1-3

224/300

MADE EASY

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Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-7 : Section A : Design of Steel Structure + Hydrology (All Topics)

Section B : Structural Analysis-1+CPM PERT-1, Flow of fluids, hydraulic machines and hydro power-2 [Part syllabus]

Name : ....

Roll No :

Test Centres	Student's Signature
Delhi ☐ Bhopal ☐ Jaipur ☐ Pune ☐ 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	48
Q.2	
Q.3	55
Q.4	55
Section-B	
Q.5	48
Q.6	18
Q.7	
Q.8	
Total Marks Obtained	224/300

Signature of Evaluator .... 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.

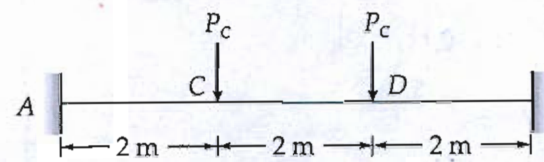
DO'S

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 : Design of Steel Structure + Hydrology

Q.1 (a) **(i)** Write the basic assumptions made in plastic analysis.

(ii) A fixed beam *AB* of span 6 m carries two-point loads *P* at distances of 2 m and 4 m from support *A*. Assuming the beam has a constant plastic moment capacity M_p, calculate the collapse load P_c.



[6 + 6 = 12 marks]

(i) → Assumptions in plastic analysis

I) The yield stress of steel section $\not>$ 450 MPa.

II) The stress strain characteristics of steel shall not be significantly different from steel section following IS 2062.

III) The tensile stress by yield stress ratio shall not be less than 1.2. $\frac{f_u}{f_y} \nless 1.2$

IV) The % elongation in gauge length $\nless$ 15 %

V) The sections should be made of hot rolled steel.

VI) Maximum bending moment $\leq$ Mp (Plastic moment Capacity)

VII) The cross-section should be symmetrical about axis ~~passing~~ $\perp$ to axis of plastic hinge rotation.

VIII) Section should not be subjected to dynamic loading

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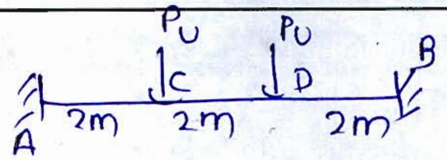
(ii)



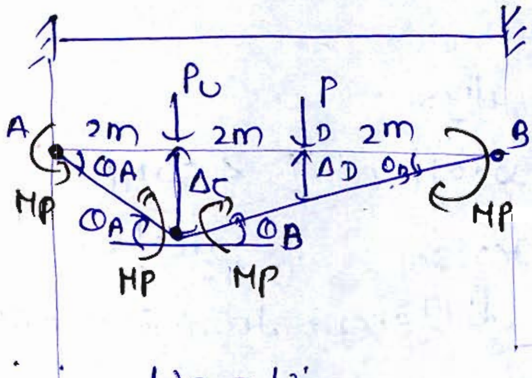
$Ds = 2$.

$\underline{P_u = P_c}$

no. of hinges $= Ds + 1$
$= 2 + 1$
$= 3$

Case I assume hinges at A, B & C

Using kinematic method



$\Delta_C = \theta_A(2) = 4\,\theta_B$

$\underline{\theta_A = 2\theta_B}$

$\Delta_D = 2\theta_B$

$U_e = U_i$

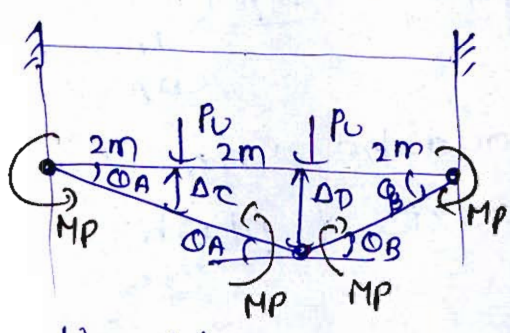
$P_u\Delta_C + P \times \Delta_D = M_p\theta_A + M_p\theta_A + M_p\theta_B + M_p\theta_B$

$P_u[4\theta_B] + P[2\theta_B] = 2M_p[2\theta_B] + 2M_p\theta_B$

$6P_u\theta_B = 6M_p\theta_B$

$\boxed{P_u = M_p}$

Case II Hinge at A, D & B



$\Delta_D = 4\theta_A = 2\theta_B$

$\Delta_C = 2\theta_A$

$\theta_B = 2\theta_A$

$U_e = U_i$

$P_u\Delta_C + P_u\Delta_D = 2M_p\theta_A + M_p\theta_A + M_p\theta_B + M_p\theta_B$

$P_u[2\theta_A] + P_u[4\theta_A] = 2M_p\theta_A + 2M_p[2\theta_A]$

$6P_u.\theta_A = 6M_p\theta_A$

$\boxed{P_u = M_p}$

Collapse load

$\boxed{P_u = M_p = P_c}$ $\underline{Ans}$

C

Q.1 (b) A steel column section ISHB 350 @ 710.2 N/m is subjected to a factored axial compressive load of 1850 kN. The column is supported by a rectangular slab base resting on a concrete pedestal of grade M25, The column end and the base plate are both machined for perfect bearing. The load is transferred to the base plate through a welded connection, and the overhangs of the base plate beyond the column flanges are to be kept equal in both the direction. Design the base slab thickness using Fe 410 grade steel. Do not design the connection.

Section properties for ISHB 350 @ 710.2 N/m:

Depth of section, D = 350 mm

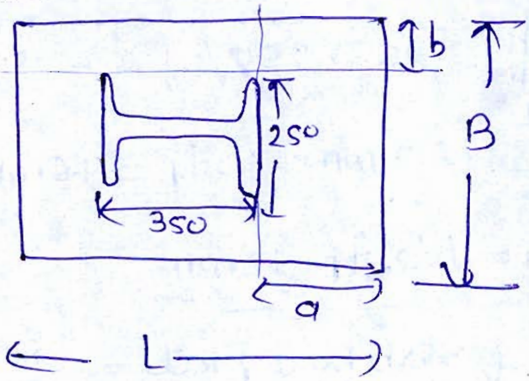
Width of flange, b_f = 250 mm

Thickness of flange, t_f = 11.6 mm

Thickness of web, t_w = 10.1 mm

[12 marks]

⇒ ISHB 350



$L = 350 + 2a$

$B = 250 + 2b$

$\because \underline{a = b}$ (Given)

$L = 350 + 2a$

$B = 250 + 2a$

Fe410

Given $P_U = 1850$ kN , M25 , $f_{ck} = 25$ N/mm^2

$\boxed{a}$ Area of base plate

$\frac{P_U}{A_B} \ngtr 0.45 f_{ck}$ (Bearing capacity of concrete

$$\frac{1850\times10^3}{0.45\times25} \le A_B$$

$$(350+2a)(250+2a) = \frac{1850\times10^3}{0.45\times25}$$

$a \simeq 54.29$ mm $\simeq$ 55mm

$b = 55$ mm

Length of plate , $L = 350 + 2\times55 = 460$ mm

$B = 250 + 2\times55 = 360$ mm

Plate → 460mm × 360mm

II Thickness of plate

Thickness of plate in slab base

$$t_p \geq \sqrt{\frac{2.5w(a^2-0.3b^2)}{f_y/\gamma_{m0}}}$$

$$w = \frac{P_u}{A_B} = \frac{1850\times10^3}{460\times360} = 11.171\ \text{N/mm}^2$$

$$t_p \geq \sqrt{\frac{2.5\times11.171\times[55^2-0.3\times55^2)}{250/1.1}}$$

$t_p = 16.13$ mm $> t_f = 11.6$ mm (OK)

Provide $t_p = 18$ mm

Thickness of slab base plate = 18 mm (Ans)

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Q.1 (c) The following rainfall mass curve data was recorded during a storm of 180 minutes at 30 minute intervals. The infiltration capacity of the soil is governed by the Horton's equation: $f(t) = 30 + 50e^{-2.2t}$, where f is in mm/hr and t is in hours. Compute the effective rainfall for the storm.

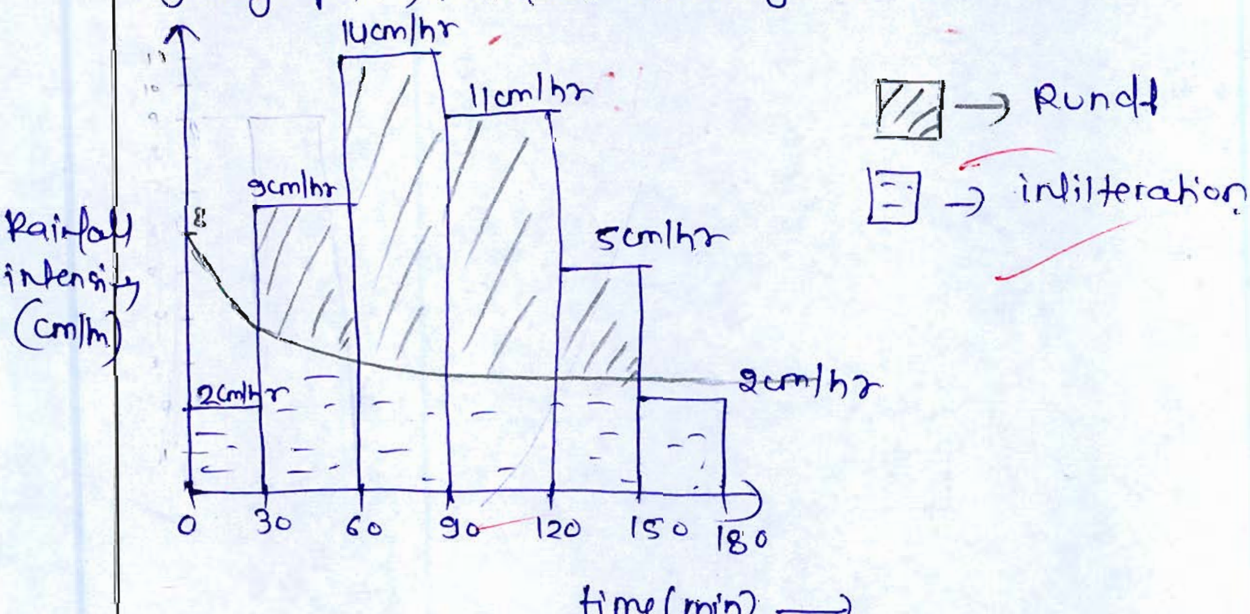
Time (min)	Accumulated Rainfall (cm)
0	0
30	1.0
60	5.5
90	12.5
120	18.0
150	20.5
180	21.5

[12 marks]

⇒

Time (min)	Accumulati P (cm)	Incremental P (cm)	Rainfall intensity (cm/hr)
0	0	0	0
30	1	1	$1 \times 60/30 = 2$
60	5.5	4.5	$4.5 \times 60/30 = 9$
90	12.5	7	14
120	18	5.5	11
150	20.5	2.5	5
180	21.5	1	2

Hyetograph → Rainfall intensity vs ~~storm~~ time



From Horton's equation

$F(t) = 30 + 50e^{-2.2t}$

t (hr)

F (mm/hr)

at $t=0$ $\quad f(0) = 30+50e^{-2.2\times 0} = 80 mm/hr$
$= 8 cm/hr$

at $t=0.5 hr$ $\quad f = 30+50e^{-2.2\times 0.5}$
$= 46.64 mm/hr = 4.66 cm/hr$

at $t = 3hr =$ $\quad f = 30+50e^{-2.2\times 3} = \cancel{30 cm}\ 30.068 mm/hr$
$\simeq 3 cm/hr$

→ ~~Total Rainfall in which rainfall~~ excess occur

Runoff = area of Rainfall in which rainfall excess occur. − infilteration in which rainfall excess occur

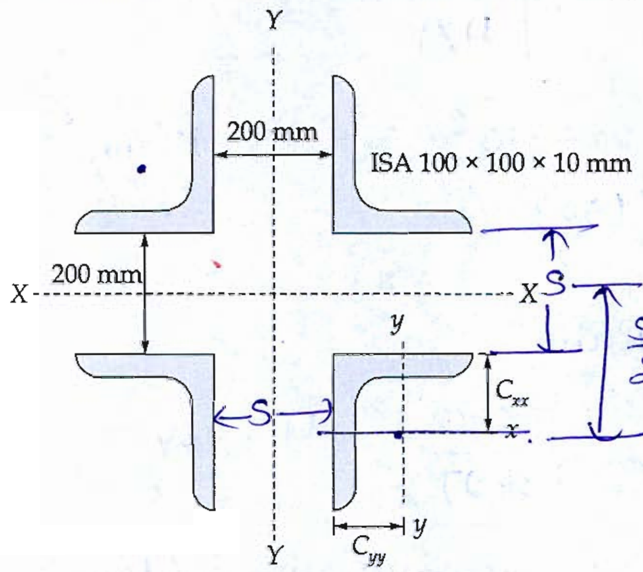
$= (4.5+7+5.5+2.5) - \int_{0.5}^{2.5} 30+50e^{-2.2t}\,dt$
mm

$= 19.5 - \frac{(67.47)}{10}$

$= 12.753 cm$ (Ans)

12

Q.1 (d) A laced built-up column of effective length 6 m to carry a factored axial load. The column consists of four equal angle sections of size ISA 100 × 100 × 10 mm arranged in the shown pattern with a clear distance of 200 mm between the adjoining faces of the angles.



The properties of a single ISA 100 × 100 × 10 mm are as follows:

Cross-sectional Area (A) = 1903 mm^2

Moment of Inertia ($I_{xx} = I_{yy}$) = 177 × 10^4 mm^4

Distance of Centroid ($C_{xx} = C_{yy}$) = 28.4 mm

Assume yield stress f_y = 250 MPa, and use IS 800:2007 specifications to determine the safe factored axial compressive load for the column.

Slenderness Ratio (λ)	Design Compressive Stress (f_{cd})
20	224 MPa
30	211 MPa
40	198 MPa
50	183 MPa
60	168 MPa

[12 marks]

Given, $l_e = 6m$ $S = 200mm$

ISA 100×100×10 $C_{xx} = 28.4mm = C_{yy}$

Moment of Inertia of whole built up ~~structure~~ section

1) $I_{XX} = 4 \times \left[I_{xx} + A\left[\frac{S}{2} + C_{xx}\right]^2 \right]$

$= 4 \times \left(177 \times 10^4 + 1903 \times \left[\frac{200}{2} + 28.4\right]^2\right)$

$= 132.575 \times 10^6 \text{ mm}^4$

$I_{YY} = 4 \times \left[I_{yy} + A\left[\frac{S}{2} + C_{yy}\right]^2 \right)$

$= 132.575 \times 10^6 \text{ mm}^4$ (section is symmetric about XX & YY)

→ Radius of gyration

$$r_{min} = r_{xx} = \sqrt{\frac{I_{xx}}{4A}}$$

$$r_{xx} = \sqrt{\frac{132.575 \times 10^6}{4 \times 1903}} = 131.97\ mm$$

→ Slenderness Ratio

$$\lambda = \frac{l_{eff}}{r_{min}} = \frac{6000}{131.97} = 45.464$$

→ Design compressive stress (f_{cd}) from table

$1.05\lambda = ??$

$$f_{cd} = 198 - (198-183)\left(\frac{45.464-40}{50-40}\right)$$

$$= 189.804\ MPa$$

→ design axial load carrying capacity

$$P_u = f_{cd} \times A$$

$$= \frac{189.804 \times (4 \times 1903)}{10^3}$$

$$= 1444.788\ kN$$

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Safe load carrying capacity

$$P = \frac{P_u}{1.5} = \frac{1444.788}{1.5} = 963.192\ kN \text{ (Ans)}$$

Q.1 (e) Explain briefly the factors affecting the evaporation and suggest methods to reduce evaporation losses in detail.

[12 marks]

⇒ Evaporation

→ Factors affecting

I] Relative humidity and vapour pressure

$E \propto [e_s - e_a]$

if Relative humidity ↑ ⇒ E ↑

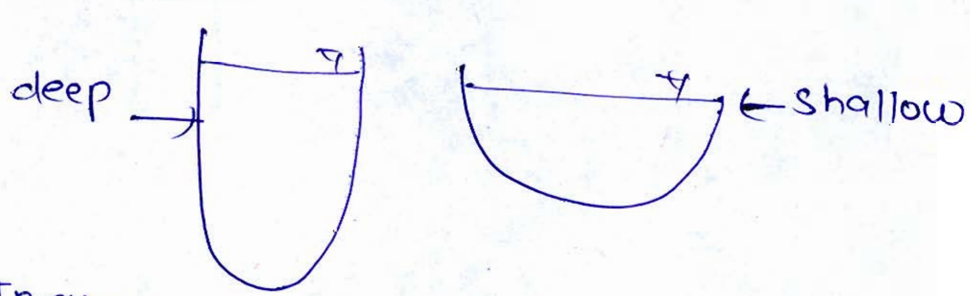
II] Temperature

$E \propto T \longrightarrow T\uparrow \Rightarrow E\uparrow$

III] Wind speed

Upto a certain limit of wind speed, E increases and then become constant.

IV] Size of water body



In summers → $E_{shallow} > E_{deep}$

In winters → $E_{deep} > E_{shallow}$

⇒ Methods to reduce evaporation losses

I) Covering the water bodies ~~by ... by~~ (Surface area ↓ ⟶ E↓

II) Adding chemical to water bodies

(Surface area of water ↓ due to addition of Chemicals ⟶ E↓

More elaboration needed

7

Q.2 (a) **(i)** Write short note on -

(a) Standard Project Flood (SPF)

(b) Probable Maximum Flood (PMF)

(c) Design flood

(ii) The annual peak flood discharges recorded over a period of 16 years at a gauging station are given. Estimate the flood discharge corresponding to a return period of 20 years using the Weibull method. Also, determine the probability that a flood discharge of 6000 cubic meters per second will be exceeded in any given year.

Year	Discharge (m^3/s)	Year	Discharge (m^3/s)
2010	3500	2018	5400
2011	6200	2019	2500
2012	3200	2020	2800
2013	3100	2021	8000
2014	7900	2022	4700
2015	6800	2023	2200
2016	4000	2024	5100
2017	3800	2025	9500

[6 + 14 = 20 marks]

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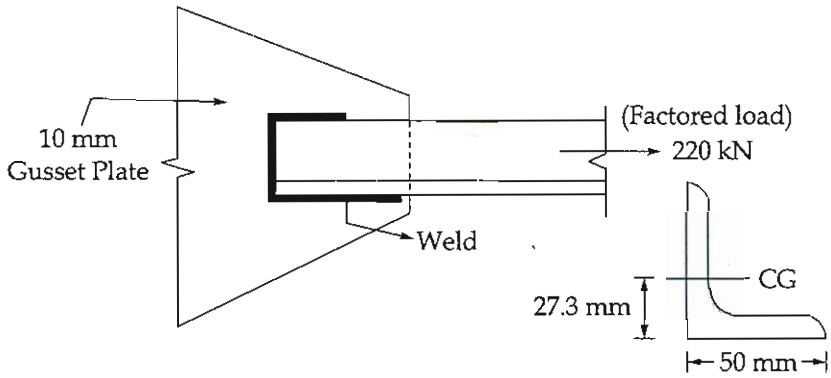
Q.2 (b) Design a welded joint to connect an unequal angle section ISA 80 × 50 × 8 to a 10 mm thick gusset plate to carry a factored tensile load of 220 kN. The longer leg is connected to the gusset plate. Welding is provided on three sides, two longitudinal and one transverse. Welding is shop welding. Yield stress of steel is 250 MPa and ultimate stress is 410 MPa. Also check the safety against Block shear.



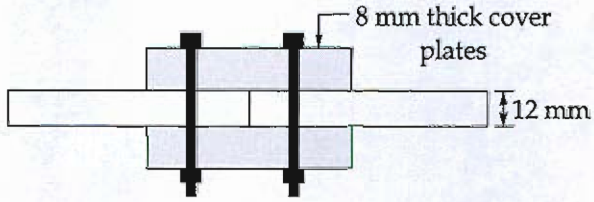
[20 marks]

Q.2 (c) Design a simply supported steel beam with an effective span of 6.0 m that carries a factored uniformly distributed load of 25 kN/m over its entire span including self-weight. The beam is laterally supported throughout its length. Use steel of grade E250 with yield stress 250 N/mm^2 and perform necessary design checks including bending capacity, shear capacity, deflection, web buckling, and web crippling. Assume the bearing length at the support is 100 mm. Sectional properties of ISMB 250 and 300 are as below. Take f_{cd} = 132 N/mm^2.

Sectional Property	ISMB 250 @ 37.3 kg/m	ISMB 300 @ 44.2 kg/m
h (mm)	250	300
b_f (mm)	125	140
t_f (mm)	12.5	12.4
t_w (mm)	6.9	7.5
I_{zz} (mm^4)	5131.6×10^4	8604×10^4
Z_e (mm^3)	410.5×10^3	574×10^3
Z_p (mm^3)	465.7×10^3	652×10^3
r_1 (mm)	13	14

[20 marks]

Q.3 (a) A double-cover butt joint is utilized to connect two main plates, each having a thickness of 12 mm. The connection is made using M24 grade 4.6 bolts with a gauge distance of 80 mm. The cover plates provided on both sides are 8 mm thick. Determine the efficiency of this joint considering a plate grade of Fe 410. Assume that the bolt experience shear such that one shear plane passes through the threaded portion (root) and the other through the unthreaded shank.



(Side view)

[20 marks]

Given, $t_p = 12mm$ $\quad f_u = 410 MPa$

M24, Grade 4.6

$d = 24mm$

$d_o = 24 + 2 = 26mm$

$f_{ub} = 400 MPa$

$f_{yb} = 240 MPa$

$n_s = 1$

$n_n = 1$

$g = 80mm$

① Strength of Bolt (Bolt Value)

a] Shear criteria

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}\left[n_s A_{sb} + n_n A_{nb}\right]$$

$$= \frac{400}{\sqrt{3} \times 1.25}\left[1 \times \frac{\pi}{4} \times 24^2 + 1 \times 0.78 \times \frac{\pi}{4} \times 24^2\right] \times \frac{1}{10^3}$$

$$= 148.77 \text{ kN}$$

b] Bearing criteria

$$V_{dpb} = \frac{2.5 k_b d t_{min} f_u}{\gamma_{mb}}$$

$e_{min} = 1.5 d_o = 1.5 \times 26 = 39mm$ — (machined cut / flame cut)

$P_{min} = 2.5 d = 2.5 \times 24 = 60mm$

$$k_b = \min\left\{\frac{e}{3d_o}, \frac{P}{3d_o} - 0.25, \frac{f_{ub}}{f_u}, 1\right\}$$

$$k_b = \min\left\{\frac{39}{3\times26}, \frac{60}{3\times26} - 0.25, \frac{400}{410}, 1\right\}$$

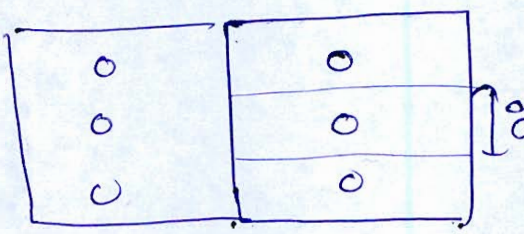
$= \min\{0.5, 0.519, 0.975, 1\}$

$k_b = 0.5$

$$V_{dpb} = \frac{2.5\times0.5\times24\times12\times410}{1.25\times10^3}$$

$= 118.08\ kN$

Bolt value $= \min\{148.77\ kN, 118.08\ kN\}$
$= 118.08\ kN$



→ For tensile capacity of plate → analyze the plate per gauge length (80mm)

a) Gross yield of section

$$T_{dg} = \frac{f_y . A_g}{\gamma_{m0}} = \frac{250\times[80\times12]}{1.1\times10^3} = 218.18\ kN$$

b) Net section Rupture

$$T_{dn} = \frac{0.9 f_u . A_n}{\gamma_{m1}} = \frac{0.9\times410\times[80-1\times26]\times12}{1.25\times10^3}$$

$= 191.2896\ kN$

→ Strength of bolted joint per gauge length
$= \min\{118.08\ kN, 191.2896\ kN\}$
$= 118.08\ kN$

20

Efficiency, $\eta = \frac{\text{Strength of bolted joint}}{\text{Strength of solid plate}} \times 100$

$$= \frac{118.08}{218.18}\times100 = 54.12\%$$

(Ans)

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Q.3 (b) (i) Write the advantages and disadvantages of weld connections over bolted connections.

(ii) During a storm of 200 minutes, the following rainfall rates were observed for successive 40 minute intervals. If the total runoff resulting from this storm is measured as 7 cm, determine the ϕ_{index} and the W_{index} for the catchment area.

Time Period (min)	0 – 40	40 – 80	80 – 120	120 – 160	160 – 200
Rainfall Rate (cm/hr)	2.5	6.0	11.0	3.5	5.0

[8 + 12 = 20 marks]

(i) Advantage of welded connection over bolted connection –

(i) welding removes the need of making hole in the section ($A_g = A_n$)

(ii) Faster and noiseless method.

(iii) Joints formed are rigid in nature

(iv) The efficiency of joints are greater than bolted joints

(ii) Disadvantage

(I) Due to rigidity of joints, brittle failure occur.

(II) less fatigue life

(III) Require power source and skilled manpower.

(IV) Expensive than bolted connection

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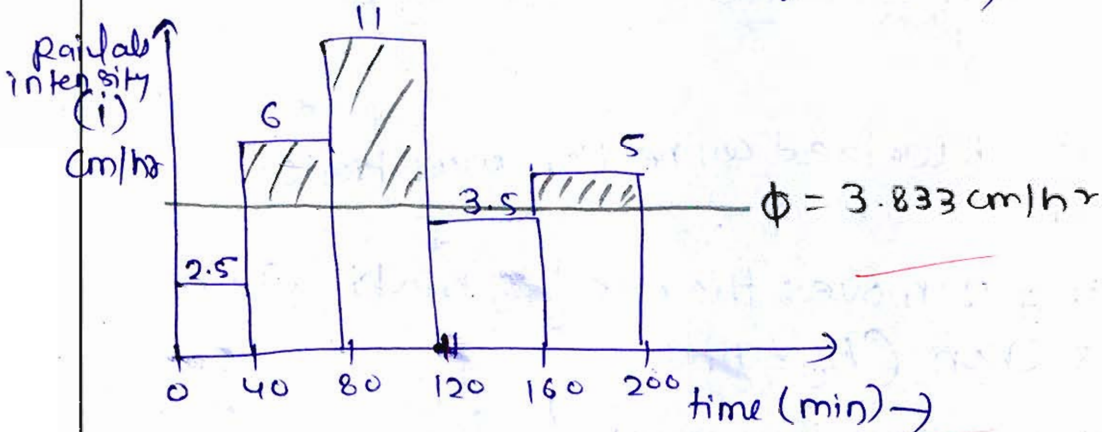
(ii)

Timeperiod (min)	0-40	40-80	80-120	120-160	160-200
Rainfall rate (cm/hr) (i)	2.5	6	11	3.5	5

Runoff = 7cm

I] Hyetograph (Rainfall intensity vs time)



a] ω-index = $\dfrac{\text{Total Rainfall} - \text{Total Runoff}}{\text{Total duration}}$

$$= \frac{(2.5+6+11+3.5+5)\frac{cm}{hr} \times \frac{40}{60}hr - 7}{200min \times \frac{1}{60} hr}$$

$= 3.5$ cm/hr (Ans)

b] ϕ index

As ϕ index $\geq$ ω-index → assuming ϕ index ≥ 3.5cm/hr which means storm intensities 2.5cm/hr & 3.5cm/hr will not result into runoff.

Case I ϕ = $\dfrac{\text{Total Rainfall which Results rainfall excess} - \text{Runoff}}{t_{excess}}$

$= \dfrac{\text{Total infilteration} - \text{infiltration that doesn't produce Runoff}}{t_{excess}}$

~~$\phi = $~~

~~Total~~

$$\phi = \frac{(6+11+5)\times\frac{40}{60} - 7}{120/60}$$

$= 3.833\ cm/hr > 3.5\ cm/hr$

Check, Runoff value if $\phi = 3.833\ cm/hr$

Runoff area

$= [6-\phi]\times\frac{40}{60} + (11-\phi]\times\frac{40}{60} + (5-\phi]\times\frac{40}{60}$

$= (6+11+5)\times\frac{40}{60} - \phi\times3\times\frac{40}{60}$

$= 22\times\frac{40}{60} - 3.833\times3\times\frac{40}{60}$

$= \underline{7cm}$ = given Runoff depth

ϕ index = $\underline{3.833\ cm/hr}$ (Ans)

12

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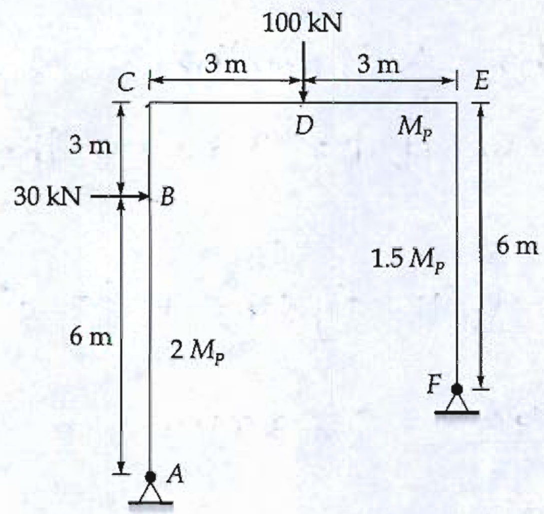
Q.3 (c) A portal frame *ABCDEF* is uniform in cross-section for the beam but varies in the columns. The frame is pin-jointed at supports *A* and *F*. It is subjected to collapse loads: a horizontal force of 30 kN at point *B* and a vertical concentrated load of 100 kN at the midpoint *D* of the beam *CE*. Determine the value of plastic section modulus (M_p). The plastic moment capacities are: Left Column (*ABC*) = $2M_p$, Right Column (*FE*) = $1.5M_p$, Beam (*CE*) = M_p.



[20 marks]

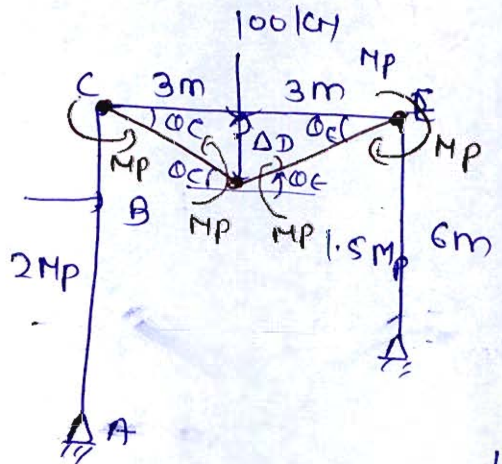
$\Rightarrow$ $D_s = 3-1-1 = 1$

P = no. of possible locations = 4 (B, C, D, E)

no. of possible mechanism = P − Ds = 4 − 1 = 3

→ 2 beam mechanism + ① sway mechanism

(a) Beam mechanism in CE



From

$\Delta_D = 3\theta_C = 3\theta_E$

$\theta_C = \theta_E$

From kinematic method

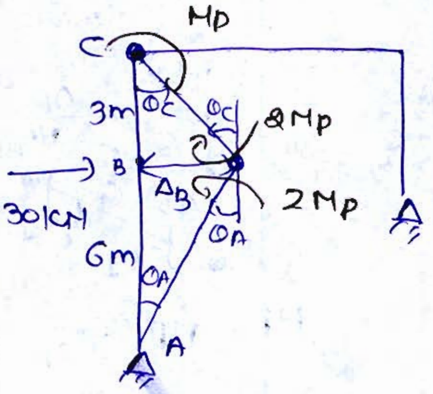
$U_e = U_i$

$100\,\Delta_D = 2M_p\theta_C + 2M_p\theta_E$

$100\,[3\theta_C] = 4M_p\theta_C$

$M_p = \frac{300}{4} = 75 \text{ kN.m}$

(b) Beam mechanism in EC



$\Delta_B = \theta_A \times 6 = \theta_C \times 3$

$\theta_C = 2\theta_A$

$U_e = U_i$

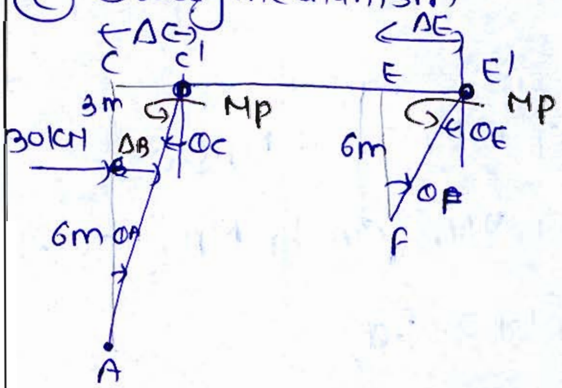
$30 \times \Delta_B = 2M_p.\theta_A + 2M_p\theta_C + M_p\theta_C$

$30 \times [6\theta_A] = 2M_p\theta_A + 3M_p(2\theta_A)$

$180\,\theta_A = [2+6]M_p\theta_A$

$M_p = \dfrac{180}{8} = 22.5\,kN.m$

(c) Sway mechanism



$\Delta C = \Delta E$

$\Delta C = 9\theta_A$

$\Delta E = 6\theta_F$

$\theta_A = \theta_C$

$\theta_E = \theta_F$

$9\theta_A = 6\theta_F$

$\theta_F = \frac{9}{6}\theta_A =$

$\theta_F = 1.5\theta_A$

$\Delta B = 6\theta_A$

$U_e = U_i$

$30\Delta_B = M_p(\theta_C) + M_p\theta_E$

$30[6\theta_A] = M_p[\theta_A] + M_p[1.5\theta_A]$

$180\,\cancel{\theta_A} = 2.5\,\cancel{\theta_A}\,M_p$

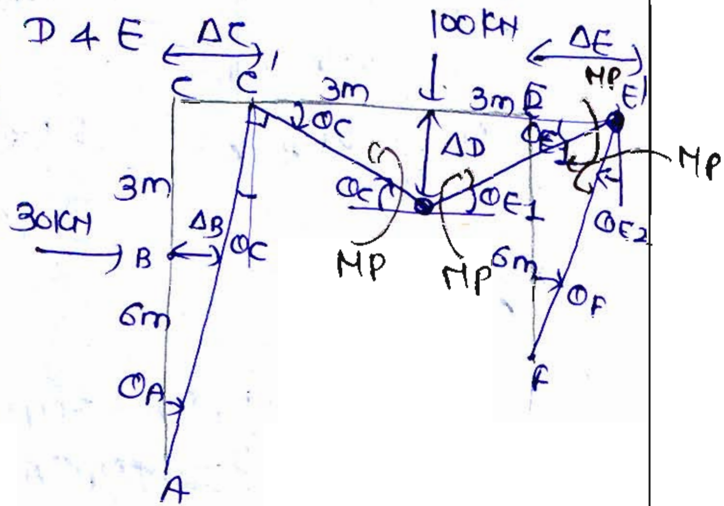
$M_p = 72\,kN.m$

(d) Combined mechanism

no. of hinges = Ds+1 = 1+1 = 2

possible locations, B, D & E

Case ① hinge at D & E



$\because \Delta C = \Delta E$

$9\theta_A = 6\theta_F$

$\theta_F = 1.5\theta_A$

$\Delta B = 6\theta_A$

$\theta_C = \theta_A$

$\theta_{E2} = \theta_F = 1.5\theta_A$

$\because \Delta D = 3\theta_C = 3\theta_{E1} \rightarrow \theta_C = \theta_{E1} = \theta_A$

$U_e = U_i$

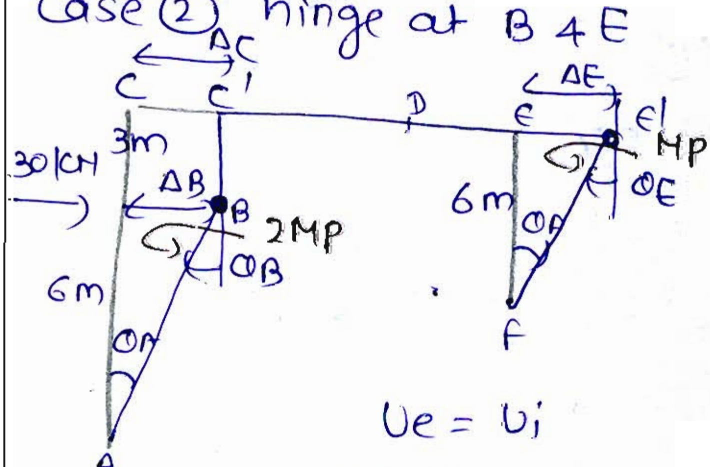
$30\Delta B + 100\Delta D = M_p\theta_C + M_p\theta_{E1} + M_p\theta_{E1} + M_p\theta_{E2}$

$30[6\theta_A] + 100[3\cancel{\theta_C}\,\theta_A] = M_p\theta_A + 2M_p[\theta_A] + M_p(1.5\theta_A)$

$\cancel{\theta_A}[180+300] = M_p\cancel{\theta_A}[1+2+1.5]$

$M_p = \frac{480}{4.5} = 106.67 \text{ kN.m}$

Case ② hinge at B & E



$\Delta C = \Delta B = 6\theta_A$

$\Delta C = \Delta E$

$6\theta_A = 6\theta_F$

$\theta_A = \theta_F$

$\theta_B = \theta_A$

$\theta_E = \theta_F$

$U_e = U_i$

$30\Delta B = 2M_p\theta_B + M_p\theta_E$

$30[6\theta_A] = 2M_p[\theta_A] + M_p(\theta_A)$

$180\theta_A = 3M_P\theta_A$

$M_P = \frac{180}{3} = 60\,kN.m$

$\Rightarrow$ Plastic moment Capacity $= 106.67\,kN.m$ (ANS

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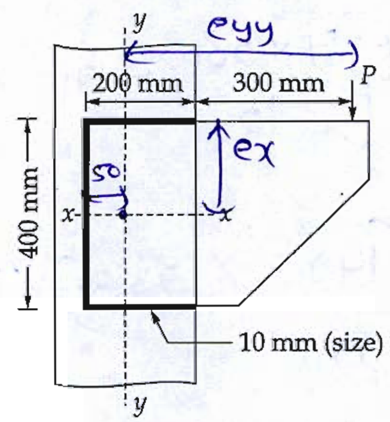
Q.4 (a) Determine the maximum safe load P that can be resisted by a bracket connection welded to a column flange using a 10 mm fillet weld. The weld is provided on three sides consisting of one vertical weld of length 400 mm and two horizontal welds each of length 200 mm. The load acts at an eccentricity of 300 mm from the face of the column. Assume shop welding and Fe 410 grade for the weld.



[20 marks]

Given, $s = 10\,mm$

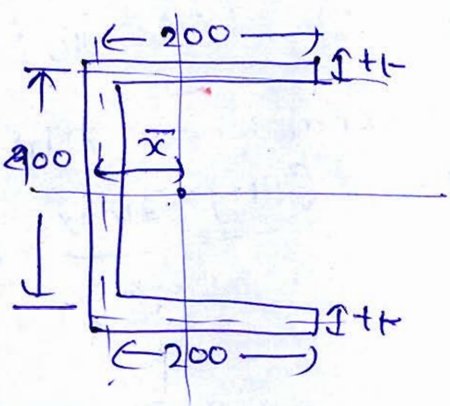
throat thickness, $t_t = 0.7\times10 = 7\,mm$

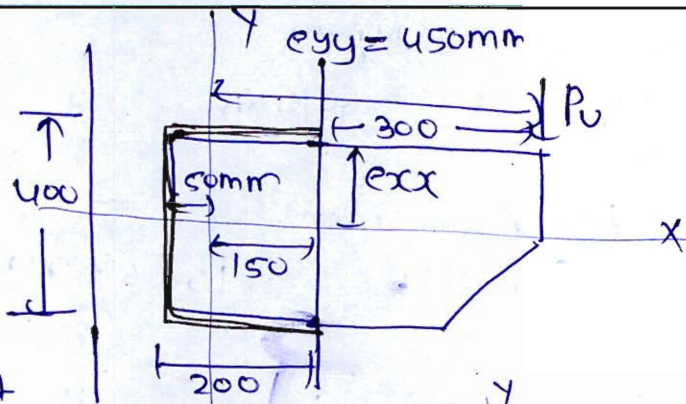
$\gamma_{mw} = 1.25$

[1] CG of weld

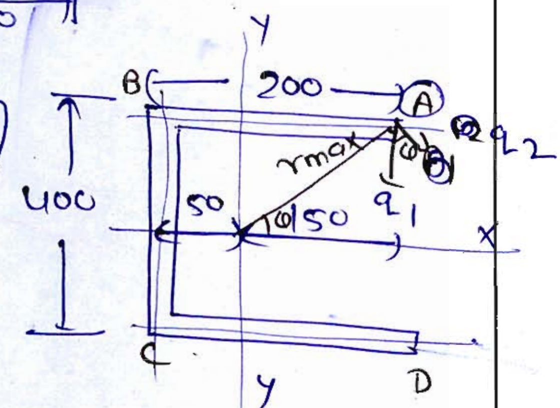
$\bar{x} = \frac{400\times0 + 200\times100\times2}{400+200\times2}$

$= 50\,mm$





$e_{yy} = 150 + 300$
$= 450mm$
$e_{xx} = 200mm$



$$J_{xx} = \frac{t_t \times 400^3}{12} + 2\times\left(\cancel{\frac{200\times t_t^3}{12}} + 200\times t_t \times 200^2\right)$$

neglect

$$= \frac{7\times 400^3}{12} + 2\left[200\times 7\times 200^2\right]$$

$$= 149.33\times 10^6 \; mm^4$$

neglect

$$J_{yy} = \left[\cancel{\frac{400\times t_t^3}{12}} + 400\times t_t \times 50^2\right] + 2\left(\frac{t_t \times 200^3}{12} + 200\times t_t \times (150-100)^2\right)$$

$$= 400\times 7\times 50^2 + 2\left(\frac{7\times 200^3}{12} + 200\times 7\times (50)^2\right)$$

$$= 23.33\times 10^6 \; mm^4$$

$$J_{zz} = J_{xx} + J_{yy} = (149.33 + 23.33)\times 10^6$$

$$= 172.66\times 10^6 \; mm^4$$

$\boxed{I}$ Direct shear stress

$$q_1 = \frac{P_u}{A_w} = \frac{P_u}{(200+400+200)\times 7}$$

$$= 1.786\times 10^{-4} P \; N/mm^2$$

(II) Torsional shear stress (Critical point A)

$$q_2 = \frac{(TM)\times r_{max}}{J_{zz}}, \quad r_{max} = \sqrt{150^2 + 200^2}$$

$$= 250mm$$

$$q_2 = \frac{P_u \times 450 \times 250}{172.66 \times 10^6}$$

$$= 6.516 \times 10^{-4} P$$

$$\cos\theta = \cos\left[\tan^{-1}\left(\frac{200}{150}\right)\right] = 0.6$$

Resultant stress

$$q_r = \sqrt{q_1^2 + q_2^2 + 2q_1q_2\cos\phi}$$

$$= \sqrt{(1.786\times10^{-4}P_u)^2 + (6.516\times10^{-4}P_u)^2 + 2\times(1.786\times10^{-4}P_u)(6.516\times10^{-4}P_u)\times0.6}$$

$$= 7.72\times10^{-4} P_u$$

$$\because q_r \le \frac{f_{uw}}{\sqrt{3}\,\gamma_{mw}}$$

$$P_u \le 245299.078\,N$$

$$7.72\times10^{-4} P_u \le \frac{410}{\sqrt{3}\times1.25} \Rightarrow P_u \le 245.3\,kN$$

Safe load, $P = \frac{P_u}{1.5} = \frac{245.3}{1.5} = 165.53\,kN$ (Ans)

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Q.4(b) (i) Define routing and its types in context of hydrology. Discuss the applications of flood routing.

(ii) A stream reach has the Muskingum coefficients K = 12 hand $x = 0.2$. The inflow hydrograph for this reach is provided in the table. Assuming the initial outflow at $t = 0$ is 10 m^3/s, determine the outflow hydrograph for the reach using a routing time interval of $\Delta t = 6\ h$. Report the attenuation in the peak and leg time.

Time (h)	0	6	12	18	24	30	36	42	48
Inflow (m^3/s)	10	20	50	60	55	45	35	25	15

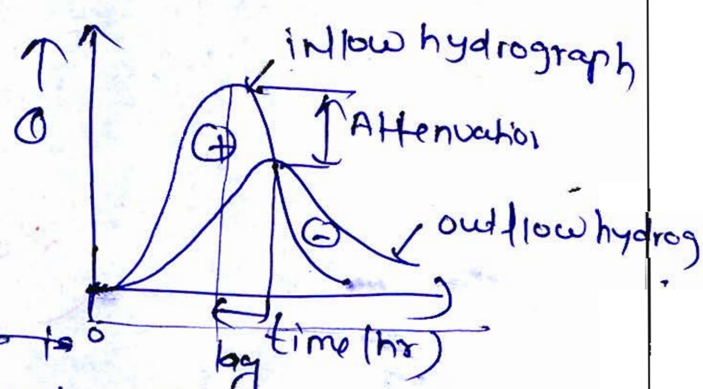
[10 + 10 = 20 marks]

(i) Routing (Flood Routing)

→ Flood routing is the ~~study~~ of safely passage of flood discharge during flooding to ~~or~~ prevent mass destruction.

→ It is of two type - Channel Routing & Reservoir Routing

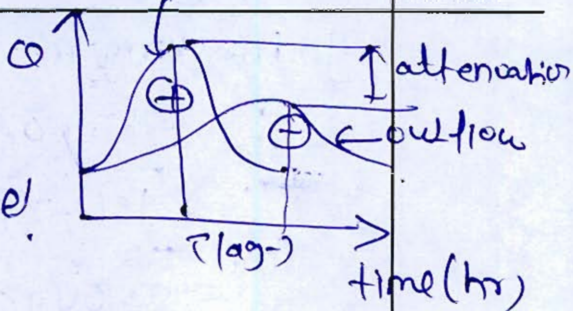
a) Reservoir Routing



In reservoir routing, when the flood enter the reservoir the ~~discharge to~~ water is released through orifices in reservoir.

→ In this, storage = f(outflow) and outflow rate is uncontrolled hence the peak of outflow hydrograph occur at junction of inflow & outflow hydrograph.

(b) Channel Routing



→ In this floods are studied in natural channel/ artificial channel

→ Storage = f(outflow, inflow)

→ Outflow rate is controlled, hence peak of outflow hydrograph occur after the junction of inflow and outflow hydrograph.

⇒ Application of flood routing

① It helps to determine the peak of outflow hydrograph and lag between inflow and outflow hydrograph which will help to ~~take~~ make necessary arrangement during severe flood (shifting of people etc)

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(ii) Given, $K = 12$, $x = 0.2$

$O_1 = 10 m^3/s$, $\Delta t = 6h$

Time(hr)	Inflow(m^3/s) (I)		outflow (m^3/s) (O)	
0	10	I_1	10	O_1
6	20	I_2	10.476	
12	50	I_3	16.439	
$\boxed{18}$	$\boxed{60}$	I_4	32.897	
24	55	I_5	~~[illegible]~~ 45.565	
$\boxed{30}$	45	I_6	$\boxed{49.582}$	
36	35	I_7	46.924	
42	25	I_8	40.769	
48	15	I_9	32.784	

I] muskingum coefficients

$$C_0 = \frac{-Kx + 0.5\Delta t}{K(1-x) + 0.5\Delta t} = -\frac{12\times0.2 + 0.5\times6}{12(1-0.2)+0.5\times6}$$

$$= 0.0476$$

$$C_1 = \frac{Kx+0.5\Delta t}{K(1-x)+0.5\Delta t} = \frac{12\times0.2+0.5\times6}{12[1-0.2]+0.5\times6}$$

$$=0.4286$$

$$C_2 = \frac{K(1-x) - 0.5\Delta t}{K(1-x)+0.5\Delta t}$$

$$= 0.5238$$

→ Calculation of outflow discharge

$$O_2 = C_0 I_2 + C_1 I_1 + C_2 O_1$$

$$= 0.0476\times20 + 0.4286\times10 + 0.5238\times10$$

$$= 10.476 \text{ m}^3/\text{s}$$

$$O_3 = C_0 I_3 + C_1 I_2 + C_2 O_2$$

$$= 0.0476\times50 + 0.4286\times20 + 0.5238\times10.476$$

$$= \cancel{16.44}\ 16.439 \text{ m}^3/\text{s}$$

$$O_4 = C_0 I_4 + C_1 I_3 + C_2 O_3$$

$$= 0.0476\times60 + 0.4286\times50 + 0.5238\times16.439$$

$$= 32.897 \text{ m}^3/\text{s}$$

$$O_5 = C_0 I_5 + C_1 I_4 + C_2 O_4$$

$$= 0.0476\times55 + 0.4286\times60 + 0.5238\times32.897$$

$$= 45.565 \text{ m}^3/\text{s}$$

$O_6 = C_0 I_6 + C_1 I_5 + C_2 O_5$

$= 0.0476 \times 45 + 0.4286 \times 55 + 0.5238 \times 45.565$

$= 49.582\ m^3/s$

$O_7 = C_0 I_7 + C_1 I_6 + C_2 O_6$

$= 0.0476 \times 35 + 0.4286 \times 45 + 0.5238 \times 49.582$

$= 46.924\ m^3/s$

$O_8 = C_0 I_8 + C_1 I_7 + C_2 O_7$

$= 0.0476 \times 25 + 0.4286 \times 35 + 0.5238 \times 46.924$

$= 40.769\ m^3/s$

$O_9 = C_0 I_9 + C_1 I_8 + C_2 O_8$

$= 0.0476 \times 15 + 0.4286 \times 25 + 0.5238 \times 40.769$

$= 32.784\ m^3/s$

The outflow hydrograph ordinates are listed in table.

→ Attenuation $= 60 - 49.582$

$= 10.418\ m^3/s$ (Ans)

lag time $= 30 - 18 = 12\ hr$ (Ans)

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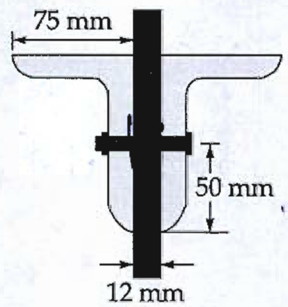
Q.4(c) Design a double angle tension member connected on both sides of a 12 mm thick gusset plate to carry an axial factored load of 450 kN. Use 20 mm diameter bolts of Grade 4.6 for the connection. The angle section selected for the design is 2 Nos. of ISA 100 × 75 × 8 mm of Grade Fe410. Assume a pitch of 60 mm and an end distance of 40 mm. One shear plane of the bolts passes through the threaded portion and the other through the shank.



M20, Grade 4.6

[20 marks]

→ $P_u = 450\,kN$, $P = 60\,mm$, $e = 40\,mm$

→ load carried by each angle $= \frac{450}{2} \approx 225\,kN$

$d = 20\,mm$
$d_0 = 22\,mm$

1. Strength of bolts

a) Shear criteria

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}\left[n_s A_{sb} + n_n A_{nb}\right]$$

$$= \frac{400}{\sqrt{3} \times 1.25}\left(1 \times \frac{\pi}{4} \times 20^2 + 1 \times 0.78 \times \frac{\pi}{4} \times 20^2\right) \times \frac{1}{10^3}$$

$$= 103.314\,kN$$

b) Bearing criteria

$$V_{dpb} = \frac{2.5\,k_b\,d\,t_{min}\,f_u}{\gamma_{mb}}$$

$$k_b = \min\left\{\frac{e}{3d_0}, \frac{p}{3d_0} - 0.25, \frac{f_{ub}}{f_u}, 1\right)$$

$$= \min\left\{\frac{40}{3 \times 22}, \frac{60}{3 \times 22} - 0.25, \frac{400}{410}, 1\right)$$

$$= \min\{0.606, 0.66, 0.976, 1)$$

$$k_b = 0.606$$

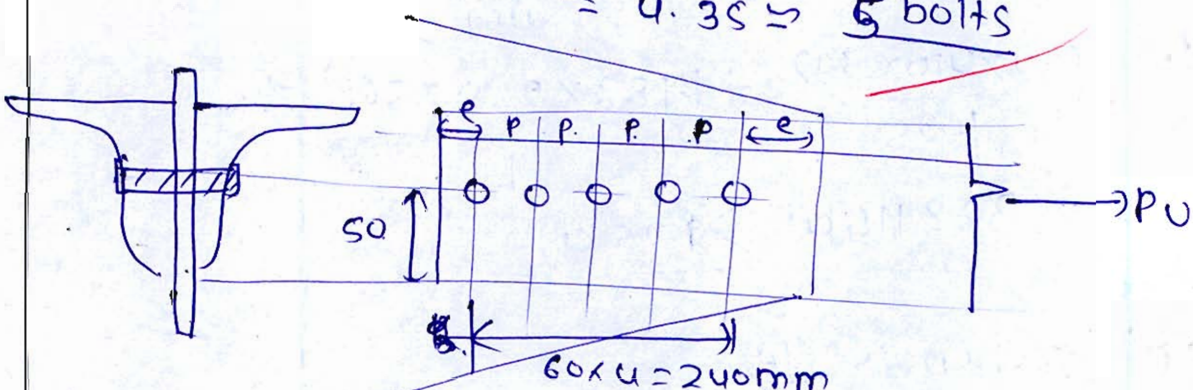
$V_{dph} = \frac{2.5 \times 0.606 \times 20 \times 12 \times 410}{1.25 \times 10^3}$

$= 119.26\ kN$

Bolt value = 103.314 kN (min)

no. of bolts required $= \frac{450}{103.314}$

$= 4.35 \simeq$ 5 bolts



Check tensile capacity of section (of one angle)

(I) Cross-section yielding

$T_{dg} = \frac{f_y A_g}{\gamma_{m0}}$

$A_g = B_e \times t \Rightarrow (100+75-8) \times 8 = 1336\ mm^2$

$T_{dg} = \frac{250 \times 1336}{1.1 \times 10^3} = 303.64\ kN > 225\ kN$ (load on one angle)

II) Net section rupture criteria

$T_{dn} = \frac{0.9 f_u A_{nc}}{\gamma_{m1}} + \beta \frac{f_y A_{go}}{\gamma_{m0}}$

$A_{nc} = \left[100 - 22 - \frac{8}{2}\right] \times 8 = 592\ mm^2$

$A_{go} = \left(75 - \frac{8}{2}\right) \times 8 = 568\ mm^2$

$\beta = 1.4 - 0.076 \left[\frac{w}{t}\right]\left[\frac{f_y}{f_u}\right]\left[\frac{b_s}{L_c}\right]$ > 0.7

$< 0.9 \frac{f_u}{f_y} \cdot \frac{\gamma_{m0}}{\gamma_{m1}}$

$w = 75mm, t = 8mm,$

$b_s = 75 + 50 - 8 = 117mm$

$l_c = 240mm$

$\beta = 1.4 - 0.076\left[\frac{75}{8}\right]\left[\frac{250}{410}\right]\left[\frac{117}{240}\right]$

$= 1.188 \quad > 0.7$

$< 0.9 \frac{f_u}{f_y} \cdot \frac{\gamma_{m0}}{\gamma_{m1}} = 1.29$

$T_{dn} = \frac{0.9 \times 410 \times 592}{1.25} + \frac{1.188 \times 250 \times 568}{1.1}$

$= 328.118 kN > 225 kN$

OK section is safe.

Provide 5 bolts in chain pattern with $P = 60mm$ & $e = 40mm$.

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Section B : Structural Analysis-1+CPM PERT-1, Flow of fluids, hydraulic machines and hydro power-2

Q.5 (a) Differentiate between

(i) Flexibility method and Stiffness method.

(ii) Framed Structures and Truss Structures **[6 + 6 = 12 marks]**

→ Flexibility ~~matrix~~ Method	Stiffness ~~matrix~~ method
I) It is a part of force method/compatibility method	I) It comes under displacement method
II) Forces are taken as redundants and coordinates are given to redundant forces	II) Deformation at joints are taken as coordinates
III) It is used when $D_s < D_K$	III) It is used when $D_K < D_S$
IV) In this flexibility matrix is formed of order D_s	IV) In this stiffness matrix is formed of order D_K and solved for deformations

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(ii)

Framed structures	Truss structure
I) In framed structure, at joints, 3 reactions are possible — two F_x & F_y ~~axial~~ and 1 moment (In 2D)	I) In truss structure, at joints only two reactions are possible (V_A & V_B) ~~and~~
II) Support at ends can be any support pins, roller, fixed, guided roller etc.	II) In trusses, the truss is supported over only pins or rollers (~~...~~ ex. one end at pin & other end at roller.

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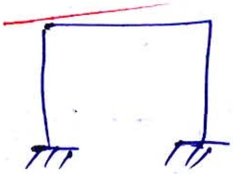
iii) In framed structure loads can be applied at anywhere in the span

iv) In framed structure, the members can develop moments & reactions

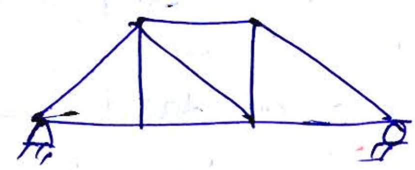
Ex.



Simple portal frame

iii) In trusses, loads will be applied only at joints.

iv) In truss, all members transfers axial forces only.



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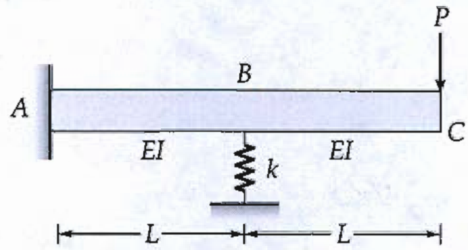
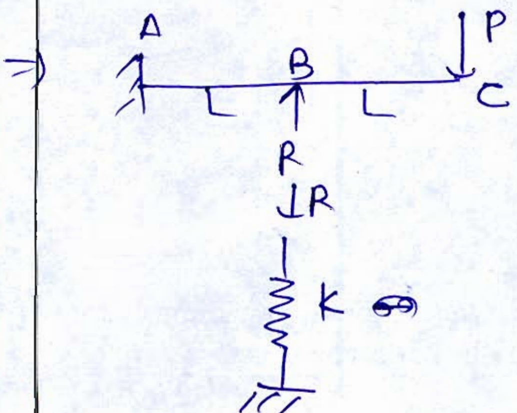
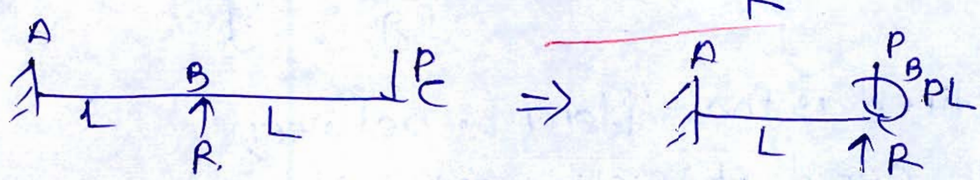
Q.5 (b) A beam is subjected to a concentrated load P and is supported at its midpoint by a vertical spring of stiffness k. The reaction in the spring is taken as the redundant force R. Using compatibility of deflections, determine the expression for the spring reaction R in terms of P, L, EI and k.



[12 marks]



$\delta_B\,(\text{beam}) = \delta_B\,(\text{spring}) = \dfrac{R}{K}$



$$\delta_{VB} = \frac{PL^3}{3EI} + \frac{(PL)L^2}{2EI} - \frac{RL^3}{3EI} \quad (\downarrow)$$

$$\frac{PL^3}{3EI} + \frac{PL^3}{2EI} - \frac{RL^3}{3EI} = \frac{R}{K}$$

$$\frac{5PL^3}{6EI} - \frac{RL^3}{3EI} = \frac{R}{K}$$

$$\frac{5PL^3}{6EI} = R\left[\frac{1}{K} + \frac{L^3}{3EI}\right]$$

$$R = \frac{5PL^3}{\cancel{6}\,2\,\cancel{EI}\left[\dfrac{3EI + KL^3}{\cancel{3}KEI}\right]} = \frac{5KPL^3}{2(3EI + KL^3)}$$

(Ans)

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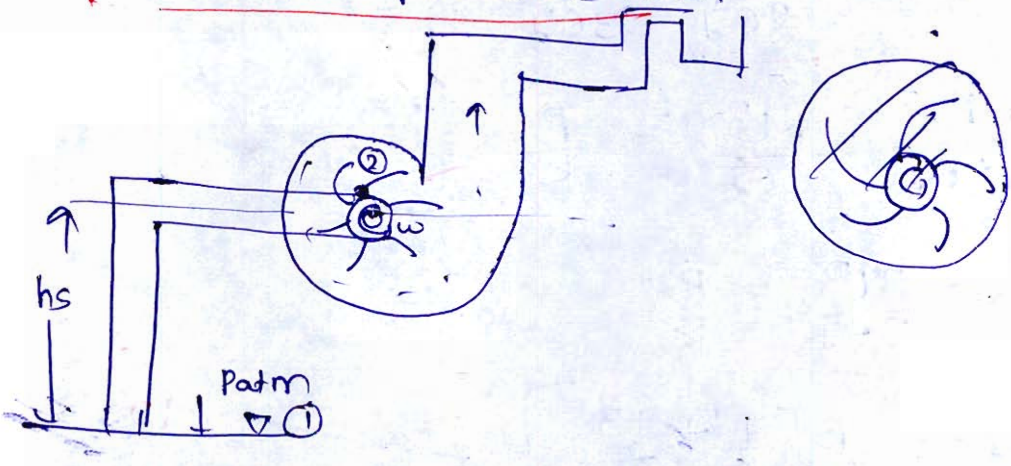
Q.5 (c) Explain the concepts of Net Positive Suction Head (NPSH) and Thoma's cavitation factor in the context of hydraulic machines, including their mathematical expressions.

[12 marks]

→ (a) NPSH

Net positive suction head $= \frac{P_2}{\rho g} - \frac{P_v}{\rho g}$

It is defined as the difference between Pressure head at suction point of centrifugal Pump to Vapour pressure head.



→ NPSH value is provided by manufacture since if pressure at 2 point falls below the $\frac{P_v}{\rho g}$ → Cavitation will start.

Thoma's Cavitation factor (σ)

-) Thoma provided a factor 'σ' which is

$$\sigma = \frac{NPSH}{H}$$

if $\sigma > \sigma_c$ → Cavitation will not occur

$\sigma < \sigma_c$ → Cavitation will start.

$$NPSH = \frac{P_2}{\rho g} - \frac{P_v}{\rho g}$$

negligible

$$= \frac{P_{atm}}{\rho g} - \left(h_s + h_f + \frac{V_2^2}{2g}\right) - \frac{P_v}{\rho g}$$

$$= \frac{P_{atm}}{\rho g} - h_s - h_f - \frac{P_v}{\rho g}$$

$$\sigma = \frac{\frac{P_{atm}}{\rho g} - h_s - h_f - \frac{P_v}{\rho g}}{H}$$

H = net head in case of turbines

H = Hm = manometric head ~~in~~ in case of pumps

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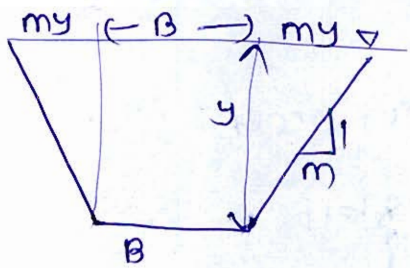
Q.5 (d) A trapezoidal channel has a bottom width of 3 m and side slopes of 1:1.5 (1 vertical to 1.5 horizontal). The channel is lined with concrete having Manning's coefficient of 0.015. If the critical depth of flow is 1.2 m, calculate the following:

(i) The critical flow rate through the channel.

(ii) The critical slope required to maintain this flow.

[12 marks]



$B = 3\,m$

$m = 1.5$

$n = 0.015$

$y_c = 1.2\,m$

⇒ At critical flow

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

$A = By + my^2 = 3 \times 1.2 + 1.5 \times 1.2^2 = 5.76\,m^2$

$T = B + 2my = 3 + 2 \times 1.5 \times 1.2 = 6.6\,m$

a) Critical flow rate

$\frac{Q^2}{9.81} = \frac{5.76^3}{6.6} \Rightarrow Q = 16.854\,m^3/s$ (Ans)

b) Critical slope

from manning's equation

$Q = \frac{A}{n}(R)^{2/3}\sqrt{S}$

$P = B + 2y\sqrt{1+m^2}$

$= 3 + 2 \times 1.2\sqrt{1+1.5^2}$

$= 7.327\,m$

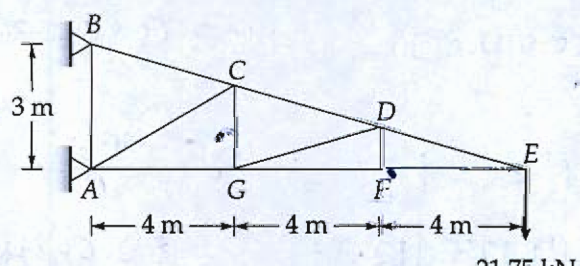
$R = \frac{A}{P} = \frac{5.76}{7.327} = 0.786\,m$

$16.854 = \frac{5.76}{0.015}(0.786)^{2/3}\sqrt{S}$

$S = 2.656 \times 10^{-3}$ (Ans)

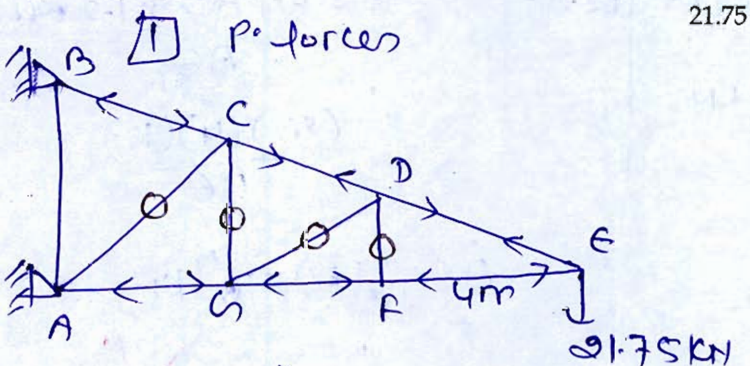
12

Q.5 (e) A pin-jointed truss is supported and loaded as shown in the figure. Considering the applied load at E to be 21.75 kN, determine the vertical deflection under the load at joint E. Assume the axial rigidity AE = 1890000 kN for all members of the truss.

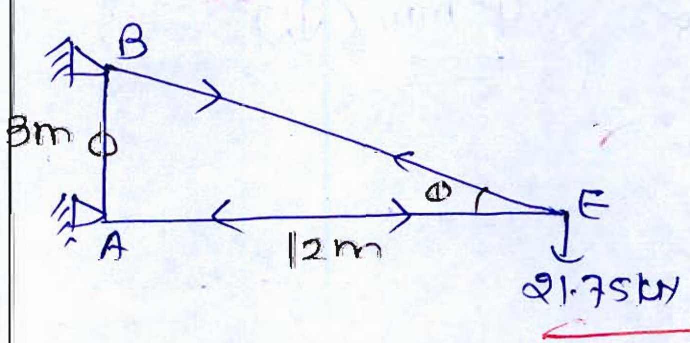


[12 marks]

$\boxed{I}$ P· forces



⇓



member AB has pins at both ends ⟹

$\delta_{AB} = 0 = \frac{PL}{AE}$

$\rightarrow P_{AB} = 0$

$\theta = \tan^{-1}\left(\frac{3}{12}\right) = 14.036^\circ$

At joint E $\rightarrow$ $\Sigma F_y = 0$

$F_{EB} \sin 14.036^\circ = 21.75$

$F_{EB} = 89.68$ kN (Tensile

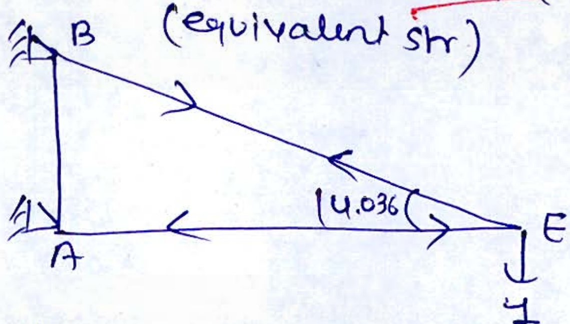
$\Sigma F_x = 0$

$F_{AE} = F_{EB} \cos 14.036$

$= 89.68 \cos 14.036$

$= 87$ kN (Compressive)

(ii) K forces (equivalent str)



$F_{EB} = \frac{1}{\sin 14.036} = 4.123$ (+)

$F_{AE} = F_{EB} \cos 14.036 = 4.123 \cos 14.036$
$= 4$ (−)

$\rightarrow$

Member	P	K	L
EB	89.68	4.123	12.37
AE	−87	−4	12

$\delta_{VE} = \frac{\Sigma PKL}{AE}$

$= \frac{89.68 \times 4.123 \times 1.237}{AE}$

$= \frac{(87)(4)(12)}{AE}$

$AE = 189 \times 10^4$ kN

$\delta_{VE} = \frac{4633.38}{AE}$

$= \frac{4633.38}{189 \times 10^4} \times 10^3 = 2.45$ mm ($\downarrow$)

7

Q.6 (a) A hydraulic jump forms in a horizontal rectangular channel having a constant width of 1.5 m. The depth of flow before the jump is observed to be 10 cm, while the depth after the jump is 45 cm. Initially, assume the channel is frictionless and estimate the discharge of water passing through the section. Subsequently, consider a scenario where the channel is not frictionless, and a resistance force of 45 N is exerted on the water over the jump length. Determine the revised estimated discharge for this second case.

[20 marks]

⇒ $B = 1.5m$ Case① Frictionless

$y_1 = 0.1m$

$y_2 = 4.5m$

Case① Frictionless channel (Rectangular)

$$\frac{q^2}{g} = \frac{y_1 y_2 (y_1 + y_2)}{2}.$$

$$q^2 = \frac{0.1 \times 4.5 (0.1 + 4.5) \times 9.81}{2}$$

$$q = 3.186 \; m^3/s/m$$

$$Q = q.B = 3.186 \times 1.5 = 4.78 m^3/s$$

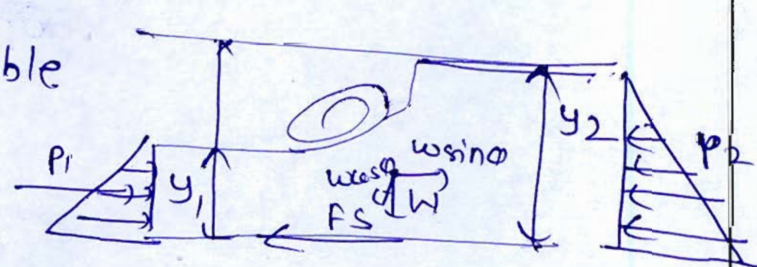
Case2) frictional force is acting

$F_F = 45N$

from momentum equation

assuming θ ≈ negligible

$w\sin\theta \to 0$



$$P_1 - F_S + \cancel{W\sin\theta}^{\,0} - P_2 = \dot{M}_2 - \dot{M}_1$$

$$\frac{P_1 + \dot{M}_1}{\gamma_w} - \frac{F_S}{\gamma_w} = \frac{\dot{M}_2 + P_2}{\gamma_w}$$

$$A_1\bar{y}_1 + \frac{Q^2}{A_1 g} - \frac{F_S}{\rho g} = A_2\bar{y}_2 + \frac{Q^2}{A_2 g}$$

$$[0.1\times1.5]\left[\frac{0.1}{2}\right] + \frac{Q^2}{(0.1\times1.5\times9.81)} - \frac{45}{1000\times9.81}$$

$$= (4.5\times1.5)\left[\frac{4.5}{2}\right] + \frac{Q^2}{(4.5\times1.5\times9.81)}$$

$$7.5\times10^{-3} + 0.6796\,Q^2 - 4.5871\times10^{-3}$$

$$= 15.1875 + Q^2(0.0151)$$

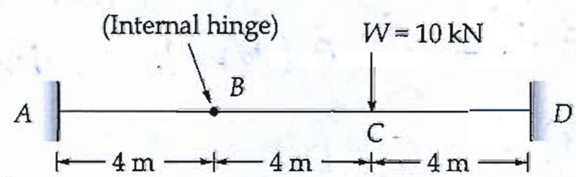
$$Q^2(0.6796-0.0151) = 15.1875 + 4.5871\times10^{-3} - 7.5\times10^{-3}$$

$$Q = 4.7803\ m^3/s$$

4

Q.6 (b) **(i)** Discuss the primary advantages of Surge tanks. Specify their location in plant by making a sketch.

(ii) Two prismatic beams with the same cross-sectional area *AB* and *BD* have fixed ends at *D* and form an internal hinge at *B*. Beam *BD* carries a single vertical load $W = 10$ kN at its mid-point C. Analyze the beam and determine the reactions and bending moments draw the shear force and bending moment diagrams.

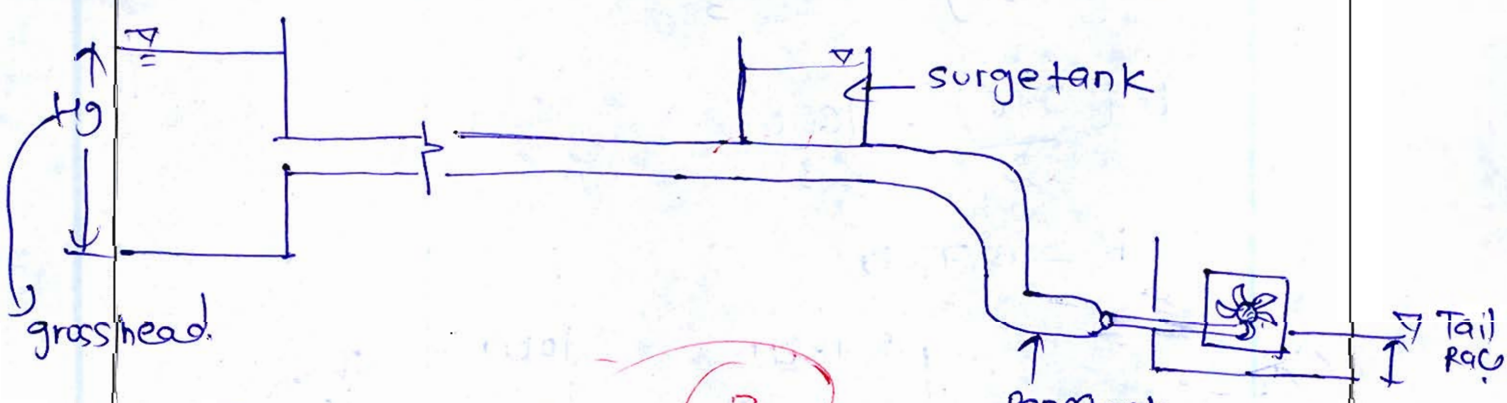


[8 + 12 = 20 marks]

(i) → Surge tanks

The surgetanks are provided in hydropower plant to prevent penstock from water hammer Pressure generated.

There are located near the end of penstock ~~where~~ near the turbine location



3

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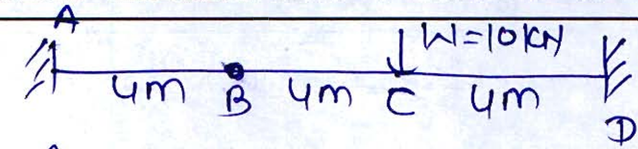
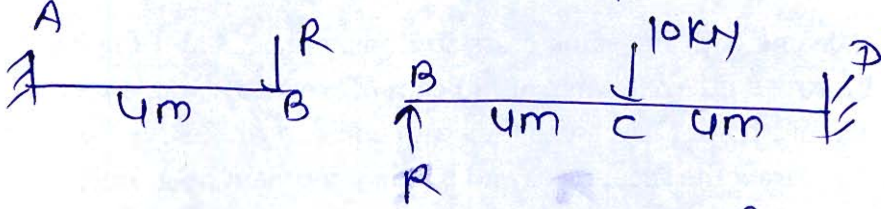
(ii)





$\delta_{VB}(AB)\downarrow = \delta_{VB}(BD)\downarrow$ From superposition Principle

$$\delta_{VB}(AB) = \frac{R(4^3)}{3EI} = \frac{64R}{3EI} \quad \text{—— (I)}$$

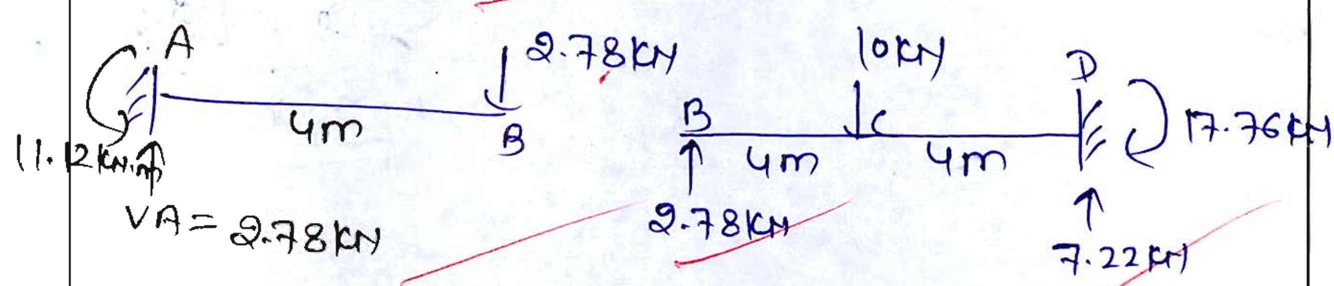
$$\delta_{VB}(BD) = \frac{10(4)^3}{3EI} + \frac{10(4)^2}{2EI}\times 4 - \frac{R(8)^3}{3EI} \quad \text{—— (II)}$$

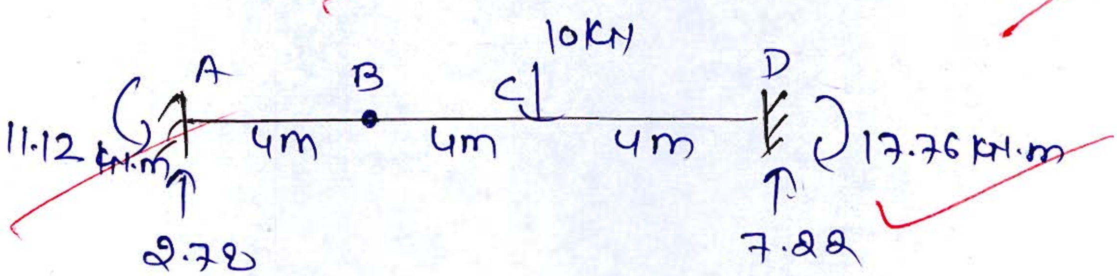
$$\frac{64R}{3\cancel{EI}} = \frac{640}{3\cancel{EI}} + \frac{320}{\cancel{EI}} - \frac{512R}{3\cancel{EI}}$$

$$R\left[\frac{64}{3} + \frac{512}{3}\right] = \frac{1600}{3}$$

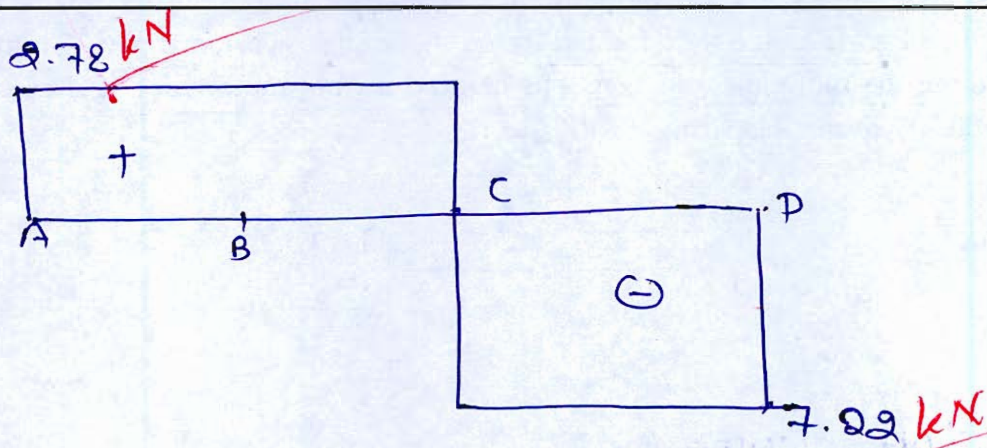
$$R\left[\frac{576}{\cancel{3}}\right] = \frac{1600}{\cancel{3}}$$

$$R = 2.78\,KN$$

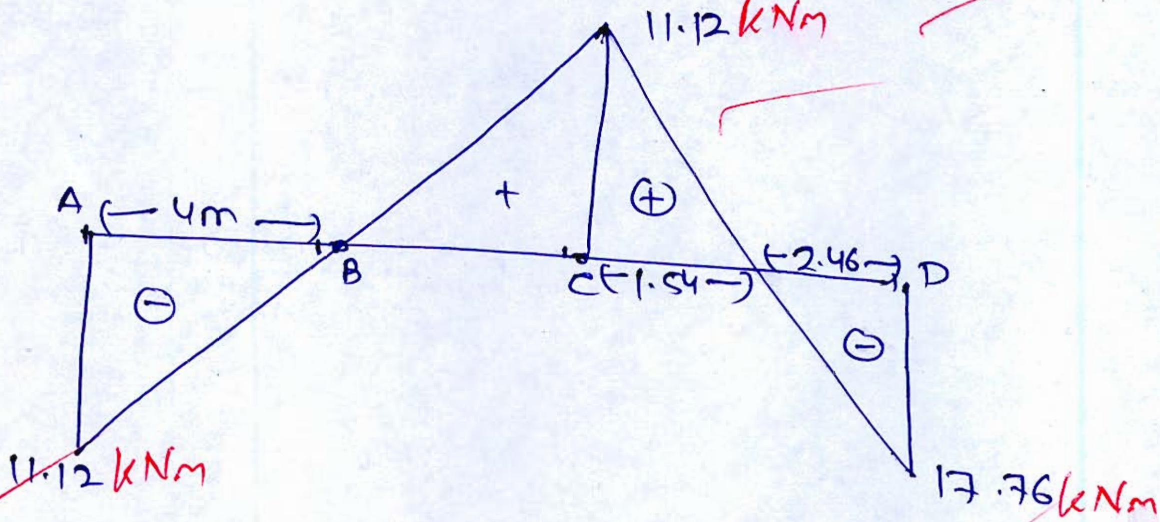




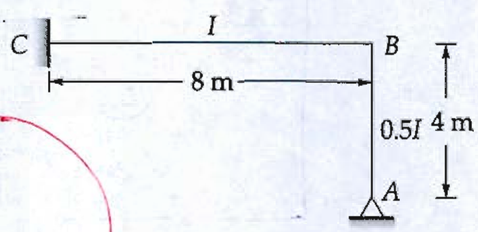
SFD



BMD



Q.6 (c) If the member *AB* in the rigid jointed frame shown below is fabricated 10 mm too long, determine the moments and reactions created in the frame when it is erected. Take $EI = 100{,}000\ \text{kNm}^2$. Also draw *BMD*.



$\delta_{AB} = +10\text{mm}$

[20 marks]

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Q.7 (a) A three-hinged circular arch of span 40 m and rise 8 m carries a concentrated load of 120 kN at a horizontal distance of 10 m from the left end. Find the maximum positive and negative bending moments and draw the bending moment diagram.

[20 marks]

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Do not write in this margin

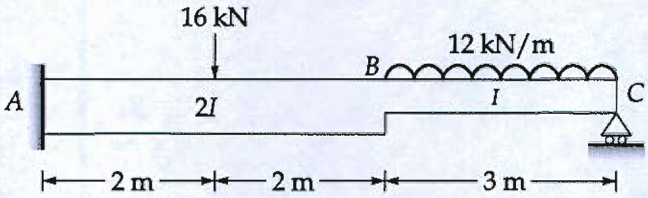
Q.7 (b) (i) Explain the work breakdown structure? What are its merits and demerits?

(ii) The objective is to plan a Civil Engineering project using CPM-Network analysis based on the provided activity data. This involves drawing the network, establishing the critical path, preparing a complete *CPM* schedule with total, free, and independent floats, and computing the total project duration.

Activity	Duration (Weeks)	Preceding Activity	Following Activity
A	3	–	E
B	4	–	D, F, G
C	14	–	H
D	3	B	H
E	5	A	–
F	6	B	–
G	4	B	I
H	1	C, D	I
I	1	G, H	–

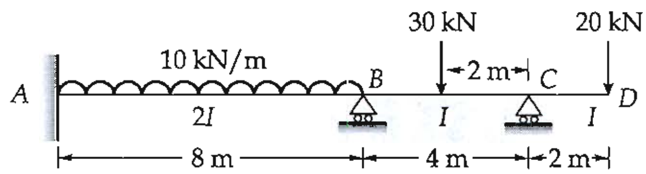
[10 + 10 = 20 marks]

Q.7 (c) Analyse the beam shown in the figure using moment distribution method.



[20 marks]

Q.8 (a) Determine the bending moments at all ends of the spans of the given continuous beam using the slope-deflection method. Draw *BMD* and *SFD*.



[20 marks]

Q.8 (b) **(i)** Show that for a wide rectangular channel, the bed slope S_0 is classified as mild or steep according to whether S_0 is less than or greater than the critical slope S_c, given by

$$S_c = \frac{n^2 g^{10/9}}{q^{2/9}}$$

where, n = Manning's coefficient

g = Acceleration due to gravity

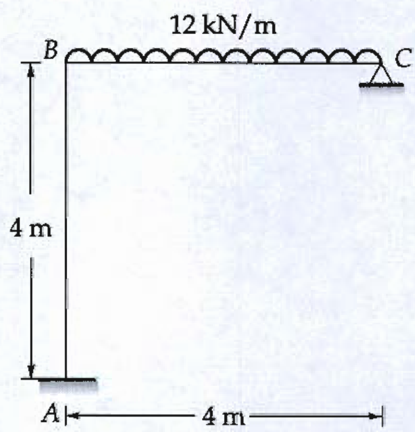
q = Discharge per unit width

(ii) Write short notes on the following types of contracts used in construction projects:

1. Lump Sum Contract
2. Item Rate Contract
3. Percentage Rate Contract
4. Cost Plus Contract
5. Turnkey Contract
6. EPC (Engineering, Procurement and Construction) Contract

[8 + 12 = 20 marks]

Q.8 (c) Analyse the portal frame shown below by strain energy method and draw the BMD. Take, EI = Constant



[20 marks]

OOOO

Space for Rough Work

Space for Rough Work