219/300

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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	52
Q.2	
Q.3	59
Q.4	
Section-B	
Q.5	42
Q.6	37
Q.7	29
Q.8	
Total Marks Obtained	219/300

Signature of Evaluator: ADS

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.

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

.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/m^3, kinematic viscosity of air, ν_{air} = 1.40 × 10^{-5} m^2/s.]

Coefficient of drag

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

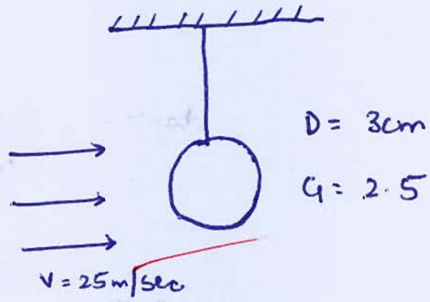
[12 marks]

a)

$Re = \dfrac{\rho_{air} V_{air} D}{\mu}$

$= \dfrac{25 m/sec \times 3\times10^{-2} m}{1.4\times10^{-5} \; m^2/sec}$

$= 53571.42$



For $Re < 3\times10^5$ $C_D = 0.5$

$\therefore$ Drag Force $(F_D) = \frac{1}{2}\times C_D \times \rho \times A \times V^2$

$= \frac{1}{2}\times 0.5\times 1.25 \times \pi\times(1.5\times10^{-2})^2 \times 25^2$

$= 0.138$ N

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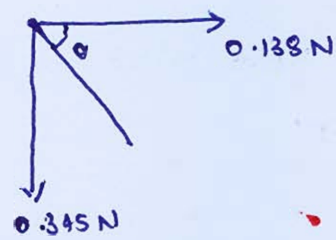
By vertical equilibrium

$T = mg$

$T = 2.5\times10^3 \times 9.81 \times \frac{4}{3}\times\pi\times(1.5\times10^{-2})^3$

$= 0.345$ N

∴ By FBD of sphere



$\tan\theta = \frac{0.345}{0.138}$

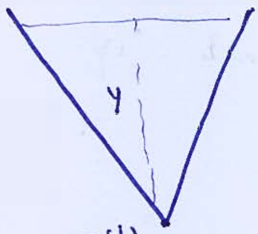
Inclination wrt horizontal = 68.19°

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

[12 marks]

b) Let depth of channel be y

& side slope = mH : 1V



∴ Area of channel = $\frac{1}{2} \times 2my \times y = my^2$ — (i)

wetted Perimeter of channel $= 2y\sqrt{1+m^2}$

For most efficient channel

$$\frac{dP}{dy} = 0$$

$$\frac{d}{dy}\left(2y\sqrt{1+m^2}\right) = 0$$

By (i) $m = \frac{A}{y^2}$

$$\therefore \frac{d}{dy}\left(2y\sqrt{1+\frac{A^2}{y^4}}\right) = 0$$

$$= 2\sqrt{1+\frac{A^2}{y^4}} + \frac{y \times 2}{2\sqrt{1+\frac{A^2}{y^4}}} \times \frac{-4}{y^5}A^2 = 0$$

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

$$= 2 + \frac{2A^2}{y^4} = \frac{4A^2}{y^4}$$

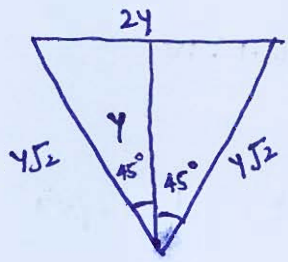
$$\frac{2A^2}{y^4} = 2 \qquad \therefore A^2 = y^4$$

$$m^2y^4 = y^4 \quad \{\text{From (i)}\}$$

$\therefore m = \pm 1$

$\therefore \theta = 45°$

$\therefore$ channel is



Since the two adjacent side are ⊥r & equal it is a half square

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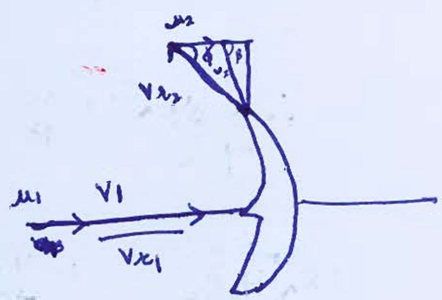
Need to prove this

(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]

For Pelton Turbine,



$\dot{m} = \rho Q$

$= \rho a V_{r_1}$

Now, by momentum eqn

$F_x = \rho Q (V_{r_1} + V_{r_2} \cos\phi)$

For smooth impact ~~$V_{r_1} = V_{r_2}$~~

~~$F_x = \rho Q (V_{r_1})(1 + \cos\phi)$~~

Power = $\rho Q (V_{r_1} + V_{r_2} \cos\phi) \times u$

$V_{r_1} = V_1 - u_1$

& $V_{r_1} = V_{r_2}$ (Smooth impact)

$\therefore P = \rho Q (V_1 - u_1)(1 + \cos\phi) \times u$

Efficiency $= \dfrac{\rho Q (V_1 - u_1)(1+\cos\phi) u}{\frac{1}{2} \times \rho Q \times V_1^2}$

$= \dfrac{2(V_1 - U_1)(1+\cos\phi) u}{V_1^2}$

For max Efficiency $= \dfrac{dP}{du} = 0$

$\dfrac{d}{du} 2(u V_1 - u^2) = 0$

$= V_1 - 2u = 0$

$\boxed{u = V_1/2}$

For max efficiency $u = \dfrac{V_1}{2}$

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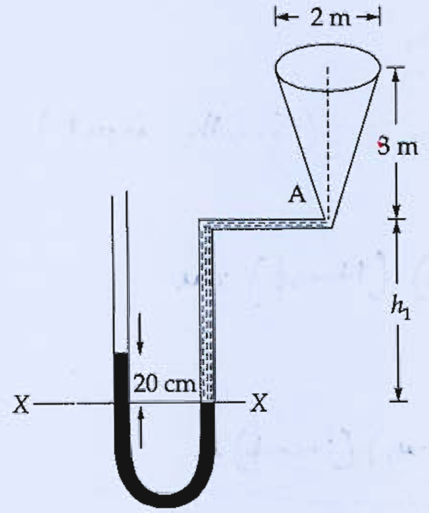
Expression for max eff $= \dfrac{\frac{2V_1}{2}(1+\cos\phi)\frac{V_1}{2}}{V_1^2} = \left(\dfrac{1+\cos\phi}{2}\right)$

(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]

(d) When empty

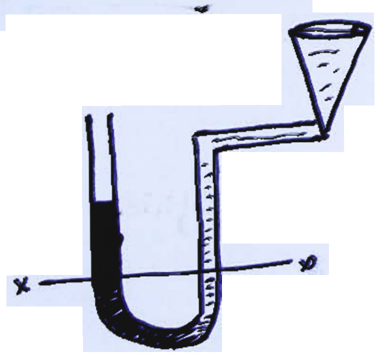
pressure at X-X = equal

$\therefore \rho_w \times g \times h_1 = \rho_m \times g \times 0.2\ m$

$h_1 = \frac{13600 \times 0.2}{1000}$

$= 2.72\,m$

Now, when vessel is filled with water



pressure at X-X = equal

$\therefore \rho_w g (h_1 + 3) = \rho_m g x$

$\rho_w g (5.72) = \rho_m g x$

$x = \dfrac{1000 \times 5.72}{13,600}$

= 0.420 m

= 42cm

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:

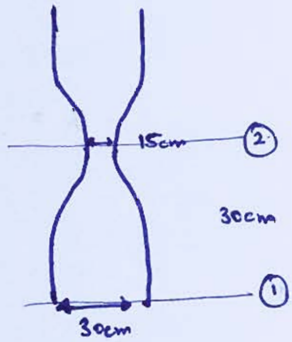
(i) The discharge of oil

(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]

Solⁿ

Applying Bernoulli eqⁿ btw ① & ②



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\therefore \frac{V_2^2}{2g} - \frac{V_1^2}{2g} = \underbrace{\frac{P_1}{\rho g} + z_1 - \left(\frac{P_2}{\rho g} + Z_2\right)}_{h} \quad \text{—(i)}$$

By continuity

$$A_1 V_1 = A_2 V_2$$

$$\frac{\pi}{4} \times (30)^2 \times V_1 = \frac{\pi}{4} \times 15^2 \times V_2$$

$$4V_1 = V_2 \quad \text{—(ii)}$$

Piezometric difference by U tube manometer

$$h = \left(\frac{\rho_m}{\rho} - 1\right) x$$

$$= 12.6 \times 0.25 = 3.15 \text{ m}$$

∴ putting in (i)

$$16V_1^2 - V_1^2 = 2 \times 9.81 \times 3.15$$

$$15V_1^2 = 2 \times 9.81 \times 3.15$$

$$V_1 = 2.02 \text{ m/sec}$$

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$\therefore$ Q_{theo} of oil $= A_1 V_1$

$= \frac{\pi}{4} \times 0.3^2 \times 2.02$

$= 0.1427\ m^3/sec$

$Q_{act} = C_d \times Q_{th} = 0.98 \times 0.1427 \approx 0.14\ m^3/sec$

(ii) Now,

In (i)

$$\frac{P_1}{\rho g} + z_1 - \frac{P_2}{\rho g} - z_2 = h = 3.15\ m$$

$$\therefore \frac{P_1 - P_2}{\rho g} + 0 - 0.3\ cm = 3.15$$

$$\frac{P_1 - P_2}{\rho g} = 3.45\ m$$

$$P_1 - P_2 = 3.45 \times 900 \times 9.81$$

$$= \boxed{30.460\ KPa}$$

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Q.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]

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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} m^2/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/m^3.

[20 marks]

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

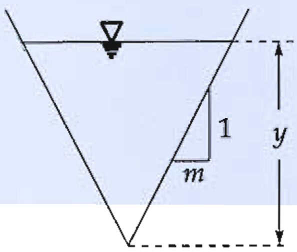
$$\phi = (x^2 - y^2) + 3xy.$$

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]

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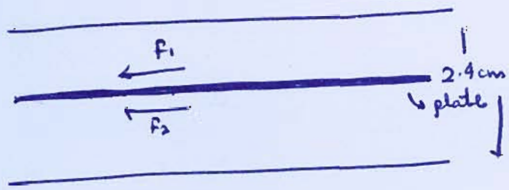
Q.3 (a) Two large plane surfaces are 2.4 cm apart. The space between the surfaces is filled with glycerine. What force is required to drag a very thin plate of surface area 0.5 square metre between the two large plane surfaces at a speed of 0.6 m/s, if:

(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) ~~Ass~~ Since distance btw plates is less, assuming linear ~~Newton~~ ~~viscosity~~ velocity distribution



$$\therefore F_{drag} = F_1 + F_2$$

$$= \mu\left(\frac{v-0}{t}\right) \times A + \mu\left(\frac{v-0}{t}\right) \times A$$

μ: dynamic viscosity of glycerine

v = velocity of plate

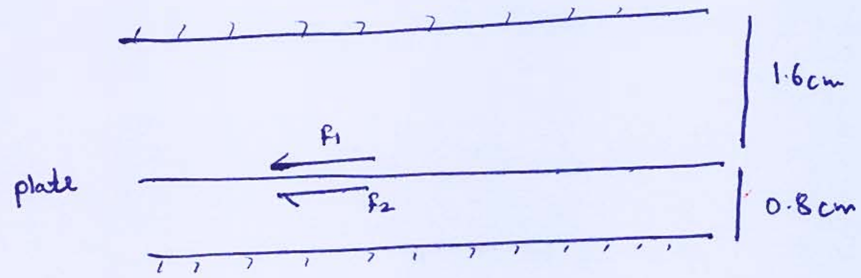
t = thickness btw plate & layer

A = SA of plate

$$= 8.1\times10^{-1}\left(\frac{0.6-0}{1.2\times10^{-2}}\right)\times 0.5 + 8.1\times10^{-1}\left(\frac{0.6-0}{1.2\times10^{-2}}\right)\times 0.5$$

$$= 40.5\ N$$

(ii)



Now,

$$F_{drag} = F_1 + F_2$$

$$= \mu\left(\frac{V-0}{t_1}\right)A + \mu\left(\frac{V-0}{t_2}\right)A$$

$$= 8.1\times10^{-1}\left(\frac{0.6-0}{0.8\times10^{-2}}\right)\times 0.5 + 8.1\times10^{-1}\left(\frac{0.6}{1.6\times10^{-2}}\right)\times 0.5$$

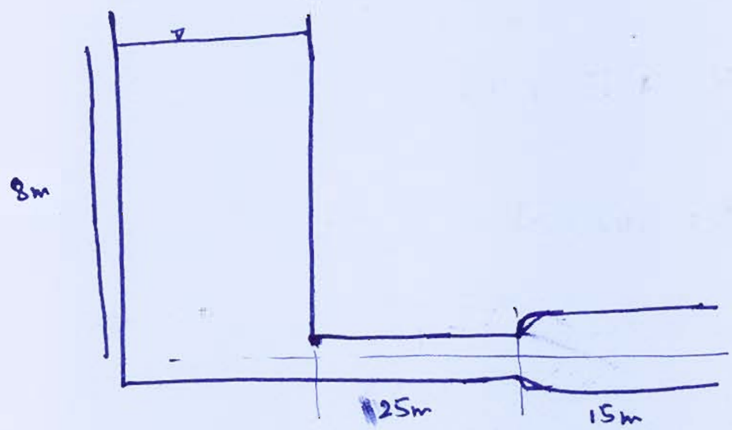
$$30.375 + 15.1875$$

$$= 45.5625\ N$$

(20)

(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]



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(b) Losses

① Sudden Entry in 150 mm pipe $= \frac{0.5 V^2}{2g}$

$$= \frac{0.5 \times Q^2}{2g \times \left(\frac{\pi}{4} \times 0.15^2\right)^2}$$

{Q = AV} by cont

② Friction loss in 150 ϕ pipe by Darcy Weisbach Eqn

$$= \frac{8Q^2 \times 4f' \times 25}{\pi^2 \times g \times 0.15^5} = \frac{8Q^2 \times 0.04 \times 25}{\pi^2 \times 9.81 \times 0.15^5}$$

③ Sudden Expansion

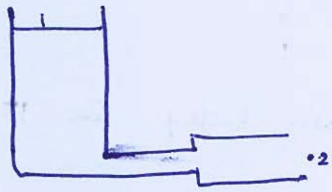
$$= \frac{(V_1 - V_2)^2}{2g} = \frac{\left(\frac{Q}{\frac{\pi}{4} \times (0.15)^2} - \frac{Q}{\frac{\pi}{4} \times (0.30)^2}\right)^2}{2g}$$

④ Friction loss in 300 ϕ pipe

$$= \frac{8Q^2 \times 0.04 \times 15}{\pi^2 \times g \times 0.3^5}$$

⑤ Sudden Exit $= \frac{V^2}{2g} = \frac{\left(\frac{Q}{\frac{\pi}{4} \times 0.3^2}\right)^2}{2g}$

Now



Applying Bernoulli btw ① & ②

$$\frac{P_{atm}}{\rho g} + \frac{V^2}{2g} + 8 = \frac{P_{atm}}{\rho g} + \frac{V^2}{2g} + 0 + h_L$$

Total h_L = 8m

Equating total loss = 8m

$$81.606\,Q^2 + 1088.09\,Q^2 + 91.807\,Q^2 + 20.401\,Q^2 + 10.2\,Q^2 = 8$$

$$\boxed{Q = 78.68\ l/sec}$$

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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]

c) Total variables = R, v, l, μ, ρ, g
= 6

No. of fundamental variables = 3

∴ No. of π terms = $m-n = 6-3 = 3$

∴ Let π terms

$= (\rho^a v^b l^c)\mu$; $(\rho^a v^b l^c)R$; $(\rho^a v^b l^c)g$

∴ I π term

$= (\rho^a v^b l^c)\mu$

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

∴ $a+1 = 0$ $\quad a = -1$

$-b-1 = 0$ $\quad b = -1$

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

$\therefore \ \pi \text{ term} = \dfrac{\mu}{\rho V l}$

II π term

$(\rho^a V^b l^c)\ R$

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

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

$-b-2 = 0 \qquad b = -2$

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

$\therefore (\rho^{-1} V^{-2} l^{-2}) R = ?$

III π term

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

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

$a = 0$

$-b-2 = 0 \qquad b = -2$

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

$\therefore (V^{-2} l) g = ?$

∴ By Buckingham π theorem

$$f(\pi_1, \pi_2, \pi_3) = 0$$

$$\therefore \frac{R}{\rho v^2 l^2} = K f^n\left(\frac{\mu}{\rho v l}, \frac{gl}{v^2}\right)$$

$$\therefore R = \rho v^2 l^2 \times K \text{ func}\left(\frac{\mu}{\rho v l}, \frac{gl}{v^2}\right)$$

where $\frac{\mu}{\rho v l}$ & $\frac{gl}{v^2}$ are dimensionless terms.

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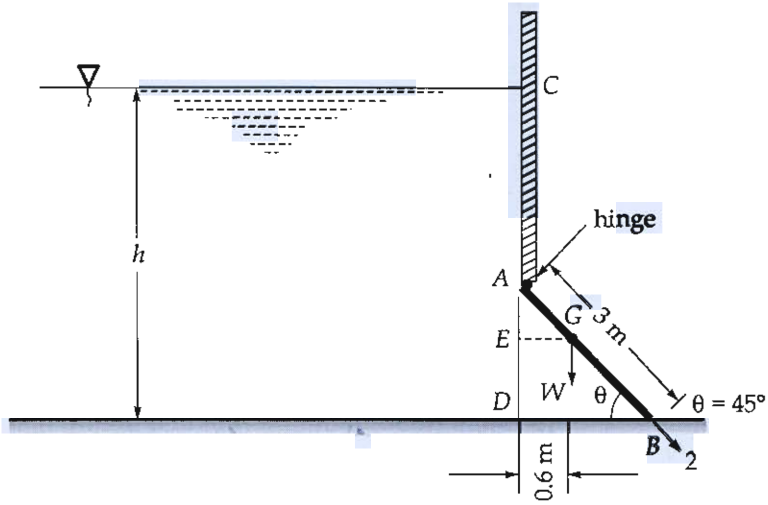
Q.4 (a) A rectangular sluice gate *AB*, 2 m wide and 3 m long is hinged at *A* as shown in figure. It is kept closed by a weight fixed to the gate. The total weight of the gate and weight fixed to the gate is 343350 N. Find the height of the water '*h*' which will just cause the gate to open. The centre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

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(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]

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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]

(a) Total precipitation

$= 20 + 40 + 30 + 50 + 40 + 5$

$= 185$ mm

Total run off $= \dfrac{\Sigma \text{ ordinates of hydrograph} \times \text{time interval}}{\text{Area}}$

$= \dfrac{354 \frac{m^3}{sec} \times 3600 \text{ sec}}{12 \times 10^6 \text{ m}} = 0.1062$ m

$= 106.2$ mm

Initial losses $= 3\text{mm} + 1.5\text{mm}$

$= 4.5$ mm

$\therefore$ w index $= \dfrac{\text{Total ppt}^n - \text{Runoff} - \text{Initial loss}}{\text{Time}}$

$= \dfrac{185 - 106.2 - 4.5}{7}$

$= \boxed{10.614 \text{ mm/hr}}$

Now, ϕ index $\geq$ w index

$\therefore$ 3rd & 7th hour don't contribute to rainfall excess

$\therefore$ $\phi_{index} = \dfrac{\text{Rainfall contributing to runoff} - \text{Runoff}}{\text{time of rainfall excess}}$

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$= \dfrac{180 - 106.2}{5} = \boxed{14.76 \text{ mm/hr}}$

(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

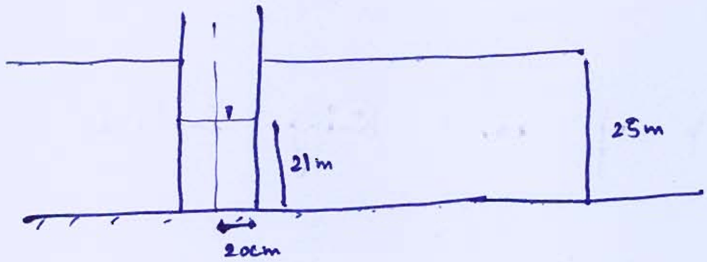
Thickness of confined aquifer = 25 m

Drawdown = 4 m

Radius of circle of influence = 300 m

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

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



Transmissibility = K × B

K = Coeff of permeability
B = Depth of aquifer

$125 \times 10^{-4} = K \times 25$

$\therefore K = 5 \times 10^{-4}$ m/sec

Now discharge from confined aquifer

$$Q = \frac{2\pi K B (h_2 - h_1)}{\ln\left(\frac{R}{r_w}\right)}$$

$$\therefore Q = \frac{2\pi \times 5 \times 10^{-4} \text{ m/sec} \times 25 \times 4}{\ln\left(\frac{300}{0.2}\right)}$$

$Q = 0.0429$ m³/sec

12

Do not write in this margin

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

[12 marks]

(c) The advantages of canal lining include

(i) Less seepage loss

(ii) Less maintenance cost

(iii) Less scouring & silting of channel

(iv) Increased life of the channel

(v) High permitted velocity

» The disadvantages of canal lining include

(i) Very high initial cost

(ii) Decreased command of channel

6

other points ??

(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]

d) Available moisture = FC − PWP

= 35 − 18

~~= 17%~~

Readily available moisture = 75% of 17%

= 12.75%

∴ OMC = 35% − 12.75% = 22.25%

∴ Depth of water (d_w) = $\frac{\gamma_d}{\gamma_w} \times d \times (FC - OMC)$

= $\frac{1.5}{1} \times 70\text{cm} \times 12.75\%$

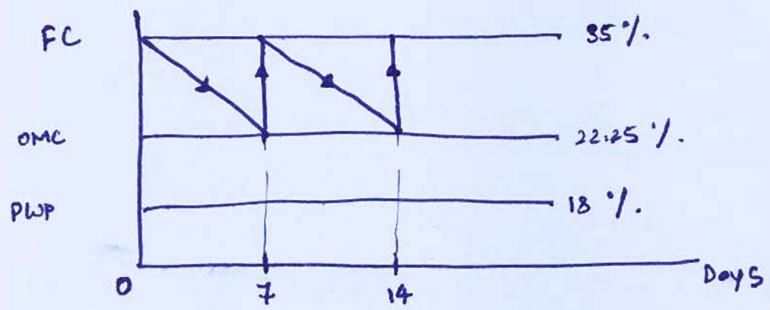
= 13.38 cm

(assuming density of soil is dry density)

12

∴ Frequency of irrigation = $\frac{d_w}{C_u}$ → daily consumptive use

= $\frac{133.8\text{ mm}}{17\text{ mm}}$ = 7.875 = 7 days



(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 Theory	Lacey Theory
(i)	Only bottom resistance was considered	Both bottom & side resistance considered
(ii)	Didn't take silt factor or coefficient in account.	Took only silt factor in account.
(iii)	Regime channel was trapezoidal	Regime channel was with rounded corner
(iv)	Took Kutter's Eq^n to give velocity	Gave his own empirical relations.

Major drawback of Lacey theory was:

(i) Was valid for silt concentration of 500-5000 mg/l

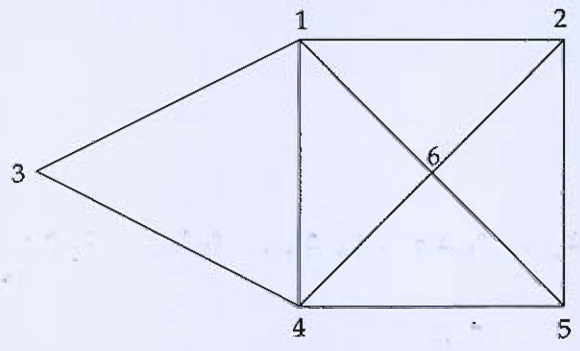
(ii) Regime channel was curved & not trapezoidal

(iii) Didn't take cohesion into consideration

(iv) All formula were empirical

8

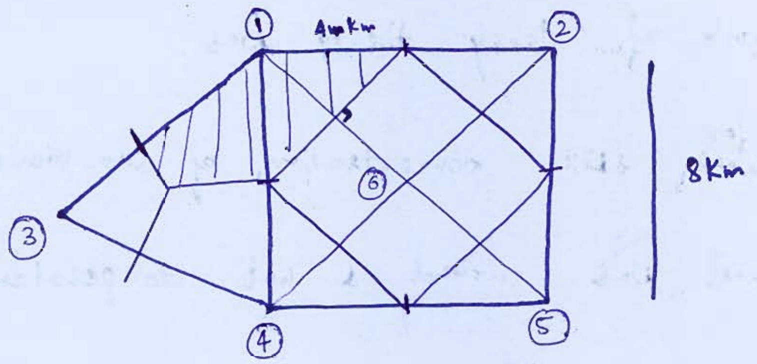
Q.6 (a) (i) Calculate the mean precipitation for the area sketched below by Thiessen's polygon method. The area is composed of a square plus an equilateral triangle of side 8 km. Rainfall reading in cm at the various stations are given in table below.



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]



Dividing the area by drawing bur bisector of line joining R4 station

$A_1 = A_4 = \frac{1}{2} \times 4 \times 4 + \frac{1}{3} \times \frac{\sqrt{3}}{4} \times 8^2$

$= 17.237 \text{ km}^2$

$A_2 = A_5 = \frac{1}{2} \times 4 \times 4 = 8 \text{ km}^2$

$A_6 = 4\sqrt{2} \times 4\sqrt{2} = 32 \text{ km}^2$

$A_3 = \frac{1}{3} \times \frac{\sqrt{3}}{4} \times 8^2 = 9.237 \text{ km}^2$

Now avg ppt^n

$= \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + P_4 A_4 + P_5 A_5 + P_6 A_6}{\Sigma A}$

$= \frac{17.237 \times 10 + 8 \times 6 + 9.237 \times 5 + 17.237 \times 12 + 8 \times 3.6 + 32 \times 8.4}{A}$

$= \frac{752.525}{A} = 8.205 \text{ cm}$

12

(II) Different forms of ppt^n include

(i) Rain : The size of particles ranging from 0.5mm to 6mm is termed as rain

(ii) Drizzle : The ppt^n in which size of particle is less than 0.5mm & intensity < 1 mm/hr is called drizzle

(iii) Hail : When size of particles is > 8mm then it is called hail

(iv) Snow : The particles of density 0.1 g/cc is called snow

(v) Sleet : Frozen raindrops are known as sleet

(vi) ~~Hail~~ Glaze : When raindrops fall on frozen surface, they freeze to form a thin layer of sheet called glaze

>> Precipitation is measured with the help of instrument called RAINGAUGE

There are two types of RAIN GAUGES

Do not write in this margin

(a) Non-Recording type : These Rain gauges don't give the mass curve of the rainfall. Eg Symon's RG

(b) Recording Type : These raingauges give the mass curve of rainfall & give info about intensity of rainfall. Eg Float Type, Tipping Bucket etc

7

Acc^n to IMD, min. 10% of total RG should be of Recording type

(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) $a = 0.6m$

$C_a = 1200$ mg/l

$y = 2m$

$C_y = ?$

We know

$$\frac{C_y}{C_a} = \left(\frac{a}{y}\frac{(D-y)}{(D-a)}\right)^{\frac{w_0}{KV^*}}$$

w_0 = Fall velocity of particles

V^* = Shear velocity

$$V^* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{\gamma_w RS}{\rho}} = \sqrt{\frac{9810 \times 6m \times 1}{5000 \times 1000}}$$

$= 0.108$ m/sec

$$\Rightarrow \frac{C_y}{1200} = \left(\frac{0.6}{2}\frac{(4)}{5.4}\right)^{\frac{0.04}{0.4 \times 0.108}}$$

$= 298.09$ mg/l

ii) By Blaney criddle formula

$$C_u/\text{month} = \frac{Kp}{40}(1.8T + 32)$$

K = crop factor

p = Monthly % day time hours

T = Temp

∴ for Aug $C_u = \frac{0.8 \times 7.20}{40}(1.8 \times 22 + 32)$

$= 10.314$ cm

Sept $C_u = \frac{0.8 \times 7.18}{40}(1.8 \times 19 + 32)$

$= 9.506$ cm

Oct $C_u = \frac{0.8 \times 7.5}{40}(1.8 \times 18.5 + 32)$

$= 9.795$ cm

Nov $C_u = \frac{0.8 \times 7.30}{40}(1.8 \times 16 + 32)$

$= 8.8768$

∴ overall C_u for 4 months $= 38.49$ cm

(b) Consumptive Irr^n Requirement $= C_u - P_{eff}$ (Eff Rainfall)

$= 38.49 - 2.1$ cm $= 36.39$ cm

(c) $FIR = \frac{CIR}{\eta_a} = 48.52$ cm {considering no leaching & pressing requirement

6

(iii) For irrigation water of good quality

→ pH should be between 6 - 8.5

→ Total Dissolved solid should be less than 2100 mg/l

→ There should be less Sodium Absorption Ratio & exchangeable cations → $SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$ in meq/l

→ Boron concentration < 2 mg/l

→ Free carbonates should be less

2

(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 depth of rainfall

$= 61.5$ cm

Total surface run off $= 27.5$ cm

$\therefore$ Avg infiltration index for basin

$$= \frac{\text{Rainfall} - \text{Runoff}}{\text{Time}} = \frac{61.5 - 27.5}{12}$$

$= 2.833$

Since 2 cm/hr, 2.5 cm/hr, 1.4 cm/hr don't contribute to runoff

$$\therefore \text{Avg infiltration index} = \frac{54.2 - 27.5}{8}$$

$= 3.3375$ cm/hr

Avg infiltration index from weighted avg

$$= \frac{A_1I_1 + A_2I_2 + A_3I_3}{A_1 + A_2 + A_3} = 3.866 \text{ cm/hr}$$

Taking min of two, avg infiltration index

= 3.3375 cm/hr

(b) Since 12 hr of rain ⟶ 27.5 cm of rainfall excess

avg hourly depth of excess

$= \frac{27.5 \text{ cm}}{12 \text{ hr}}$

= 2.291 cm/hr

5

Approach not correct

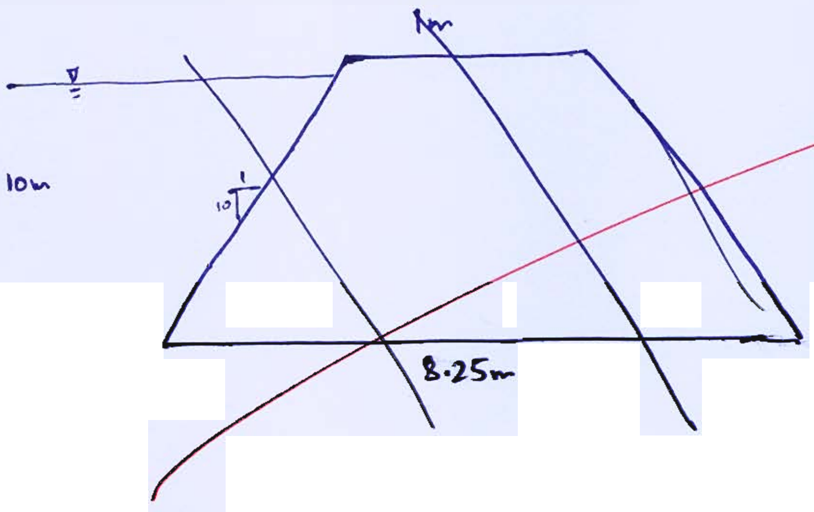
.7 (a) A masonry dam 10 m high is trapezoidal in section with top width of 1 m and bottom width of 8.25 m. The face exposed to water has a batter of 1:10. Depth of water at upstream level is 10 m. Calculate:

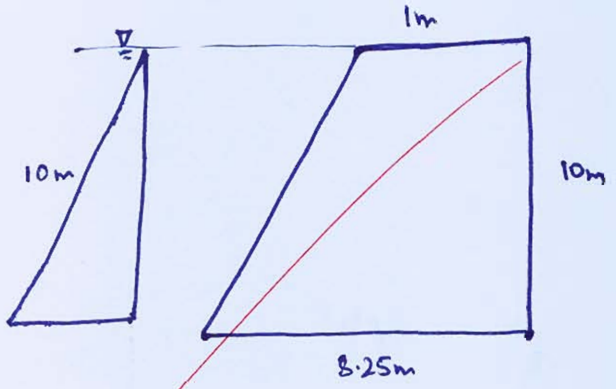
1. Factor of safety against overturning
2. Factor of safety against sliding
3. Shear friction factor

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]

(a)





(a) Total weig

Do not write in this margin

(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]

(ii) we know by gumbel method

$$x_T = \bar{X} + K\sigma \qquad K = \frac{y_T - y_n}{S_n}$$

$$\therefore x_T = \bar{X} + \frac{y_T\sigma}{S_n} - \frac{y_n\sigma}{S_n}$$

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

$\therefore$ for RP of 100 yr $y_T = 4.6$

RP of 50 yr $y_T = 3.901$

RP of 1000 years $y_T = 6.907$

$$\Rightarrow 485 = \bar{X} + \frac{4.6\sigma}{S_n} - \frac{y_n\sigma}{S_n}$$

$$445 = \bar{X} + \frac{3.901\sigma}{S_n} - \frac{y_n\sigma}{S_n}$$

$$X_{\circ} = \bar{X} + \frac{6.907\sigma}{S_n} - \frac{y_n\sigma}{S_n}$$

Let $\bar{X} - \frac{Y_n \sigma}{S_n} = A$

$\therefore$ $485 = A + 4.6B$

$445 = A + 3901B$

$\Rightarrow$ $B = 57.22$

$A = 221.78$

$\therefore$ Flood discharge for 1000 year RP is

$X = A + 6.907B$

$= 617\ m^3/sec$

10

b) Various methods of surface irrigation are

i) Free Flooding : This is method is employed for close growing crop when there is ample supply of water. Eg Paddy

ii) Border strip : In this the entire area is divided into strips & f water is flow irrigated in each strip individually

Do not write in this margin

(c) Check Basin : In this the leeves are constructed both along & in transverse dirn & water is ensured in each area.

(d) Ring Basin : This is employed for orchard trees & water is supplied to each tree individually There is less wastage of water in this system

(e) Furrow : This is employed for crops requiring less water & close growing crop. There is less wastage of water as less land get water at once

(f) Sprinkler : This method has highest application efficiency & is suitable for irregular topography & permeable soil. Evaporation loss is highest & it ~~badly~~ requires high initial & maintenance cost.

It is not surface method of irrigation

Do not write in this margin

Contour Irrigation : This method is used when the ground is irregular.

In this method levees are constructed along the contour & is usually employed in steep slopy terrain

8

(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]

(ii)

	Area	P	R = A/P	$K = \frac{A}{n} R^{2/3}$
Sxn ①	206 m²	65 m	3.169 m	9876.5
Sxn ②	200	53.8	3.717 m	10664.63

∴ K_{avg} = avg conveyance of channel

$= \sqrt{K_1 K_2}$

$= 10263$

Let K_e ~~= 0.1~~

It1 Let $V_1 = V_2$

Applying Bernoulli btw 2 sxn

$$\frac{P}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P}{\rho g} + \frac{V_2^2}{2g} + Z_2 + K_e\left(\frac{V_1^2 - V_2^2}{2g}\right) + H_f$$

$\therefore H_f = Z_1 - Z_2$

$= 0.98 m$

$$Q = K\sqrt{S} = 10263\sqrt{\frac{0.98}{125}} = 908.72 \ m^3/sec$$

2

$v_1 = \frac{Q}{A_1} = \frac{908.72}{206} = 4.411$ $\quad V_2 = \frac{908.72}{200} = 4.54$

∴ Applying Bernoulli

$$\frac{P}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P}{\rho g} + \frac{v_2^2}{2g} + z_2 + K_c\left(\frac{v_1^2 - v_2^2}{2g}\right) + H_f$$

$$\therefore H_f = 0.98 + 0.9\left(\frac{v_1^2 - v_2^2}{2g}\right)$$

$$= 0.927$$

$$\therefore Q = K\sqrt{S} = 10263\sqrt{\frac{0.927}{125}}$$

$$= 883.81 \text{ m}^3/\text{sec}$$

3

$v_1 = \frac{883.81}{206} = 4.29$ $\quad v_2 = \frac{883.81}{200} = 4.42$

∴ Applying Bernoulli

$$\frac{P}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P}{\rho g} + \frac{v_2^2}{2g} + z_2 + K_e\left(\frac{v_1^2 - v_2^2}{2g}\right) + H_f$$

$$H_f = 0.98 + 0.9\left(\frac{v_1^2 - v_2^2}{2g}\right)$$

$$= 0.928$$

$$Q = 10263\sqrt{\frac{0.928}{125}} = 884.2 \text{ m}^3/\text{sec}$$

∵ Q is same as it2 ∴ Peak $Q = 884.2 \text{ m}^3/\text{sec}$

(10)

Do not write in this margin

(i) The height of water surface elevation from bottom is called stage of the river

datum

Different Method to measure stage of river include

(i) Wire gauge

1

(ii) ~~Bubble~~ compressed Bubble gauge

(iii) Float gauge

Do not write in this margin

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]

(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]

Space for Rough Work

Space for Rough Work

Space for Rough Work