



# MADE EASY

India's Best Institute for IES, GATE & PSUs

## ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

### Civil Engineering

#### Test-5

Flow of fluids, Hydraulic machines and Hydro power [All Topics]

Design of Concrete and Masonry Structures-1 [Part Syllabus]

+ Geo-technical & Foundation Engineering-2 [Part Syllabus]

Name : .....

Roll No :

#### Test Centres

Delhi ☐ Bhopal ☐ Jaipur ☐ Pune ☐  
Kolkata ☐ Bhubaneswar ☐ Hyderabad ☐

#### Student's Signature

#### 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	37
Q.2	25
Q.3	45
Q.4	—
Section-B	
Q.5	26
Q.6	32
Q.7	—
Q.8	—
<b>Total Marks Obtained</b>	<b>165</b>

Signature of Evaluator

*[Signature]*

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

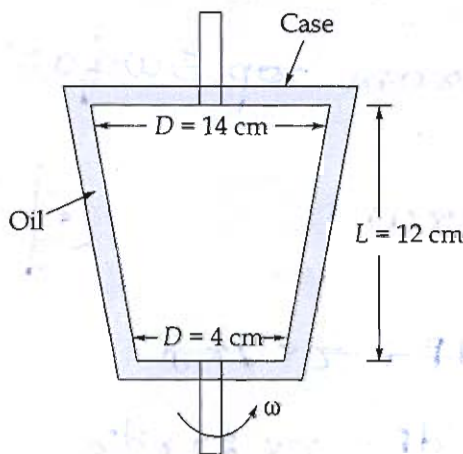
1. Read the Instructions on the cover page and **strictly** follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough 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.

- Excellent work in Section-A
- Accuracy is good.
- Question selection is good.
- Improve presentation.
- Keep practising.



## Section A : Flow of fluids, Hydraulic machines and Hydro power

- Q.1 (a) A frustum-shaped body is rotating at a constant angular speed of 100 rad/s in a container filled with an oil of viscosity 0.099 Pa.s, as shown in figure. If the thickness of the oil film on all sides is 1.4 mm, determine the power required to maintain this motion.



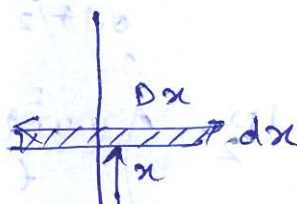
[12 marks]

Soln) Given,  $\omega = 100 \text{ rad/sec}$

Soln  $\mu = 0.099 \text{ Pa-s}$

$t = 1.4 \text{ mm}$

we know,  $\tau = \mu \left( \frac{dv}{dy} \right)$



$$Dx = 4 + \frac{(14-4)}{12} x$$

$$Dx = \left( 4 + \frac{10}{12} x \right)$$

$$\text{Power} = \tau \times \omega$$

$$(dF) = (\tau) \times (\pi Dx) \cdot dx$$

$$v = \left( \frac{Dx}{2} \right) \omega$$

$$\text{Power} \Rightarrow dP = \left( dF \times \frac{Dx}{2} \right) \omega \quad (\text{for curved surface only})$$

$$dP_i = \left( 0.099 \times \left( 4 + \frac{10}{12} x \right) \times \omega \times 10^{-2} \right) \times \pi \times \left( 4 + \frac{10}{12} x \right) \times 10^{-2} \times dx \times \omega$$

$$\int dP_i = \int_0^{0.12} 0.099 \times \frac{\left( 4 + \frac{10}{12} x \right)^3}{4} \times \frac{\omega^2 \times 10^{-4}}{1.4 \times 10^{-3}} \times \pi \, dx = 63.58 \text{ Wt}$$

$$P_1 = 63.58 \text{ Watt}$$

$P_2$  = Power from top surface

$$dP = (dF) \times r \times \omega$$



~~$$dF = r \times 2\pi r$$~~

~~$$dF = r \times 2\pi r dr$$~~

~~$$dF = \mu \times \frac{(\omega r)}{t} \times 2\pi r dr$$~~

~~$$dF = \left( \frac{\mu \omega 2\pi}{t} \right) r^2 dr$$~~

$$\int dP_2 = \int_0^{0.14/2} \frac{\mu \omega^2 2\pi}{t} r^3 dr$$

$$P_2 = \frac{0.0999 \times 100^2 \times 2\pi}{1.4 \times 10^{-3}} \times \left[ \frac{r^4}{4} \right]_0^{0.07}$$

$$P_2 = 26.67 \text{ Wt}$$

$$P_3 \text{ of bottom} = 0.178 \text{ Wt}$$

$$P_1 + P_2 + P_3 = \boxed{90.43 \text{ Wt}} \text{ power required}$$



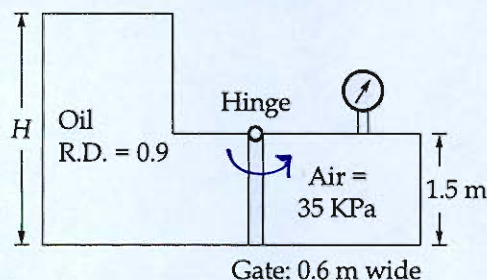
$$\frac{21}{8} \times \frac{(21 \times 21 \times 21 - 4 \times 21 \times 21 + 11 \times 21 \times 21)}{(21 \times 21 - 11 \times 21 \times 21)}$$

per month

$$(11 \times 21 \times 21) \times \frac{1}{2}$$

$$21 \times 21 \times 21 = 21 \times 21 \times 21 \times (21 \times 21 - 11 \times 21 \times 21) \times \frac{1}{2}$$

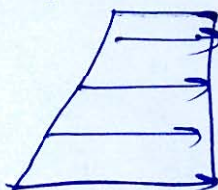
- Q.1 (b) For the system shown in figure, calculate the height  $H$  of oil at which the rectangular hinged gate will just begin to rotate counterclockwise.



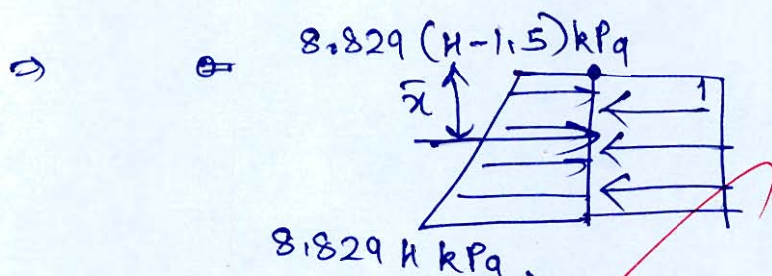
$$\rho_{\text{oil}} = 900 \text{ kg/m}^3$$

[12 marks]

$$\rho_{\text{oil}} \times g \times (H - 1.5)$$



$$\rho_{\text{oil}} g (H)$$



Assuming  
uniform air  
pressure.

$$F_{\text{oil}} = \frac{1}{2} \times (17.658 H - 13.243) \times 1.5 \times 0.6$$

Torque about hinge

$$\bar{x} = \frac{(2 \times 8.829 H + 8.829 H - 8.829 \times 1.5)}{(17.658 H - 13.243)} \times \frac{1.5}{3}$$

Balancing

(C)

$$\Rightarrow \frac{1}{2} \times (17.658 H +$$

$$\Rightarrow \frac{1}{2} \times (26.487 H - 13.243) \times 0.9 \times 0.5 = 35 \times 1.5 \times 0.6$$

$$\times \frac{1.5}{2}$$



$$\Rightarrow H = 4.464 \text{ m}$$

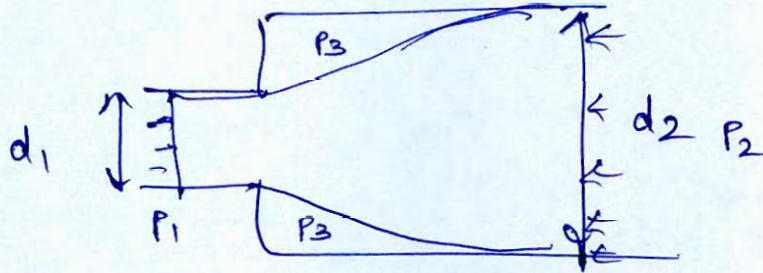
12

$$m \frac{d^2 x}{dt^2} + \left( \frac{d}{dt} \right) = 0 + \frac{d}{dt} \left( \frac{d}{dt} \right)$$

$$(K - W) \delta x = (K - W) \delta x + W \delta x$$

- Q.1 (c) Determine the optimum ratio between the diameter of the pipe before expansion and the diameter of the pipe after expansion so that pressure rise may be maximum for sudden expansion in pipe flow. What will be the corresponding pressure rise?

[12 marks]



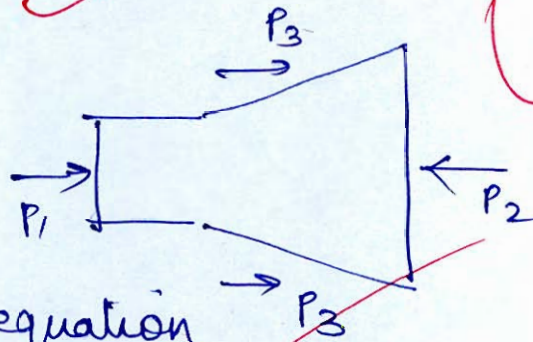
Writing energy equation:

$$(h_L = \frac{(V_2 - V_3)^2}{2g})$$

$$\left(\frac{P_1}{\gamma}\right) + \frac{V_1^2}{2g} + 0 = \left(\frac{P_2}{\gamma}\right) + \frac{V_2^2}{2g} + h_L$$

From Continuity

$$A_1 V_1 = A_2 V_2 = Q$$



Writing Momentum equation

$$P_1 A_1 + P_3 (A_2 - A_1) - P_2 A_2 = \rho Q (V_2 - V_1)$$

$P_1 A_1$



of land is marked by a small letter (C)

railroad is to be placed at a point in the

line of the road which is the most

convenient for the passengers of the

road and the road is to be placed

at a point in the line of the road which is the most

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$$\left( \frac{a^2 - b^2}{a^2} \right) = \frac{a^2 - b^2}{a^2}$$

- Q.1 (d) (i) Explain cavitation in reaction turbine. What is Thoma's cavitation factor?
- (ii) A conical draft tube having inlet and outlet diameters 0.8 m and 1.2 m respectively discharges water at outlet with a velocity of 3 m/sec. The total length of the draft tube is 8 m and 2 m of the length of draft tube is immersed in water. If the atmospheric pressure head is 10.3 m of water and loss of head due to friction in the draft tube is equal to 0.25 times the velocity head at outlet of the tube then find:
1. Pressure head at inlet.
  2. Efficiency of the draft tube.

[4 + 8 marks]

Soln)

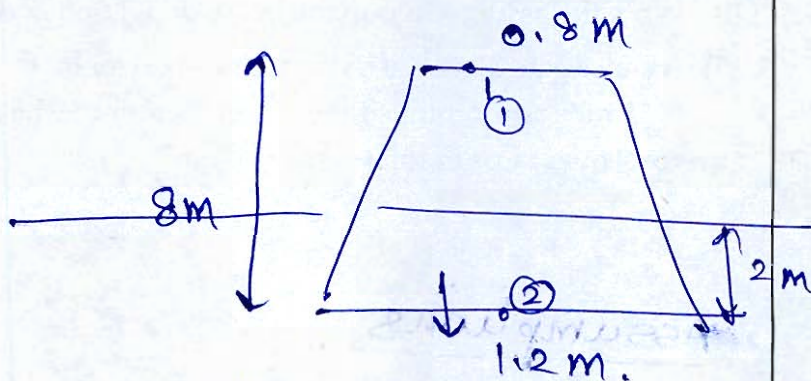
(1) Cavitation is a phenomenon in which, if absolute pressure at a point in reaction turbine (mainly in draft tube start point) falls below the vapour pressure of water, as a result of which, water starts boiling and bubbles form <sup>and combine</sup>. When this ~~can~~ bubble collapses it creates cavity to which surrounding water rushes to fill, hence causing huge stress accumulation on that portion of the turbine tube.

$$\sigma = \left( \frac{H_a - H_s}{H_a} \right)$$

$\sigma$  is known as  
Thoma's  
cavitation number



(11)



$$\frac{P_{atm}}{\gamma} = 10.3 \text{ m.}$$

$$V = 3 \text{ m/sec}$$

$$h_f = 0.25 \times \frac{V_2^2}{2g} = 0.25 \times \frac{3^2}{2 \times 9.81} = 0.01885 \text{ m}$$

writing energy equation

$$\left(\frac{P_1}{\gamma}\right) + \frac{V_1^2}{2g} + 8 = \left(\frac{P_{atm}}{\gamma} + 2\right) + \frac{V_2^2}{2g} + h_L$$

$$\Rightarrow \left(\frac{P_1}{\gamma}\right) + \frac{6.75^2}{2 \times 9.81} + 8 = (10.3 + 2) + \frac{1.25 \times 3^2}{2 \times 9.81}$$

$$A_1 V_1 = A_2 V_2$$

$$V_1 = \left(\frac{1.2 \times 3}{0.8^2}\right) \text{ m/s}$$

$$V_1 = 6.75 \text{ m/s.}$$

$$\left(\frac{P_1}{\gamma}\right) = 2.55 \text{ m.}$$

Pressure head at inlet.

$$\eta = \frac{\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_L}{\frac{V_1^2}{2g}} = \frac{\left(\frac{6.75^2}{2g} - \frac{3^2}{2 \times 9.81}\right) - 0.25 \times \frac{3^2}{2 \times 9.81}}{\frac{6.75^2}{2 \times 9.81}} \times 100$$

$$= 70.37 \% \text{ efficiency.}$$

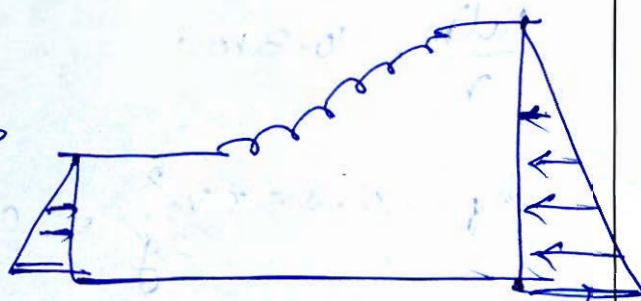


- Q.1 (e) (i) Write the assumptions made in the derivation of depth of hydraulic jump.
- (ii) A sluice gate discharges water into a horizontal rectangular channel with a velocity of 10 m/s and depth of flow of 1 m. Determine the depth of flow after the jump and consequent loss in total head.

[12 marks]

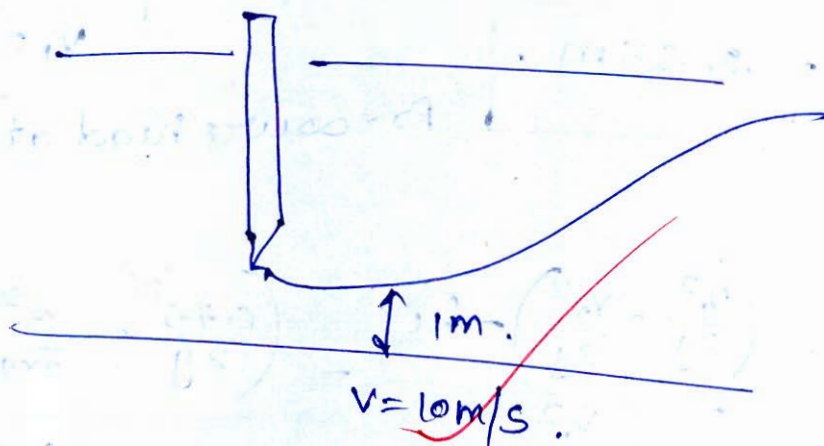
### Assumptions

- Water is non-viscous
- channel bottom is smooth.
- Pressure is hydrostatic before and after the jump.
- specific force is constant before and after jump.



$$\frac{P_1 + M_1}{\gamma} = \frac{P_2 + M_2}{\gamma}$$

(ii)



$$Fr_1 = \frac{v}{\sqrt{gy}} = \frac{10}{\sqrt{9.81 \times 1}} = 3.19 > 1. \text{ Hence flow is supercritical}$$



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

$$\Rightarrow \left(\frac{y_2}{1}\right) = \frac{1}{2} \left[ -1 + \sqrt{1 + 8 \times 3.19^2} \right]$$

$$\Rightarrow \boxed{y_2 = 4.043 \text{ m}}$$

$$h_L = \frac{(y_2 - y_1)^3}{4y_1 y_2} = \frac{(4.043 - 1)^3}{4 \times 4.043 \times 1}$$

$$= \boxed{1.742 \text{ m}}$$

loss in  
head.

9

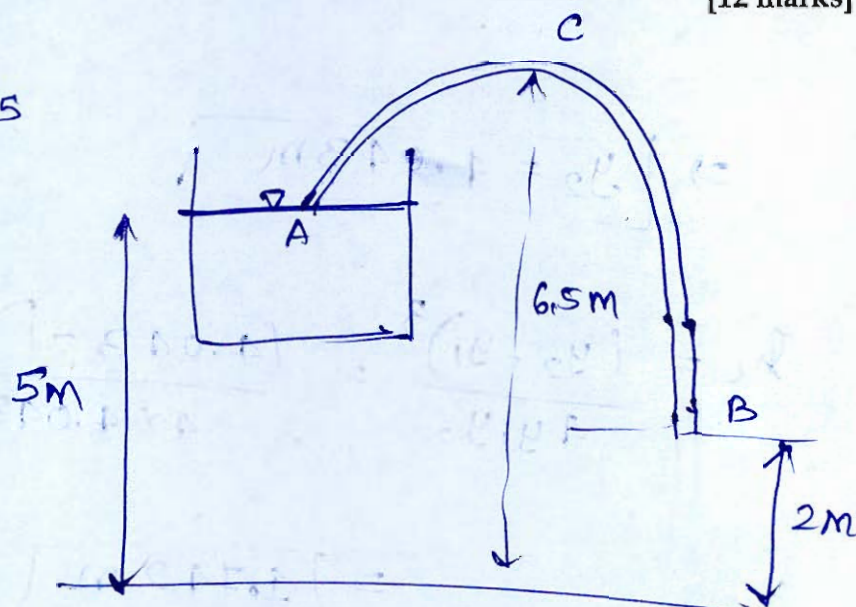
- Q.2 (a) (i) A siphon consisting of a pipe of 20 cm diameter is used to empty oil of relative density 0.85 from tank A. The siphon discharges to the atmosphere at an elevation of 2.00 m. The oil surface in the tank is at an elevation of 5.00 m. The centreline of the siphon pipe at its highest point C is at an elevation of 6.50 m. Estimate:
- the discharge in pipe.
  - pressure at point C.

The losses in the pipe can be assumed to be 0.4 m up to the summit and 1.2 m from the summit to the outlet.

[12 marks]

Sol<sup>n</sup>

$$\rho_{oil} = 0.85$$



writing energy equation b/w A & B

$$\left( \frac{P_{atm}}{\rho} \right) + \left( \frac{V_1^2}{2g} \right) + 5 = \left( \frac{P_{atm}}{\rho} \right) + \frac{V_2^2}{2g} + 2 + h_L$$

Assuming  $V_1 \approx 0$ .

$$\left( \frac{V_2^2}{2g} \right) = 3 - h_L$$

$$\frac{V_2^2}{2g} = 3 - (0.4 + 1.2)$$

$$V_2 = 5.24 \text{ m/s.}$$



$$\text{Discharge in pipe} = A \times V$$

$$= \frac{\pi}{4} \times 0.2^2 \times 5.24$$

$$= \boxed{164.65 \text{ l/sec}}$$

Writing energy equation b/w A and C.

$$\left(\frac{P_{\text{atm}}}{\gamma}\right) + \left(\frac{V_1^2}{2g}\right) + 5 = \left(\frac{P_2}{\gamma}\right) + \left(\frac{V_2^2}{2g}\right) + 6.5 + h_L$$

$$\left(\frac{P_2 - P_{\text{atm}}}{\gamma}\right) = \frac{5.24^2}{2 \times 9.81} - 5 - 6.5$$

$$12$$

$$\left(\frac{P_2}{\gamma}\right) = \left(\frac{P_{\text{atm}}}{\gamma}\right) + 5 - \frac{5.24^2}{2 \times 9.81} - 6.5 - 0.4$$

$$\left(\frac{P_2}{\gamma}\right) = \left(\frac{101325}{850 \times 9.81}\right) + 5 - 1.4 - 6.5 - 0.4$$

$$\left(\frac{P_2}{\gamma}\right) = 8.85 \text{ m}$$

$$\text{and } P_{\text{gauge}} = -27.517 \text{ kPa}$$

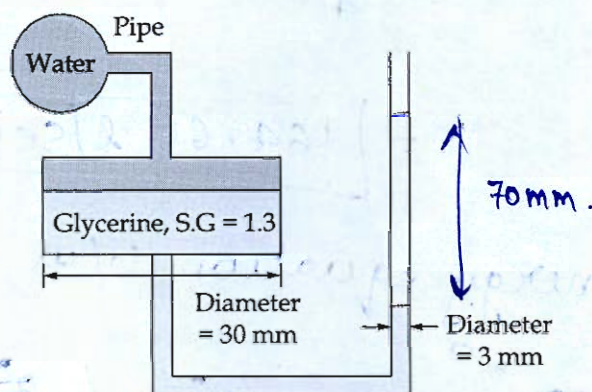
$$P_2 = 73.808 \text{ kPa}$$

absolute

pressure at c point.

below  
atmosphere

- Q.2 (a) (ii) The system shown in the figure is used to accurately measure the pressure changes when the pressure is increased by  $\Delta P$  in the water pipe. Corresponding to a rise of 70 mm in the level of glycerin in the vertical pipe, what will be the change in the pipe pressure?



[8 marks]

Equating the resultant forces.

$$(\Delta P) = \rho g h \times \frac{(3^2)}{(30)^2}$$

$$= 1.3 \times 1000 \times 9.81 \times \frac{70}{1000} \text{ Pascal} \times \left(\frac{3}{30}\right)^2$$

①

$$= \boxed{892.7 \text{ Pascal}} \times \frac{3^2}{30^2}$$

$$= \boxed{8.927 \text{ Pascal}}$$





$$\left(\frac{y}{3}\right)^2 + \left(\frac{y}{2}\right)^2 = \left(\frac{y}{5}\right)^2 + \left(\frac{y}{1}\right)^2$$

$$4y^2 + 9y^2 = y^2 + 9y^2$$

$$13y^2 = 10y^2$$

$$3y^2 = 0$$

$$y^2 = 0$$

$$y = 0$$

$$5x^2 + 40x + 40 = 0$$

$$x^2 + 8x + 8 = 0$$

Let's assume that

is a root of the equation

then

we have

$$x^2 + 8x + 8 = 0$$

$$x = -4 \pm 2\sqrt{2}$$

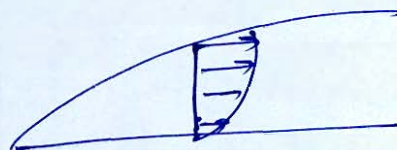
$$x = -4 + 2\sqrt{2}$$

Q.2 (b) Given the velocity distribution in a laminar boundary layer on a flat plate as

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - 2\left(\frac{y}{\delta}\right)^3 + \left(\frac{y}{\delta}\right)^4$$

Obtain expressions for the boundary layer thickness, shear intensity and force on one side of the plate.

[20 marks]



Given,  $\left(\frac{u}{U}\right) = 2\left(\frac{y}{\delta}\right) - 2\left(\frac{y}{\delta}\right)^3 + \left(\frac{y}{\delta}\right)^4$

$$\frac{\delta}{x} = \frac{5}{\sqrt{Re_x}}$$

$$C_{fx} = \frac{0.664}{\sqrt{Re_x}}$$

$$\tau = \mu \frac{dv}{dy} \Rightarrow$$

$$F = 0.6 \quad C_{fxy} = \frac{1.328}{\sqrt{Re_x}}$$

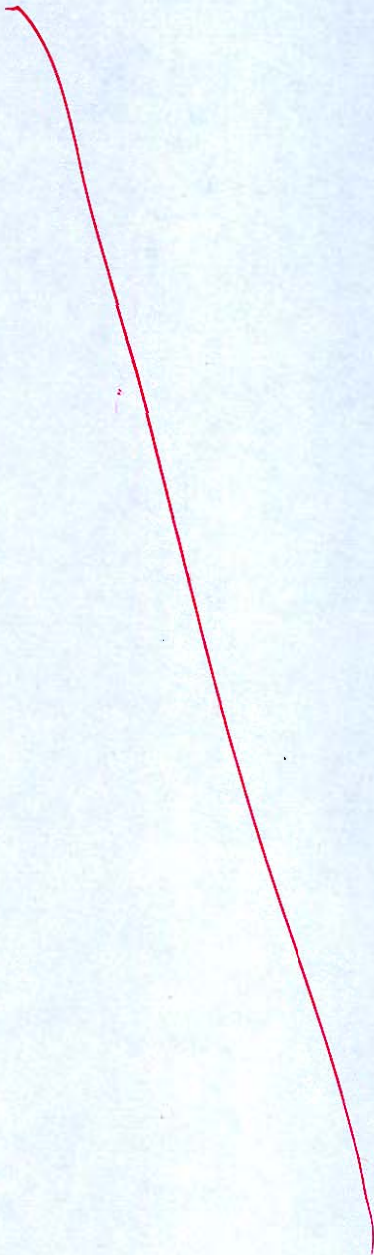
$$Force = \frac{1.328}{\sqrt{Re_x}} \times \frac{1}{2} \rho U^2 \times B \times L$$

drag force.

$\tau$  Shear intensity =  $\frac{1.328}{\sqrt{Re_x}}$   $Re_x \Rightarrow$  Reynolds number.

$$(\tau_x) = \frac{1}{2} \rho U^2 \times \frac{0.664}{\sqrt{Re_x}}$$



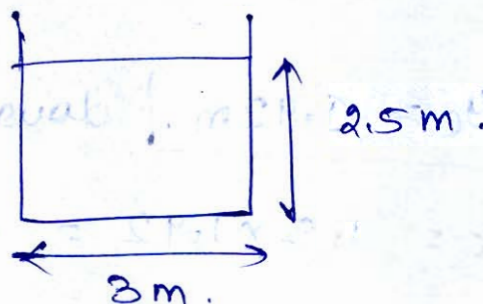






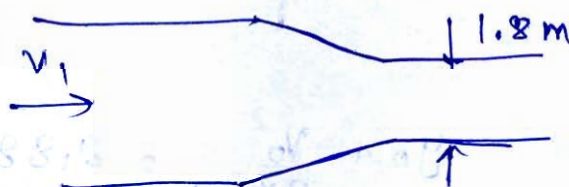
- Q.2 (c) (i) A rectangular channel is 3 m wide and conveys a discharge of  $15 \text{ m}^3/\text{sec}$  at a depth of 2.5 m. It is proposed to reduce the width of the channel at hydraulic structure. Assuming the transition to be horizontal and the flow to be frictionless, determine the water surface elevations upstream and downstream of the constriction when the constricted width is 1.8 m.

[12 marks]



$$Q = 15 \text{ m}^3/\text{s}$$

$$V_1 = \frac{15}{(3 \times 2.5)} = 2 \text{ m/sec}$$



$$E_1 = y_1 + \frac{V_1^2}{2g} = 2.5 + \frac{2^2}{2 \times 9.81} = 2.704 \text{ m}$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$\text{Also, } 15 = V_2 \times y_2 \times 1.8$$

$$V_2 = \frac{15}{y_2 \times 1.8}$$

$$\text{So, } E_2 = y_2 + \frac{15^2}{(y_2^2 \times (1.8)^2 \times 2 \times 9.81)}$$

$$E_2 = y_2 + \frac{3.54}{y_2^2} = 2.704$$

Equating the energy,  $E_1 = E_2$

$$\Rightarrow y_2^3 + 3.54 = 2.704 y_2^2 \Rightarrow y_2 = \begin{cases} -0.98 \text{ m} \\ \text{Not possible!} \end{cases}$$

$$(q) = \left(\frac{15}{1.8}\right) = 8.33 \text{ m}^2/\text{sec}$$

$$y_c = \left(\frac{8.33^2}{9.81}\right)^{1/3}$$

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

$$y_c = 1.92 \text{ m.} \text{ downstream depth.}$$

$$E_c = 1.5 \times 1.92 = 2.88 \text{ m.}$$

Hence upstream conditions will change.

$$y_0 + \frac{v_0^2}{2 \times 9.81} = 2.88$$

$$v_0 \times y_0 = \frac{15}{3} = 5$$

$$y_0 + \frac{25}{2 \times 9.81 \times y_0^2} = 2.88$$

$$\rightarrow y_0 = 2.706 \text{ m} \quad \text{Hence upstream level will}$$

$$y_0 = 0.78 \text{ m} \times$$

change to

$$y_0 = 2.706 \text{ m}$$

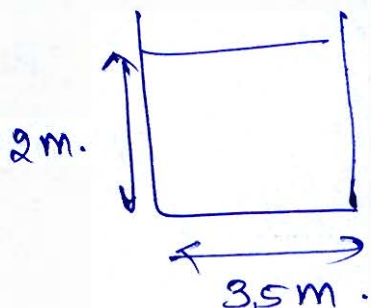
$$\text{downstream level} = 1.92 \text{ m.}$$

12



- Q.2 (c) (ii) A 3.5 m wide rectangular channel carries a discharge of  $15 \text{ m}^3/\text{sec}$  at a depth of 2 m. Calculate the height and velocity of a surge produced when the flow is suddenly stopped completely by the full closure of a sluice gate at the downstream end.

[8 marks]

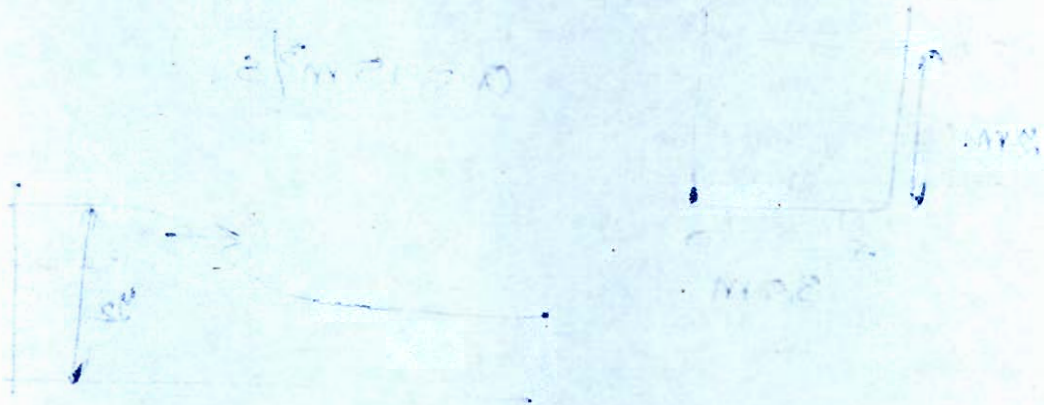


$$Q = 15 \text{ m}^3/\text{s}$$



$$C = \sqrt{\frac{g \times y_1 y_2 (y_1 + y_2)}{2}}$$

$$v = \frac{15}{2 \times 3.5} = 2.142 \text{ m/s}$$



$$\begin{aligned} \sum F_x &= 0 \\ \sum F_y &= 0 \\ \sum M_A &= 0 \end{aligned}$$





- Q.3 (a) (i) An inward flow turbine (reaction type with radial discharge) with an overall efficiency of 85% is required to develop 160 kW power. The head is 8 m; peripheral velocity of the wheel is  $0.96\sqrt{2gH}$ ; the radial velocity of the flow is  $0.36\sqrt{2gH}$ . The wheel is to make 160 rpm and the hydraulic losses in the turbine are 24% of the available energy.

Determine:

1. The angle of the guide blade at inlet.
2. The wheel vane angle at inlet.
3. The diameter of the wheel.
4. The width of the wheel at inlet.

[15 marks]

Soln)

$$\eta_o = 85\% \quad P = 160 \text{ kW} \quad N = 160 \text{ rpm}$$

$$H = 8 \text{ m}$$

$$u_o = 0.96\sqrt{2gH}$$

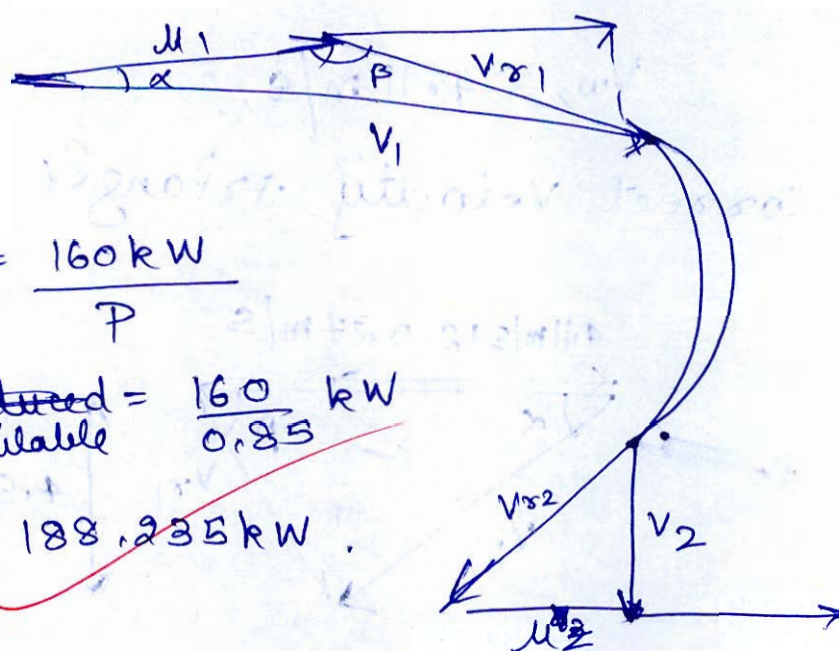
$$V_f = 0.36\sqrt{2gH}$$

$$u_o = 0.96 \times \sqrt{2 \times 9.81 \times 8}$$

$$V_f = 4.51 \text{ m/s}$$

$$= 12.027 \text{ m/s}$$

hydraulic loss = 24%



$$\eta_o = 0.85 = \frac{160 \text{ kW}}{P}$$

$$\text{Power produced available} = \frac{160}{0.85} \text{ kW}$$

$$= 188.235 \text{ kW}$$

$$\eta_{\text{hydraulic efficiency}} = (100 - 24)\%$$

$$= 76\%$$



$$0.76 = \frac{gQ [v_{w1} x_1]}{}$$

Useful energy <sup>to</sup> power develop =  $0.76 \times 188.235 \text{ kW}$

$$= 143.06 \text{ kW}$$

$$\rightarrow H_{eq} = \frac{143.06}{9.81 \times 2.4}$$

$$188.23 \text{ kW} = gHQ \quad = 6.076 \text{ m}$$

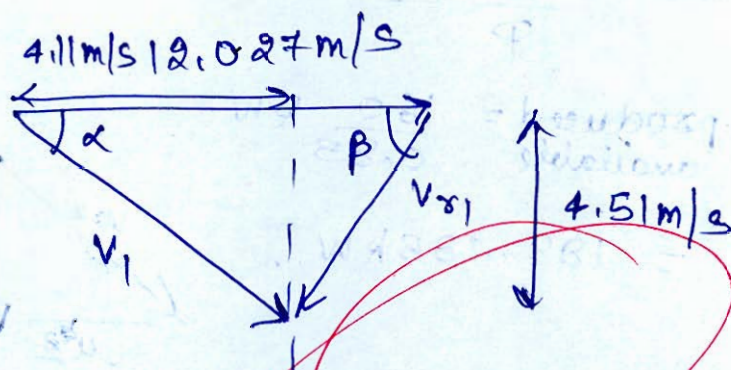
$$Q = \left( \frac{188.23}{9.81 \times 8} \right) = 2.4 \text{ m}^3/\text{sec}$$

$$H = \frac{v_{w2} H_2}{g} + \frac{v_2^2}{2g}$$

$$6.076 \text{ m} = \frac{v_{w2} \times 12.027}{9.81} + \frac{4.51^2}{2 \times 9.81}$$

$$v_{w2} = 4.11 \text{ m/s}$$

So, correct Velocity triangle



$$\tan \alpha = \left( \frac{4.51}{4.11} \right)$$

$$\alpha = 47.65^\circ$$

guide  
blade  
angle



$$\beta = \tan^{-1} \left( \frac{4.51}{12.027 - 4.11} \right)$$

$$\beta = 29.67^\circ \text{ wheel vane angle.}$$

$$u_o = \frac{\pi D N}{60} = 12.027 \text{ m/s}$$

$$D = 1.435 \text{ m} \text{ dia meter at inlet.}$$

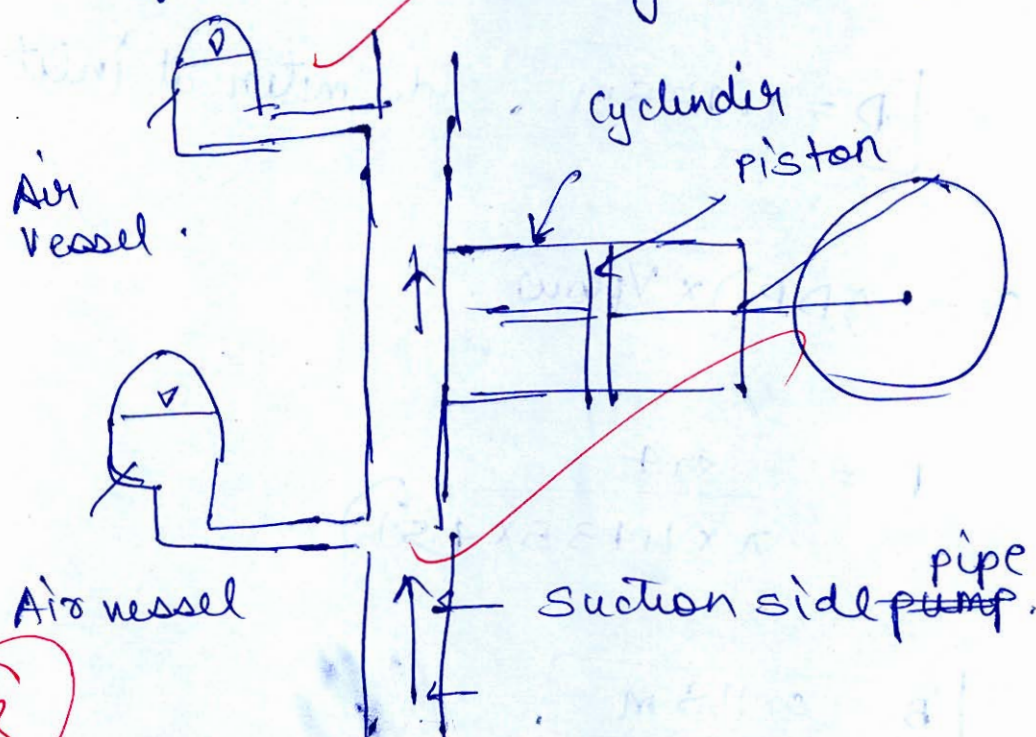
$$Q = (\pi D B) \times V_{\text{flow}}$$

$$B = \frac{Q}{\pi \times 1.435 \times 4.51}$$

$$B = 0.118 \text{ m}$$

- Q.3 (a) (ii) What is an air vessel? Describe the function of the air vessel for reciprocating pumps. [5 marks]

Air vessels are water storage chambers provided at the suction and delivery side of the reciprocating pump's cylinders.



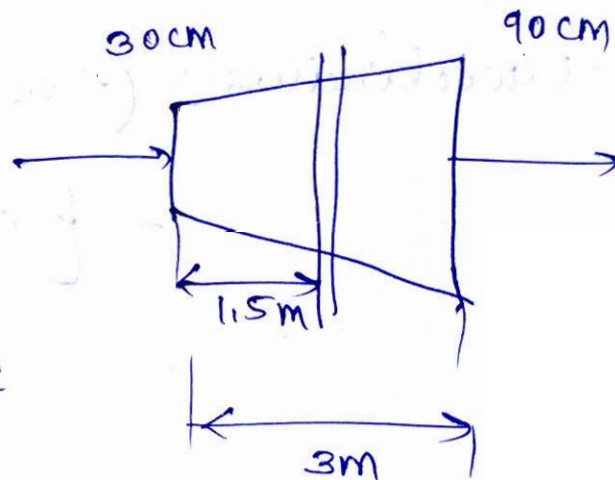
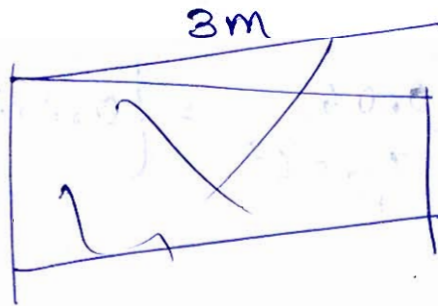
- Primary function is to maintain constant flow i.e. eliminating the fluctuating discharge.

- They also reduce the accelerating head thereby keeping ~~and~~ discharge into cylinder constant.
- Load fluctuation can be adjusted.



- Q.3 (b) (i) A 3.0 long conical diffuser 30 cm in diameter at the upstream end has 90 cm diameter at the downstream end. At a certain instant the discharge through the diffuser is observed to be 300 L/s of water and is found to increase uniformly at the rate of 60 L/s per second. Estimate the local, convective and total acceleration at a section 1.5 m from the upstream end.

[12 marks]



$$Q = 0.3 \text{ m}^3/\text{sec}$$

$$\left(\frac{dQ}{dt}\right) = 0.06 \text{ m}^3/\text{sec}$$

$$(dx) = 30 + \frac{60 \times 1.5}{3} = 60 \text{ cm} = 0.6 \text{ m}.$$

$$(V_x) = \frac{0.3}{\frac{\pi}{4} \times 0.6^2} = 1.061 \text{ m/sec}$$

local acceleration,  $(dx) = (0.3 + 0.2x) \cdot \text{m}.$

$$V_x = \frac{0.3 \times 4}{\pi (0.3 + 0.2x)^2} = \frac{0.382}{(0.3 + 0.2x)^2}$$

we know convective acceleration.

$$a_x = (V_x) \times \left(\frac{dV}{dx}\right) = (1.061) \times (-0.707) = \boxed{-0.75 \text{ m/s}^2}$$

Local acceleration =

$$\frac{d(AxV)}{dt} = 0.06 \text{ m}^3/\text{s}$$

$$\left(\frac{dV}{dt}\right) = \frac{0.06}{\frac{\pi}{4} \times 0.6^2} = \boxed{0.212 \text{ m/s}^2}$$

$$\begin{aligned} \text{Total acceleration} &= (-0.75 + 0.212) \text{ m/s}^2 \\ &= \boxed{-0.538 \text{ m/s}^2} \end{aligned}$$

12



- Q.3 (b) (ii) A proposed model of a river stretch of 20 km is to have a horizontal scale of  $\frac{1}{250}$  and vertical scale of  $\frac{1}{50}$ . If the normal discharge, width and depth of the river are  $150 \text{ m}^3/\text{s}$ , 100 m and 4 m respectively, estimate the corresponding model quantities. Also calculate the Manning's roughness 'n' to be provided in the model to represent a prototype roughness value of 0.030.

[8 marks]

$$\left(\frac{L_m}{L_p}\right)_H = \frac{1}{250}$$

$$L = 20 \text{ km.}$$

$$\left(\frac{L_m}{L_p}\right)_V = \frac{1}{50}$$

$$Q = 150 \text{ m}^3/\text{s}$$

$$B = 100 \text{ m}$$

$$\text{Depth} = 4 \text{ m.}$$

$$n = 0.03.$$

For Model

$$\text{Width, } b = \frac{100}{250} = \boxed{0.4 \text{ m}}$$

$$\text{depth, } d = \frac{4}{50} = \boxed{0.08 \text{ m}}$$

$$Q = \text{Area} \times \text{Velocity}$$

$$Q = L_H \times L_V \times \sqrt{L_V} \rightarrow$$

$$Q_m = \frac{150}{(250 \times 50^{1.5})}$$

$$= \boxed{1.697 \text{ l/sec}}$$

we know  $V = \frac{1}{n} \times R^{2/3} \times S_0^{1/2}$

$$(\sqrt{L_V})_r = \left(\frac{1}{n_r}\right) \times (L_V)^{2/3}$$

$$n_r = (L_V)^{1/6}$$

$$R = \frac{A}{P} = \left(\frac{By}{B+2y}\right)$$

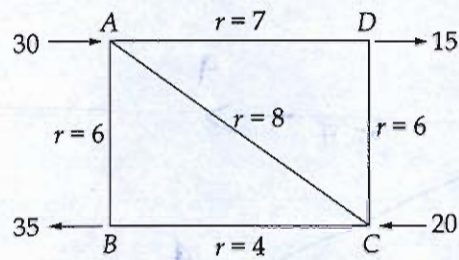
$$\boxed{R = y.} \quad B \gg y$$

$$\frac{n}{0.03} = \left(\frac{1}{50}\right)^{1/6}$$

$$n = 0.01563$$



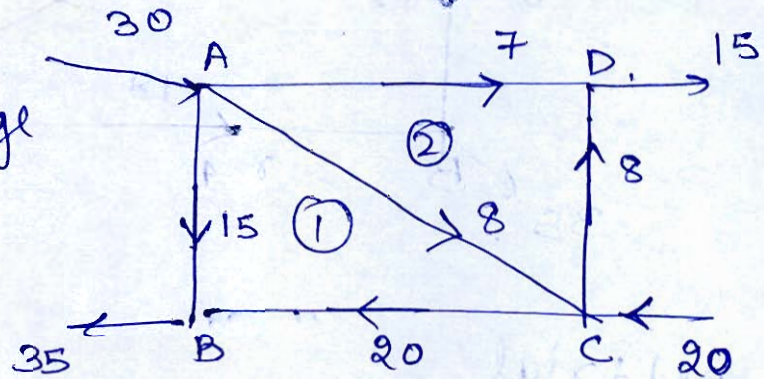
- Q.3 (c) For the network shown in figure, the head loss is given by  $h_f = rQ^2$ . The values of  $r$  for each pipe, and the discharge into or out of various nodes are shown in the sketch. The discharges are in arbitrary unit. Obtain the distribution of discharge in the network.



[20 marks]

Trial 1 >

Assuming discharge  
as shown.

For loop ABC

Pipe	$rQ^2$	$ 2rQ $
AB	-1350	180
AC	512	128
BC	1600	160
	<u>762</u>	<u>468</u>

$$\Delta Q = - \frac{\sum rQ^2}{|2rQ|}$$

$$\Delta Q = - \frac{762}{468} = -1.62 \approx -2$$

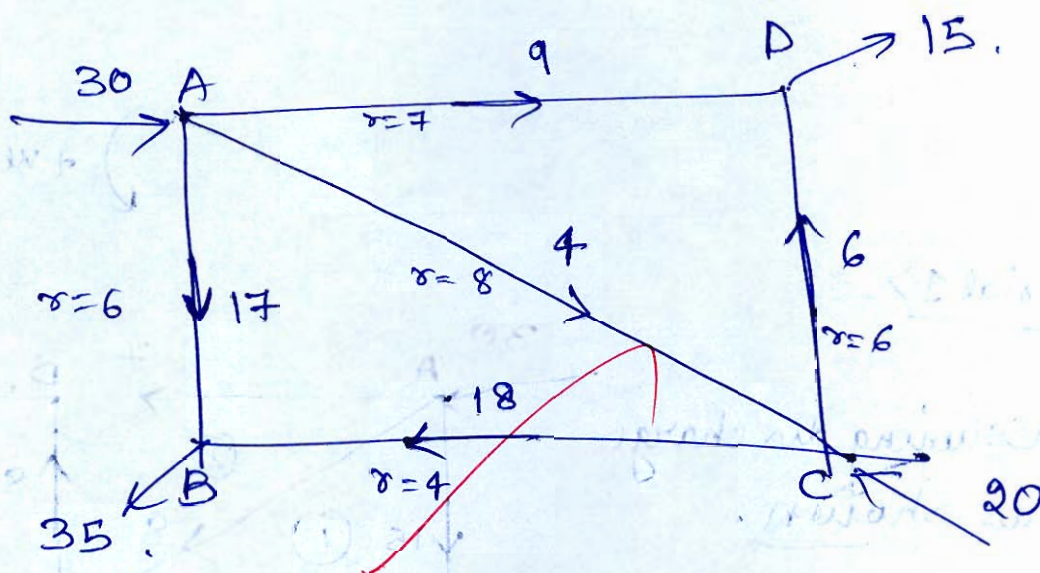
For loop ADC

Pipe	$rQ^2$	$ 2rQ $
AD	343	98
DC	-384	96
AC	-512	128
	<u>-553</u>	<u>322</u>

$$\Delta Q = \frac{553}{322} = 1.717 \approx 2$$



Discharge after First trial



2nd trial

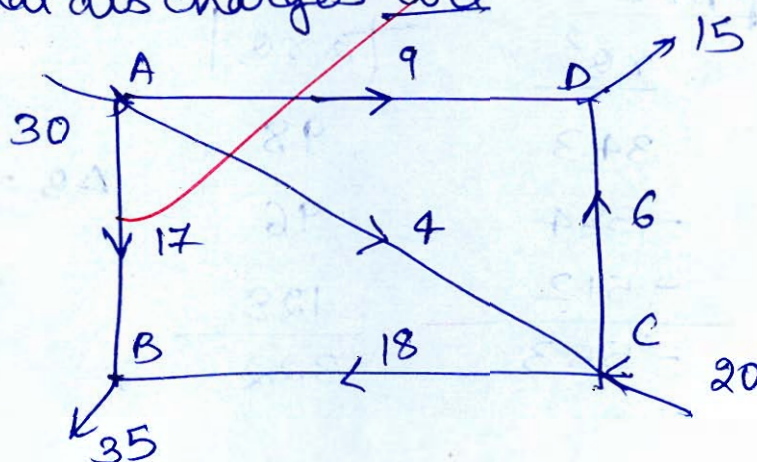
Pipe	$\Sigma Q^2$	$ 2rQ $
AB	-1734	204
AC	128	64
BC	1296	144
	<u>-310</u>	<u>412</u>

15

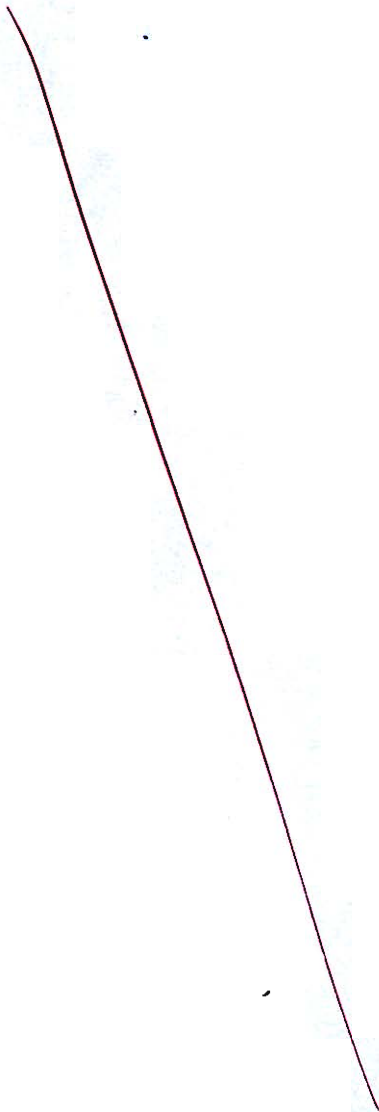
one more trial  
required

$$\Delta Q = \left( \frac{310}{412} \right) = 0.75 \geq 0$$

Hence final discharges are



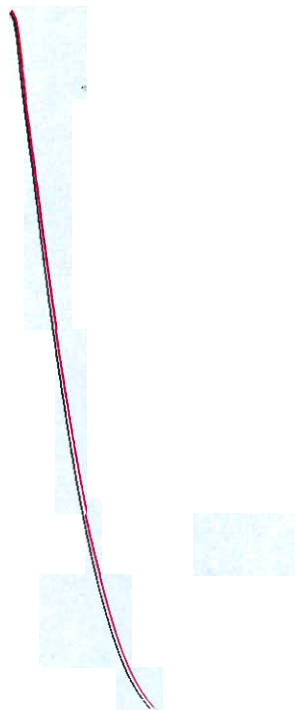




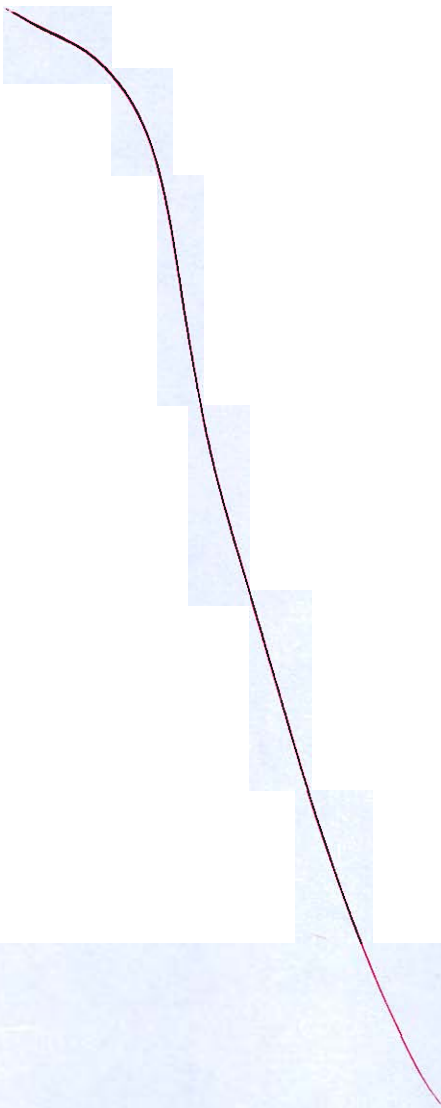
Q.4 (a) (i) A 4 m wide rectangular channel has a Manning's coefficient of 0.025. For a discharge of  $6 \text{ m}^3/\text{sec}$ , identify and draw the possible types of GVF profiles produced in the following break in grades:

1.  $S_{01} = 0.0004$  to  $S_{02} = 0.005$ .
2.  $S_{01} = 0.015$  to  $S_{02} = 0.0045$ .

[12 marks]



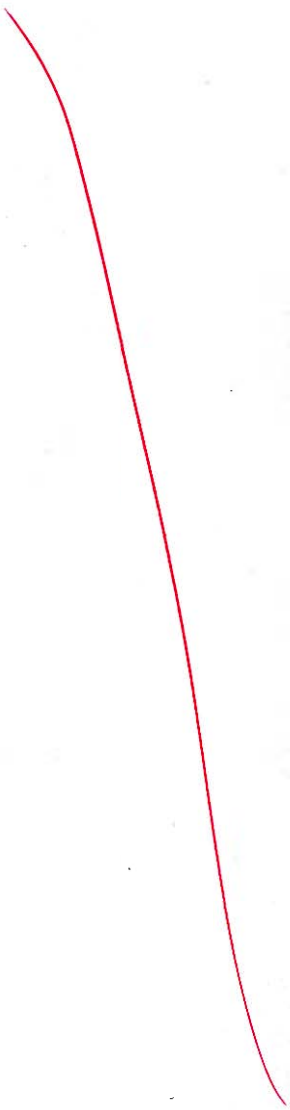




- Q.4 (a) (ii) A 1.5 m wide rectangular channel carries a discharge of  $5.0 \text{ m}^3/\text{s}$  at a depth of 1.5 m. At a section the channel undergoes transition to a triangular section of side slopes 2 H : 1 V. If the flow in the triangular section is to be critical without changing the upstream water surface, find the location of the vertex of triangular section relative to the bed of rectangular channel. What is the drop/rise in the water surface at the transition? (Assume zero energy loss at the transition)

[8 marks]

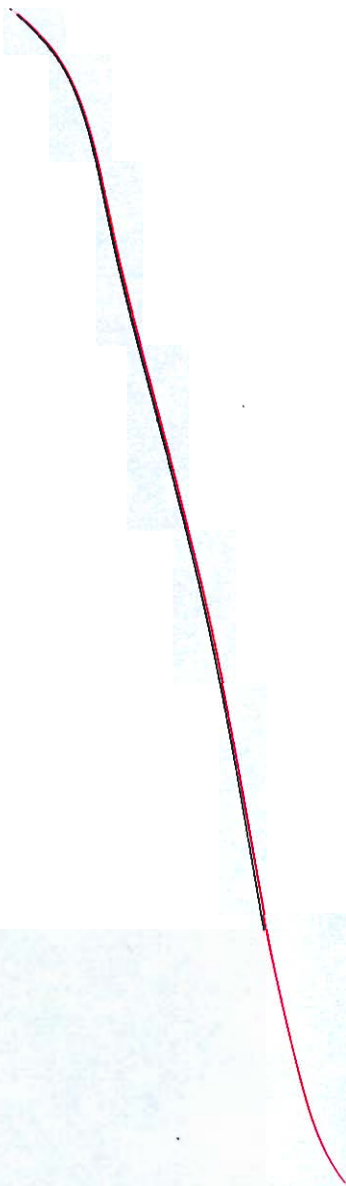




- Q.4 (b) (i) An open cylinder 30 cm in diameter and 50 cm high is filled with water and rotated about its axis. Calculate the amount of water spilled when the speed of rotation is (a) 150 rpm and (b) 250 rpm.

[12 marks]





- Q.4 (b) (ii) In a turbulent flow through a pipe of radius  $r_0$ , at what distance from the boundary would the local velocity
1. be equal to the mean velocity?
  2. be equal to half the mean velocity if the shear velocity is  $1/10$  of the mean velocity?

[8 marks]



- Q.4 (c) A centrifugal pump operates against a manometric head of 30 m with a manometric efficiency of 80%. The pressure rise through the impeller is 60% of the total head developed by the pump. The radial velocity of flow which is constant is 3.5 m/s. The outer diameter of the impeller is 450 mm and the width at outlet is 15 mm. The blades at inlet are curved backwards at  $60^\circ$  to the wheel tangent.

**Calculate:**

- (i) the discharge in liters per minute.
- (ii) speed of the pump.
- (iii) blade angle at outlet.
- (iv) diameter of impeller at inlet.

[20 marks]

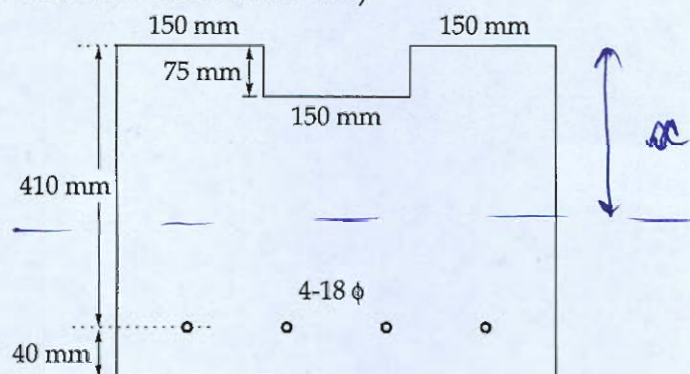






**Section B : Design of concrete and Masonry Structures-1  
+ Geo-technical & Foundation Engineering-2**

- Q.5 (a) The beam section shown in the figure is subjected to a bending moment of 50 kN-m. Determine the maximum compressive stress in concrete and the tensile stress in steel. (Take  $m = 13.33$  and assume cracked section)



[12 marks]

Given,  $M = 50 \text{ kN-m}$ .

finding depth of neutral axis for cracked section.

$$\frac{bx^2}{2} = m A_{st} (d - x)$$

$$\Rightarrow \left( 300 \times x \times \frac{x}{2} \right) + \left( 150 \times \frac{(x-75)^2}{2} \right) = m A_{st} (d - x)$$

$$\Rightarrow 150x^2 + 75(x-75)^2 = 13.33 \times 4 \times \frac{\pi}{4} \times 18^2 \times (410 - x)$$

$$\Rightarrow 225x^2 - 11250x + 421875$$

$$= 5562997.81 - 13568.29x$$

$\Rightarrow$

$$x = 146.09 \text{ mm}$$

we know,  $\left(\frac{\sigma}{y}\right) = \left(\frac{M}{I}\right)$ .

$$I = 2 \times \frac{150 \times 146.09^3}{3} + \frac{150 \times 71.09^3}{3} + 13.33 \times \pi \times 18^2 \times (263.91^2)$$

$$I = 12.75 \times 10^8 \text{ mm}^4.$$

$$(\sigma_{\text{top}})_{\text{compressive}} = \frac{50 \times 10^6 \times 146.09}{12.75 \times 10^8} = \boxed{5.73 \text{ MPa}} \text{ max.}$$

$$(\sigma_{\text{tensile}}) = \frac{50 \times 10^6 \times 263.91}{12.75 \times 10^8} \times 13.33 = \boxed{137.96 \text{ MPa}}$$

12

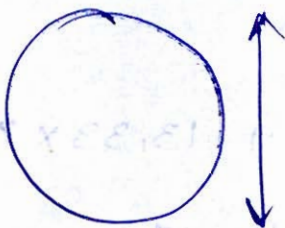


- Q.5 (b) A circular column of 400 mm diameter is subjected to a factored load of 1500 kN. The column has an unsupported length of 3.2 m. The column is held in position but not restrained against rotation at both ends. Design the helical reinforcement. Use M25 grade concrete and Fe415 grade steel.

[12 marks]

$$e_{\min} = \max \left\{ \frac{L}{500} + \frac{D}{30} = 19.73 \text{ mm}, 20 \text{ mm} \right\}$$

$0.05D = 20 \text{ mm}$



$D = 400 \text{ mm}$

$P_u = 1500 \text{ kN}$ , Hence we can use

$$P_u = 1.05 (0.4 f_{ck} A_c + 0.67 f_y A_{sc})$$

$$\frac{1500 \times 10^3}{1.05} = 0.4 \times 25 \times \left( \frac{\pi}{4} \times 400^2 - A_{sc} \right) + (0.67 \times 415 \times A_{sc})$$

$$\Rightarrow (A_{sc}) = 641.426 \text{ mm}^2$$

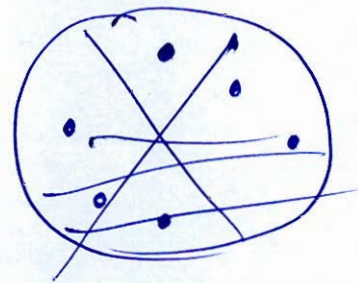
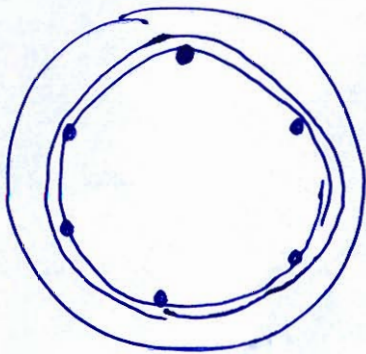
$$(A_s)_{\min} = 0.8\% = \frac{0.8}{100} \times \frac{\pi}{4} \times 400^2 = 1005.31 \text{ mm}^2$$

Hence, Provide  $(A_s) = 1005.31 \text{ mm}^2$

Adopt  $\phi = 16 \text{ mm}$

$$\text{No. of bars} = \frac{1005.31}{\frac{\pi}{4} \times 16^2} = 5$$

Provide 6-16 $\phi$  bars



8

check

$$0.36 \frac{b_{ck}}{b_y} \left[ \frac{V_h}{V_c} \right] \geq$$

$$0.36 \frac{b_{ck}}{b_y} \left[ \frac{V_h}{V_c} \right] \geq 0.36 \frac{b_{ck}}{b_y} \left[ \frac{A_{gross} - 1}{A_{core}} \right]$$

Adopt  $\phi_t = \text{max}$   $\left\{ \begin{array}{l} 16/4 \text{ mm} = 4 \text{ mm} \\ \boxed{6 \text{ mm}} \end{array} \right.$

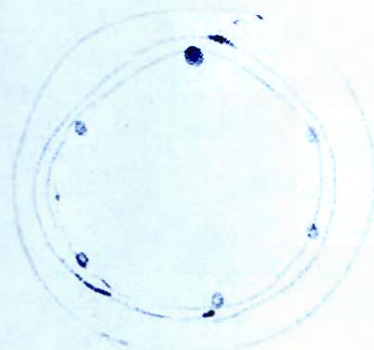
6mm spiral  
stirrups.

pitch  $\leq \begin{array}{l} 75 \text{ mm} \\ \frac{D}{4} = 400 \text{ mm} \end{array}$

pitch  $\geq \begin{array}{l} 25 \text{ mm} \\ 3\phi_t = 18 \text{ mm} \end{array}$

Provide 6mm spiral stirrups @ 60 mm pitch.





For the first part of the question, we have to find the value of  $x$  and  $y$  such that the system of equations is consistent.

For the second part, we have to find the value of  $x$  and  $y$  such that the system of equations is inconsistent.

For the third part, we have to find the value of  $x$  and  $y$  such that the system of equations is consistent and the solution is unique.

For the fourth part, we have to find the value of  $x$  and  $y$  such that the system of equations is consistent and the solution is infinite.



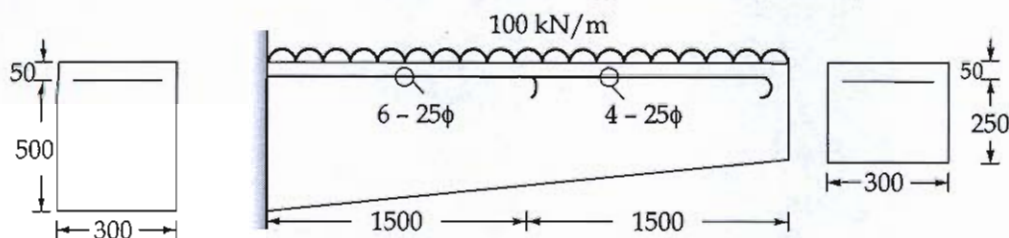
Q.5 (c) Explain the following terms:

- (i) Arching effect in sand.
- (ii) Anchored bulkhead.
- (iii) Cofferdams.
- (iv) Geocells and Geogrids.

[3 + 3 + 3 + 3 marks]



- Q.5 (d) Design shear reinforcement for a tapered cantilever beam of span 3 m, having a section of 250 mm effective depth and 300 mm width at the free end, and 500 mm effective depth and 300 mm width at the support as shown in figure. The beam has to support a factored uniform load of 100 kN/m, including its self weight. Assume an effective cover of 50 mm, Fe415 steel and M20 concrete. Use 2-legged 8 mm- $\phi$  stirrups.



(All dimension in mm)

Design shear stress of M20 concrete is given in table below:

$\%P_t = \frac{A_{st}}{bd} \times 100$	$\tau_c \text{ (N/mm}^2\text{)}$
$\leq 0.15$	0.28
0.25	0.36
0.50	0.48
0.75	0.56
1.00	0.62
1.25	0.67
1.50	0.72
1.75	0.75
2.00	0.79

[12 marks]







Amplitude = 3

1.2 x 10<sup>10</sup> N/m  
1000

$$\frac{(0.0001) \times 2 \times 10^4 \times 10^4}{1.2 \times 10^{10}} = \frac{0.0001}{1.2 \times 10^4}$$

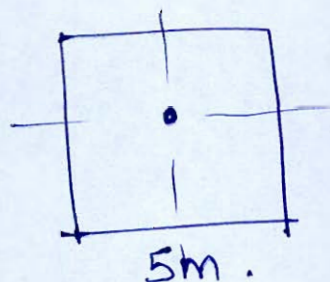
$$\frac{1000}{1.2 \times 10^4} = \frac{1}{12}$$



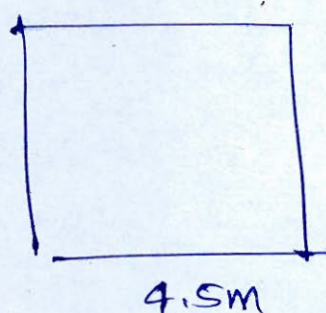
- Q.5 (e) Determine the immediate settlement beneath the centre of (i) 5 m size square flexible footing (ii) 4.5 m size square rigid footing, resting at 1 m depth and applying a stress of  $125 \text{ kN/m}^2$  in dry dense sand with an average  $E$  value of  $30 \times 10^3 \text{ kN/m}^2$  upto a depth of 10 m and an average value of  $60 \times 10^3 \text{ kN/m}^2$  for a depth between 10 m and 25 m. The soil is having a Poisson's ratio of 0.35.

(Consider Influence factor,  $I_f$  for  $\frac{L}{B} = 1$  at centre as 1.12 for flexible footing)

[12 marks]



$$E = 30 \times 10^3 \text{ kN/m}^2$$



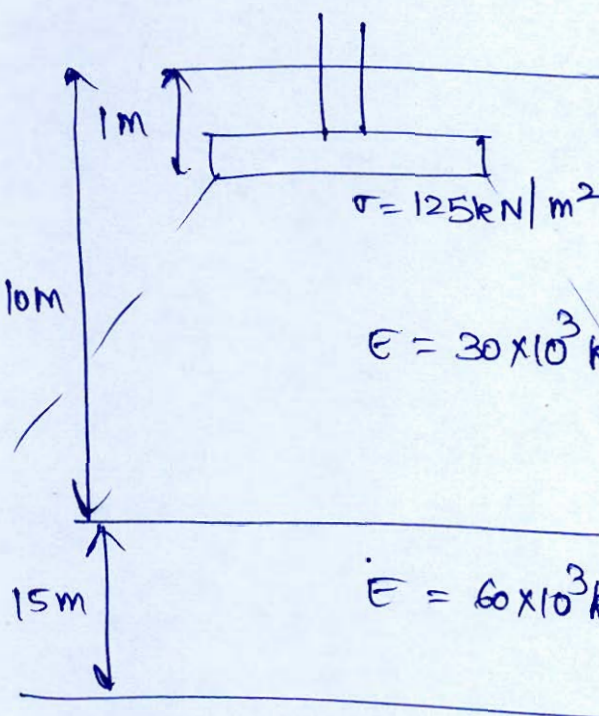
Rigid

$$S = \frac{QIB(1-\nu^2)}{E}$$

$$E_{eq} = \frac{30 \times 10^3 \times 10 + 60 \times 10^3 \times 15}{25} \text{ kN/m}^2$$

$$= 48 \times 10^3 \text{ kN/m}^2$$

6



$$S_{\text{flexible}} = \frac{125 \times 1.12 \times 5 \times (1 - 0.35^2)}{48 \times 10^3}$$

$$= 12.79 \text{ mm}$$





- Q.6 (a) A rectangular RC beam is 25 cm wide and 40 cm deep (overall). The beam is simply supported over an effective span of 4 m. The superimposed load over the beam is 50 kN/m. Using M20 grade concrete and Fe415 grade steel, design the beam for flexure only. Consider an effective cover of 40 mm.

Stress-strain values for Fe415

Maximum Design stress	Total strain
$0.8 \times 0.87 f_y$	0.00144
$0.925 \times 0.87 f_y$	0.00217
$0.950 \times 0.87 f_y$	0.00241
$0.9625 \times 0.87 f_y$	0.00259
$0.975 \times 0.87 f_y$	0.00276
$0.9875 \times 0.87 f_y$	0.00328
$1.0 \times 0.87 f_y$	0.00380

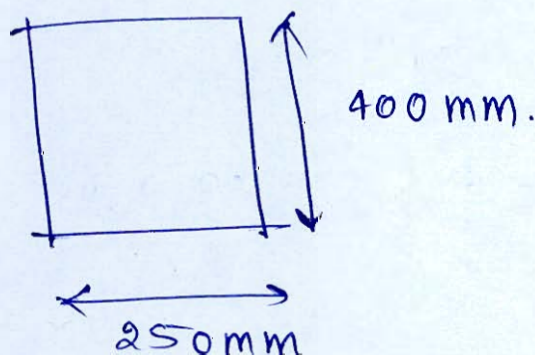
[20 marks]

$$L_{eff} = 4 \text{ m.}$$

$$W_s = 50 \text{ kN/m}$$

M20

Fe415.



$$d = 400 - 40 = 360 \text{ mm}$$

$$(w_d) = 25 \times 0.25 \times 0.4$$

$$= 2.5 \text{ kN/m.}$$

Assuming

$$\gamma_c = 25 \text{ kN/m}^3$$

$$(w_d)_{lim} = 0.48 \times 360$$

$$= 172.8 \text{ mm}$$

$$(M_u) = \frac{(50 + 2.5) \times 1.5 \times 4^2}{8} = 157.5 \text{ kNm.}$$

$$(M_u)_{lim} = 0.138 b c k b d^2$$

$$= 0.138 \times 20 \times 250 \times 360^2$$

$$= 89.424 \text{ kNm} < M_u.$$



Hence we need to design doubly reinforced section.

$$(A_{st})_1 = 0.5 \frac{bck}{b_y} \left[ 1 - \sqrt{1 - \frac{4.6 \times (M_u)_{lim}}{bck b d^2}} \right] \times b \times d$$

$$= 953.465 \text{ mm}^2$$

$$\text{Also, } (M_2) = 157.5 - 89.424$$

$$= 68.076 \text{ kNm.}$$

$$0.87 f_y (A_{st})_2 \times (d - d') = 68.076 \text{ kNm.}$$

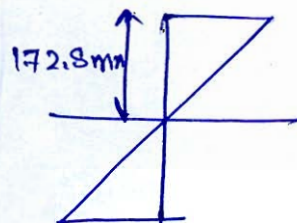
$$(A_{st})_2 = \frac{68.076 \times 10^6}{0.87 \times 415 \times (360 - 40)}$$

$$= 589.22 \text{ mm}^2$$

Using

$$(\epsilon_s) = \frac{0.0035 \times (172.8 - 40)}{172.8}$$

$$= 0.00269$$



$$\text{design stress} = 0.975 - \frac{(0.975 - 0.9625) \times (0.00276 - 0.00269)}{(0.00276 - 0.00259)}$$

$$= 0.96985 \times 0.87 \times f_y$$

$$C = T$$

$$0.96985 \times 0.87 \times 415 \times A_{sc} = 0.87 \times 415 \times 589.22$$

$$A_{sc} = 607.535 \text{ mm}^2$$



$$(A_{st})_{\text{total}} = A_{st1} + A_{st2}$$

$$= 1542.685 \text{ mm}^2$$

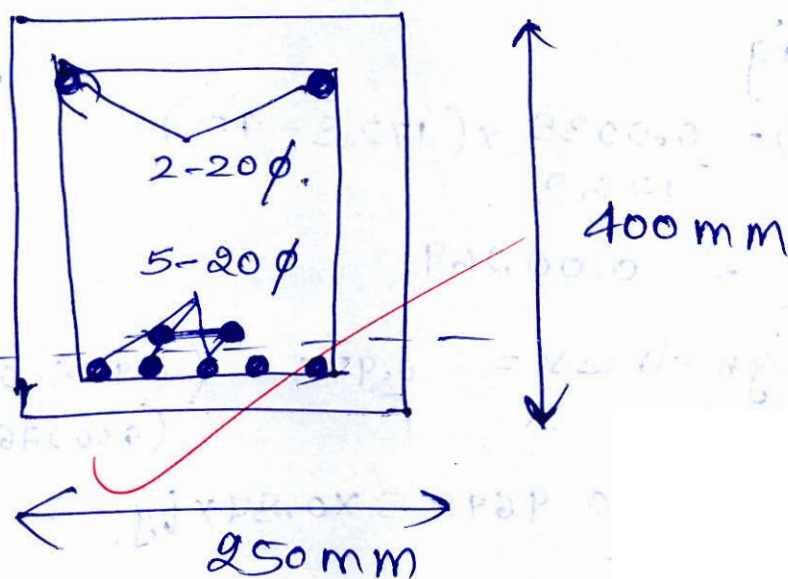
$$(A_{sc}) = 607.535 \text{ mm}^2$$

Adopt  $\phi_{\text{tensile}} = 20 \text{ mm}$

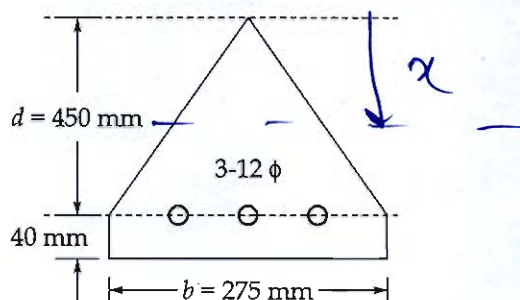
So provide 5-20  $\phi$  as tensile  
8/6

$$(A_{st})_{\text{provided}} = 1570.8 \text{ mm}^2$$

and 2 bars of 20  $\phi$  as compression  
reinforcement



- Q.6 (b) A triangular reinforced concrete beam section is as shown in the figure. Find the depth of neutral axis and the moment of resistance of the beam section. Safe stresses in concrete and steel are  $7 \text{ N/mm}^2$  and  $230 \text{ N/mm}^2$  respectively. (Take  $m = 13.33$ )



[20 marks]

$$\frac{x}{b'} = \frac{450}{275} \Rightarrow b' = 0.611x$$

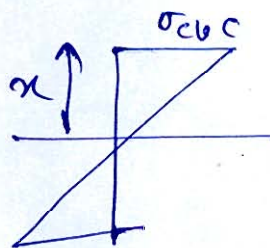
$$\Rightarrow \frac{1}{2} \times 0.611x \times x \times \frac{x}{3} = 13.33 \times 3 \times \frac{\pi}{4} \times 12^2 \times (450 - x)$$

$$\Rightarrow 0.10183x^3 = 2035243.102 - 4522.76x$$

$$x = 217.7 \text{ mm}$$

(MOR) =

$$x_{balanced} = \left( \frac{7}{7 + \frac{230}{13.33}} \right) \times 450 = 129.87 \text{ mm}$$



Hence section is over reinforced.

$$(MOR) = \frac{1}{2} \times \sigma_{ccc} \times x \times \left( \frac{1}{2} \times 0.611 \times 217.7^2 \right)$$

$$= 11.03 \text{ kNm}$$



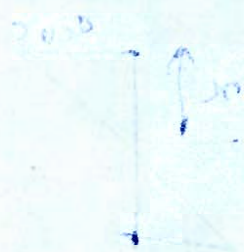


$$\frac{\partial F}{\partial x} = 0 \quad \text{or} \quad \frac{\partial F}{\partial x} = 0$$

$$(x - 0.5) \times 10 \times 10^3 \times 10^3 \times 10^3 = \frac{x}{2} \times 10 \times 10^3 \times 10^3 \times 10^3$$

$$x = 0.5 \times 10^3 \times 10^3 \times 10^3 = 0.5 \times 10^9 \times 10^3$$

$$\frac{\partial F}{\partial x} = 0$$



(G.M.)

$$\frac{\partial F}{\partial x} = 0 \quad \text{or} \quad \frac{\partial F}{\partial x} = 0$$

There is a maximum value of the function

$$\left( \frac{x}{2} \times 10 \times 10^3 \times 10^3 \times 10^3 \right) \times 10 \times 10^3 \times 10^3 \times 10^3 = (G.M.)$$

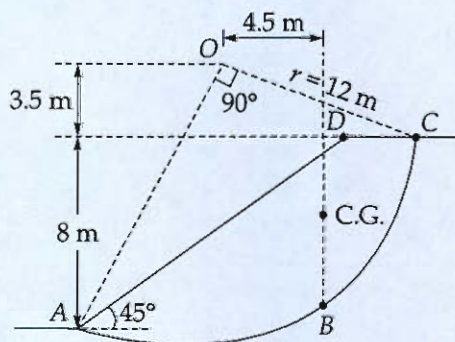
$$\frac{\partial F}{\partial x} = 0$$



*[Faint handwritten text, possibly bleed-through from the reverse side of the page, is visible through the paper. The text is mostly illegible due to fading and the angle of the page.]*

- Q.6 (c) (i) A  $45^\circ$  slope has been excavated to a depth of 8 m in a saturated clay having cohesion of  $60 \text{ kN/m}^2$ , angle of internal friction as zero and unit weight of  $20 \text{ kN/m}^3$ . Area of the failure wedge (ABCD) is taken as  $70 \text{ m}^2$ . Determine (a) the factor of safety for the trial failure surface specified in the figure. (b) The minimum value of factor of safety for the given slope.

(Assuming that the depth factor is zero)



[14 marks]

$$c = 60 \text{ kN/m}^2 \quad \phi = 0$$

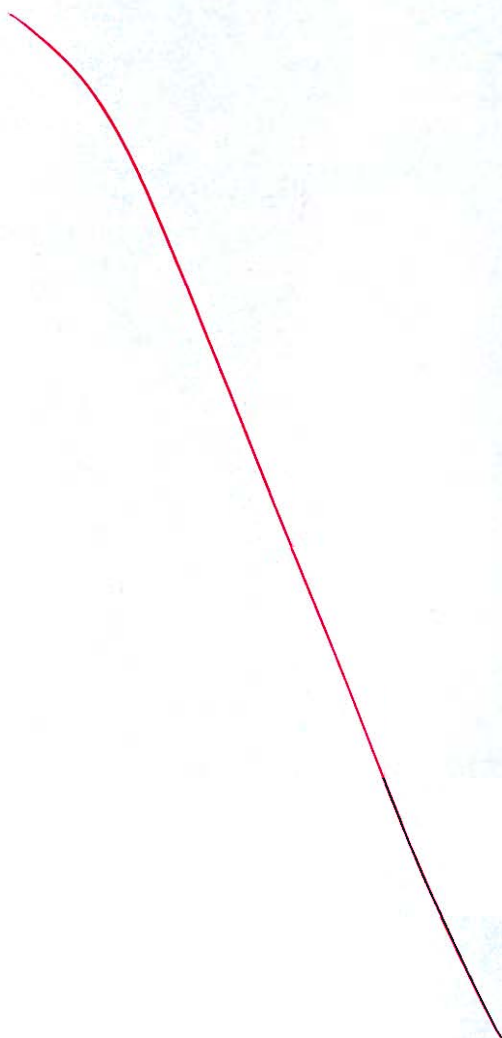
$$\gamma = 20 \text{ kN/m}^3$$

For trial failure surface,  $A = 70 \text{ m}^2$

$$\text{FOS} = \left( \frac{60 \times 12 \times \frac{\pi}{2} \times 1 \times 12}{20 \times 70 \times 4.5} \right)$$

$$= \boxed{2.154}$$

7





- Q.6 (c) (ii) Briefly explain the assumptions of Rankine's earth pressure theory and Coulomb's earth pressure theory.

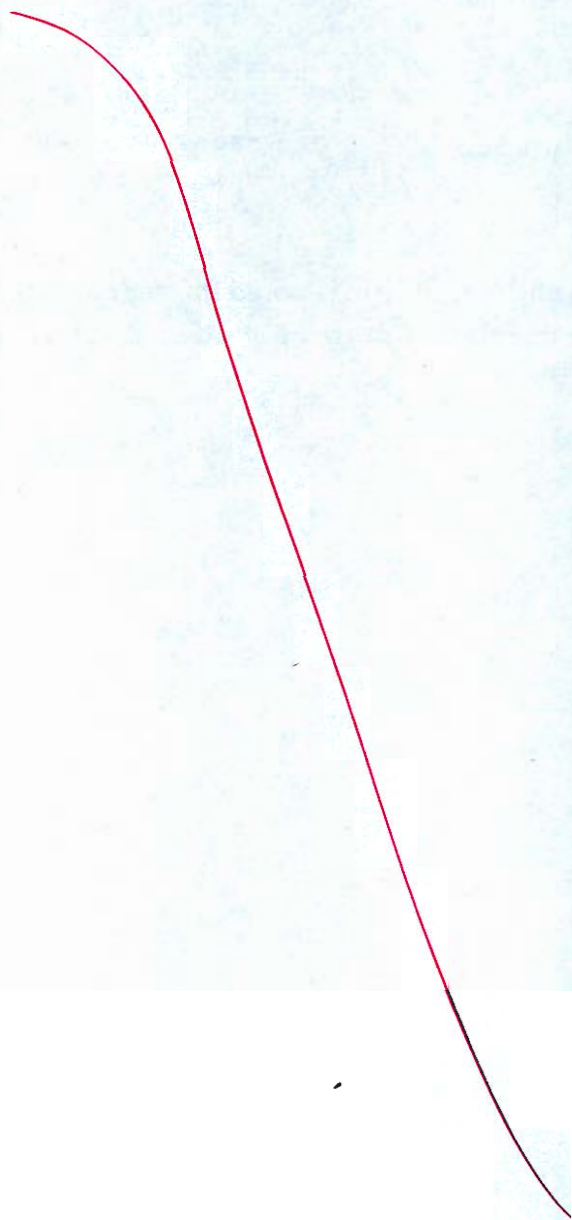
[6 marks]

- 2.7 (a) Design a wall of a rectangular water tank to resist a pull of 60 kN and a bending moment of 7.5 kN-m/m width. Use M30 concrete and Fe 415 grade steel.  
Effective cover = 30 mm.  
Permissible stress in direct tension in concrete = 1.5 MPa.  
Permissible stress in bending tension in concrete = 2 MPa.  
Permissible stress in bending compression in concrete = 10 MPa.  
Modular ratio,  $m = 9.33$ .  
Permissible stress in steel = 130 MPa.

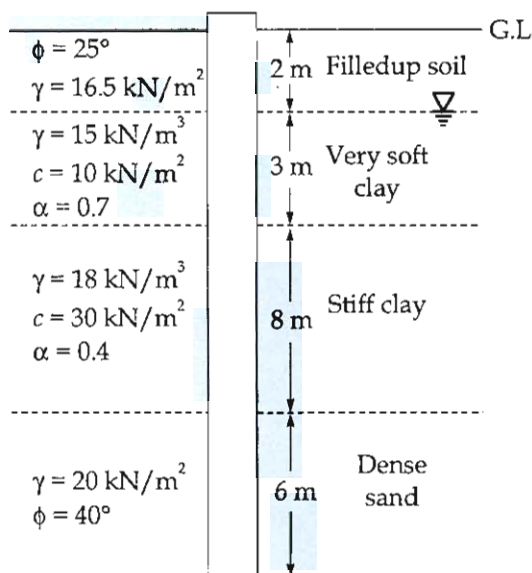
[20 marks]







- Q.7 (b) At a particular site, the soil profile consists of four different layers as shown in the figure below with respective soil properties. The water table is at 2 m below the ground level.



A pile of diameter 600 mm and length 19 m is bored through the soil. Calculate the safe load that can be carried by the pile with a factor of safety of 2.5.

(Take,  $N_q = 140$  and  $N_\gamma = 152$ )

[20 marks]





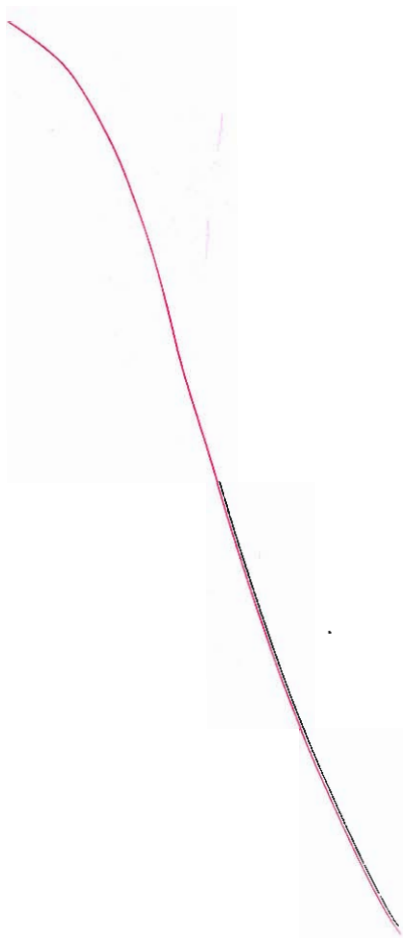


- 2.7 (c) A retaining wall of 8 m height has backfill soil in three different layers. Top 1 m and bottom 3 m clay layer has unconfined compressive strengths equal to  $50 \text{ kN/m}^2$  and  $75 \text{ kN/m}^2$  respectively. The void ratio of top and bottom-most clay is 0.7 and 0.5 respectively. Middle 4 m sand layer has a void ratio of 0.45 and when tested in tri-axial test the confining pressure comes out to be  $300 \text{ kN/m}^2$  and deviator pressure comes out to be  $350 \text{ kN/m}^2$ .

Calculate the line of action of the total active earth pressure force from the bottom of wall, if water table exists at a depth of 3 m from the top of wall and a surcharge of  $40 \text{ kN/m}^2$  is applied at the ground level.

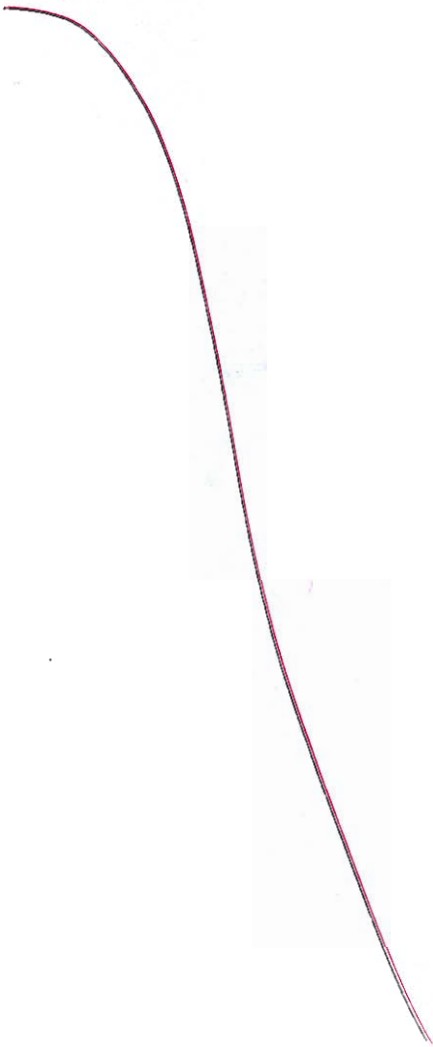
(Take specific gravity of clay,  $G_{\text{clay}} = 2.7$ , Specific gravity of sand,  $G_{\text{sand}} = 2.68$ , Water content of clay above water table = 8%, Water content of sand above water table = 8%)

[20 marks]











2.8 (a) Design a waist slab type dog-legged staircase for a building given the following data:

Height between floors = 2.7 m

Riser = 150 mm

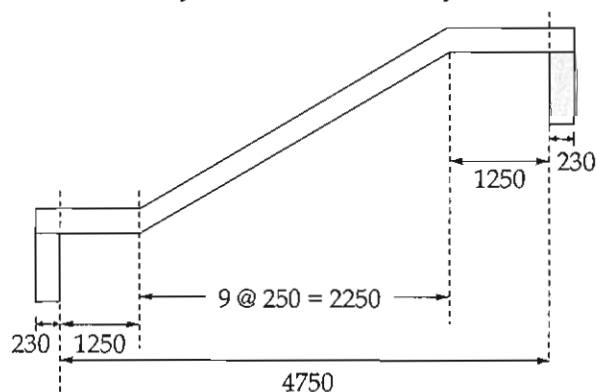
Tread = 250 mm

Width of flight and landing width = 1.25 m

Imposed load =  $4.0 \text{ kN/m}^2$

Floor finishes =  $0.6 \text{ kN/m}^2$

Assume that the stair is to be supported on 230 mm wide beam at the outer edges of the landing, parallel to the risers as shown in figure. Use M20 concrete and Fe415 grade steel. Assume any other data suitably.

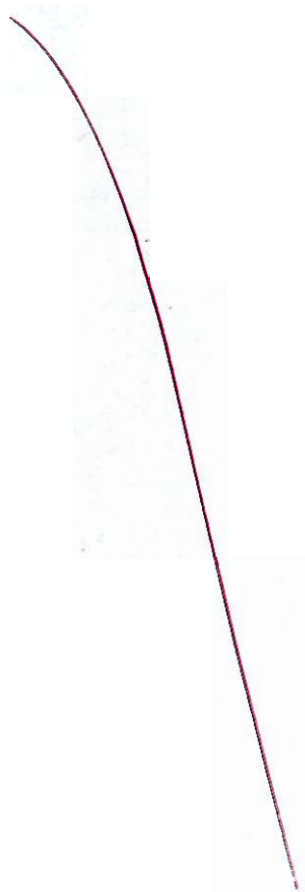


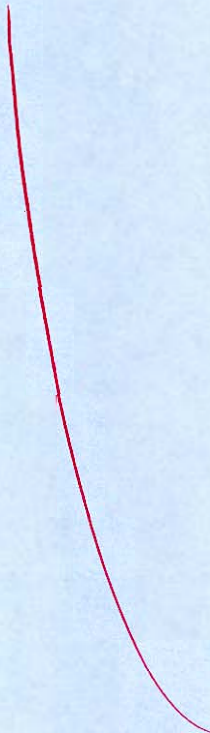
(All dimension in 'mm')

[20 marks]











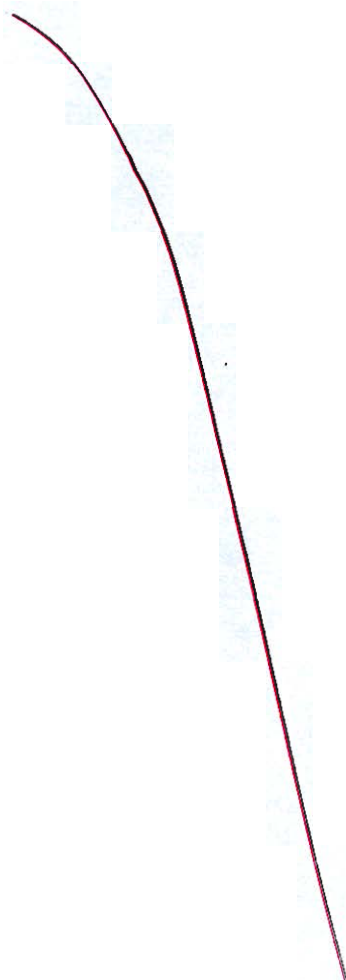
- 8 (b) A square footing, placed at a depth of 1.4 m below the ground surface, carrying a safe load of 1050 kN. The soil beneath the footing is having void ratio of 0.64, specific gravity of 2.67, cohesion as 12 kN/m<sup>2</sup> and angle of internal friction of 30°. The soil upto 1.4 m depth is having void ratio of 0.55, degree of saturation 50% (above water table) specific gravity 2.79, cohesion as 10 kN/m<sup>2</sup> and angle of internal friction 32°. The bearing capacity factors for respective friction angles are given as :

$\phi$	$N_c$	$N_q$	$N_\gamma$
30°	37.2	22.5	19.7
32°	44.14	28.5	27.5

Find the size of the footing if the desired factor of safety is 3. (Water table is present at 0.5 m depth from the ground level).

[20 marks]

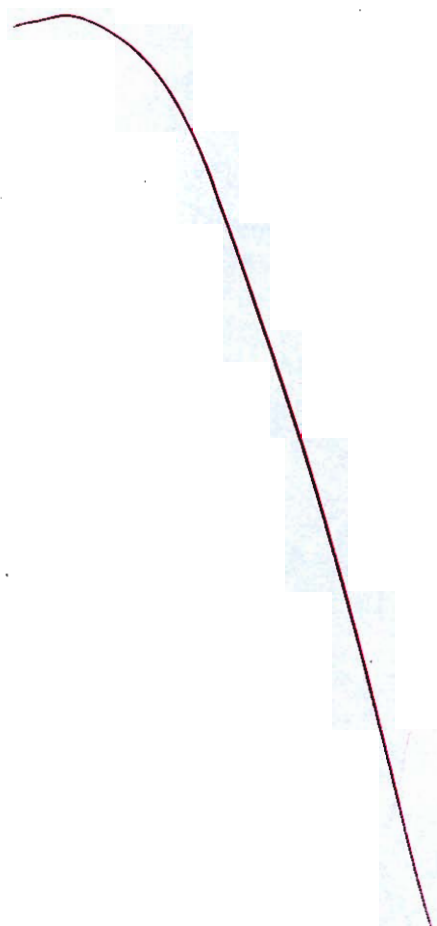


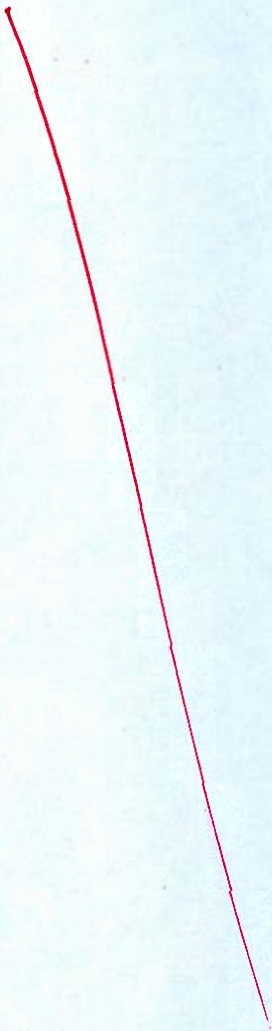




- Q.8 (c) (i) Discuss in brief about the various types of soil samplers.  
(ii) Write a short note on pressuremeter test.

[12 + 8 marks]







## Space for Rough Work

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