic in nature.

~~2D~~

⑤ water seeps only in vertical direction.

4

Q.3 (b) An agitator of diameter D, requires power P, to rotate at a constant speed N, in a liquid of density ρ and viscosity μ.

(i) Show with the help of π theorem that

$$P = \rho N^3 D^5 \phi\left(\frac{\rho N D^2}{\mu}\right)$$

where ϕ represents a function of $\left(\frac{\rho N D^2}{\mu}\right)$.

(ii) An agitator of 300 mm in diameter rotating at 25 rev/s in water requires a driving torque of 1.2 N-m. Calculate the corresponding speed and torque required to drive a similar agitator of 750 mm diameter rotating in water using the relation derived above.

	Air	Water
Viscosity (Pa-s)	1.86×10^{-5}	1.01×10^{-3}
Density (kg/m^3)	1.2	1000

[10+10 = 20 marks]

To	Variable	Dimension
	D	L
	P	ML^2T^{-3}
	N	T^{-1}
	ρ	ML^{-3}
	μ	$ML^{-1}T^{-1}$

Total no of variab = 5 = m

No of fundamental var = 3 = n

No of π terms = m − n = 2

Let us take ρ, N, D as repeating var

$\therefore \pi_1 P = \rho^a N^b D^c P$

$M^0L^0T^0 = [ML^{-3}]^a [T^{-1}]^b [L]^c \; ML^2T^{-3}$

equat LHS = RHS dimens

$a + 1 = 0 \Rightarrow a = -1$

$-b - 3 = 0 \Rightarrow b = -3$

$-3(-1) + c + 2 = 0 \Rightarrow c = -5$

$\pi_1 = \dfrac{P}{\rho N^3 D^5}$

$\pi_2 = \rho^a N^b D^c \mu$

$M^0L^0T^0 = [ML^{-3}]^a [T^{-1}]^b [L]^c [ML^{-1}T^{-1}]$

LHS = RHS dimensio

$a + 1 = 0 \Rightarrow a = -1$

$-b - 1 = 0 \Rightarrow b = -1$

$-3a - 3(-1) + c - 1 = 0$

$c = -2$

$\pi_2 = \dfrac{\mu}{\rho N D^2}$

$\therefore \quad \pi_1 = \phi\left(1/\pi_2\right)$

$$\frac{P}{\rho N^3 D^5} = \phi\left(\frac{\rho N D^2}{\mu}\right)$$

$$\Rightarrow \boxed{P = \rho N^3 D^5 \phi\left(\frac{\rho N D^2}{\mu}\right)} \equiv$$

Hence proved.

12

11) For 1st eq^n

$D = 300\text{ mm} = 0.3\text{ m}$.

$N = 25 \text{ rev/s} \Rightarrow \omega = \frac{2\pi N}{60} = \frac{2\pi(25)}{60} = 157.08 \text{ rad/s} = 2618 \text{ rad/s}$

$T = 1.2\text{ N-m}$

$P = T\omega = (1.2)(157.08) = 188.496\text{ W} = 3.142\text{ kW}$

For 2nd eq^n, $D = 0.75$

$(\pi_2)_{1st} = (\pi_2)_{2nd}$

$$\left(\frac{\mu}{\rho N D^2}\right)_{1st} = \left(\frac{\mu}{\rho N D^2}\right)_{2nd}$$

$$\frac{N_2}{N_1} = \frac{D_1^2}{D_2^2} \Rightarrow N_2 = \frac{(25)(0.3)^2}{(0.75)^2}$$

$\boxed{N_2 = 4 \text{ rev/s}}$ → speed required

$(\pi_1)_{1st} = (\pi_2)_{2nd}$

$$\left(\frac{P}{\rho N^3 D^5}\right)_1 = \left(\frac{P}{\rho N^3 D^5}\right)_2$$

$$\frac{188.469}{(25)^3 (0.3)^5} = \frac{P_2}{(4)^3 (0.75)^5}$$

$\Rightarrow \boxed{P_2 = 75.388\text{ W}}$

$P_2 = (T_2)(2\pi N_2)$

$75.388 = (T_2)(2\pi \times 4)$

$\boxed{T_2 = 3\text{ N-m}}$ → torque required

.3 (c) An anticlockwise traverse *ABCD* has data tabulated below and contains the lengths and included angles of a traverse ABCDA. The bearing of line *AB* was observed as 222°01′30″. Check the traverse for angles and closing errors, if any. Find the correct latitudes and departures by transit method.

Line	Length (m)	Station	Included angle
AB	155.25	A	101°39′30″
BC	170.4	B	95°32′50″
CD	202.6	C	75°15′30″
DA	139.4	D	87°32′50″

L (a)

correct Include angle (a - 0°0'40"
101°39'30"
95°32'40"
75°15'20"
87°32'40"

Sum of Interior angle $\Sigma IA = 360°0'40''$

[20 marks]

Designated sum of Internal angle = $(2n-4)90$

$=(2\times4-4)\times90$

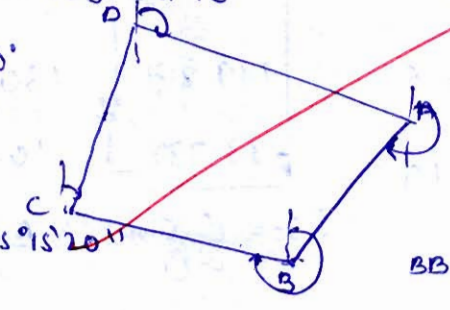
$= 360°$

correction for each an = $\frac{TV-MV}{4} = \frac{360-360°0'40''}{4}$

$= -10''$

FB of DA = 231°13′30″ − 101°39′20″

= 129°34′10″



BB of CD
= 51°13′30″ + 180°
= 231°13′30″

FB of CD
= 126°28′50″ − 75°15′20″
= 51°13′30″

BB of BC
= 306°28′50″ − 180°
= 126°28′50″

BB of AB
= 222°01′30″ − 180°
= 42°1′30″

FB of BC = 360° − 95°32′40″ + 42°1′30″
= 306°28′50″

Lines	Bearing θ	ΔL (Latitude) L cos θ	ΔD (Departure) L sin θ
AB	222°01′30″	~~+5~~ −115.3	−103.9
BC	306°28′50″	101.31	−137
CD	51°13′30″	126.88	157.94
DA	129°34′10″	−88.79	107.45
		$\Sigma\Delta L = 24.064$	24.46 $= \Sigma\Delta D$

$e_L = \Sigma \Delta L = 24.064$

$e_D = \Sigma \Delta D = 24.461$

7

$C_L = -\left[\frac{|L_B|}{|L_T|} \times e_L\right]$

$L_T = \Sigma |BL| = 115.3 + 101.31 + 126.88 + 88.79$

$= 432.28\ m$

$D_T = \Sigma |\Delta D| = 103.9 + 137.4 + 157.94 + 107.49$

$= 506.29\ m$

	C_L	C_D	$\Delta L + C_L$	$\Delta D + C_D$
AB	-6.418	-5.019	-121.718	-108.919
BC	-5.639	-6.619	95.871	-143.619
CD	-7.063	-7.63	119.817	150.31
DA	-4.942	-5.19	-93.732	102.26

$\Sigma L_C = 0.04 \approx 0$

$\Delta \Sigma D_C = 0.03 \approx 0$

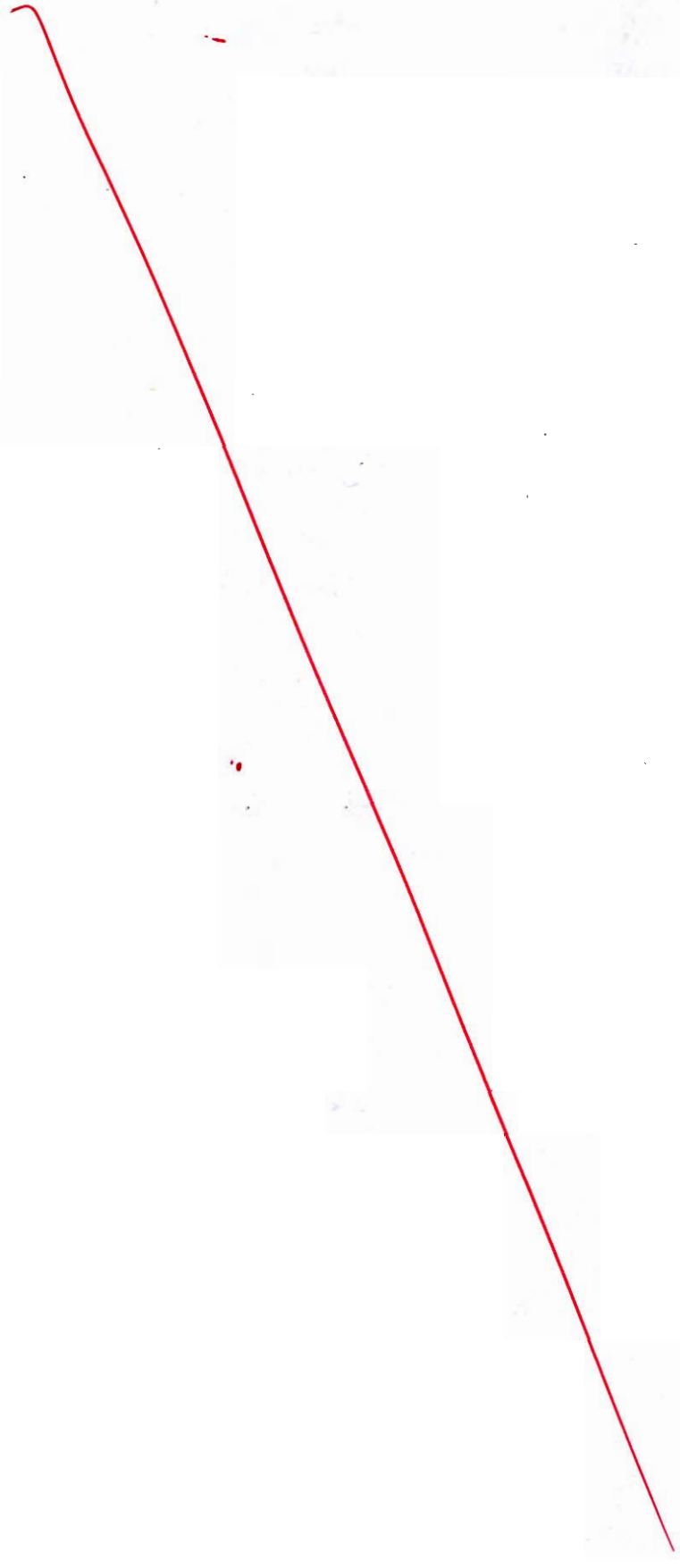
calc

$(C_L)_{AB} = -\left[\frac{115.3}{432.8} \times 24.064\right]$

$L_C = -115.3\ m$

$(C_D)_{AB} = -\left[\frac{103.9}{506.29} \times 24.461\right]$

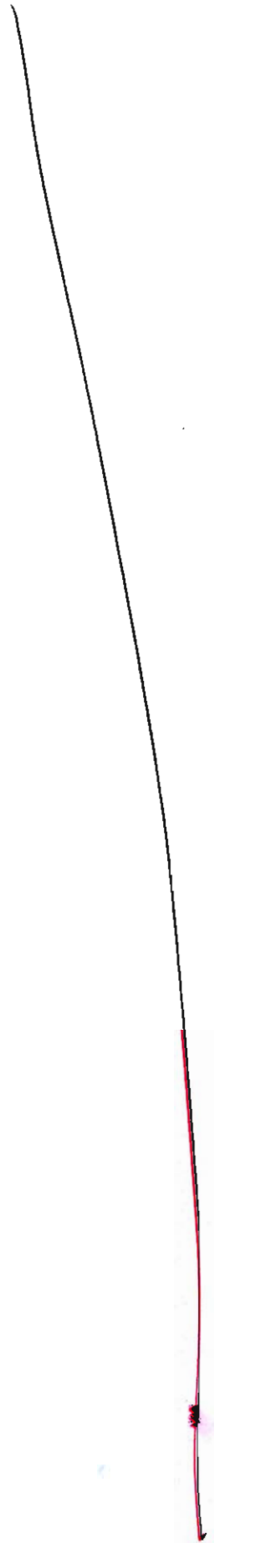
$D_C = -103.9\ m$



Q.4 (a) **(i)** A building has to be supported on a R.C. raft foundation of dimensions 10 m × 20 m. The subsoil is clay which has average unconfined compressive strength of 160 kN/m^2. The pressure on soil due to weight of building and the loads that it will carry will be 300 kN/m^2 at base of the raft. If the unit weight of excavated soil is 18 kN/m^3, at what depth should the bottom of raft to be placed to provide a factor of safety of 3 against shear failure? Use Skempton's approach.

(ii) What are the limitations of dynamic formulaes for calculating load carrying capacity of pile?

[12 + 8 = 20 marks]

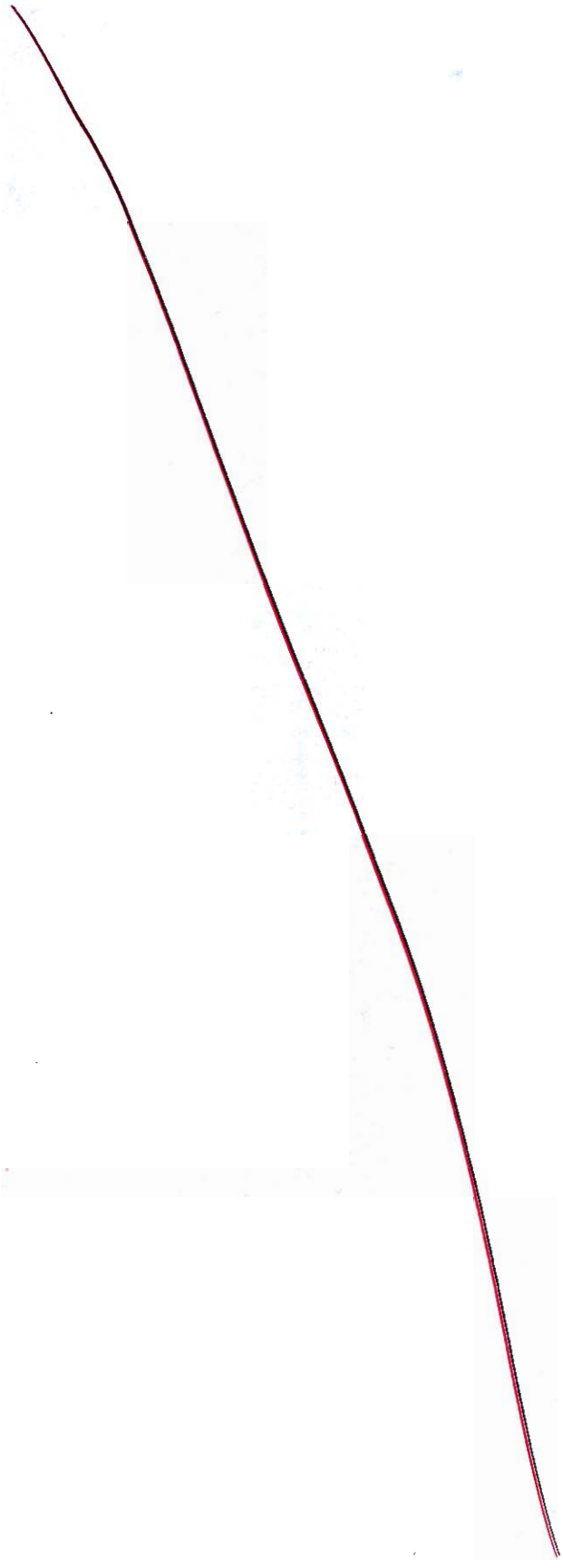


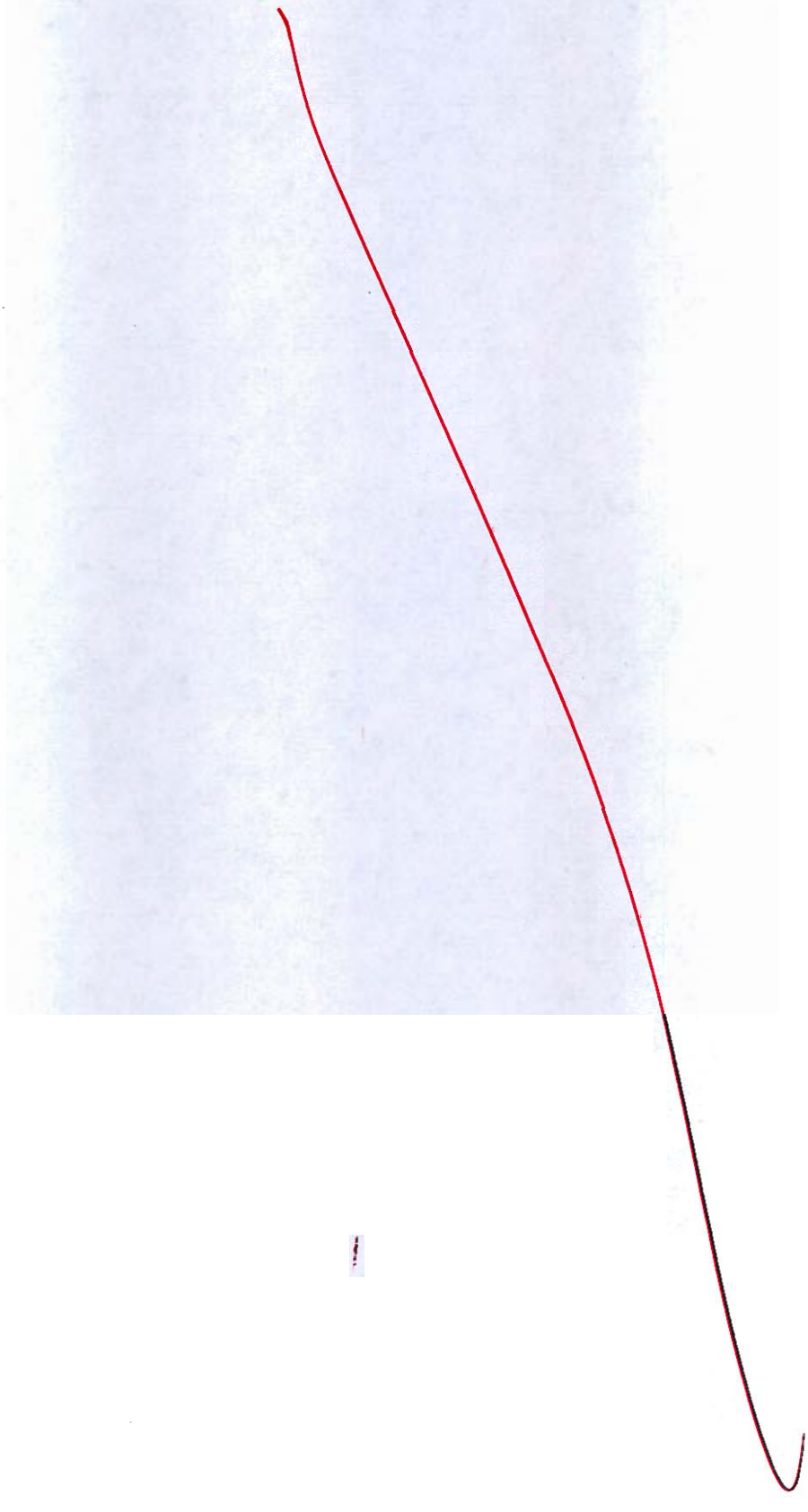
Q.4 (b) (i) A clay layer 8 m thick, having double drainage settles by 40 mm in 4 years after it has been subjected to loads. Its final consolidation settlement is calcualted as 160 mm.

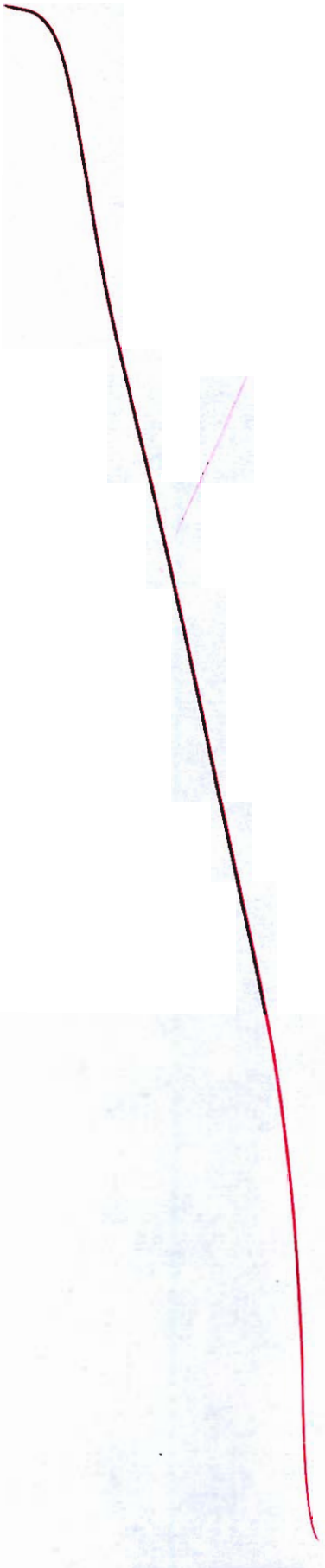
1. Determine the coefficient of consolidation of soil.
2. If a layer of sand of negligible thickness were to be present at 2 m from top of clay layer, then what will be the settlemnt of clay layers above and below the sand layer after 6 years? Also find the total settlement of clay in this case after 6 years.

(ii) What are the various factors affecting shear strength of soil?

[12 + 8 = 20 marks]



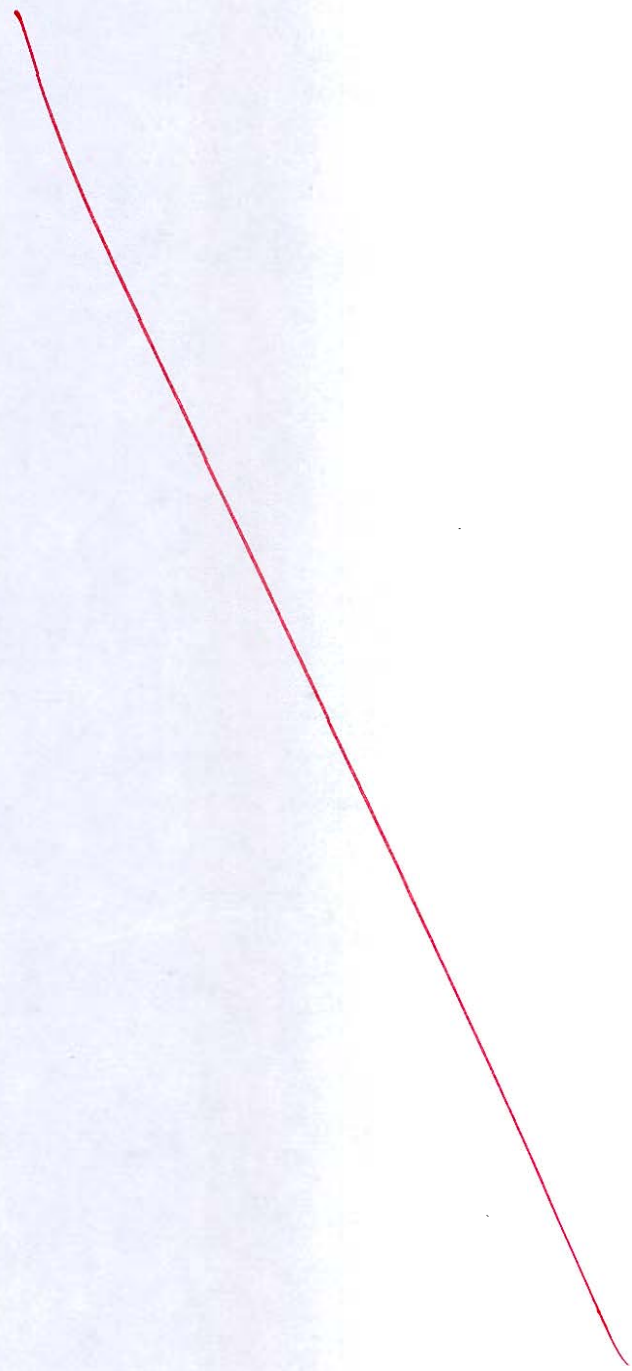


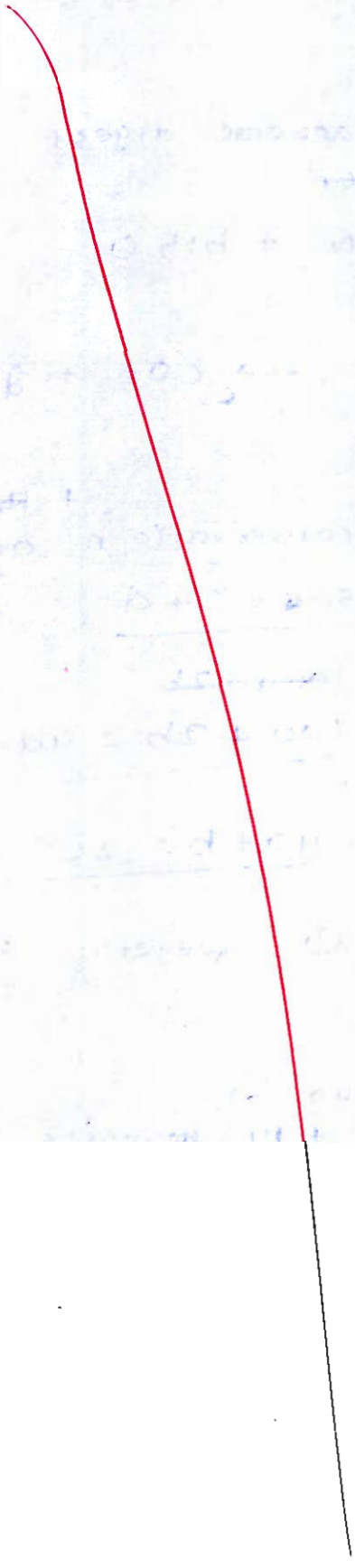


Q.4 (c) (i) Enlist the fundamental lines of a theodolite. State the desired relationships among these lines.

(ii) The following are the bearings of three lines: $AB = 18°30'$, $BC = 88°30'$ and $CD = 140°45'$. If BC is 235 m long, find the radius of a curve which is tangential to all the three lines. Also, find the tangent lengths.

[8 + 12 = 20 marks]





Section-B

Q.5 (a) Estimate the theoretical volume of methane gas that would be expected from anerobic digestion of a tonne of a waste having the composition $C_{50}H_{100}O_{40}N$. (Take density of methane gas as 0.72 kg/m^3).

[12 marks]

⇒ Reaction for Anaerobic digest

~~Finding Theoretical~~

$$C_{50}H_{100}O_{40}N + bH_2O \rightarrow cCO_2 + dCH_4 + NH_3$$

By conservation of element ma

Carbon → $50 = c + d$ — (1)

Hydro- → $100 + 2b = 4d + 3$ — (2)

Oxyge = $40 + b = 2c$ — (3)

From (1), (2) (3) we get $b = 5.75$, $c = 22.875$, $d = 27.125$ ✓

$(50 \times 12 + 100 + 40(16) + 14)$ g waste release

(1354 g) → (27.125) (20 g of CH_4) → 16 g

1000 kg → $\frac{542.5}{1354} \times 1000 = 400.66$ kg

Volume of methane gas release by 1 tonne of wast

$= \frac{400.66 \text{ Kg}}{0.72 \frac{\text{kg}}{\text{m}^3}} = 556.472 \text{ m}^3$

Q.5 (b) Briefly explain different methods of conducting origin and distination studies?

[12 marks]

Origin and destination studies are conducts to to when designi an ~~a~~ new facility to stud the usage or ~~use~~ demand,

diff method of conduct

① Interviewing techniq.

↳ Here vehicles are stoped at predecided station and are interviewed by trained proffess lor ~~Data collected~~.

↳ Data collected is

① No of passange
② type of vehic
③ Freauency of traf
④ orig and destinat

② Number plate ~~vehicle~~ Number method

↳ Here at entry and exit plat Number of vehicle is noted

↳ It ~~is t~~ has tedious ~~office~~ task, as origing & destinat needs to matched for allve

③ Tag on car method

↳ Precoded tags are sticked on vehicles and entry and which get recorde at exit.

↳ used fore heavy traffic flow

④ Return post card method

↳ prepaid post car with Questionare init It is given to users by

↳ Less trained proffesional are not reqm

↳ traffic flow is not obstructed much

(f) Office Interview

↳ Here a trained professional are send to interviewaw at work places

↳ This is suitable to study O&D in commercial places.

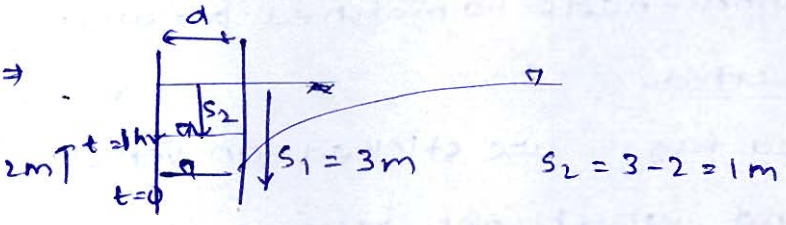
10

Q.5 (c) During a recuperation test, the water level in an open well was depressed by pumping by 3 m and is recuperateed by an amount of 2 meter in 1 hour.

(i) Determine the yield from a well of 2.5 m diameter under a depression head of 4 m.

(ii) Determine the diameter of well to yield 10 litres/second under a depression head of 3 m.

[6 + 6 = 12 marks]



⇒ discharge Q ∝ drawdown

$Q = CAS$ A → C/s of area of well

$C = \frac{1}{t} \ln\left(\frac{S_1}{S_2}\right) = \frac{1}{1} \ln\left(\frac{3}{1}\right)$

For $S = 4m$, $d = 2.5m$

$Q = \ln(3) \times \frac{\pi}{4} \times (2.5)^2 \times 4$

$Q = 21.57 \frac{m^3}{hr}$

For $Q = 10 l/s = (10\times10^{-3})(3600)\ \frac{m^3}{h}$, $S = 3m$

From above a"

$(10\times10^{-3})(3600) = \ln(3)\left(\frac{\pi}{4} \times d^2\right)(3)$

$\Rightarrow \boxed{d = 3.729\ m}$

↳ diameter of well required.

12

Q.5 (d) Analysis of annual peak data of river Damodar at Rhondia, covering a very large duration yielded a mean of 8520 m^3/s and a standard deviation of 3900 m^3/s. A proposed hydraulic structure on this river near this location has an expected life of 40 years and is to be built with a reliability of 85%.

(i) Using Gumbel's method, recommend the flood discharge for this hydraulic structure.

(ii) If a safety factor of 1.3 is desired, what discharge is to be adopted? What would be the corresponding safety margin?

[12 marks]

$\bar{X} = 8520\ m^3/s$

$\sigma = 3900\ m^3/s$

$T = 40\ yr$

$X_T = \bar{X} + K\sigma$

$K = \frac{y_T - \bar{y_n}}{S_n}$

For large n

$y_n = 0.577$

$S_n = 1.2825$

$y_T = -\ln\left(\ln\left(\frac{T}{T-1}\right)\right)$

$= -\ln\left(\ln\left(\frac{40}{39}\right)\right)$

$= 3.676$

$K = \frac{3.676 - 0.577}{1.2825}$

$= 2.416$ (3)

$X_T = 8520 + (2.416)(3900)$

$= 17942.4\ m^3/s$

For 85% relib

$X \rightarrow X_T + f(C)\sigma$

For $f(C) = 1 \Rightarrow 68\%$

$f(C) = 2 \rightarrow 84$

Q.5 (e) Briefly explain full face method and drift method of tunneling in hard rocks along with their advantages.

[12 marks]

Q.6 (a) A rigid pavement is designed making use of Westergaard's wheel load and warping stress equations at edge region of slab. Following data is used for the design:

Design wheel laod, $P = 7000$ kg

Contact pressure, $p = 7.5$ kg/cm^2.

Spacing between longitudinal joints = 3.75 m

Spacing between contraction joints = 4.2 m

Elastic modulus of pavement material, $E = 3 \times 10^5$ kg/cm^2.

Poisson ratio, $\mu = 0.15$

Thermal coefficient of CC per °C, $\alpha = 1 \times 10^{-5}$/°C

Modulus (k - value) of subgrade of base course = 30 kg/cm^3

Maximum temperature differential at location for pavement thickness values of 22, 24, 26 and 30 cm are 14.8, 15.6, 16.2 and 16.8°C respectively. If a thickness of 25 cm is selected for pavement, then what is the factor of safety with respect to load and warping stresses at edge region if flexural strength of pavement material is 45 kg/cm^2?

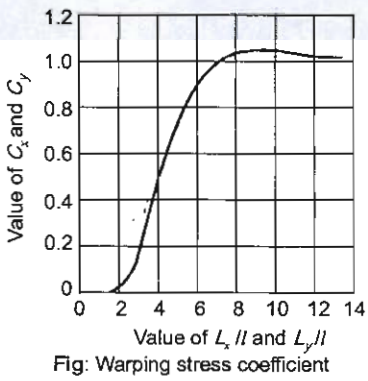
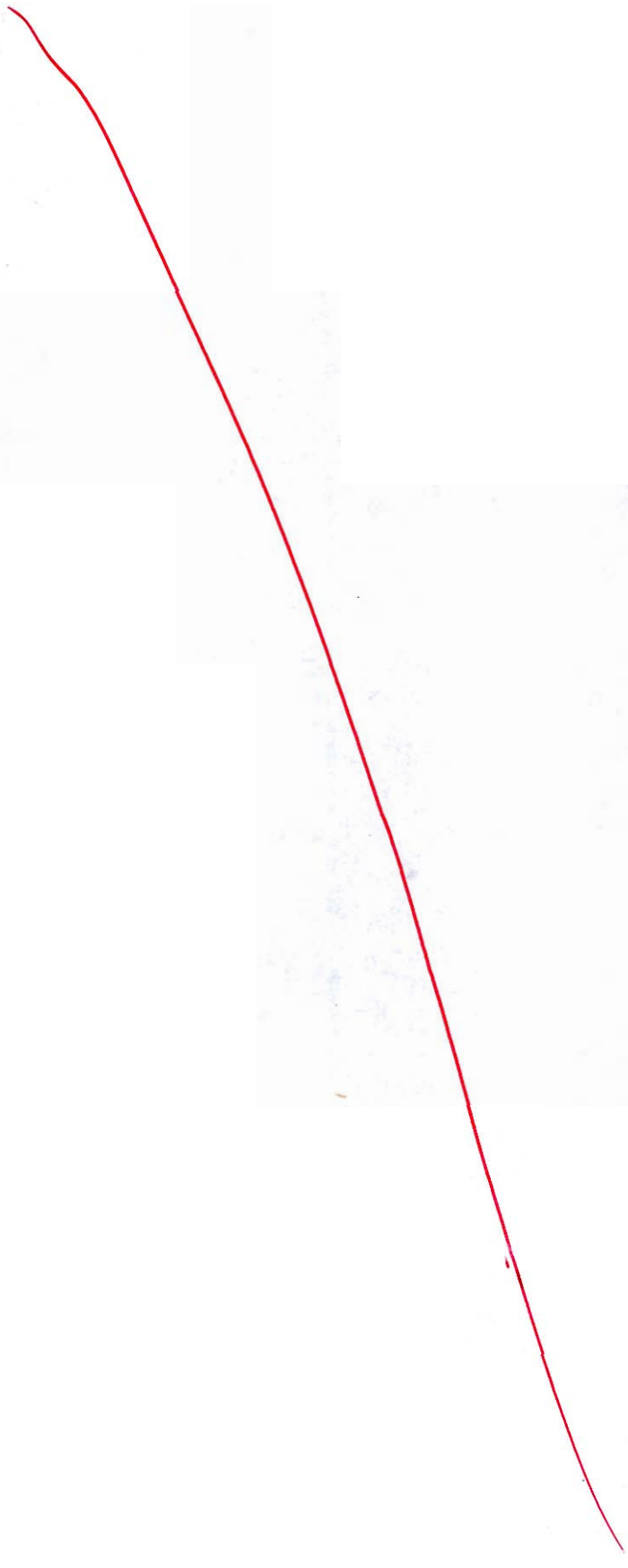
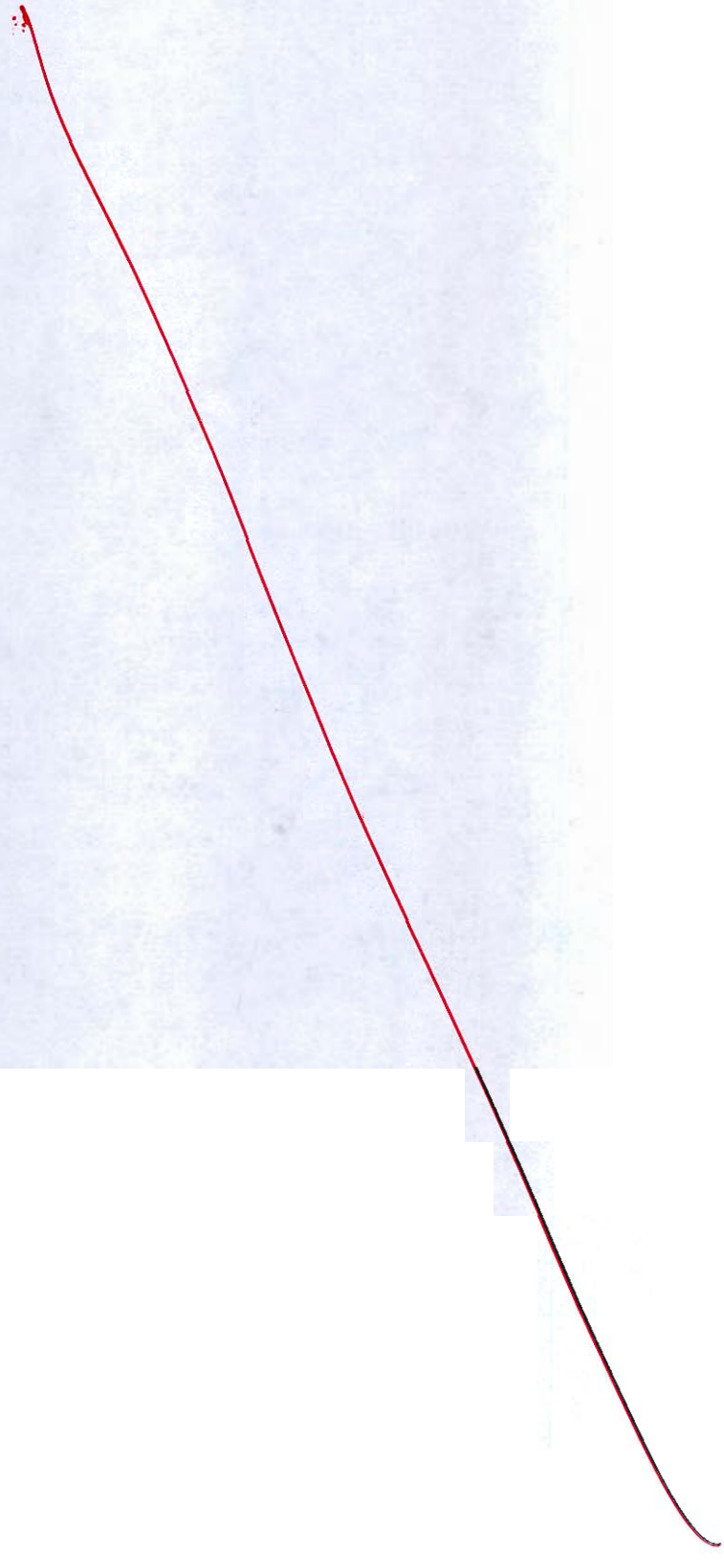


Fig: Warping stress coefficient

Also, find warping stress at interior and corner region of pavement if thickness of 25 cm is provided.

[20 marks]





Q.6 (b) A city with a population of 2 lakhs has to be supplied with water at 180 litres per person per day. The hourly variation in the rate of demand is tabulated below:

Period of day (in hours)	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12
Percentage of average hourly flow expected	25	25	25	25	35	45	100	150	190	250	210	150

12 – 13	13 – 14	14 – 15	15 – 16	16 – 17	17 – 18	18 – 19	19 – 20	20 – 21	21 – 22	22 – 23	23 – 24
120	90	100	120	150	160	130	100	80	50	40	30

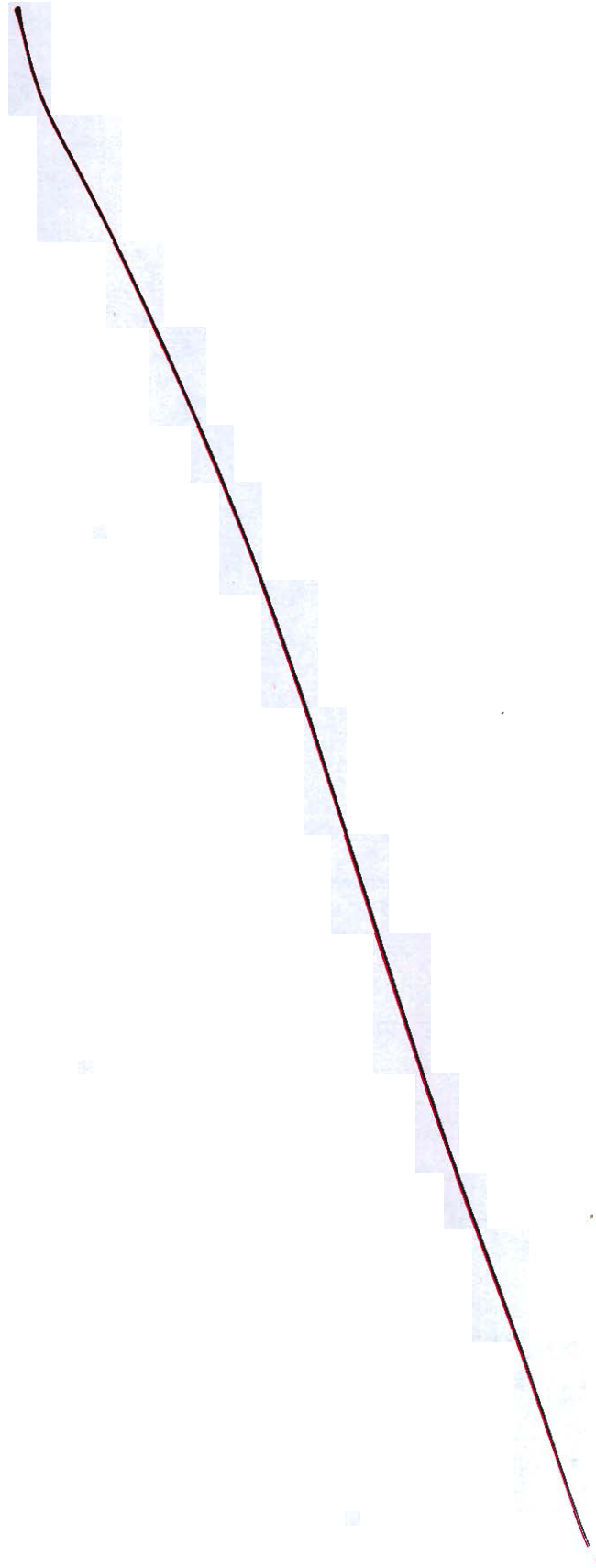
Determine the capacity of balancing reservoir to be provided for balancing the variable demand against a constant rate of pumping,

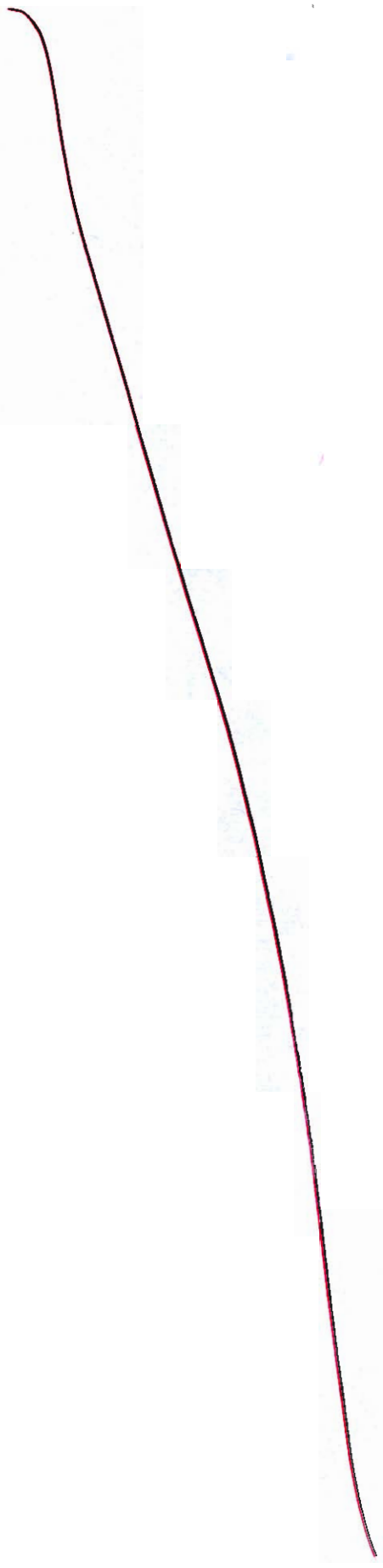
(i) If the pumping is done for all the 24 hours.

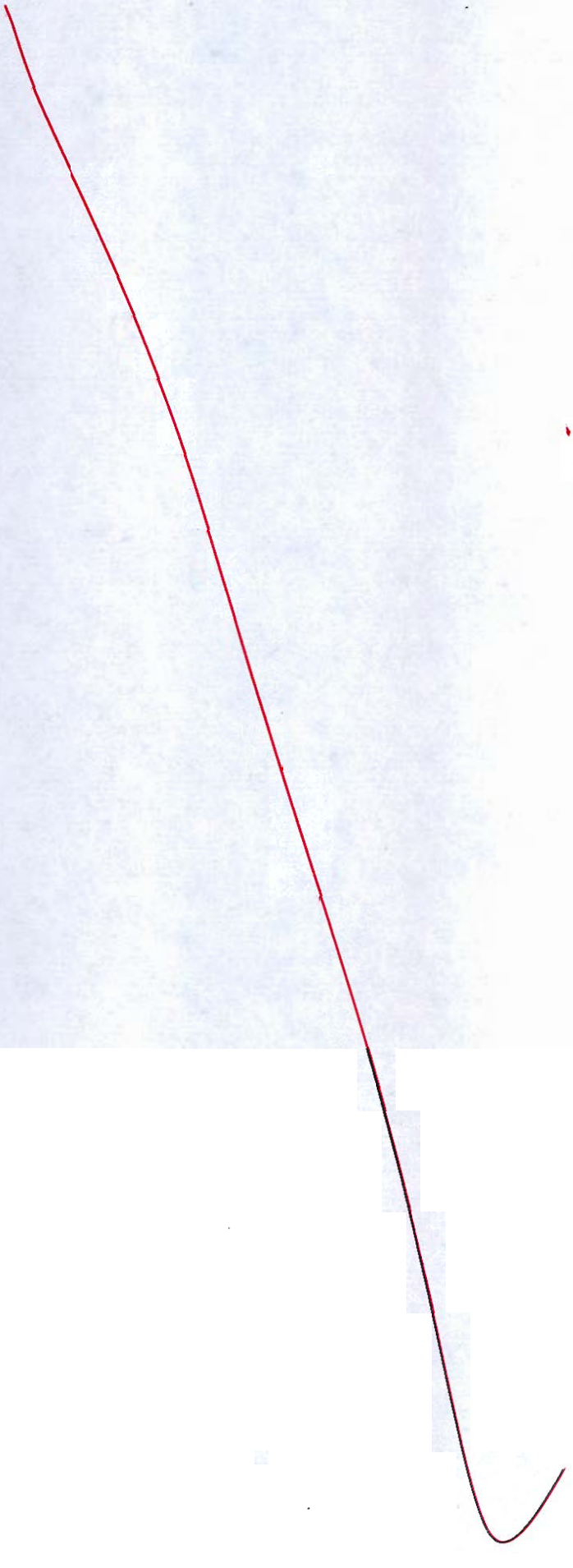
(ii) If the pumping is to be done only from 5.00 am to 11 am and 2 pm to 8 pm.

Also, mention the rate of pumping required in both the cases.

[20 marks]





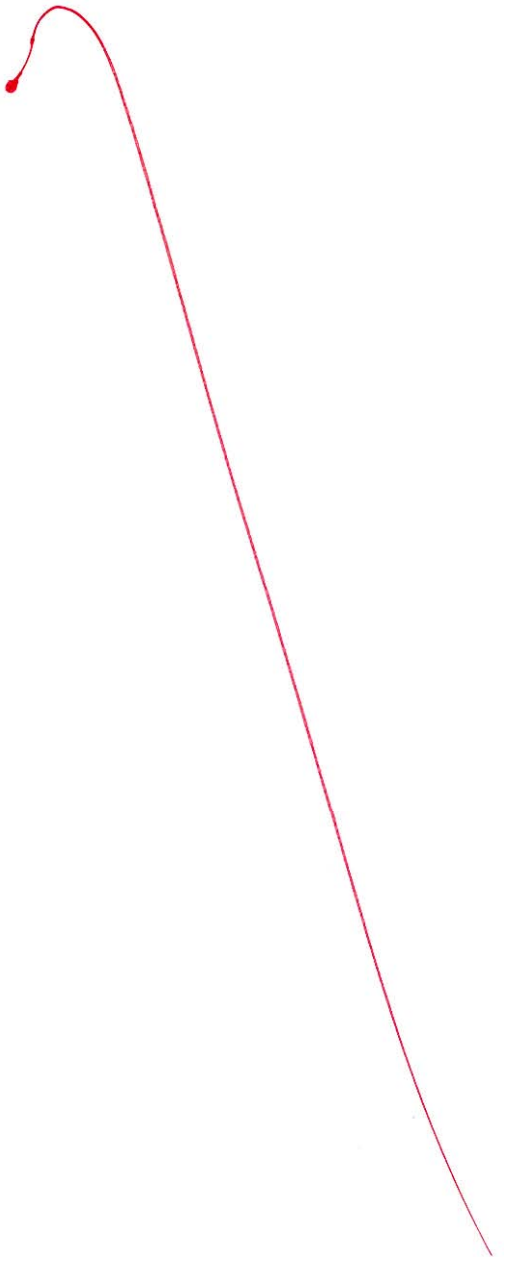


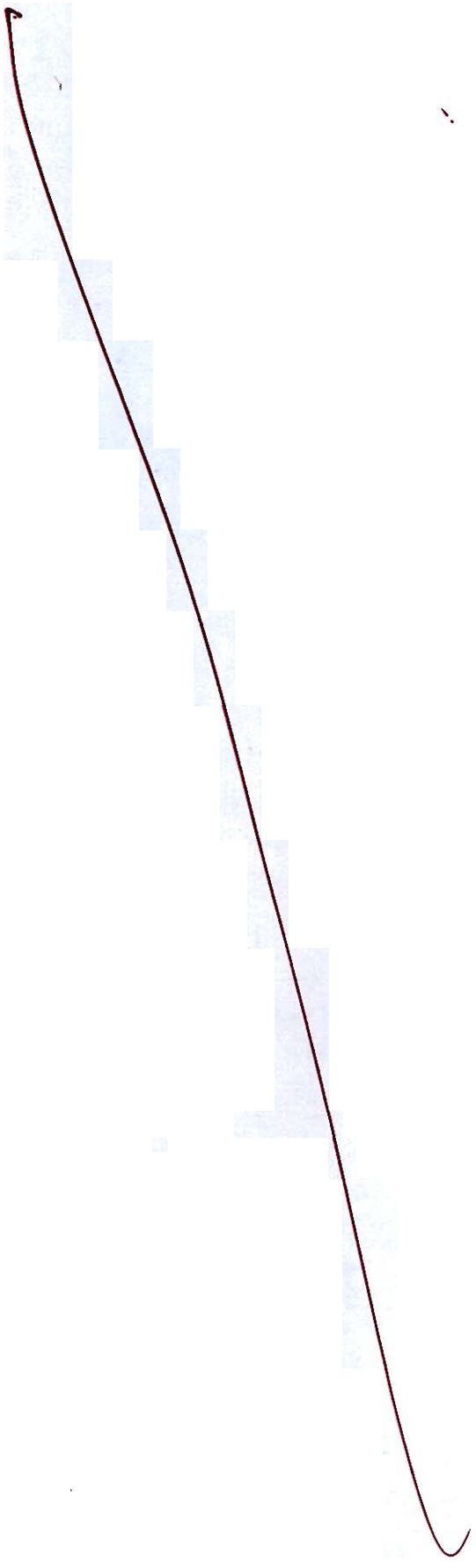
Q.6 (c) A water treatment plant is being designed to process 50000 m^3/d of water. Jar testing and pilot plant indicates that an alum dosage of 40 mg/l with flocculation at a '*Gt*' value of 4×10^4 produces optimal results at the expected water temperature of 15°C. Determine:

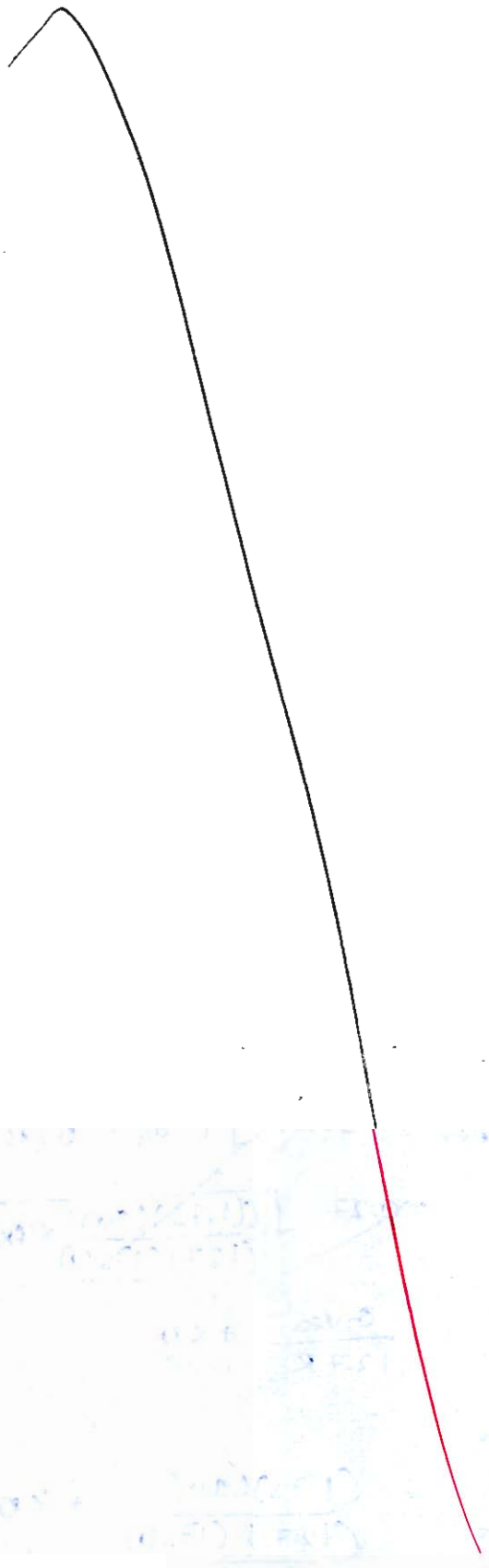
1. Monthly alum requirement.
2. The flocculation basins dimension if three cross-flow horizontal paddles are to be used and maximum width and depth of flocculator can be 12 m and 5 m respectively.
3. Power requirement.
4. Paddle configuration

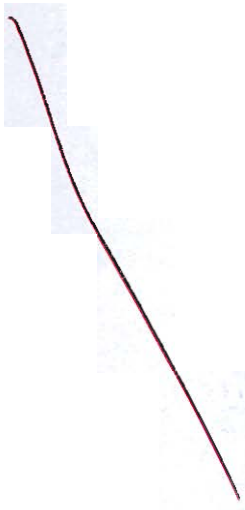
Take average value of *G* as 30 sec^{-1} and viscosity of water as 1.1×10^{-3} Ns/m^2.
Assume any other data suitably.

[20 marks]









Q.7 (a) (i) A 2° curve on a broad gauge railway track has a maximum sanctioned speed of 120 kmph. Assuming the equilibrium speed of 90 kmph and the speed of slow moving trains as 50 kmph, calculate the superelevation and the maximum permissible speed on the railway track. Assume that the maximum cant deficiency is equal to 100 mm and the permissible cant excess is equal to 75 mm.

(ii) Draw a labelled sketch of right hand turnout, clearly highlighting the movement of train on both the routes i.e. main line and branch line.

[10 + 10 = 20 marks]

⇒ $V_{sanction} = 120\ km/h = V_{max}$

$V_{eq} = 90\ km/hr$

$V_{slow} = 50\ km/hr$

⇒ $e_{max} = e_{eq} + C_D$ By superelevation formula

$\frac{GV_{max}^2}{127} \quad (V_{max})_{per} = 0.27\sqrt{(e_{eq}+C_D)R}$

$e = \frac{GV^2}{127R}$

$= 0.27\sqrt{\frac{(1.75)(90)^2}{(127)\left(\frac{1750}{2}\right)} \times 1000 + }$

$\frac{GV_{max}^2}{127R} = \frac{GV_{eq}^2}{127R} + C_D$

For $V_{max} = 120\ km/h$

$\frac{(1.75)(120)^2}{(127)\left(\frac{1750}{2}\right)} = \frac{(1.75)(90)^2}{(127)\left(\frac{1750}{2}\right)} + C_D$

$C_D = 0.09921\ m$

$= 9.92\ cm < (C_D)_{per}$ OK

$\therefore$ $V_{max} = 120$ km/hr

For slow train

$$\frac{G V_{slow}^2}{127R} = \frac{G V_{eq}^2}{127R} + CE$$

$$\frac{(1.75)(50)^2}{(127)\left(\frac{1750}{2}\right)} = \frac{(1.75)(90)^2}{(127)\left(\frac{1750}{2}\right)} - EE$$

$CE = 0.1213$ m

$(CE)_{req} = 12.13$ cm $>$ CE perm (0.075 m)

10

$\therefore$ For slower train to move,

$$e_{eq\ req} = \frac{(1.75)(50)^2}{(127)\left(\frac{1750}{2}\right)} + 0.075)$$

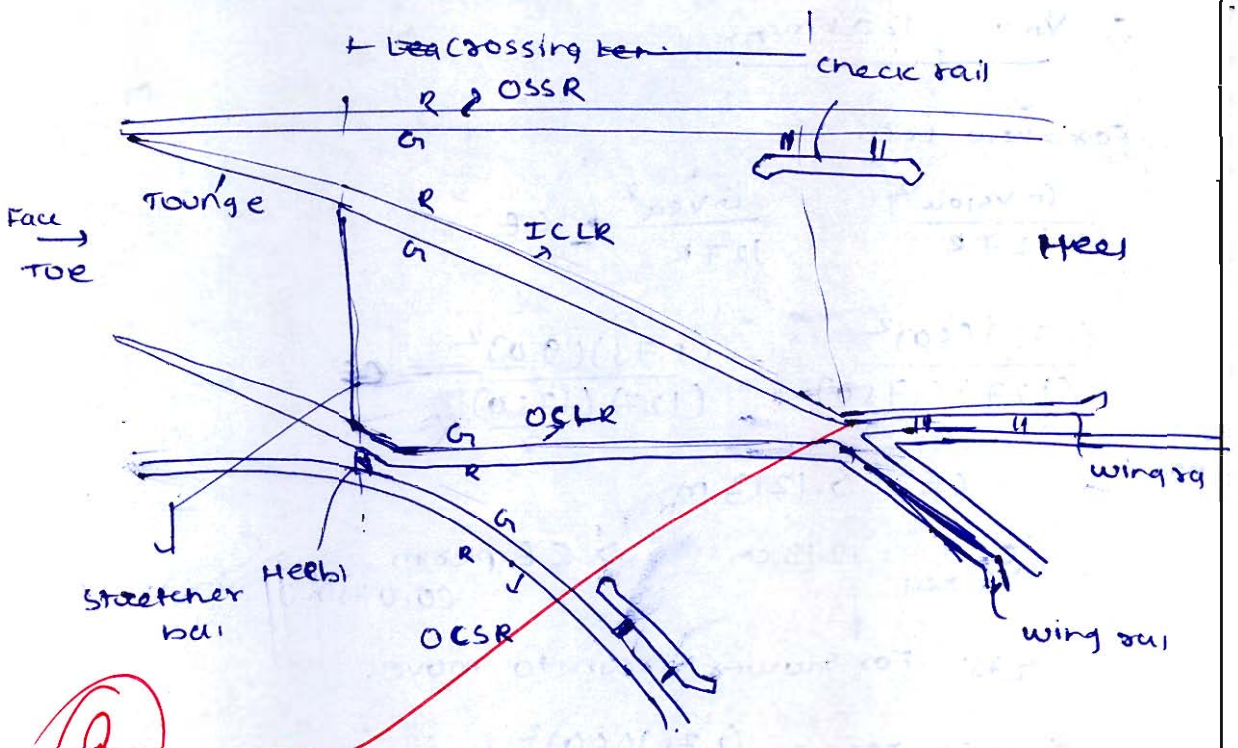
$e_{eq} = 0.1144$ m $\rightarrow$ SE

$e_{max} = e_{eq} + CD$

$$\frac{G(1.75)V_{max}^2}{(127)\left(\frac{1750}{2}\right)} = 0.1144 + 0.1$$

$V_{max} = 116.88$ km/hr $\Rightarrow$ max permissible speed.

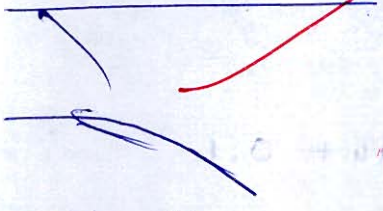
(i)



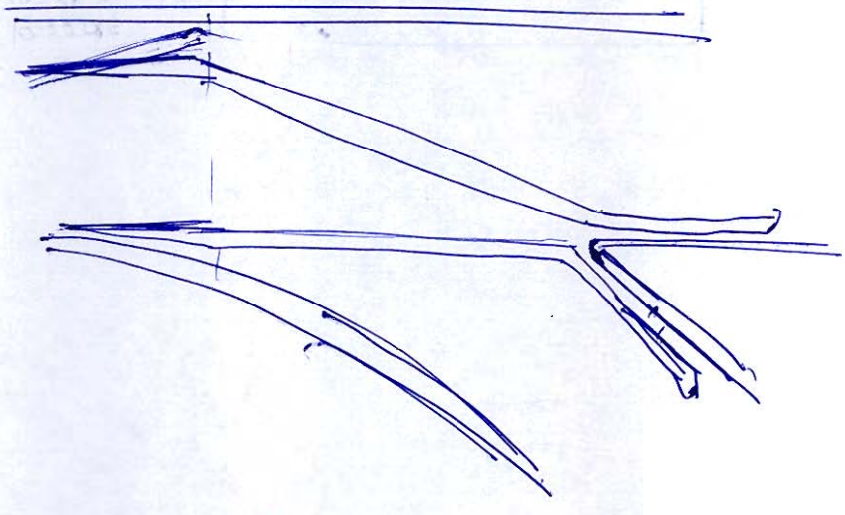
(8)

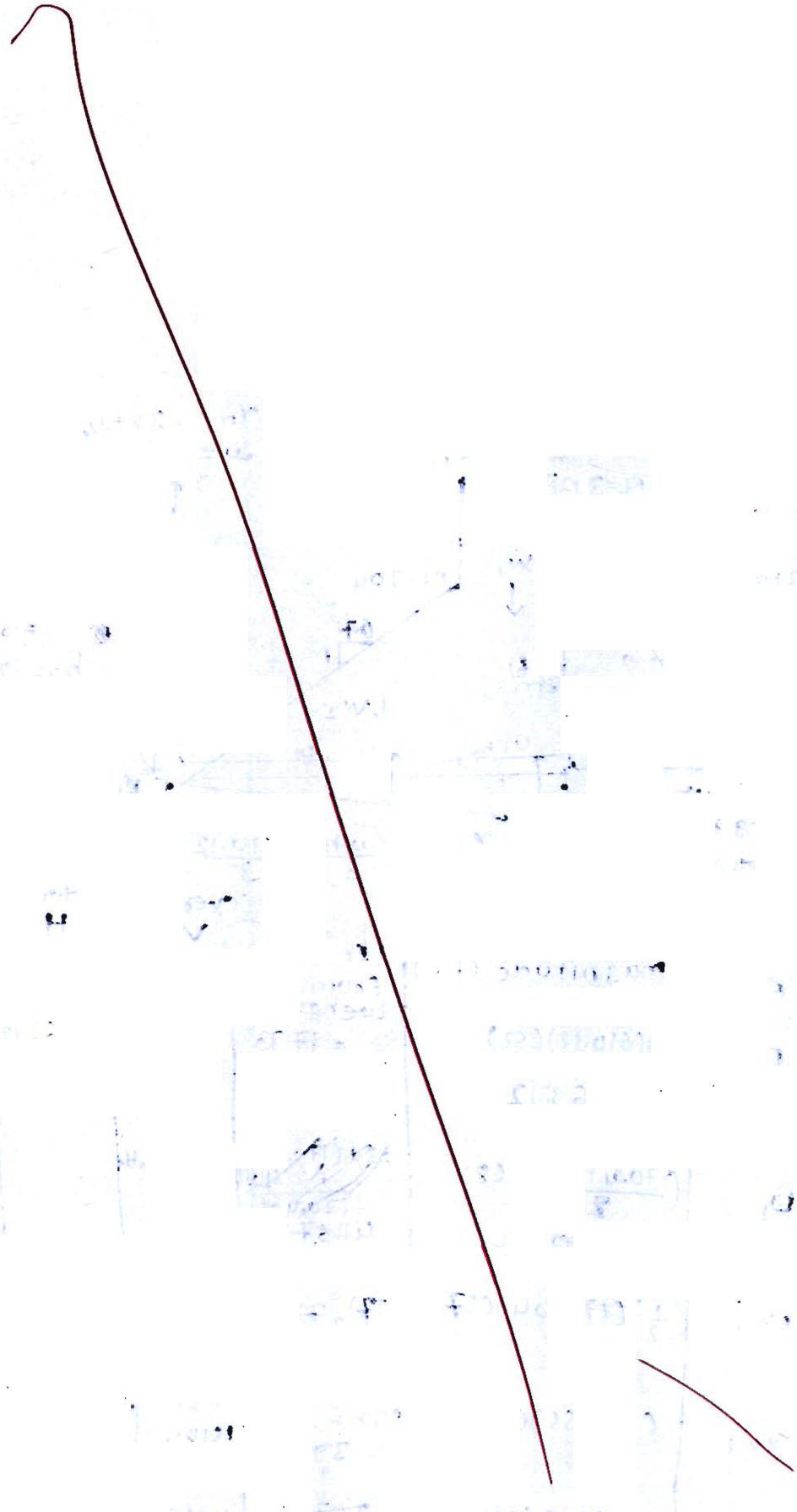
Right hand turnout.

(For movement along Branch line)



For main line)





Q.7 (b) The following data refers to the non-overflow section of a gravity dam:

R.L. of top of dam = 315 m.

R.L. of bottom of dam = 260 m

R.L. of full reservoir level = 312 m

Top width of dam = 12 m

Unit weight of masonry = 23 kN/m^3

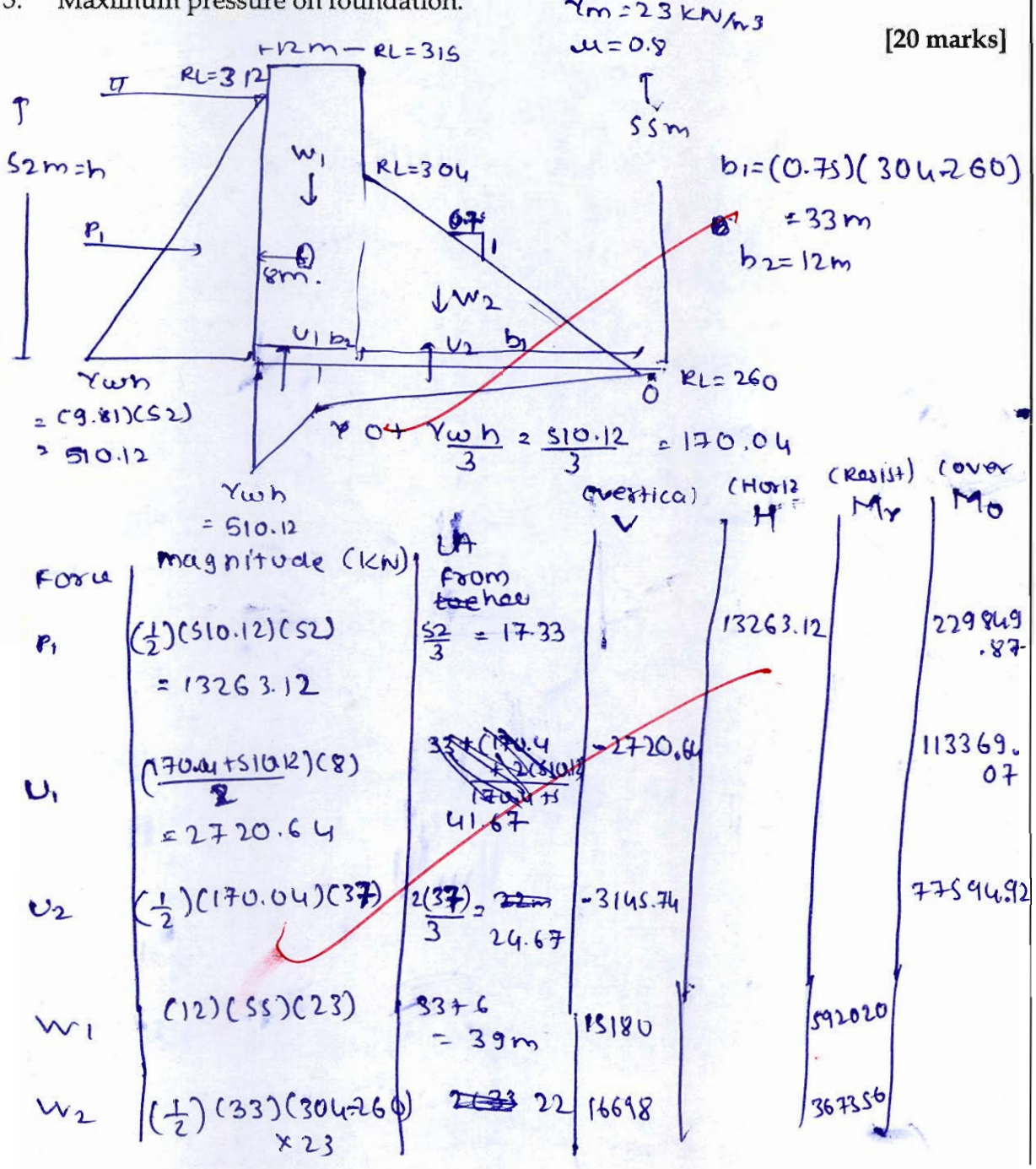
Coefficient of friction between masonry and foundation material = 0.8

Upstream face is vertical. Downstream face is vertical upto R.L. 304 m and after that downstream face slopes at 0.7H : 1 V upto base. Draiange gallery is provided at 8 m from upstream face.

If forces due to water thrust, uplift and self-weight of dam is considered only, then determine:

1. Factor of safety against overturning.
2. Factor of safety against sliding.
3. Maximum pressure on foundation.

[20 marks]



LA for U_1 = $37 + \left(\frac{170.04 + 2(510.12)}{170.04 + 510.12}\right)\left(\frac{12}{3}\right)$

$= 41.67$

Resisting moment

$\Sigma M_r = 592020 + 367356 = 959376$ kNm

overturning moment

$\Sigma M_o = 229849.87 + 113369.07 + 77594.92$

$= 420813.86$ kNm.

Net vertical Normal react from bu

$N = \Sigma V = 16698 + 15180 - 3145.74 - 2720.64$

$= 26011.62$ kN

① FOS for overturning = $\frac{\Sigma M_r}{\Sigma M_o}$

$= \frac{959376}{420813.86}$

$= 2.28$

② FOS For sliding = $\frac{\mu \Sigma V}{H}$

$= \frac{(0.8)(26011.62)}{13263.12}$

$= 1.57$

③ $\bar{x} = \frac{\Sigma M_r - \Sigma M_o}{\Sigma V}$

$= 20.705$ m

$e = \frac{B}{2} - \bar{x} = \frac{41}{2} - 20.705$

$= 1.795$ m

~~max~~ max pressure on ~~b~~ foundation

p_{max} at ~~toe~~ heel $= \frac{\Sigma V}{B}\left(1 + \frac{6e}{B}\right)$

$= \frac{26011.62}{45}\left(1 + 6\frac{(1.795)}{45}\right)$

$= 716.38 \frac{kN}{m^2}$

16

check calculations

.7 (c) (i) Calculate the minimum size of particle that will be removed with 96 percent efficiency from a settling chamber under the following conditions:

Air: Horizontal velocity is 0.4 m/s.

Temperature is 77°C

Viscosity of air is 2.1×10^{-5} kg/m.s

Particle: Specific gravity is 2.0.

Chamber: Length is 8 m.

Height is 1.6 m.

Assume correction factor equal to 1.

(ii) Explain the concept of Equivalent Noise level (L_{eq}). If a 80 db noise lasting for 10 minutes, followed by 60 dB for 80 minutes followed by 100 dB for 5 minutes, followed by 50 dB for 10 minutes is followed by 60 dB for 5 minutes, then what is L_{eq} of the noise? Also, compute the average sound level of the given sound pressure readings.

[8 + 12 = 20 marks]

For gravity setting chamber

minimum

Let particle with V_s → 100% velocity of settl

V → 96%

$\eta = \frac{V}{V_s} = \Rightarrow$

$\propto \frac{d^2}{d_s^2} \Rightarrow \boxed{d = d_s\sqrt{0.96}}$ (2)

For 100% particle size d_s,

$d_s = C\sqrt{\frac{18\mu VH}{(\rho_s - \rho_a)gL}}$ $C = 1$

$= \sqrt{\frac{(18)(2.1\times10^{-5})(1.6)}{(2000-1)(9.81)(8)}}$ $\rho_a \approx 1\ \frac{kg}{m^3}$

$= 62.09\ \mu m$

$d = 62.09\sqrt{0.96}$

$\boxed{d = 60.83\ \mu m}$

↳ 96% of removal

ii) - equivalen noise level ~~refer~~ to pressure level of sound which releases equivalent amount of energy as ~~as~~ earned as different ~~as~~ exposu of sound level for correspon ~~time duration~~ proportion. in a particular time duration.

~~Sodb~~ Level	t	$t_i = \frac{t}{\Sigma t}$
80db	10min	1/11
60dB	80min	8/11
100dB	5min	1/22
50dB	10min	1/11
60dB	5min	1/22
	$\Sigma t = 110$min.	

10

$$L_{eq} = 10 \log_{10}\left(\Sigma t_i 10^{\frac{L_{eq}}{10}}\right)$$

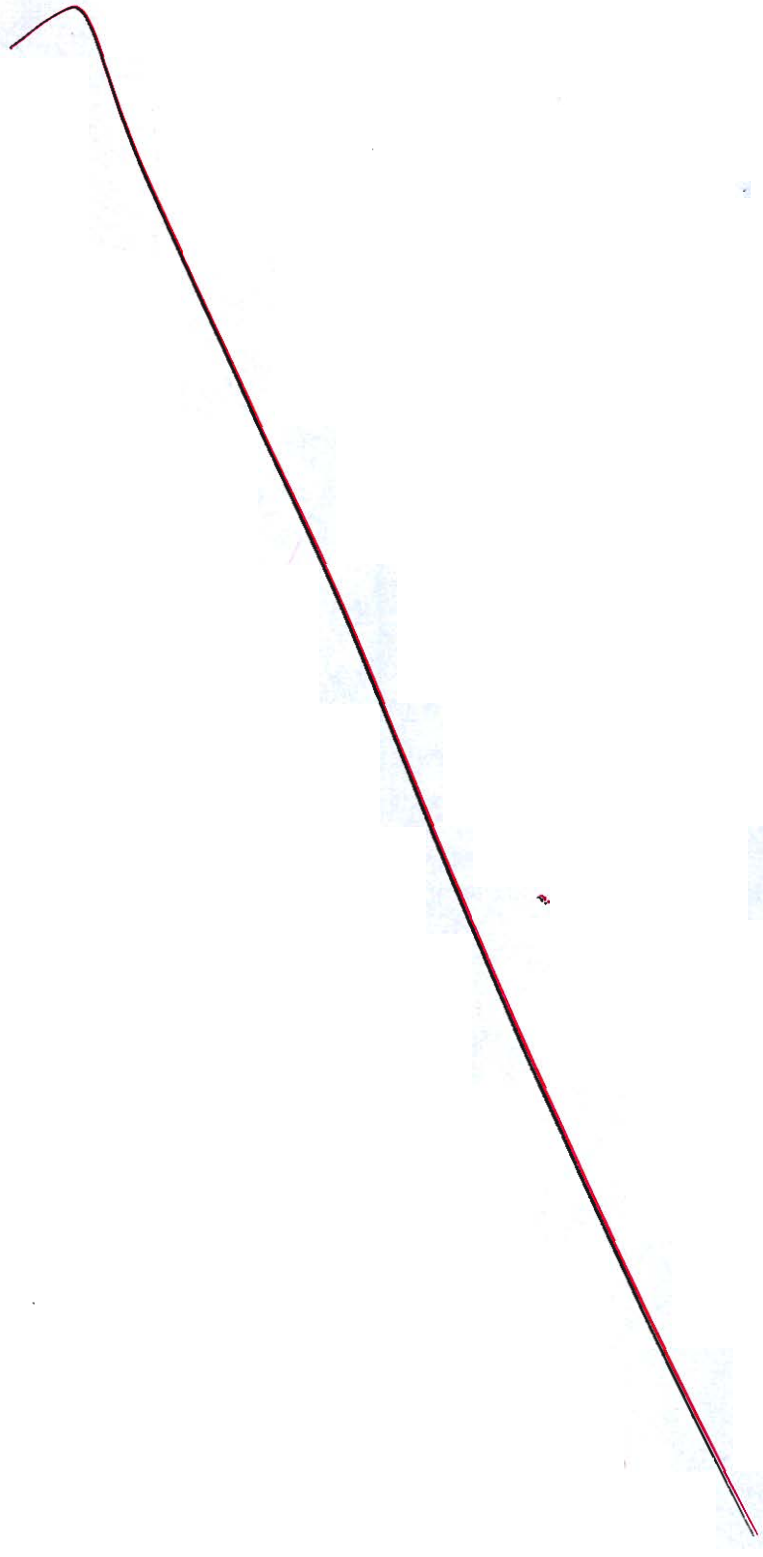
$$= 10 \log_{10}\left(\frac{1}{11}\times 10^{8} + \frac{8}{11} 10^{6} + \frac{1}{22} 10^{10} + \frac{1}{11} 10^{5} + \frac{1}{22} 10^{6}\right)$$

$$L_{eq} = 86.67 \text{ dB}$$

$$L_{avg} = 20 \log_{10}\left(\frac{1}{N}\left(\Sigma 10^{\frac{L}{20}}\right)\right)$$

$$= 20 \log_{10}\left(\frac{1}{5}\left(10^{\frac{80}{20}} + 10^{\frac{60}{20}} + 10^{\frac{100}{20}} + 10^{\frac{50}{20}} + 10^{\frac{60}{20}}\right)\right)$$

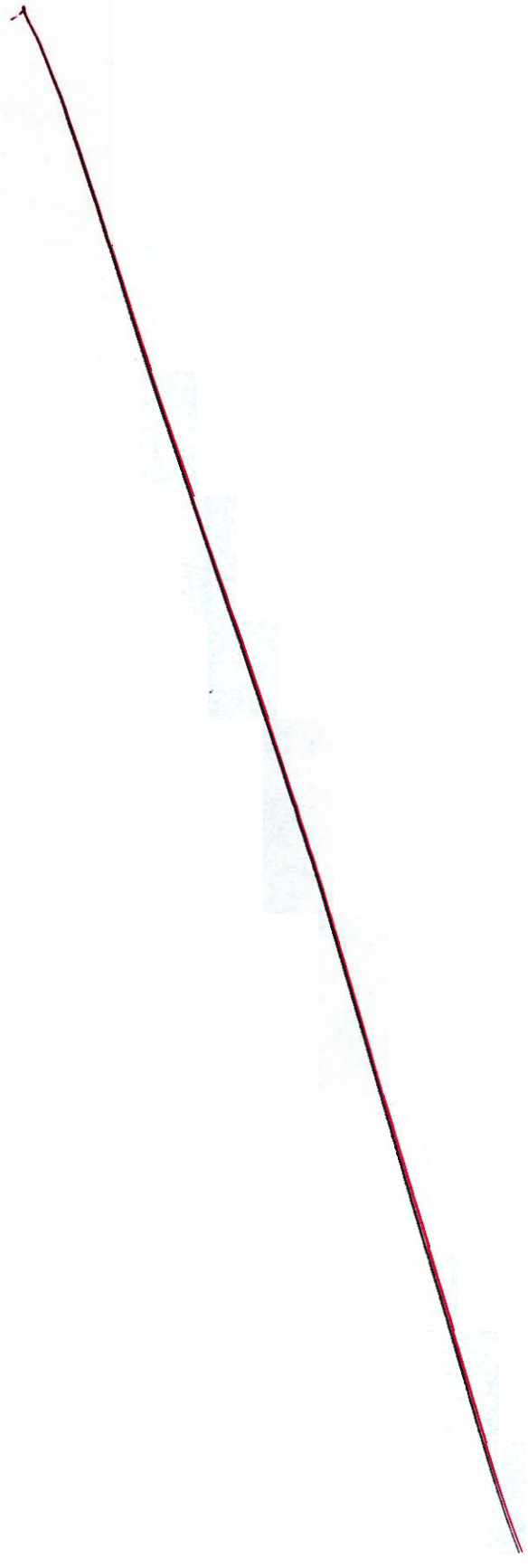
$$L_{avg} = 87.03 \text{ dB}$$

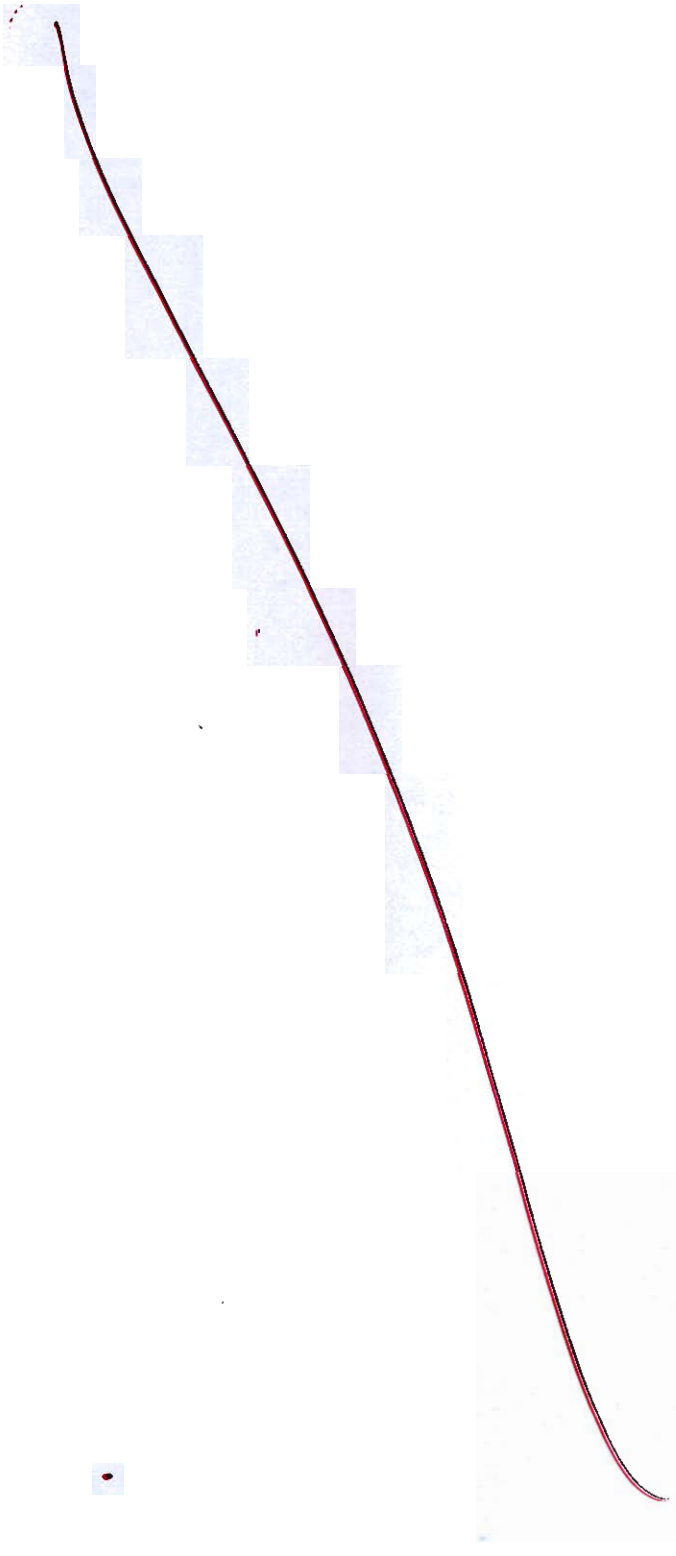


Q.8 (a) On a two-lane national highway in rolling terrain, two straights intersect at chainage of 82.5 chain length with an angle of intersection of 146°. It is proposed to constant a circular arc of 16 chains radius with transitions curves at each ends. Determine the length of transition curve and chainage at the beginning of each of first transition curve, circular curve and second transition curve.

(Assume speed of vehicle as 80 kmph and length of one chain as 20 m.)

[20 marks]





8 (b) The stage-discharge data of a river are given below:

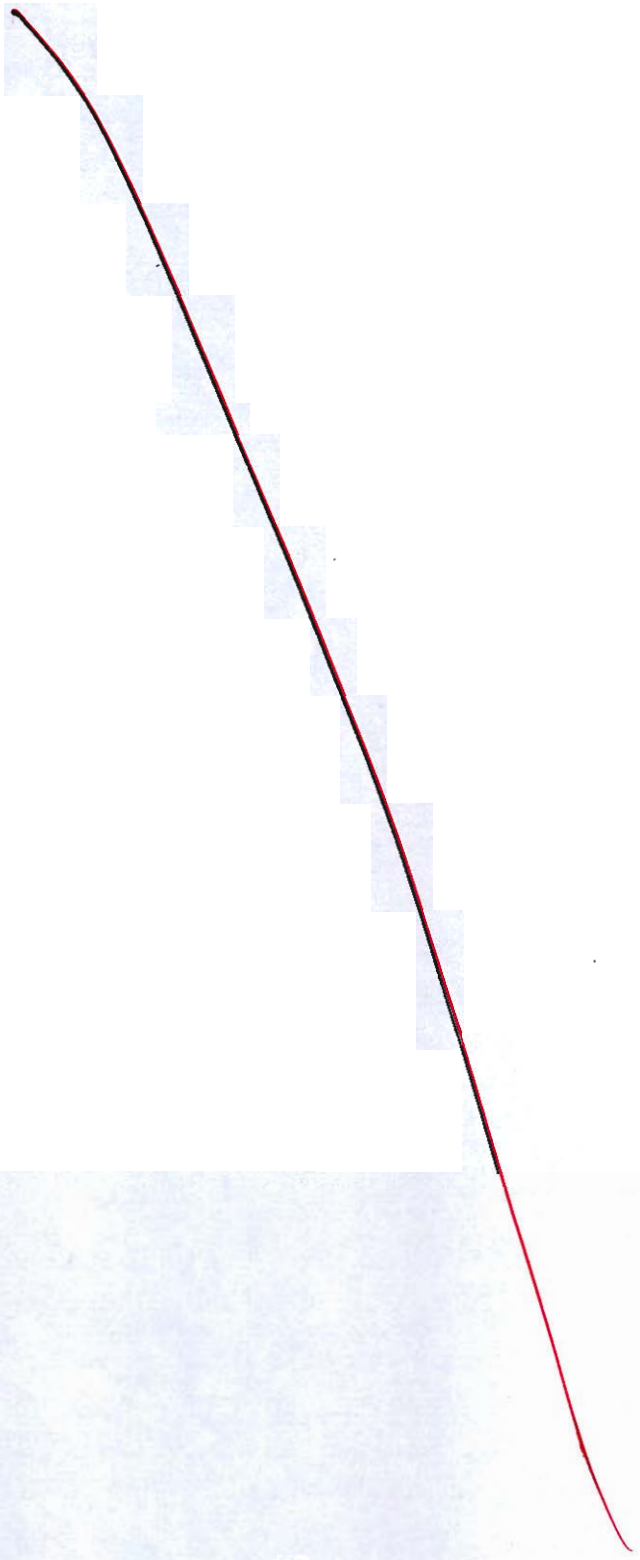
(i) Estimate a stage-discharge relationship to predict the stage for a known discharge. Assume the stage value for zero discharge as 20.5 m.

(ii) Determine the stage of river corresponding to a discharge of 2600 m^3/s.

(iii) What is the correlation coefficient of relationship established above?

Stage (m)	Discharge (m^3/s)
21.95	100
22.80	295
23.40	490
23.75	640
24.55	1010
25.10	1300
25.55	1550

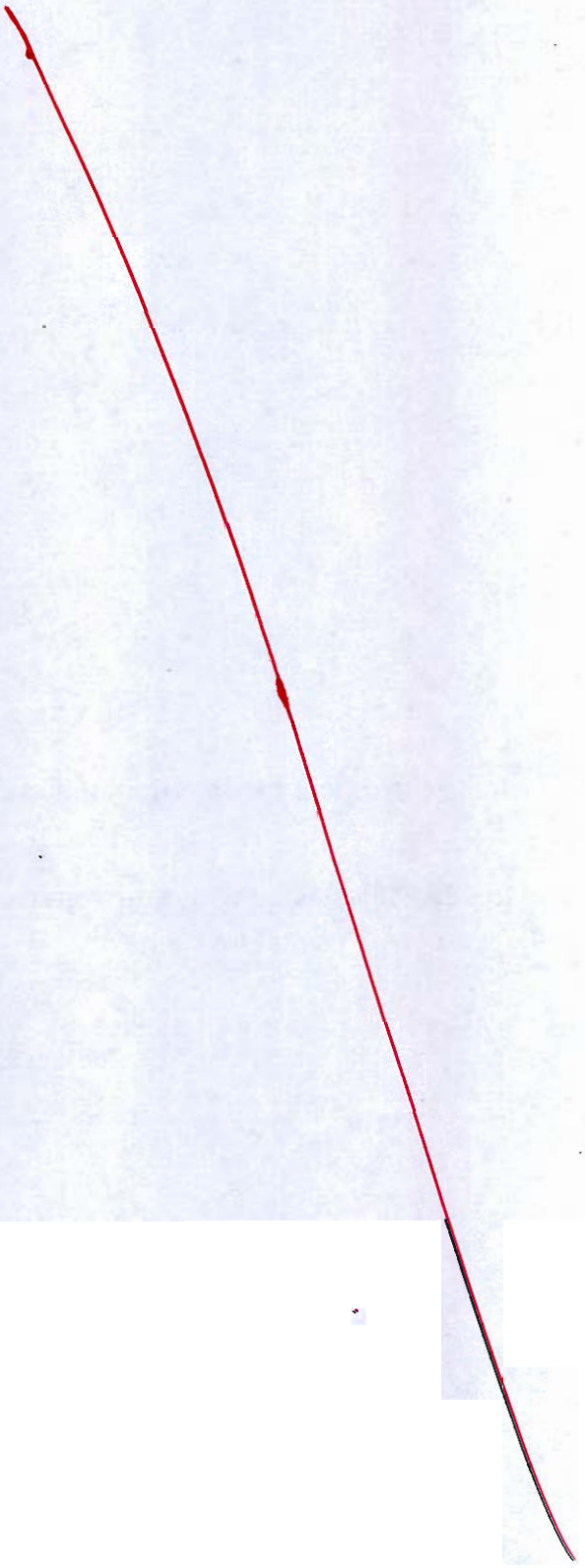
[20 marks]



8 (c) (i) What are the factors responsible for selection of a particular type of lining for a canal?

(ii) Design a regime trapezoidal channel with side slopes as 0.4 H : V for a discharge of 60 m^3/s and silt factor of 1.1 using Lacey's theory.

[10 + 10 = 20 marks]



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Space for Rough Work

Space for Rough Work