219/300

MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-6

Section A : Flow of Fluids, Hydraulic Machines and Hydro Power [All Topics]

Section B : Water Resource Engineering and Hydrology [All Topics]

Name : ....

Roll No :

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

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	36
Q.2	48
Q.3	59
Q.4	
Section-B	
Q.5	41
Q.6	35
Q.7	
Q.8	
Total Marks Obtained	219/300

Signature of Evaluator: ....MDS.......... 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.

Section A : Flow of Fluids, Hydraulic Machines and Hydro Power

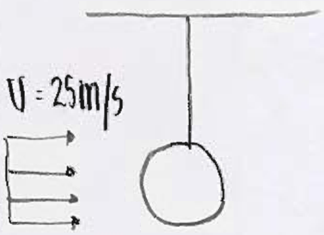
Q.1 (a) A sphere 3 cm in diameter and of relative density 2.5 is attached to a string and is suspended from the roof of a wind tunnel. If an air stream of 25 m/s flows past the sphere then determine the inclination of the string to horizontal and the tension in the string. (Neglect the weight and drag of the string).

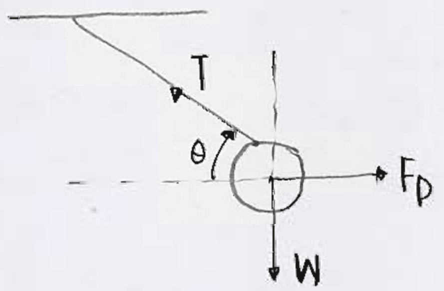
[Take : Mass density of air, ρ_{air} = 1.25 kg/m³, kinematic viscosity of air, $\nu_{air} = 1.40 \times 10^{-5}$ m²/s.]

Coefficient of drag

$$C_D = \begin{cases} 0.5 \text{ for } 10^4 < R_e \le 3\times10^5 \\ 0.2 \text{ for } R_e \ge 3\times10^5 \end{cases}$$

[12 marks]





$Re = \frac{\rho V D}{\mu} = \frac{25 \times 0.03}{1.4\times10^{-5}} = 53571.428 > 10^4$ and $< 3\times10^5$

$C_d = 0.5$

$F_D = \frac{1}{2} \times C_d \times \rho \times A_p \times U_\infty^2 = \frac{1}{2} \times 0.5 \times 1.25 \times \pi \times (0.03)^2 \times 25^2$

$F_D = 0.5522$ N

$W = \rho V g = 2500 \times 9.81 \times \frac{4}{3}\pi (0.03)^3 = 2.773$ N

From the figure $T\cos\theta = F_D$ and $T\sin\theta = W$

$T = \sqrt{F_D^2 + W^2} = \sqrt{0.5522^2 + 2.773^2} = 2.8274$ N //

$T\cos\theta = F_D$

$2.8274 \cos\theta = 0.5522$ $\theta = 78.737°$

(1)

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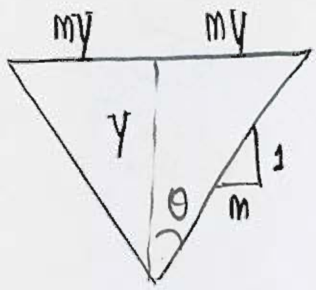
(b) Prove that the most efficient triangular cross-section channel is half of a square with its diagonal horizontal

[12 marks]

Let y be the depth of flow

Side slope mH : 1V as shown



Area $A = \frac{1}{2}(y \times 2my) = my^2$

Perimeter, $P = 2 \times \sqrt{y^2 + m^2y^2} = 2y\sqrt{m^2+1}$

So for most efficient channel for const Area P should be minimum

If P is minimum → P^2 should be minimum

$P^2 = 4y^2(m^2+1)$ $\quad A = my^2 \Rightarrow y^2 = \frac{A}{m}$

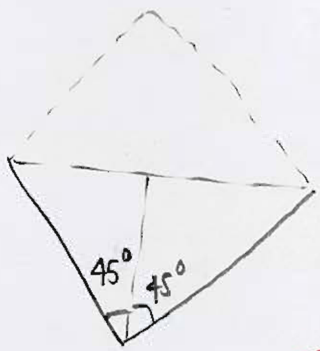
$P^2 = \frac{4A}{m}(m^2+1) = 4A\left(m + \frac{1}{m}\right)$

$\frac{dP^2}{dm} = 0 \Rightarrow 4A\left(1 - \frac{1}{m^2}\right) = 0 \Rightarrow m^2 = 1$

$m = \pm 1$

Neglecting -ve value $m = 1$

$\tan\theta = \frac{my}{y} = m = 1 \quad \theta = 45^\circ$



→ The angle b/w sides is 90°

→ Both the sides are of equal length

This proves that is a half square with one diagonal horizontal

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(c) Derive the expression for the efficiency of a Pelton turbine. Also determine the condition for maximum efficiency and obtain the expression for the maximum efficiency of turbine.

[12 marks]

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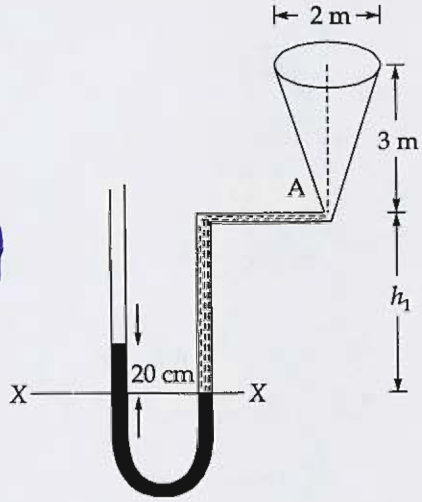
(d) A conical vessel having its outlet at A to which a U-tube manometer is connected is shown in figure below. The reading of the manometer given in the figure shows when the vessel is empty. Find the reading of the manometer when the vessel is completely filled with water.



[12 marks]

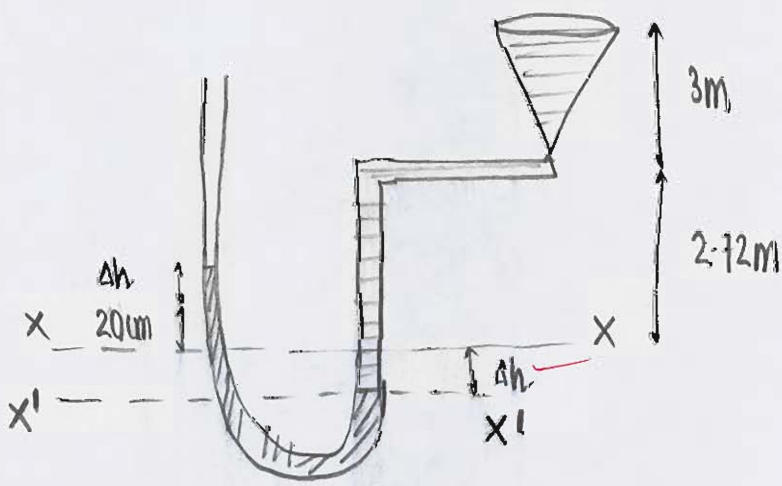
When vessel is empty

Evaluating pressure at X–X from both sides

$$P_{atm} + 13600 \times 9.81 \times 0.2 = P_{atm} + 1000 \times 9.81 \times h_1$$

$$h_1 = 2.72\text{m}$$

When vessel is completely filled the new configuration will be



Equating pressure at x'–x' from both sides

$$P_{atm} + (\Delta h + 0.2 + \Delta h) \times 13600 \times 9.81 = P_{atm} + 1000 \times 9.81 \times (3 + 2.72 + \Delta h)$$

$$\Delta h = 0.1145 \text{ m}$$

So new manometric reading $= 0.2 + 2\Delta h$

$= 0.429$ m or 42.9 cm

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(e) A 30 cm × 15 cm venturimeter is provided in a vertical pipe line carrying oil of specific gravity 0.9, the flow being upwards. The difference in elevation of the throat section and entrance section of the venturimeter is 30 cm. The differential U-tube mercury manometer shows a gauge deflection of 25 cm. Calculate:

(i) The discharge of oil

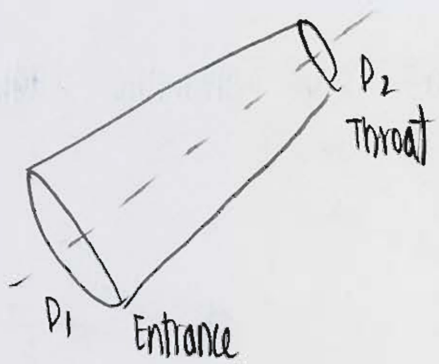
(ii) The pressure difference between the entrance section and the throat section. Take the coefficient of venturimeter as 0.98 and specific gravity of mercury as 13.6.

[12 marks]

$D_1 = 30cm \quad D_2 = 15cm \quad \rho = 900\ kg/m^3$

$z_2 - z_1 = 30cm \quad x = 25cm$

manometer reading



$C_d = 0.98 \quad S_{Hg} = 13.6$

$$h = x\left|\frac{S_{Hg}}{S_{oil}} - 1\right| = 25cm\left|\frac{13.6}{0.9} - 1\right| = 352.78\ cm = 3.5278m$$

Discharge $\quad Q = \dfrac{C_d A_1 A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2gh}$

$A_1 = \pi/4 \times 0.3^2 = 0.07m^2$

$A_2 = \pi/4 \times 0.15^2 = 0.0176m^2$

on subst^n we get

$$Q = 0.1482\ m^3/s$$ //

(ii) The value h shows the piezometric head difference between entrance and throat $\quad h = 3.5278m$

$$\left(\frac{P_1}{\rho g} + z_1\right) - \left(\frac{P_2}{\rho g} + z_2\right) = h$$

Do not write in this margin

$$\left(\frac{P_1-P_2}{\rho g}\right) + (Z_1-Z_2) = h$$

$$\frac{P_1-P_2}{900\times 9.81} + (-0.3) = 3.5278$$

$$\Rightarrow \quad P_1-P_2 = 33795.64 \text{ Pa} \quad \text{or} \quad \frac{N}{m^2}$$

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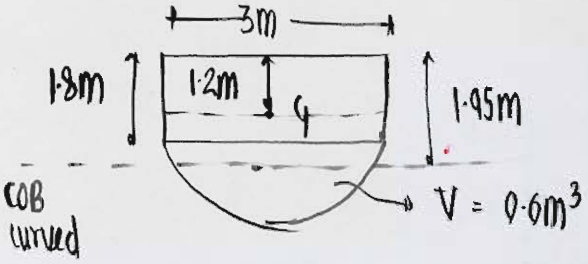
2 (a) A body has the cylindrical upper portion of 3 m diameter and 1.8 m deep. The lower portion is a curved one, which displaces a volume of 0.6 m^3 of water. The centre of buoyancy of the curved portion is at a distance of 1.95 m below the top of the cylinder. The centre of gravity of the whole body is 1.20 m below the top of the cylinder. The total displacement of water is 3.9 tonnes. Find the meta-centric height of the body.

[20 marks]



Total water displaced

$= 3.9 \times 10^3 = 3900$ kg

$\forall = \frac{M}{\rho} = \frac{3900}{10^3} = 3.9 m^3$

Let h ht of cylinder is inside water

$\forall$ of cylinder inside $= 3.9 m^3 - 0.6 m^3 = 3.3 m^3$

$\frac{\pi D^2}{4} \times h = 3.3 m^3$ $\qquad h = 0.4668 \approx 0.467 m$

Centre of buoyancy of cylinder from top of cylinder

$= 1.8 - 0.467 + \frac{0.467}{2} = 1.5665 m$

Centre of Buoyancy of whole solid $= \frac{(\forall dis)_1 h_1 + (\forall)_{dis} h_2}{(\forall dis)_1 + (\forall dis)_2}$

$= \frac{3.3 \times 1.5665 + 0.6 \times 1.95}{3.9}$

COB $= 1.6255$

COG $= 1.2m$ $\qquad BG = 0.4255 m$

Metacentric height $= \frac{I}{\forall dis} - BG$

$I = \frac{\pi}{64} D^4 = \sout{3.976 m^4}$

$$GM = \frac{3.976}{3.9} - 0.4255$$

$GM = 0.594m$ //

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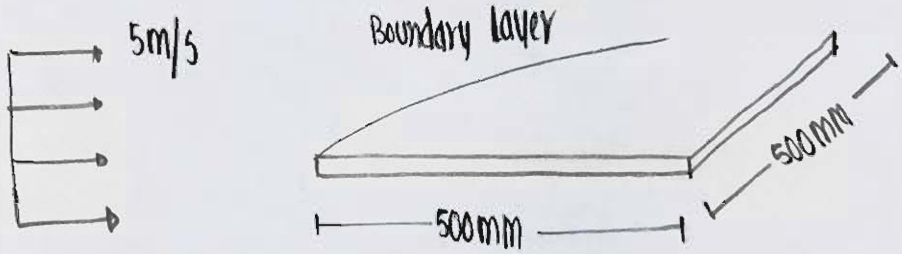
(b) Air is flowing over a flat plate 500 mm long and 500 mm wide with a velocity of 5 m/s. The kinematic viscosity of air is 0.1×10^{-4} m²/s. Determine:

(i) the boundary layer thickness at the end of the plate.

(ii) shear stress at the end of the plate.

The velocity profile over the plate is $\frac{u}{U_\infty} = \sin\left(\frac{\pi y}{2\delta}\right)$ and density of air is 1.2 kg/m³.

[20 marks]



$$\frac{U}{U_\infty} = \sin\left(\frac{\pi y}{2\delta}\right)$$

→ momentum thickness $\theta = \int_0^\delta \frac{U}{U_\infty}\left(1 - \frac{U}{U_\infty}\right) dy$

$$= \int_0^\delta \sin\left(\frac{\pi y}{2\delta}\right)\left(1 - \sin\left(\frac{\pi y}{2\delta}\right)\right) dy = \int_0^\delta \left[\sin\frac{\pi y}{2\delta} - \sin^2\left(\frac{\pi y}{2\delta}\right)\right] dy$$

$$= \left[-\cos\left(\frac{\pi y}{2\delta}\right) \times \frac{2\delta}{\pi}\right]_0^\delta - \int_0^\delta \left[\frac{1 - \cos\left(\frac{\pi y}{\delta}\right)}{2}\right] dy$$

$$= \frac{2\delta}{\pi} - \left[\frac{y}{2} - \frac{\sin\left(\frac{\pi y}{\delta}\right)}{2}\right]_0^\delta = \frac{2\delta}{\pi} - \frac{\delta}{2}$$

Von Karmann momentum integral eqn $\frac{\tau_0}{\rho U_\infty^2} = \frac{\partial \theta}{\partial x}$

$$\frac{\tau_0}{\rho U_\infty^2} = \left(\frac{2}{\pi} - \frac{1}{2}\right)\frac{\partial \delta}{\partial x} \qquad \frac{\tau_0}{\rho U_\infty^2}\partial x = 0.1366\, \partial \delta$$

Integrate $0.1366\,\delta = \frac{\tau_0 x}{\rho U_\infty^2} + C_1$

At $x=0$ $\delta = 0$ so $C_1 = 0$

~~At x=~~ ~~$\delta = \frac{\tau_0 x}{\rho U_\infty^2}$~~ $\delta = \frac{7.319\,\tau_0 x}{\rho U_\infty^2}$

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Incomplete

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(c) **(i)** The velocity potential function for a two-dimensional flow is given by

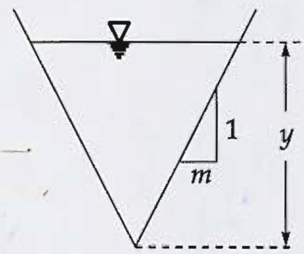
$$\phi = (x^2 - y^2) + 3xy.$$

Determine

1. The stream function
2. The flow rate between the streamlines passing through points (1, 1) and (1, 2).

(ii) Show that in a triangular channel, the Froude numbers F_1 and F_2 corresponding to alternate depths y_1 and y_2 respectively are related as

$$\left(\frac{F_1}{F_2}\right)^2 = \left(\frac{4+F_1^2}{4+F_2^2}\right)^5$$



[10 + 10 = 20 marks]

(i) $\phi = (x^2 - y^2) + 3xy$

$\frac{\partial \phi}{\partial x} = 2x + 3y$ and $\frac{\partial \phi}{\partial y} = -2y + 3x$

$\frac{\partial \phi}{\partial x} = \frac{\partial \psi}{\partial y}$ $\quad \frac{\partial \psi}{\partial y} = 2x + 3y$ Integrate

$\psi = \int (2x+3y)dy = 2xy + \frac{3y^2}{2} + f(x)$

Now $\frac{\partial \phi}{\partial y} = \frac{-\partial \psi}{\partial x}$ so $-2y+3x = -\frac{\partial}{\partial x}\left[2xy + \frac{3y^2}{2} + f(x)\right]$

$-2y+3x = -2y - f'(x)$ $f'(x) = -3x$ $f(x) = \frac{-3x^2}{2} + c$

so $\psi = 2xy + \frac{3}{2}(y^2 - x^2) + c$ //

Flow rate b/w two points A and B per unit width is given by $\psi_B - \psi_A$

$\psi_{(1,2)} = 2(1)(2) + \frac{3}{2}(2^2 - 1^2) + c = 8.5 + c$

$\psi(1,1) = 2(1)(1) + \frac{3}{2}(1^2 - 1^2) + c = 2 + c$

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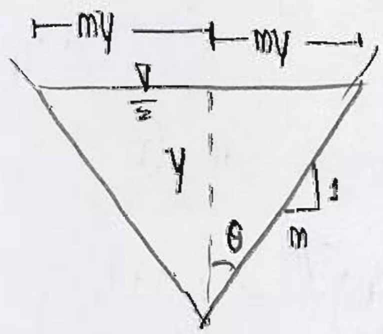
Flow rate $= (8.5+c) - (2+c) = 6.5\ m^3/s/m$ //

(ii) If y_1 and y_2 are alternate depths specific energy will be same



$E = y + \frac{V^2}{2g} = y + \frac{Q^2}{2gA^2}$

$y_1 + \frac{Q^2}{2gA_1^2} = y_2 + \frac{Q^2}{2gA_2^2}$

$A = \frac{1}{2} \times y \times 2my$

$= my^2$

$$y_1 + \frac{Q^2}{2g m^2 y_1^4} = y_2 + \frac{Q^2}{2g m^2 y_2^4} \quad \text{——} \quad (1)$$

Also $F_1^2 = \frac{Q^2 T}{g A^3} = \frac{Q^2 \times 2my}{g \times (my^2)^3} = \frac{Q^2 \times 2my}{g \times m^3 y^6} = \frac{2Q^2}{g m^2 y^5}$

$$\frac{Q^2}{g m^2} = \frac{F_1^2 y^5}{2}$$

for y_1 and y_2: $\frac{Q^2}{g m^2} = \frac{F_1^2 y_1^5}{2} = \frac{F_2^2 y_2^5}{2}$ — (2)

Sub (2) in (1)

$$y_1 + \frac{F_1^2 y_1^5}{2 \times 2 \times y_1^4} = y_2 + \frac{F_2^2 y_2^5}{2 \times 2 \times y_2^4}$$

$$\frac{y_1(4+F_1^2)}{4} = \frac{y_2(4+F_2^2)}{4} \Rightarrow \frac{y_2}{y_1} = \frac{4+F_1^2}{4+F_2^2} \quad \text{—} \quad (3)$$

Also from (2) $\left(\frac{y_2}{y_1}\right)^5 = \left(\frac{F_1}{F_2}\right)^2$ so $\frac{y_2}{y_1} = \left(\frac{F_1}{F_2}\right)^{2/5}$ — (4)

Sub (4) in (3)

$$\left(\frac{F_1}{F_2}\right)^{2/5} = \left(\frac{4+F_1^2}{4+F_2^2}\right) \quad \text{so} \quad \left(\frac{F_1}{F_2}\right)^2 = \left(\frac{4+F_1^2}{4+F_2^2}\right)^5$$

Hence proved

Q.3 (a) Two large plane surfaces are 2.4 cm apart. The space between the surfaces is filled with glycerine. What force is required to drag a very thin plate of surface area 0.5 square metre between the two large plane surfaces at a speed of 0.6 m/s, if:

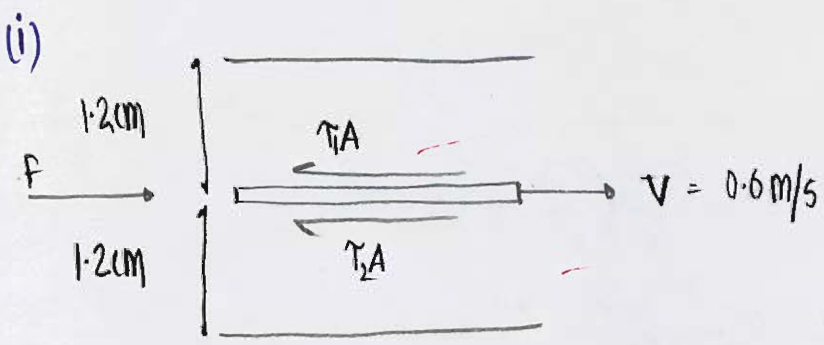
(i) The thin plate is in the middle of the two plane surfaces, and

(ii) The thin plate is at a distance of 0.8 cm from one of the plane surface? Take dynamic viscosity of glycerine as 8.10×10^{-1} Ns/m^2.

[20 marks]

$A_{plate} = 0.5 m^2$ $\mu = 8.1 \times 10^{-1} = 0.81 \frac{Ns}{m^2}$ $V = 0.6 m/s$

(i)

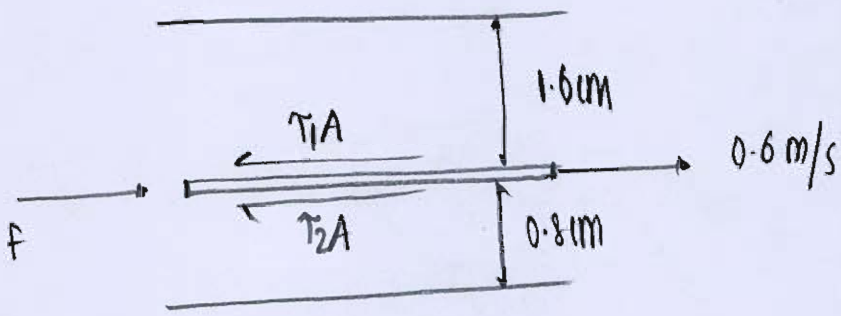


$F = \tau_1 A + \tau_2 A$ Since plates is equidistant from the two planes $\tau_1 = \tau_2$

$\tau = \mu \frac{du}{dy} = 0.81 \times \left(\frac{0.6 - 0}{1.2 \times 10^{-2}} \right) = 40.5 N/m^2$

$F = 2\tau A = 2 \times 40.5 \times 0.5 = 40.5\,N$ //

(ii)



$\tau_1 = \frac{\mu du}{dy_1} = \frac{0.81 \times 0.6}{1.6 \times 10^{-2}} = 30.375\ N/mm^2$

$\tau_2 = \frac{\mu du}{dy} = \frac{0.81 \times 0.6}{0.8 \times 10^{-2}} = 60.75\ N/mm^2$

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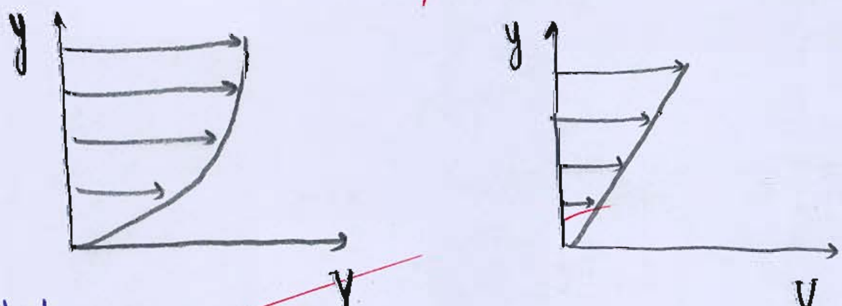
$F = (\tau_1 + \tau_2)A = (60.75 + 30.375) \times 0.5$

$= 45.5625\ N$

Assumption used

As t is very small (distance b/w plates) we have taken linearisation of st newton's law of viscosity



Actual $\frac{du}{dy}$

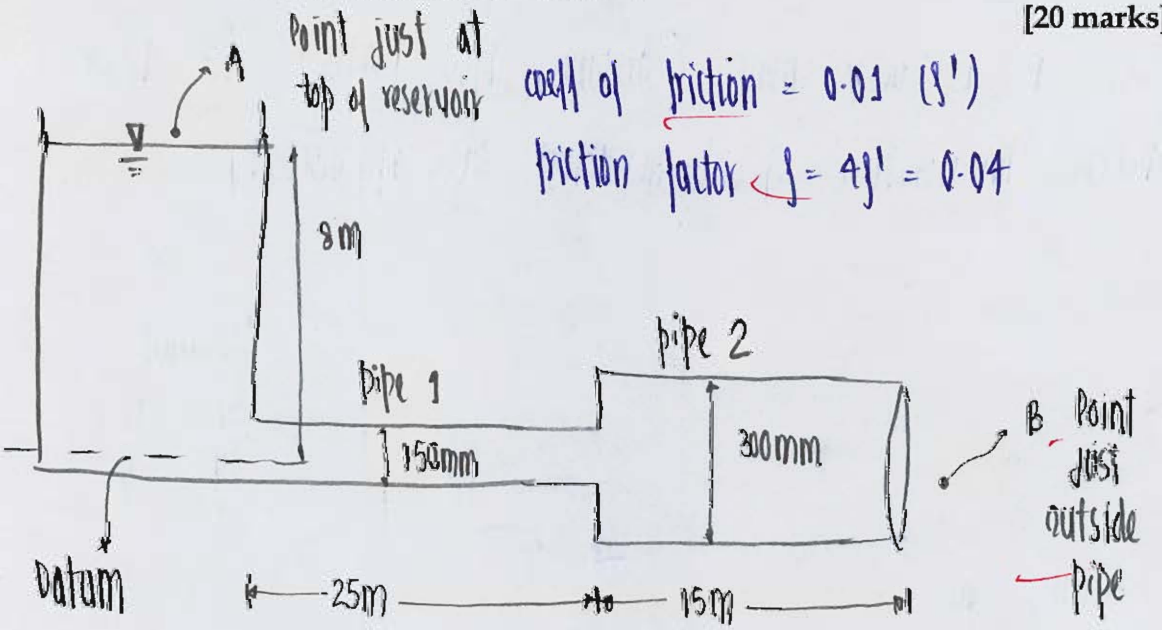
Assumed $\frac{du}{dy} = \frac{V}{Y}$

(b) A horizontal pipe line 40 m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end. For the first 25 m of its length from the tank, the pipe is 150 mm in diameter and its diameter is suddenly enlarged to 300 mm thereafter. The height of water level in the tank is 8 m above the centre line of the pipe. Considering all losses of head which occur, determine the rate of flow. Take coefficient of friction, $f = 0.01$ for both sections of the pipe.

[20 marks]

coeff of friction = 0.01 (f')

friction factor, $f = 4f' = 0.04$



Apply energy eqn at A and B

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

$P_A \simeq P_{atm}$ $z_A = 8m$

$P_B \simeq P_{atm}$ $V_A \approx 0$ (reservoir) $z_B = 0\,m$

$$8 = \frac{V_B^2}{2g} + h_f$$

$V_B \approx V_2$ velocity in pipe 2

$h_f = h_L$ (sudden contraction) $+ h_{f_1}$ (friction along first 25m) $+ h_L$ (sudden expansion) $+ h_{f_2}$ (friction for last 15m)

h_L (sudden contraction) $= \left(\frac{1}{C_c} - 1\right)^2 \frac{V_1^2}{2g}$ assume $\left(\frac{1}{C_c} - 1\right)^2 = 0.5$

$$h = \frac{0.5 V_1^2}{2g}$$

Also $V_1 A_1 = V_2 A_2$ (By continuity)

$$V_1 \times \frac{\pi}{4} \times (150)^2 = V_2 \times \frac{\pi}{4} \times (300)^2$$

$$V_1 = 4V_2$$

$$= \frac{0.5 (4V_2)^2}{2g} = \frac{8V_2^2}{2g}$$

h_{f_1} (friction for first 25m) $= \frac{f L V_1^2}{2gd} = \frac{0.04 \times 25 \times (4V_2)^2}{2 \times g \times 0.15}$

$$= \frac{106.67 V_2^2}{2g}$$

$$h\,(\text{sudden expansion}) = \frac{(V_1 - V_2)^2}{2g} = \frac{(4V_2 - V_2)^2}{2g} = \frac{9V_2^2}{2g}$$

$$h\,(\text{friction for } 15m) = \frac{fLV_2^2}{2gd} = \frac{0.04 \times 15 \times V_2^2}{2g \times 0.3} = \frac{2V_2^2}{2g}$$

$$8 = \frac{8V_2^2}{2g} + \frac{106.67V_2^2}{2g} + \frac{9V_2^2}{2g} + \frac{2V_2^2}{2g} = \frac{125.67V_2^2}{2g}$$

$$V_2 = 1.1175 \text{ m/s}$$

$$Q = A_2 V_2 = \frac{\pi}{4} \times (0.3)^2 \times 1.1175 = 0.07899 \text{ m}^3/\text{s}$$

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(c) The resistance R experienced by a partially submerged body depends upon the velocity V, length of the body l, dynamic viscosity of the fluid μ, density of the fluid ρ and gravitational acceleration g. Obtain a dimensionless expression of R. Also relate R to some special dimensionaless numbers.

[20 marks]

Dependent variable = R

Independent variables = V, L, μ, ρ, g

$m = 6$ $\quad n = 3$ no of fundamental dimensions involved

no. of π terms = $m - n = 3$

let L, V and ρ be the repeating variables

L → Geometric, V → Kinematic, ρ → Dynamic

→ 1st π term

$$\pi_1 = (L)^a (V)^b (\rho)^c \mu$$

$$M^0 L^0 T^0 = (L)^a (LT^{-1})^b (ML^{-3})^c (ML^{-1}T^{-1})$$

$$\pi_1 = \frac{\mu}{\rho V L}$$

$c + 1 = 0$ $\quad$ $-b - 1 = 0$ $\quad$ $a + b - 3c - 1 = 0$

$c = -1$ $\quad$ $b = -1$ $\quad$ $a - 1 + 3 - 1 = 0$

$a = -1$

→ Π_2 term

$$\Pi_2 = (L)^a (V)^b (\rho)^c g$$

$$M^0L^0T^0 = (L)^a (LT^{-1})^b (ML^{-3})^c LT^{-2}$$

$c = 0$ $\quad -b-2=0$ $\quad a+b-3c+1=0$

$b = -2$ $\quad a-2+1=0$

$a = 1$

$$\Pi_2 = \frac{Lg}{V^2}$$

→ Π_3 term

$$\Pi_3 = (L)^a (V)^b (\rho)^c R$$

$$M^0L^0T^0 = (L)^a (LT^{-1})^b (ML^{-3})^c MLT^{-2}$$

$c+1=0$ $\quad -b-2=0$ $\quad a+b-3c+1=0$

$c=-1$ $\quad b=-2$ $\quad a-2+3+1=0$

$a=-2$

$$\Pi_3 = \frac{R}{\rho V^2 L^2}$$

$$f(\Pi_1, \Pi_2, \Pi_3) = 0$$

$$f\left(\frac{\mu}{\rho V L}, \frac{Lg}{V^2}, \frac{R}{\rho V^2 L^2}\right) = 0$$

$$\Rightarrow \frac{R}{\rho V^2 L^2} = k f\left(\frac{\mu}{\rho V L}, \frac{Lg}{V^2}\right) \quad k = \text{const}$$

$$R = k \rho V^2 L^2 f\left(\frac{\mu}{\rho V L}, \frac{Lg}{V^2}\right)$$

20

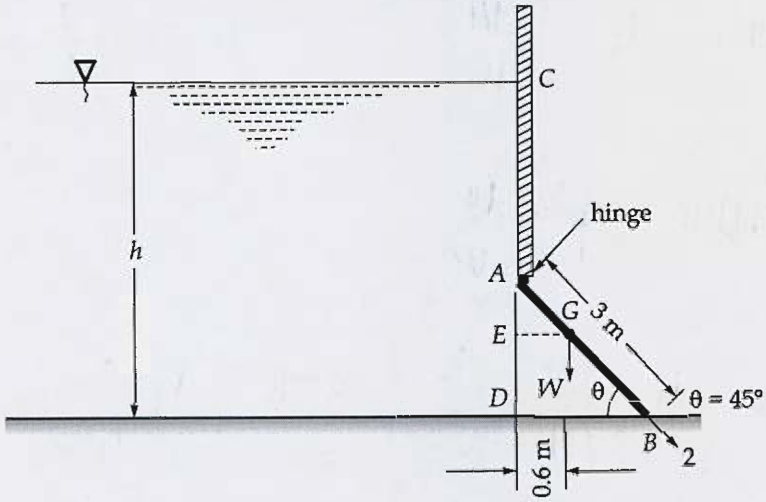
R is a function of $\frac{\mu}{\rho V L}$

Reynold's number $R_e = \frac{\rho V L}{\mu}$ so $R = f\left(\frac{1}{R_e}\right)$

R is a function of $\frac{Lg}{V^2}$

Froude Number $F_r = \frac{V}{\sqrt{gL}}$ so $R = f\left(\frac{1}{F_r^2}\right)$

Q.4 (a) A rectangular sluice gate AB, 2 m wide and 3 m long is hinged at A as shown in figure. It is kept closed by a weight fixed to the gate. The total weight of the gate and weight fixed to the gate is 343350 N. Find the height of the water 'h' which will just cause the gate to open. The centre of gravity of the weight and gate is at G.



[20 marks]

(b) **(i)** Explain radial flow reaction turbine. Describe its main components with the help of schematic diagram.

(ii) A Francis turbine with an overall efficiency of 75% is required to produce 150 kW power. It is working under a head H of 7.5 m. The peripheral velocity = $0.25\sqrt{2gH}$ and the radial velocity of flow at inlet is $0.95\sqrt{2gH}$. The wheel runs at 160 rpm and hydraulic losses in the turbine are 20% of the available energy. Assuming radial discharge, determine:

1. The guide blade angle
2. The wheel angle at inlet
3. Diameter of wheel at inlet, and
4. Width of the wheel at inlet

[10 + 10 = 20 marks]

(c) Find the convective acceleration at the middle of a pipe which converges uniformly from 0.4 m diameter to 0.2 m diameter over 2 m length. The rate of flow is 20 lit/s. If the rate of flow changes uniformly from 20 lit/s to 40 lit/s in 30 seconds, find the total acceleration at the middle of the pipe at 15^{th} second.

[20 marks]

Section B : Water Resource Engineering and Hydrology

Q.5 (a) For a catchment area of 12 km^2, a 7 hr storm pattern is as follows:

Time (h)	1	2	3	4	5	6	7
Precipitation (mm)	20	40	0	30	50	40	5

The discharge observed at the gauging site is as follows:

Time(h)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Discharge(Q)(m^3/s)	0	8	19	34	68	58	48	40	25	19	15	11	6	3	0

Assume the evaporation loss to be 3 mm and the seepage loss equal to 50% of the evaporation loss. Calculate ϕ-index and w-index.

[12 marks]

Total Precipitation = 20 + 40 + 30 + 50 + 40 + 5 = 185 mm

Evap^n losses = 3mm   seepage loss = 0.5 × 3 = 1.5 mm

Total Runoff : Since the time interval b/w the ordinates of the Flood runoff hydrograph are equal so

Volume = Σordinates × time interval

$= \frac{354\ m^3}{s} \times 1 \times 60 \times 60 = 1274400\ m^3$

Depth of runoff = $\frac{V}{A} = \frac{1274400}{12 \times 10^6} = 0.1062$ m

= 106.2 mm

From mass conservation principle

$P = E + S + I + R$ Infiltration $= 185 - 3 - 1.5 - 106.2$

$= 74.3$ mm

W-index $= \dfrac{\text{Total infiltration}}{\text{Total time of rainfall}} = \dfrac{74.3}{6} = 12.383$ mm/hr

$q \geq W$ so 5 mm/hr will not contribute to runoff

Assume every other rainfall contributes to runoff

$20 + 40 + 30 + 50 + 40 - 5\phi = 106.2$ $\phi = 14.76$ mm/hr

~~Then I = 14.76×5 + 5 = 78.8 mm ≠ 74.3 mm~~

~~Assume 20 mm/hr is also not contributing~~

~~40 + 30 + 50 + 40 − 4φ = 106.2~~

~~φ = 13.45 mm/hr~~

Time	Ppt	Intensity
1	20	20 mm/hr
2	40	40 mm/hr
3	0	0 mm/hr
4	30	30 mm/hr
5	50	50 mm/hr
6	40	40 mm/hr
7	5	5 mm/hr

8

(b) A tube well penetrates fully into a confined aquifer. The following data was collected during observations. Calculate the discharge from the well.

Radius of tube well = 20 cm → r_w

Thickness of confined aquifer = 25 m → Taken as B

Drawdown = 4 m → S_w

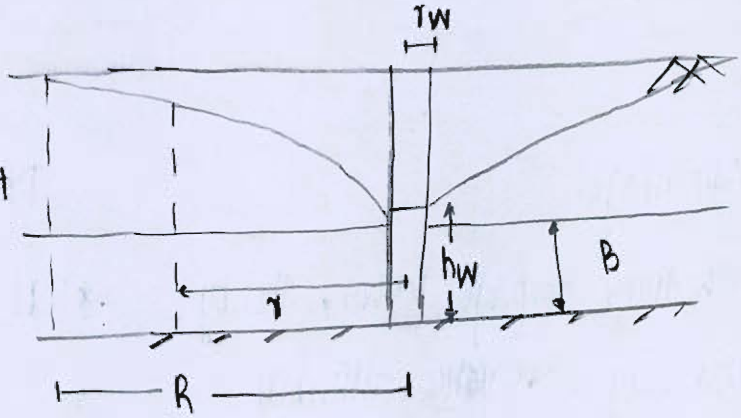
Radius of circle of influence = 300 m → R

Coefficient of transmissibility = 125×10^{-4} m^2/sec. → T

Also calculate the coefficient of permeability. **[12 marks]**

Assumptions for derivation of discharge formula ↑ Given of notations

let at any distance r
the head w be h



dh / dr

And for dr dist travelled
it losses dh head

so $i = \frac{dh}{dr}$ from Darcy's law $Q = kiA$

$$Q = k \times \frac{dh}{dr} \times 2\pi B r$$

$$Q \cdot \frac{dr}{r} = 2\pi k B \, dh$$ Integrate it

$$Q \int_{r_w}^{R} \frac{dr}{r} = 2\pi k B \int_{h_w}^{H} dh \Rightarrow Q = \frac{2\pi k B (H - h_w)}{\ln \frac{R}{r_w}}$$

Now $r_w = 0.2m$ $B = 25m$ $S_w = H - h_w = 4m$ $R = 300m$

$T = kB = 125 \times 10^{-4}$

$$Q = \frac{2\pi \times 125 \times 10^{-4} \times (4)}{\ln\left(\frac{300}{0.2}\right)} = 0.0429 \ m^3/s \text{ or } 42.9 \ L/s$$

$$k = \frac{T}{B} = \frac{125 \times 10^{-4}}{25} = 5 \times 10^{-4} \ m/s$$

(12)

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(c) Explain the advantages and disadvantages of canal lining in irrigation canal.

[12 marks]

Advantages

* Reduces seepage losses, thereby increasing conveyance efficiency.
* Helps in avoiding water logging
* Helps in prevent scouring and erosion of soil

Disadvantages

* It is costly

other points ??

2

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(d) Determine the frequency of irrigation from the following data:
Field capacity of soil = 35%
Permanent wilting point = 18%
Density of soil = 1.5 g/cm³
Depth of root zone = 70 cm
Daily consumptive use of water = 17 mm
(Take: Readily available moisture as 75% of the available moisture.)

[12 marks]

FC = 35% pwp = 18% γ_d = 1.5 g/cm³ d = 0.7m

C_u = 17mm/day

Readily available moisture = 0.75 (FC − pwp)

From $d_w = \frac{\gamma_d}{\gamma_w} \times d \times$ (Moisture content)

depth of water ~~provided~~ req'd ~~on every~~ irrigation by root zone

$d_w = \frac{1.5}{1} \times 0.7 \times 0.75(0.35 - 0.18)$

= 0.133875 m = 133.875 mm

Frequency of irrigation = $\frac{d_w}{C_u} = \frac{133.875}{17}$ = 7.875 days

So Frequency = 7 days

12

(e) Compares Kennedy's theory and Lacey's theory for the design of alluvial canals. Also discuss about the major drawbacks of Lacey's theory in the design of stable channels in alluvial soils.

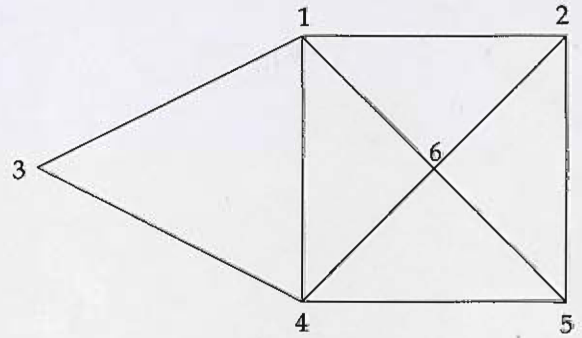
[12 marks]

Kennedy's Theory	Lacey's Theory
→ Trial and error method ~~valo~~ depth has to be assumed and then $V = 1.55 m y^{0.64}$	→ No need to assume depth we can get v directly $V = \left(\frac{Qf^2}{140}\right)^{1/6}$
→ No factor for particle size taken.	$f = 1.76\sqrt{d_{mm}}$ silt factor → factor for silt size taken
→ No seperate eqn ~~of~~ for slope of channel	→ Eqn to evaluate slope is given $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$
→ Eddies assumed to be generated over bed only	→ Eddies assumed to be generated over bed and side ~~slope~~ both

Drawbacks ??

7

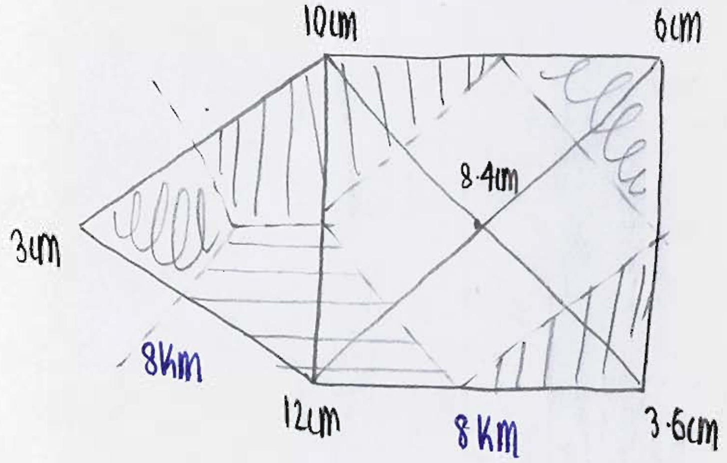
Q.6 (a) (i) Calculate the mean precipitation for the area sketched below by Thiessen's polygon method. The area is composed of a square plus an equilateral triangle of side 8 km. Rainfall reading in cm at the various stations are given in table below.



Rain gauge	1	2	3	4	5	6
Rainfall reading	10 cm	6 cm	3 cm	12 cm	3.6 cm	8.4 cm

(ii) Discuss different forms of precipitation. How measurement of precipitation is done?

[12 + 8 = 20 marks]



After drawing ⊥er bisectors the area is divided and alloted to diff raingauges as follows

A for 3cm : $\frac{1}{3} \times \frac{\sqrt{3}}{4} \times 8^2 = 9.237 \, km^2$

A for 10 cm and 12cm : $\frac{1}{3} \times \frac{\sqrt{3}}{4} \times 8^2 + \frac{8^2 - 32}{4} = 9.237 + 8$
$= 17.237 \, km^2$

A for 6 cm and 3.6 cm : $\frac{8^2 - 32}{4} = 8 \, km^2$

A for 8.4cm : $\frac{1}{2} \times 8^2 = 32 \, km^2$

$$\bar{P} = \frac{\Sigma P_i A_i}{\Sigma A_i} = \frac{3 \times 9.237 + (10+12) 17.237 + (6+3.6) \times 8 + 8.4 \times 32}{~~91.72~~}$$

$\bar{P} = 8.2 cm$ //

(12)

Forms of Precipitation

Rain

- Droplet size 0.5 mm to 6 mm
- Intensity > 2.5 mm/hr

Drizzle

- Droplet size < 0.5 mm
- Intensity < 1 mm/hr

Snow

- Ice flakes falling down with $\rho < 1 g/cm^3$

Hail

- Snow of size > 8 mm
- Dangerous

Glaze

- When rain drop is falling and due to surrounding low temp it converts into ice in air itself.

Sleet

When rain drop falls on ground and then converts into ice due to freezing temp of ground.

(5)

Rainfall measurement ??

(b) **(i)** In a wide stream, a suspended load sample taken at a height of 0.6 m from the bed indicated a concentration of 1200 mg/l of sediment by weight. The stream is 6 m deep and has a bed slope of 1/5000. The bed material can be assumed to be of uniform size with a fall velocity of 4 cm/s. Determine the concentration of the suspended load at 2 m below top surface. Assume Von Karman's constant = 0.40.

(ii) Table below gives the details for a certain crop. Using Blaney-Criddle equation and a crop factor K = 0.80, determine the following :

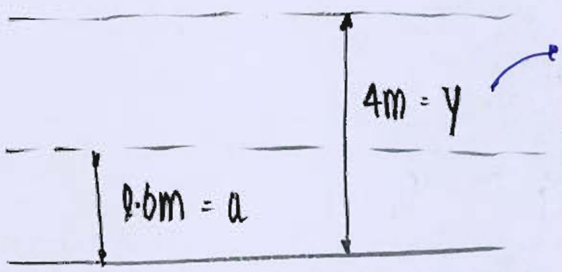
1. consumptive use
2. consumptive irrigation requirement
3. field irrigation requirement, if water application efficiency is 0.75. The latitude of the place is 30° N.

Month	Monthly Temp. (°C)	Monthly (%) of day time hours of the year	Useful rainfall (cm)
August	22	7.20	–
September	19	7.18	1.5
October	18.5	7.50	0.6
November	16	7.30	–

(iii) Write a short note on quality of irrigation water.

[10 + 6 + 4 = 20 marks]

(i)



$W_0 = 0.04 m/s \quad k = 0.4$

$\tau_0 = \gamma_w R S$ wide stream $R \approx y = 6m$

$\tau_0 = 9810 \times 6 \times \frac{1}{5000} = 11.772 \frac{N}{m^2} \quad V_* = \sqrt{\frac{\tau_0}{\rho}} = 0.1085 m/s$

We know that $\frac{C_y}{C_a} = \left[\frac{a(D-y)}{y(D-a)}\right]^{\frac{W_0}{kV_*}}$

$\frac{C_y}{1200} = \left[\frac{0.6(6-4)}{4(6-0.6)}\right]^{\frac{0.04}{0.4 \times 0.1085}}$

10

$\Rightarrow C_y = 83.6$ mg/L //

(ii)

Month	Temp	p%	Rainfall	$\frac{C_u}{E_t} = \frac{kP}{40}(1.8t+32)$
Aug	22	7.2	-	10.3104 cm
Sept	19	7.18	1.5	9.50632 cm
Oct	18.5	7.5	0.6	9.795 cm
Nov	16	7.3	-	8.8768 cm

Blaney criddle eqn : $\frac{kP}{40}(1.8t+32)$ k = ~~0.8~~ 0.8

1. Consumptive use. $C_u = 10.3104 + 9.50632 + 9.795 + 8.8768$

$= 38.48852$ cm

2. Consumptive Irrigation reqm't $= C_u - P_e$

$= 38.48852 - (1.5 + 0.6) = 36.38852$ cm (CIR)

3. Field irrigation reqm't $= \frac{CIR}{\eta_a}$ ~ application efficiency

$FIR = \frac{36.38852}{0.75} = 48.518$ cm //

6

(iii) Quality of Irrigation Water

- It plays an important role in productivity of crops. It is determined by various substances (harmful) present in irrigation water.

- Irrigation water should be free from ~~magnesium and calcium~~ sodium ions.

sodium adsorption ratio $SAR = \frac{Na^+}{\sqrt{\frac{Mg^{+2} + Ca^{+2}}{2}}}$

	Suitable for
SAR < 10	Almost all crops
SAR 10 to 18	most crops except which are very susceptible
SAR 18 to 26	High resistent crops
SAR >26	not suitable

2

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(c) A 12-hour storm rainfall with the following depths (in cm) occurred over a basin :
2.0, 2.5, 7.6, 3.8, 10.6, 5.0, 7.0, 10.0, 6.4, 3.8, 1.4 and 1.4
The surface runoff resulting from the above storm is equivalent to 27.5 cm of depth over basin. Calculate the average infiltration index for the basin.
Also calculate the average depth of hourly rainfall excess for a basin of area of 150 hectares. The basin consists of area A_1, A_2 and A_3 having average infiltration indices as given below :

Area	A_1	A_2	A_3
Area (hectares)	40	60	50
Infiltration index (cm/hr)	7.5	4	0.8

[20 marks]

Total precipitation = ΣP_i = 61.5 cm

Total runoff = 27.5 cm

Assuming other losses to be zero

from mass conservation $P = I + R$

$I = P - R = 34$ cm

Avg Infiltration = $\frac{\text{Total infiltration}}{\text{Total Time}}$ = 2.83 cm/hr

00

.7 (a) A masonry dam 10 m high is trapezoidal in section with top width of 1 m and bottom width of 8.25 m. The face exposed to water has a batter of 1:10. Depth of water at upstream level is 10 m. Calculate:

1. Factor of safety against overturning
2. Factor of safety against sliding
3. Shear friction factor

Assume coefficient of friction as 0.75, unit weight of masonry as 2240 kg/m^3.

Permissible shear stress of joint = 14 kg/cm^2. Based on the results give your remarks.

[Neglect uplift pressure and water level at downstream side]

[20 marks]

(b) (i) Describe various methods of surface irrigation with their advantages and disadvantages.

(ii) For a river, the estimated flood peaks for two return periods by the use of Gumbel's method, are given below.

Return period (years)	Peak flood (m^3/s)
100	485
50	445

What flood discharge in this river will have a return period of 1000 years?

[10 + 10 = 20 marks]

(c) (i) What do you meant by 'Stage' of a river? List the different methods of measurement of stage of a channel, by distinguishing it from gauge height.

(ii) Compute the flood discharge in a stream by the slope-area method for the following data:

	Area of cross-section (m^2)	Wetted perimeter (m)	Roughness coefficient (n)
Section 1-1	206	65	0.045
Section 2-2	200	53.8	0.045

The drop in head and length between the two sections are 0.98 m and 125 m, respectively.

[6 + 14 = 20 marks]

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8 (a) (i) The base period, intensity of irrigation and duty of various crops under a canal system are given in the table below. Calculate the reservoir capacity if the canal losses are 25% and the reservoir losses are 10%.

Crop	Base Period (days)	Duty at the field (hectare / cumec)	Area under the crop (hectares)
Wheat	110	1600	4800
Sugarcane	360	720	5800
Cotton	200	1800	2500
Rice	140	1000	3600
Vegetable	180	800	1500

(ii) Define the following terms :

1. Effective rainfall
2. Consumptive irrigation requirement
3. Net irrigation requirement
4. Field irrigation requirement
5. Gross irrigation requirement

[15 + 5 = 20 marks]

(b) (i) Explain the term "Exit Gradient". Using Khosla's theory, estimate the value of exit gradient for a weir with a horizontal floor on a permeable foundation having width b = 10m, and depth of downstream sheet pile = 1.5 m. Given the difference between upstream and downstream water levels is 4 m.

(ii) What do you understand by river training? State its objectives and also write in brief about groynes, their types and support your answer with suitable sketches.

(iii) Design a regime channel for a discharge of 50 m^3/s and silt factor 1.1 using Lacey's Theory.

[Assume any other data suitably]

[4 + 4 + 12 = 20 marks]

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(c) In Muskingum method by McCarthy, the storage in a stream is given by $S = K[xI + (1-x)O]$ where K is storage constant. Also, basic routing equation written for discrete time is

$$\left(\frac{I_1 + I_2}{2}\right)t - \left(\frac{O_1 + O_2}{2}\right)t = (S_2 - S_1)$$

Derive from these the Muskingum equation of flood routing and determine the coefficients therein. What is the sum of these coefficients?

[20 marks]

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Space for Rough Work

Space for Rough Work

1, 2, 3
5, 6 //

$Q = kiA$

$dQ = k \cdot \frac{dh}{dr} \cdot 2\pi r$

$dQ \cdot \frac{dr}{r} = K\, 2\pi$

$\frac{V}{dt}$

$\frac{W_0}{kV_*}$

$Q = \frac{2\pi KB\,(h_1 - h_2)}{\ln \frac{r_2}{r_1}}$

$Q \ln r$

$\frac{Q}{r}\, dr = 2\pi KB\, dh$

$R = F = Ma$

MLT^{-2}

$F_1^2 = \frac{Q^2 T}{gA^3} = \frac{Q^2 \times 2my}{g \times m^3 y^6} = \frac{2Q^2}{gm^2}\left[\frac{1}{y_1^5}\right]$

$\frac{\tau_0}{\rho U_\infty^2} = \frac{\partial \theta}{\partial x} \quad \frac{\partial \delta}{\partial x}$

$\frac{Q^2}{gm^2} = \frac{y_1^5 F_1^2}{2}$

$y_1 + \frac{F_1^2 y_1^5}{2 \cdot 2 y_1^4}$

$= y_1 \left(4 + F_1^2\right]$

$\frac{\rho U_\infty x}{\mu} = \frac{U_\infty x}{\nu}$

$A = my^2 \qquad m = \frac{A}{y^2} \quad y^2 = \frac{A}{m}$

$P = 2y\sqrt{m^2+1} \qquad P^2 = 4y^2\,(m^2+1)$

$\frac{A}{m}\left(m^2+1\right) \qquad A\left(m + \frac{1}{m}\right)$

$1 - \frac{1}{m^2}$