237/300

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ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-6 : Section A : Structural Analysis + CPM Pert (All Topics)

Section B : Flow of fluids, hydraulic machines and hydro power-1 + Design of Concrete and Masonry Structures-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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator .... Cross Checked by ....

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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 : Structural Analysis + CPM Pert

Q.1 (a) Explain the concept of Resource Levelling in Construction Project Management. How is it different from Resource Loading?

[12 marks]

Sol^n)

Resource levelling

→ In Resource levelling resource are arranged such that the resource at any point of time does n't exceed, defined particular value of resource.

→ In resource levelling duration of project may or may not be not be change if there is contraint on resources than project duration may change.

Resource loading

→ It is kind of allocation of resource to different activity

→ It is diff. from Resource levelling because in ~~this~~ in resource levelling activity are adjusted by their available total float to achieve uniform demand of resource, but in resource loading allocation of resources is done.

Elaborate and explain is more with graph

3

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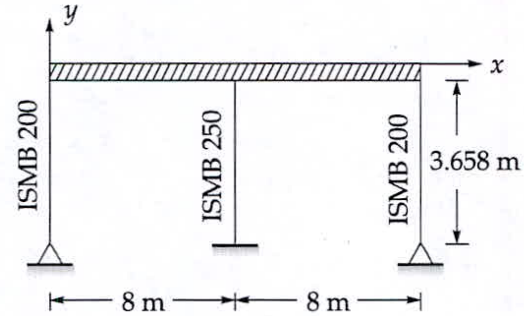
Q.1 (b) In an industrial facility located in Chennai, a heavy machinery platform is supported by a rigid horizontal floor system with a total weight of 222,411.08 N. The supporting structure consists of three ISMB columns, each having a clear height of 3.658 m. The two outer columns are ISMB 200 sections with pinned base connections, while the central column is an ISMB 250 section with a fixed base connection. The modulus of elasticity of steel is $E = 210$ GPa and acceleration due to gravity is $g = 9.81\ m/s^2$. Neglecting the mass of the columns, determine the natural frequency of horizontal vibration of the platform.

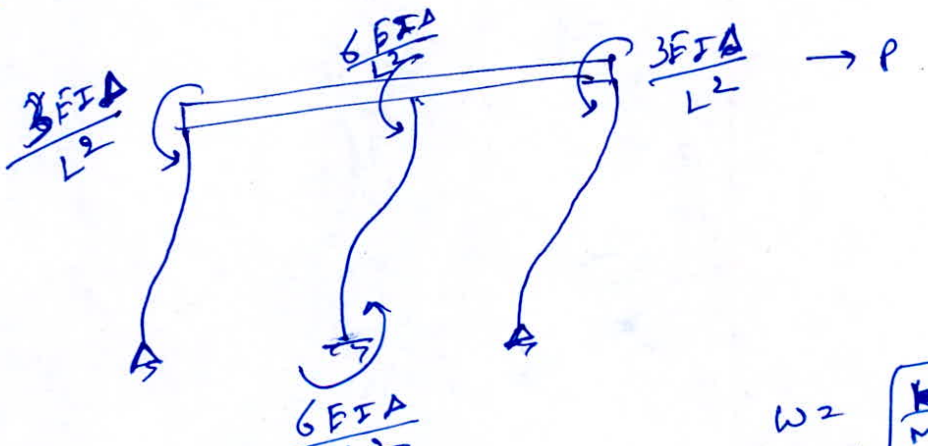
Take, for ISMB 200, $I = 2235\ cm^4$,

for ISMB 250, $I = 5131.6\ cm^4$



[12 marks]

Sol^n



$$\omega = \sqrt{\frac{K}{M}}$$

$$K = \left[\frac{3EI}{L^3}\right]_1 + \left[\frac{12EI}{L^3}\right]_2 + \left[\frac{3EI}{L^3}\right]$$

$$K = \left[2\times\left[\frac{3\times 2235\times10^4}{3658^3}\right] + \left[\frac{12\times5131.6\times10^4}{3658^3}\right] + [\ ]\right] \times 210\times10^3$$

~~K = 3,217 N/mm~~

$K = 3217265.573$ N/m

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$$\omega = \sqrt{\frac{3217265.573}{\left(\frac{222411.08}{9.81}\right)}} = 11.912 \text{ rad/s}$$

12

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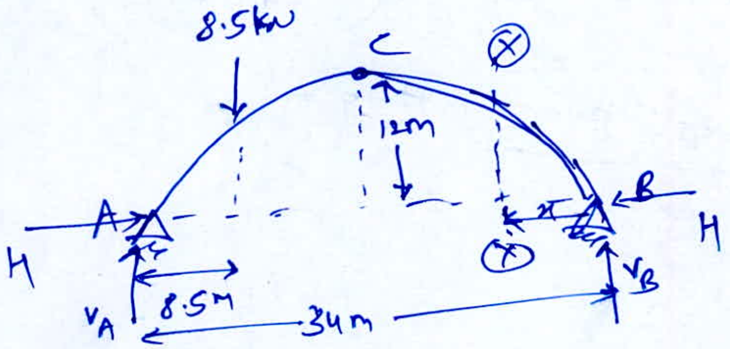
Q.1 (c) A three-hinged parabolic arch has a span of 34 m and a rise of 12 m. It carries a point load of 15 kN at the quarter-span position, which is located 8.5 m from the left support. Calculate the vertical and horizontal reactions at the supports, also calculate the values of the maximum positive bending moment occurring in the arch.

[12 marks]



① Support reactions

$\Sigma M_A = 0$

$8.5 \times 8.5 - V_B \times 34 = 0$

$V_B = 2.125$ kN

$\Sigma F_y = 0$

$V_A = 6.325$ kN

$\Sigma M_c = 0$

$17 \times V_B = 12 \times H$

$H = 3.01$ kN

Eqn of parabolic arch

$$y = \frac{4 \times 12 \times x(34-x)}{34^2} = \frac{x(34-x)}{24.08334}$$

$$M_x = 2.125x - 3.01 \times \left(\frac{x(34-x)}{24.08334}\right)$$

for max. BM

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

$$\Rightarrow 2.125 = \frac{3.01}{24.08334} \times (34-2x)$$

$x = 8.5\,m$

0

$BM_{max} = 2.125 \times 8.5 - 3.01 \times \left(\frac{8.5 \times (34 - 8.5)}{24.08334}\right)$

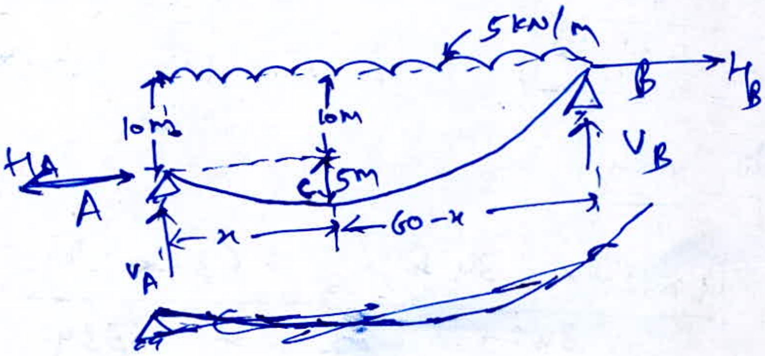
$BM_{max} = -9.0275$ kN-m (Hogging)

Cal. mistake

Q.1 (d) A cable is suspended between two supports A and B, which are at different levels. Support A is at the origin (0, 0) and support B is located at a horizontal distance of 60 m and a vertical height of 10 m above A. The cable carries a uniformly distributed load of 5 kN/m along the horizontal span. The lowest point of the cable (the vertex) is known to be at a vertical distance of 5 m below support A. Determine the horizontal and vertical reactions at both supports and calculate the maximum and minimum tension in the cable.

[12 marks]

Sol^n



$\Sigma F_x = 0$

$H_A = H_B$

$H = \frac{wl^2}{8h}$ from this

$\frac{l_1}{l_2} = \sqrt{\frac{h_1}{h_2}}$

$$\frac{x}{60-x} = \sqrt{\frac{5}{15}}$$

$x = 21.96\,m = l_1$

$60 - x = 38.04\,m = l_2$

Calculate Horizontal thrust

$$H_A = H_B = \frac{w(2l)^2}{8h_1}$$

$$= \frac{5 \times (2 \times 21.96)^2}{8 \times 5} = 241.12\ kN$$

$V_A = w \cdot l_1 = 109.8\ kN$

from $\Sigma F_y = 0$ $V_B = 190.2\ kN$

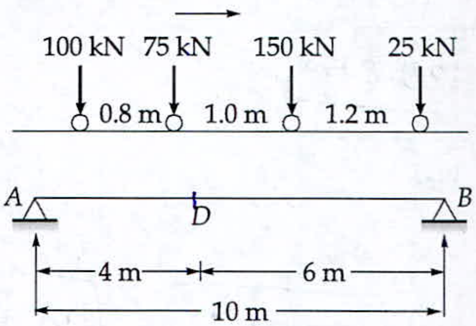
Max. tension $= \sqrt{V_B^2 + H_B^2} = \sqrt{190.2^2 + 241.12^2}$

max. tension $= 307.1\ kN$

min. tension $= H_A = H_B = 241.12\ kN$ at point C

12

Q.1 (e) The train of wheel loads as shown in figure roll over from left to right along a girder of span 10 meters. Find out the maximum bending moment which can occur at section 4 m from the left end of the girder.



[12 marks]

	Avg. load on AD		Avg. load on DB
when 150 kN crosses point D	$\frac{75+100}{4} = 43.75$	>	$\frac{175}{6} = 29.16$
when 75 kN cross point D	$\frac{100}{4} = 25$	<	$\frac{75+150+25}{6} = 41.66$

Max. BM at Section will occur when 75 kN load placed at point D.

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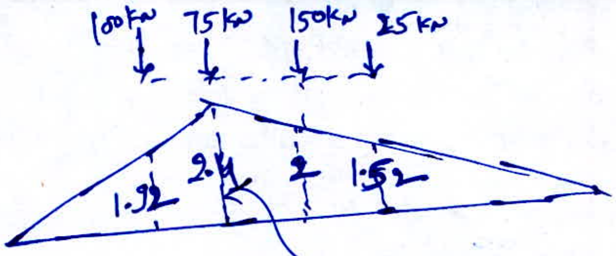


(ILD for BMd D)

$\frac{ab}{l} = \frac{4\times6}{10} = 2.4$

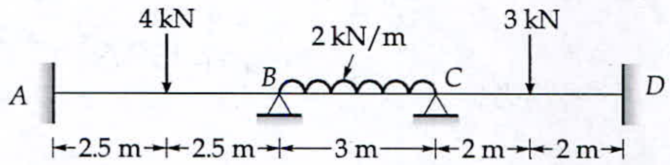
max BM = $100\times1.92 + 75\times2.4 + 150\times2 + 25\times1.52$

= **710 kN-m**

12

Q.2 (a) A continuous beam *ABCD* having a total span length of 12 m is subjected to loading as shown in the figure. The beam is to be analysed using the slope deflection method considering that certain support movements occur simultaneously. Support A undergoes a rotation of $\frac{1}{500}$. Radians in the clockwise direction. Support *B* experiences a vertical settlement of 15 mm downward, and support *C* undergoes a vertical settlement of 10 mm downward. Draw the bending moment diagram.

(Take $EI = 764$ kN-m^2)



[20 marks]

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Q.2 (b) Write short notes on the following terms related to the tendering and contract process:

1. Notice Inviting Tender (NIT)
2. Earnest Money Deposit (EMD)
3. Bid Security
4. Performance Guarantee
5. Letter of Acceptance (LOA)
6. Mobilization Advance
7. Variation Order
8. Defect Liability Period (DLP)
9. Liquidated Damages (LD)
10. Escalation Clause

[20 marks]

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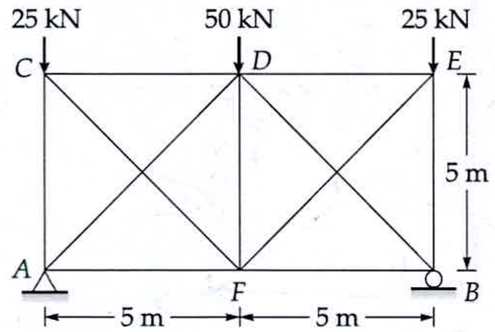
Q.3 (a) Determine the member forces in the pin Jointed truss shown below in the figure. Take the area of each member as A and the modulus of elasticity as E. Make use of symmetry.



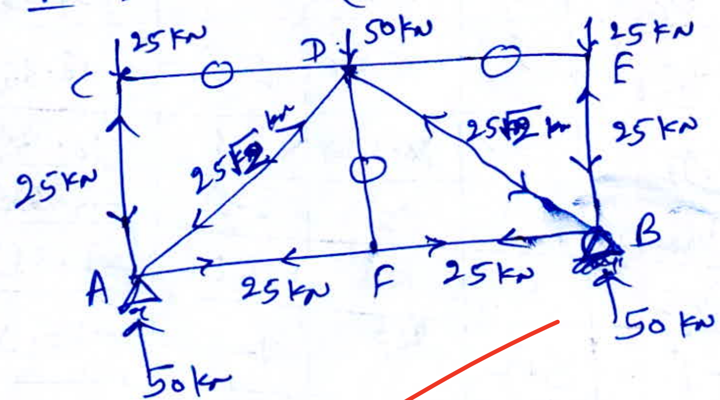
[20 marks]

Sol^n)

Since given is indeterminate to two degree so remove two redundant i.e. FC & FE

$$F_{CF} = F_{EF} = X = \frac{-\Sigma PkL}{\Sigma k^2 l}$$

Step① P-value { →← tension, ←→ compression }



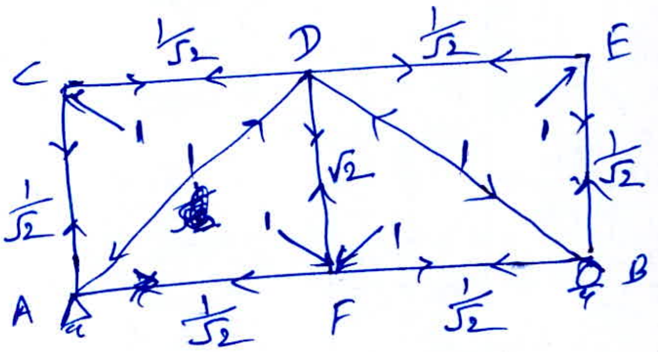
$V_A = V_B = 50$ kN { $\Sigma F_y = 0$ & Symmetry }

from FBD of joint B

$$F_{DB} \times \cos 45° + 25 = 50$$

$$\boxed{F_{DB} = 25\sqrt{2} \text{ kN (compressive)}}$$

Step ② K-values



Step ③ $X = F_{CF} = F_{EF} = -\frac{\Sigma PKL}{\Sigma K^2 L}$

(final forces in kN)

member	P-value (kN)	K-value	L	PKL	K^2L	$F = P + KX$ (kN)
AC	-25	$\frac{1}{\sqrt{2}}$	5	-88.388	2.5	-31.63
FD	0	$\sqrt{2}$	5	0	10	-13.27
BE	-25	$1/\sqrt{2}$	5	-88.388	2.5	-31.63
AF	25	$\frac{1}{\sqrt{2}}$	5	88.386	2.5	18.364
FB	25	$1/\sqrt{2}$	5	88.388	2.5	18.364
CD	0	$1/\sqrt{2}$	5	0	2.5	-6.635
DE	0	$1/\sqrt{2}$	5	0	2.5	-6.635
AD	$-25\sqrt{2}$	-1	$5\sqrt{2}$	250	7.071	-25.97
DB	$-25\sqrt{2}$	-1	$5\sqrt{2}$	250	7.071	-25.97
CF	—	-1	$5\sqrt{2}$	0	7.071	9.3836
EF	—	-1	$5\sqrt{2}$	0	7.071	9.3836

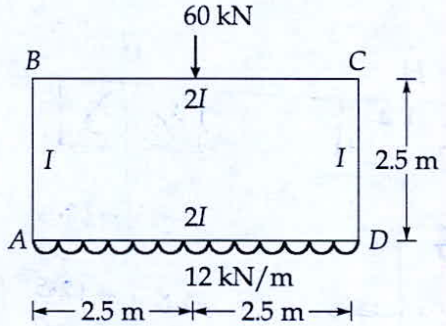
$\Sigma PKL = 500$ $\Sigma K^2L = 53.2842$

$X = F_{CF} = F_{EF} = \frac{-500}{53.2842} = -9.3836$ kN

(– sign implies assumed dir is opposite)

{+ → tensile } in table.
{− → compressive }

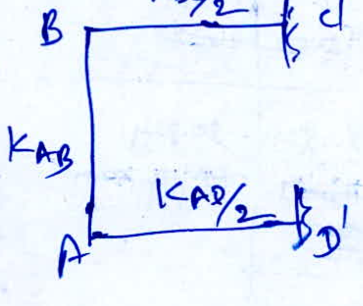
Q.3 (b) Analyse the plane box frame (by moment distribution method) shown in the figure. Also draw the bending moment diagram.



[20 marks]

Sol^n)

Given frame is Symmetrical so using concept of symmetry.



Step (i) fixed End moments

$M_{fbc} = -37.5$ kN-m , $M_{fcb} = +37.5$ kN-m

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Mfad = +25 kN-m (~~+37.5 kN-m~~), Mfda = −25 kN-m (~~37.5 kN-m~~)

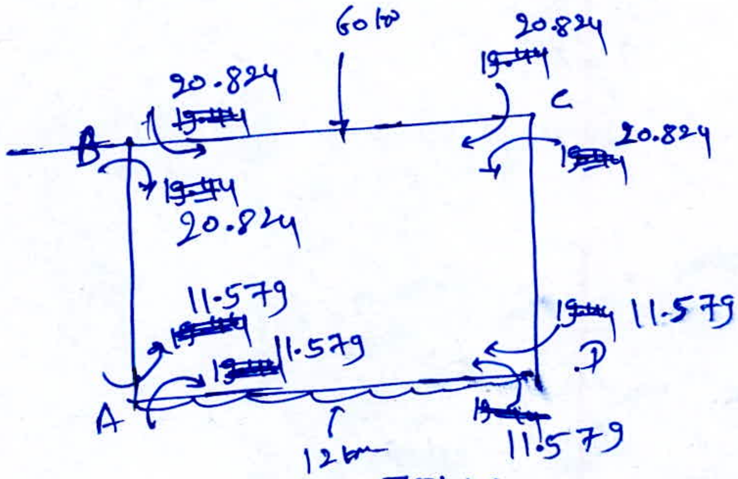
Step② distribution factors

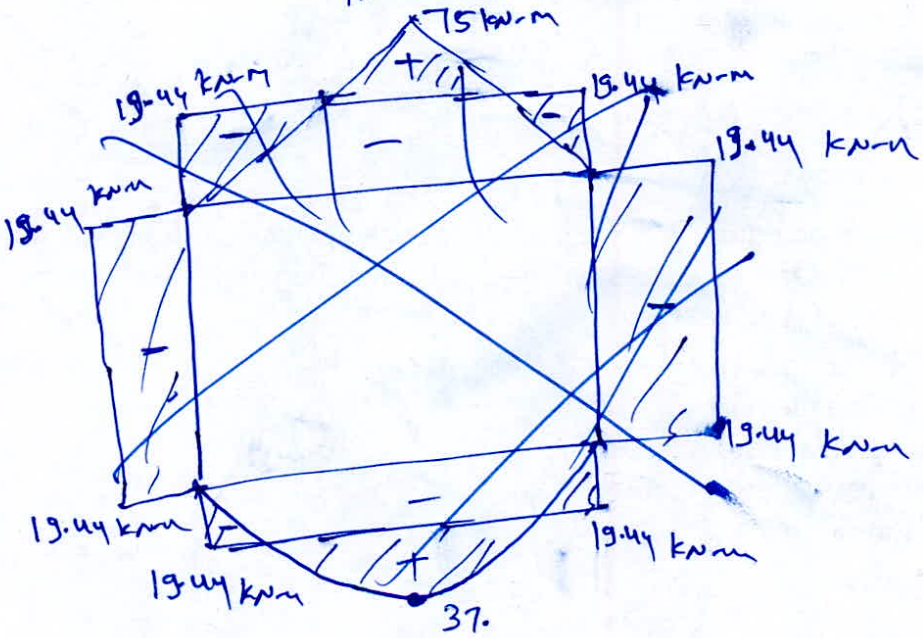
Joint	member	k	Σk	DFs
B	BC'	$\frac{4(2EI)}{5\times2}$	2.4EI	1/3
	BA	$\frac{4EI}{2.5}$		2/3
A	AB	$\frac{4EI}{2.5}$	2.4EI	2/3
	AD'	$\frac{4(2EI)}{5\times2}$		1/3

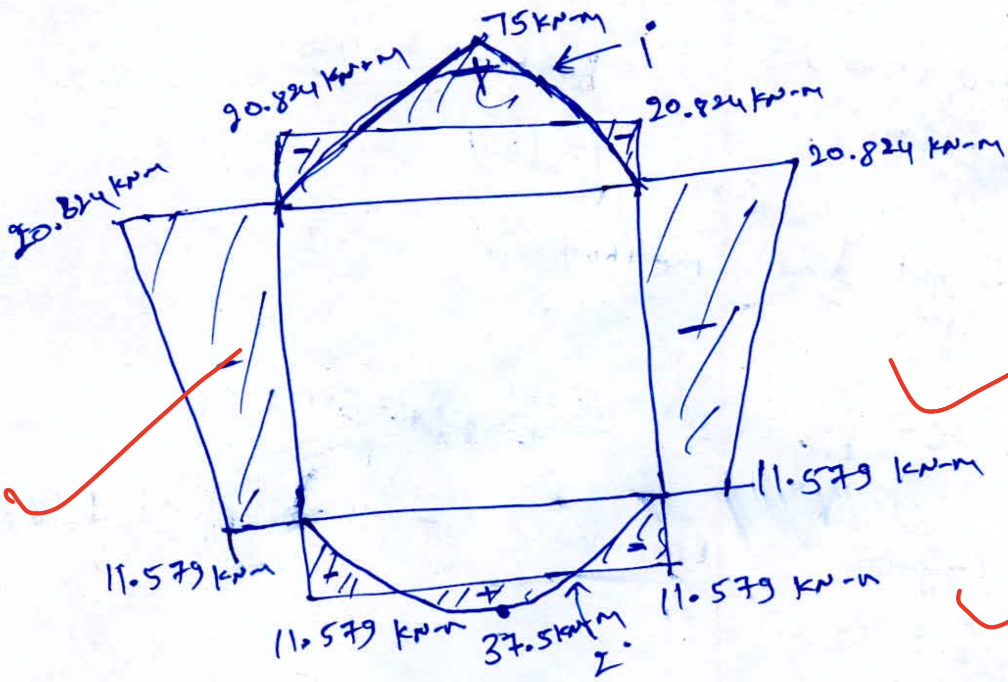
Step③ End moment distribution

Joint	D'	A	A	B	B	C'
DFs	-	1/3	2/3	2/3	1/3	-
FEMs		+25	0	0	−37.5	-
Bal		−8.33 (~~−12.5~~)	−16.66 (~~25~~)	+25	+12.5	
Com			+12.5 (~~+12.5~~)	−8.33 (~~+12.5~~)		
Bal		−4.166 (~~−4.166~~)	−8.33 (~~−8.33~~)	+5.58 (~~+8.33~~)	+2.77 (~~+4.166~~)	
Com			+2.77 (~~+4.166~~)	−4.166 (~~−4.166~~)		
Bal		−0.925 (~~−1.388~~)	−1.85 (~~−2.77~~)	+2.77 (~~+2.77~~)	+1.388 (~~+1.388~~)	
final end moments	-	+11.578 (~~+19.44~~)	−11.58 (~~−19.44~~)	+20.824 (~~+19.44~~)	−20.824 (~~−19.44 kN-m~~)	

8(a) Bending moment diagram







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Q.3 (c) The initial cost of an equipment is Rs. 2200, the salvage value is Rs. 200, and the useful life is 4 years. The rate of interest is 10%. Calculate the yearly depreciation and book value at the end of each year by

(Solve in table format)

(i) Straight-line method

(ii) Declining balance method

(iii) Sum of years digits method

(iv) Sinking fund method

[20 marks]

Soln

C_i = ₹ 2200, n = 4 yrs

C_s = ₹ 200, i = 10 %

(i) By straight line method

$D_1 = D_2 = D_3 = D_4 = \frac{2000}{4}$ = ₹ 500

B_1 = ₹ 1700 (Book value at the end of 1 yr)

B_2 = ₹ 1200

B_3 = ₹ 700

B_4 = ₹ 200

(ii) By declining balance method

$FDB = 1 - \left(\frac{C_s}{C_i}\right)^{1/n} = 1 - \left(\frac{200}{2000}\right)^{1/4} = 0.4509$

$D_1 = C_i \times FDB = ₹ 992$ | $B_1 = ₹ 1208$

$D_2 = (C_i - D_1) FDB = ₹ 554.68$ | $B_2 = ₹ 653.32$

$D_3 = ₹ 294.58$ | $B_3 = ₹ 358.8$

$D_4 = ₹ 161.305$ | $B_4 = ₹ 200$

(iii) $D_m = (C_i - C_s)\left(\frac{n-m+1}{\frac{n(n+1)}{2}}\right)$

$D_1 = ₹ 800$ | $B_1 = ₹ 1400$

$D_2 = ₹ 600$ | $B_2 = ₹ 800$

$D_3 = ₹ 400$ | $B_3 = ₹ 400$

$D_4 = ₹ 200$ | $B_4 = ₹ 200$

(iv) $D_m = D(1+i)^{m-1}$

$D = (C_i - C_s)\left(\frac{i}{(1+i)^n - 1}\right)$

$D = 2000 \times \left(\frac{0.1}{1.1^4 - 1}\right) = 430.9416$

$D_1 = ₹ 430.9416$ | $B_1 = ₹ 1769.05$

$D_2 = ₹ 474.03$ | $B_2 = ₹ 1295.0284$

$D_3 = ₹ 521.44$ | $B_3 = ₹ 773.588$

$D_4 = ₹ 573.58$ | $B_4 = ₹ 200$

20

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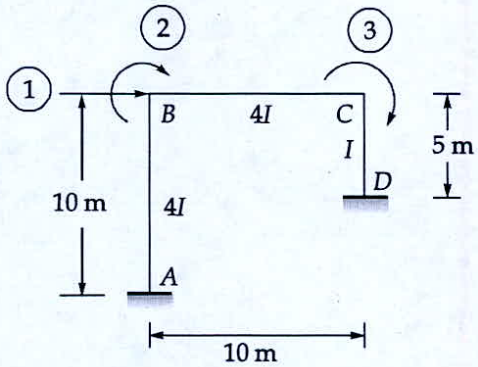
Q.4 (a) Develop the stiffness matrix for portal frame ABCD with reference to the coordinates shown in figure.



[20 marks]

Q.4 (b) The cost and benefit details for two alternative schemes *A* and *B* are given. Scheme *A* requires an initial investment of 15 lacs, has an annual running cost of 2 lacs, and provides an annual benefit of 4.5 lacs starting after 1 year for a total life of 6 years. Scheme *B* requires an initial investment of 25 lacs, has an annual running cost of 2.5 lacs, and provides an annual benefit of 6.2 lacs starting after 2 years for a total life of 12 years. Taking the rate of interest as 12%, determine the most economical proposal using the present worth method.

[20 marks]

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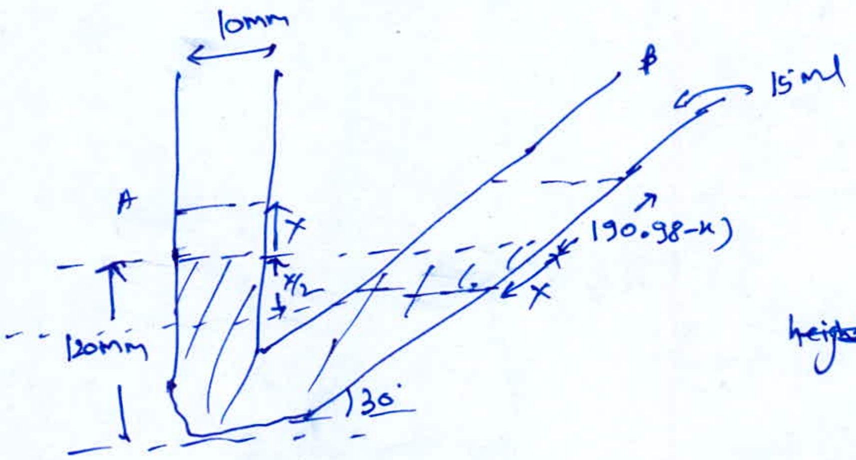
Section B : Flow of fluids, hydraulic machines and hydro power-1 + Design of Concrete and Masonry Structures-2

Q.5 (a) A U-tube has a constant internal diameter of 10 mm. The left leg is vertical, while the right leg is inclined at an angle of 30° to the horizontal. Initially, the tube contains mercury ($SG = 13.6$) such that the vertical height of mercury in both legs is 120 mm. If 15.0 mL of water is poured into the inclined right-hand leg, determine the vertical height of the mercury levels in both legs.

[12 marks]

Sol^n)



~~height of water filled~~

height of water that will stand in pipe =

$$= \frac{15 \times 10^{-6}}{\frac{\pi}{4} \times (10 \times 10^{-3})^2} = 190.98\,mm$$

(10)

$$p_A + 13.6 \times 9.81 \times 10^3 \times \left(x + \frac{x}{2}\right) = \left(\frac{190.98}{2} \times 10^3 \times 9.81\right) + p_B$$

(p_A, p_B = atm)

$$x = 4.68\,mm$$

Vertical Height in left tube = $120 + 4.68 = 124.68\,mm$

Vertical Height in right tube = $120 - \frac{4.68}{2} = 117.66\,mm$

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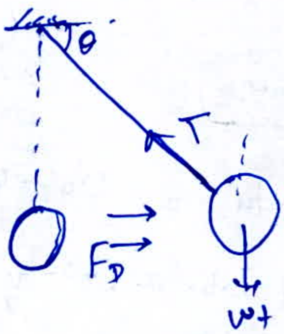
Q.5 (b) A sphere 3 cm in diameter and of relative density 2.5 is attached to a string and is suspended from the roof of a wind tunnel. If an air stream of 25 m/s flows past the sphere then determine the inclination of the string to horizontal and the tension in the string. (Neglect the weight and drag of the string).

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

Coefficient of drag $C_D = \begin{cases} 0.5 \text{ for } 10^4 < R_e < 3\times10^5 \\ 0.2 \text{ for } R_e \geq 3\times10^5 \end{cases}$

[12 marks]

Soln)



Weight of the sphere = $\rho \forall g = 2.5 \times 1000 \times \frac{4}{3}\times\pi\times\left(\frac{1.5}{100}\right)^3 \times 9.81$

~~= 4.16856 × 10⁻⁴ kg~~

= 0.3467 N

$$Re = \frac{\rho V D}{\mu} = \frac{25 \times (3/100)}{1.4\times10^{-5}} = 53571.42$$

So $C_D = 0.5$

(Drag force) $F_D = C_D \times \frac{1}{2} \rho_a V^2$

$$= 0.5 \times 0.5 \times 1.2 \times \frac{\pi}{4} \times \left(\frac{3}{100}\right)^2 \times 25^2 = 0.1325\ N$$

$$T = \sqrt{F_D^2 + W_t^2} = \boxed{0.3711\ N}$$

$T \sin\theta = W_t$

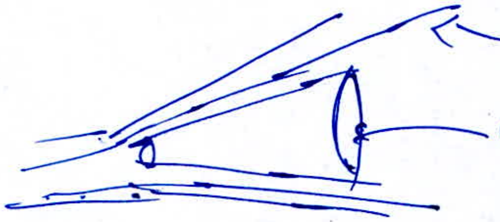
$$\sin\theta = \frac{0.3467}{0.3711}$$

$$\boxed{\theta = 69.1^\circ}$$

12

Q.5 (c) Explain with neat sketches about Freyssinet prestressing system. Also discuss its advantages and disadvantages.

[12 marks]



→ In fressinet prestressing system, there is conical mould which hold the wire b/w them.

(2)

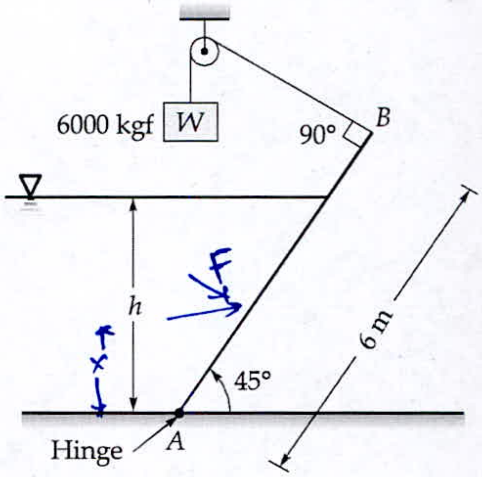
Adv

→ Any no. of wire can be prestressed simultaneously

→ Hold the wires more perfectly than others.

elaborate

Q.5 (d) A rectangular gate of dimensions 6 m × 3 m is hinged at its base and inclined at an angle of 45° to the horizontal. To maintain the gate's stability, a counterweight of 6000 *kgf* is attached to the top edge of the gate through a cable and pulley system. Determine the depth of water h at which the gate is just on the verge of falling. Neglect the self-weight of the gate and friction in the system.



[12 marks]

Soln)

weight = 6000 × 9.81 = 58860 kN

Calculate force of gate in term of h

$F = \rho g A \bar{x}$

$= 10^3 \times 9.81 \times (\sqrt{2}h) \times 3 \times \left(\frac{h}{2}\right)$

location for force from top

$h_{cp} = \frac{h}{2} + \frac{\frac{(\sqrt{2}h)^3 \times 3}{12} \times (\sin 45)^2}{(\sqrt{2}h) \times 3 \times \left(\frac{h}{2}\right)}$

$h_{cp} = \frac{2h}{3}$ (from top)

x from bottom = $h/3$

take moment about A

$$F \times \left(\frac{h}{3}\sqrt{2}\right) = T \times 6$$

$$10^3 \times 9.81 \times (\sqrt{2}\, h) \times 3 \times \frac{h}{2} \times \frac{h}{3} \times \sqrt{2} = 58860 \times 6$$

$$h = 3.302 m$$

12

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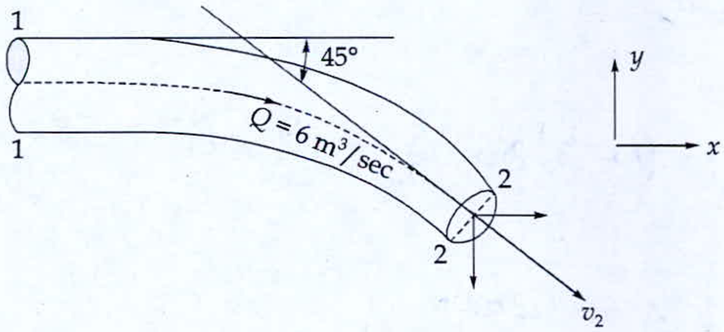
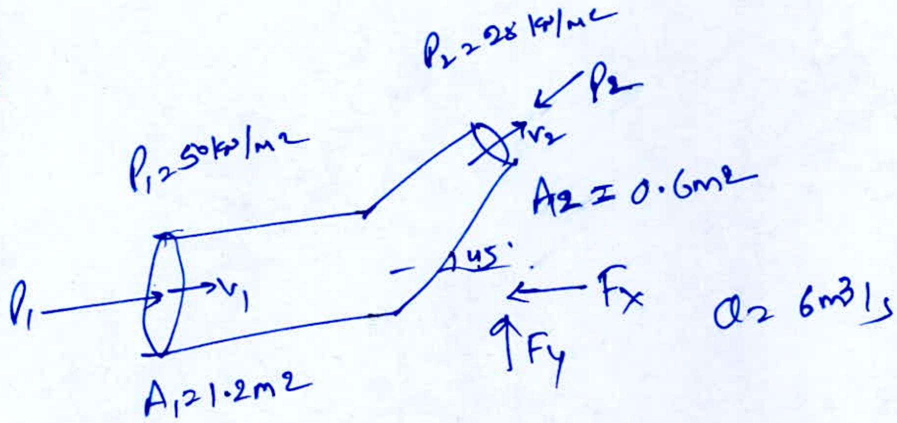
Q.5 (e) A pipeline carrying water has a 45° reducing bend in a horizontal plane. The crosssectional area at the inlet of the bend is 1.2 m^2 and at the outlet is 0.6 m^2. The pressure at the inlet is 50 kN/m^2, while at the outlet it is 25 kN/m^2. The discharge through the pipe is 6 m^3/s. Taking the density of water as 1000 kg/m^3, determine the magnitude and direction of the force required to hold the bend in position.



[12 marks]

sol)



find force req. in x-dir^n

$$P_1 A_1 - P_2 A_2 \cos(45) - F_x = \dot{m}(V_2 \cos\theta - V_1)$$

$$50 \times 1.2 - 25 \times 0.6 \times \cos(45°) - F_x = 10^3 \times 10^{-3} \times 6 \times \left(\frac{6}{0.6} \times \cos 45 - \frac{6}{1.2}\right)$$

$$F_x = 36.966 \text{ kN}$$

force req. in y-dir^n

$$F_y - P_2 A_2 \sin(45°) = 6 \times \left(\frac{6}{0.6} \times \sin 45°\right)$$

$$F_y = 53.033 \text{ kN}$$

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$F_R = \sqrt{F_x^2 + F_y^2} = \boxed{64.64\ kN}$

θ (with horizontal) $= \tan^{-1}\left(\frac{F_y}{F_x}\right) = \boxed{55.122^\circ}$

12

Q.6 (a) The difference in water surface levels in two tanks connected by three pipes in series of lengths 300 m, 170 m, and 210 m with diameters 300 mm, 200 mm, and 400 mm respectively is 12 m. The coefficients of friction for the three pipes are 0.005, 0.0052, and 0.0048 respectively. Determine the rate of flow of water considering–

(i) Minor losses

(ii) Neglecting minor losses.

Also calculate the percentage error in discharge estimation.

[20marks]

Q.6 (b) **(i)** What is thrust line (C-line) in prestressed beam? Explain its significance with respect to kern.

(ii) A prestressed concrete beam of rectangular section 300 mm wide and 600 mm deep spans over 10 m. The beam is prestressed by a parabolic cable carrying an effective force of 1000 kN. The cable has an eccentricity of 50 mm above the neutral axis at the supports and 150 mm below the neutral axis at mid-span. The beam supports a uniformly distributed live load of 10 kN/m in addition to its self-weight (density of concrete is 24 kN/m^3). Calculate the position of the thrust line (C-line) relative to the cable profile at intervals of 2.5 m along the span Based on the position of C-line also draw the locus of C-line.

[5 + 15 = 20 marks]

Q.6 (c) **(i)** Derive the equation of pressure in vortex motion. Prove that the isobars in forced vortex motion are parabolic in nature and also prove that the volume of paraboloid formed is half the volume of circumscribing cylinder.

(ii) A 15 cm diameter vertical cylinder rotates concentrically inside another cylinder of diameter 15.10 cm. Both cylinders are 25 cm high. The space between the cylinder is filled with a liquid whose viscosity is unknown. If a torque of 12 Nm is required to rotate the inner cylinder at 100 rpm, then determine the viscosity of the fluid. Assume linear velocity profile within the thin oil film.

[10 + 10 = 20 marks]

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Q.7 (a) **(i)** A head of water of 6 m is maintained over an orifice of 150 mm diameter. The water issuing from the orifice is collected in a circular measuring tank of 2.5 m diameter, where the rise of water level is observed to be 0.5 m in 25 *sec*. The coordinates of a point on the jet measured from the vena contracta are 120 cm horizontally and 6.5 cm vertically. Determine the hydraulic coefficients of the orifice, namely the coefficient of discharge, coefficient of velocity, and coefficient of contraction.

(ii) Consider a laminar boundary layer where the velocity profile is approximated by the expression

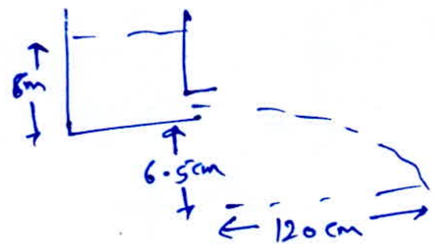
$$\frac{u}{u_\infty} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Here, u represents the velocity in the x-direction at a distance y from the boundary, δ denotes the boundary layer thickness, and u_∞ is the free stream velocity. Determine the ratio of the displacement thickness to the boundary layer thickness for this specific parabolic profile. Also work out the momentum thickness.

[10 + 10 = 20 marks]

Sol^n

(i)



$C_v = \frac{x}{2\sqrt{yH}} = \frac{1.2}{2\sqrt{0.065 \times 6}} = \boxed{0.9607}$

$Q_{th} = a \times V_{th}$

$= \frac{\pi}{4} \times 0.15^2 \times \sqrt{2 \times 9.81 \times 6} = 0.19173 \ m^3/s$

$Q_{act} = \frac{0.5 \times \frac{\pi}{4} \times 2.5^2}{25} = 0.09817$

10

$C_d = \frac{Q_{act}}{Q_{th}} = \frac{0.09817}{0.19173} = \boxed{0.512}$

$C_c = \frac{C_d}{C_v} = \frac{0.512}{0.9607} = \boxed{0.533}$

Do not write in this margin

(ii)

Displacement thickness is given as

$$\delta^* = \int_0^\delta \left(1 - \frac{U}{U_\infty}\right) dy$$

$$\delta^* = \int_0^\delta \left(1 - \left(2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right)\right)$$

$$\delta^* = \frac{\delta}{3}$$

$$\boxed{\frac{\delta^*}{\delta} = \frac{1}{3}}$$

momentum thickness

$$\delta^{**} = \int_0^\delta \left(\frac{U}{U_\infty}\right)\left(1 - \frac{U}{U_\infty}\right) dy$$

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

$$\boxed{\delta^{**} = \frac{2}{15}\delta}$$

6

elaborate steps and calculation details

Q.7 (b) **(i)** A solid wooden cylinder of diameter 400 mm and length 600 mm has a specific gravity of 0.6. The cylinder is placed vertically in water so that its longitudinal axis remains vertical while floating. Determine the metacentric height of the cylinder and state whether the equilibrium is stable or unstable.

(ii) A simply supported post-tensioned concrete beam of 10 m span, 230 mm wide and 400 mm deep is prestressed with a straight cable having a cross-sectional area of 385 mm^2 located at 60 mm from the soffit of the beam. The cable is subjected to an initial stress of 1200 N/mm^2 at the one jacking end. Estimate the total percentage loss of prestress.

Use the following data:

Modulus of Elasticity of steel (E_s) = 2.1×10^5 N/mm^2

Grade of concrete = M50 ($E_c = 5000\sqrt{f_{ck}}$)

Relaxation of stress in steel = 4.5%

Shrinkage strain of concrete = 0.0003

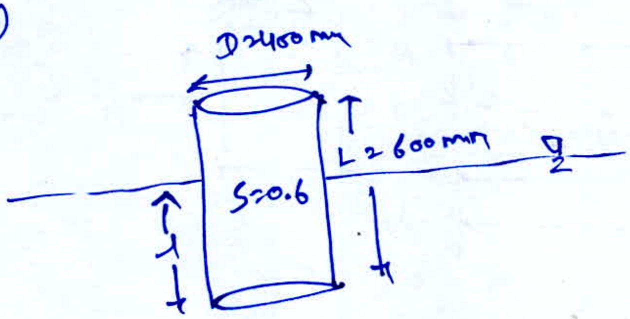
Creep coefficient of concrete (ϕ) = 1.6

Friction coefficient for wave effect (k) = 0.0025 per metre

Slip at anchorage = 2 mm

[8 + 12 = 20 marks]

(i)



F_B = wt of cylinder

$\left(\frac{\pi}{4} \times D^2 \times h\right) \times 1 = 0.6 \times \left(\frac{\pi}{4} \times D^2 \times 600\right)$

$h = 360 mm$

Metacentric Height (GM) = BM − BG

BG

$BG = 300 - \frac{360}{2} = 120$ mm

(8)

BM

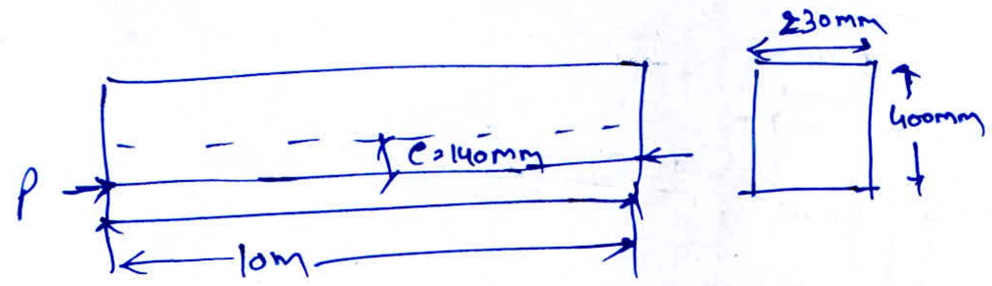
$= \frac{I}{V_{dis}} = \frac{\frac{\pi}{64} \times 0.4^4}{\frac{\pi}{4} \times 0.4^2 \times 0.36} = 27.77$ mm

metacentric Height (GM) = BM − BG

$= 27.77 - 120 = -92.23 < 0$

→ It is in unstable Equilibrium.

(ii)



$P = f \times A_c = 1200 \times 385 = 462$ kN

① loss due to creep

$w_{DL} = 0.23 \times 0.4 \times 25 = 2.3$ kN/m

$M_{DL} = \frac{2.3 \times 10^2}{8} = 28.75$ kN-m

f_{c_1} (at Ends)

$f_{c_1} = \frac{P}{A} + \frac{Pe^2}{I} = \frac{462 \times 10^3}{230 \times 400} + \frac{462 \times 10^3 \times 140^2}{\frac{230 \times 400^3}{12}}$

5

$f_{c_1} = 12.4036$ MPa

$f_{c_2} = \frac{P}{A} + \frac{Pe^2}{I} - \frac{M_{DL} \times e}{I} = 9.1224$ MPa

$f_{cay} = 12.4036 - \frac{2}{3}(12.4636 - 9.1224)$
$= 10.216$

$= \phi m f_{cay} = 1.6 \times \frac{2.1 \times 10^5}{5000\sqrt{50}} \times 10.216$

loss $= 97.087$ MPa

(ii) Loss due to friction

$$\text{Loss} = P_0 (kx + \mu\alpha) \rightarrow \text{Not given}$$

$$= 1200 \times (0.0025 \times 10 + 0 \times \alpha) = 30 \text{ mpa}$$

(iii) Due to Relaxation

$$= \frac{4.5}{100} \times 1200 = \boxed{54 \text{ mpa}}$$

(iii) Due to shrinkage

$$\varepsilon_s \cdot E_s = 3 \times 10^{-4} \times 2.1 \times 10^5 = \boxed{63 \text{ mpa}}$$

Total loss

$$= 97.087 + 30 + 54 + 63 = \boxed{244.087 \text{ mpa}}$$

Anchorage slip ?

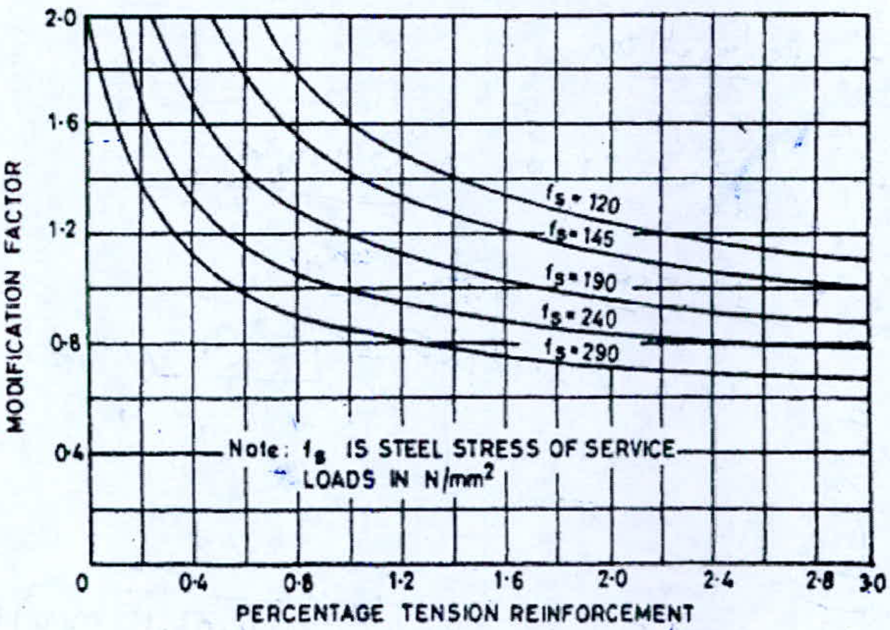
Incomplete

Read question carefully

Asked about %age loss

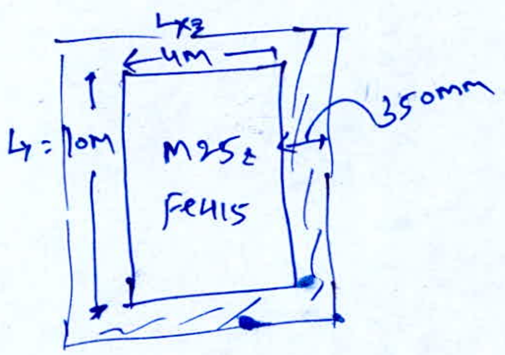
Q.7 (c) Design a simply supported reinforced concrete slab for a clear room dimension of 4.0 m × 10.0 m. The slab is supported on masonry walls 350 mm thick. The slab is subjected to a live load of 3 kN/m^2 and a floor finish load of 0.75 kN/m^2. Use M-25 grade concrete and Fe-415 grade steel. Perform all necessary design checks, including shear and deflection, to ensure structural safety and serviceability. Assume any other data suitably. Relevant chart from IS 456 is enclosed here.

$\frac{100\,Ast}{bd}$	0.25	0.5	0.75	1.0	1.25	1.50	1.75
τ_c (MPa)	0.36	0.49	0.57	0.64	0.70	0.74	0.78



[20 marks]

Soln)



$W_{LL} = 3\ kN/m^2$

$W_{FF} = 0.75\ kN/m^2$

① Assume depth of slab

$$d = \frac{4000 + d}{20 \times 1.1}$$

$d = 190.47$

Provide $d = 200$ mm & 30mm effective cover.

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(2) Effective length of slab

$L_x = 4 + 0.2 = 4.2 m$

$L_y = 10 + 0.2 = 10.2 m$

Aspect ratio $= \frac{L_y}{L_x} = \frac{10.2}{4.2} = 2.42 > 2$ (one way slab)

(3) Calculate loads & max. BM

$w_{LL} = 3 \times 1 \times 1 = 3 kN/m$

$w_{FF} = 0.75 \times 1 \times 1 = 0.75 kN/m$

$w_{DL} = 0.23 \times 1 \times 1 \times 25 = 5.75 kN/m$

$w_0 = 9.5 kN/m$

$w_{u0} = 14.25 kN/m$ (for 1m width)

(4) max. BM

$BM_u = \frac{14.25 \times 4.2^2}{8} = 31.4212 kN\text{-}m$

(5) Check dreq

$d_{req} = \sqrt{\frac{BM_u}{QB}} = \sqrt{\frac{31.4212 \times 10^6}{0.138 \times 25 \times 1000}} = 95.433 m$

$d_{req} < d_{prov.}$ — ok

(6) Calculate Ast

$$A_{st_x} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} B d^2}}\right] \times B d$$

$$A_{st_x} = \frac{0.5 \times 25}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 31.42 \times 10^6}{25 \times 1000 \times 200^2}}\right] \times 1000 \times 200$$

$A_{st_x} = 452.32 mm^2$

Check for min. Ast

$A_{st,min} = \frac{0.12}{100} \times 1000 \times 200 = 240 mm^2$

(7) Calculate spacing

~~Provid~~

• Spacing of main bars

Use 10mmϕ bars

$S_x = \frac{1000 \times \frac{\pi}{4} \times 10^2}{452.32} = 173.63 mm$

Provide 10mm ϕ @ 170mm c/c

Spacing of distribution bars

$S_y = \frac{1000 \times \frac{\pi}{4} \times 10^2}{240} = 327.25 mm \not> 300 mm$

Provide 10mm ϕ @ 300 mm c/c.

(8) Check for shear

$V_u = \frac{W_u L_{clx}}{2} = \frac{14.25 \times 4}{2} = 28.5 kN$

$\tau_v = \frac{28.5 \times 10^3}{1000 \times 200} = 0.1425 < \tau_c$ (min. i.e. 0.36 MPa)

— OK.

(9) Check for deflection

$$d \geq \frac{\text{Eff. span}}{(A) \times MF_t}$$

14

$$f_{st} = 0.58 \times f_y \times \frac{A_{st\,req}}{A_{st\,pro}}$$

$$= 0.58 \times 415 \times \frac{452.32}{\frac{1000}{170} \times \frac{\pi}{4} \times 10^2} = 235.65 \text{ MPa}$$

$$P_t\% = \frac{\left(\frac{1000}{170} \times \frac{\pi}{4} \times 100\right)}{1000 \times 200} \times 100 = 0.231\%$$

MF_t (from table) = 1.5

$$d \geq \frac{4200}{20 \times 1.5}$$

$d \geq 140$ mm — ok. ($d_{pro} = 200$ mm)

R/F Details?

Assume data suitably as per codal provision

Apply all necessary check

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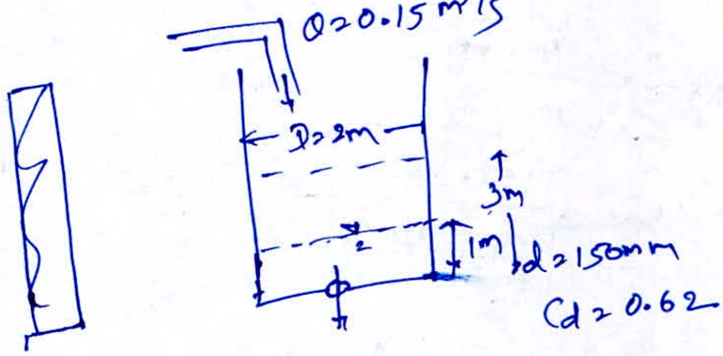
Q.8 (a) A Vertical cylindrical tank of 2 m diameter initially contains water up to a height of 1 m. Water enters the tank at a constant rate of 0.15 m^3/s through an inlet pipe, while it simultaneously discharges through a sharp-edged orifice of 150 mm diameter provided at the base. The coefficient of discharge of the orifice is 0.62. Determine the time required for the water level to rise from 1 m to 3 m.

[20 marks]

Sol^n



~~Water~~: water incom − water outgo = water stored.

$$\left(Q - C_d a\sqrt{2gh}\right) \times dT = A\,dh$$

$$\left(0.15 - 0.62 \times \frac{\pi}{4} \times 0.15^2 \times \sqrt{2 \times 9.81 \times h}\right) dT = \frac{\pi}{4} \times 2^2 \times dh$$

$$\int_0^T dT = \int_1^3 \left(\frac{\frac{\pi}{4} \times 2^2 \times dh}{0.15 - 0.62 \times \frac{\pi}{4} \times 0.15^2 \times \sqrt{2 \times 9.81 \times h}} \right)$$

$$\boxed{T = 77.68\ \text{sec}}$$

15

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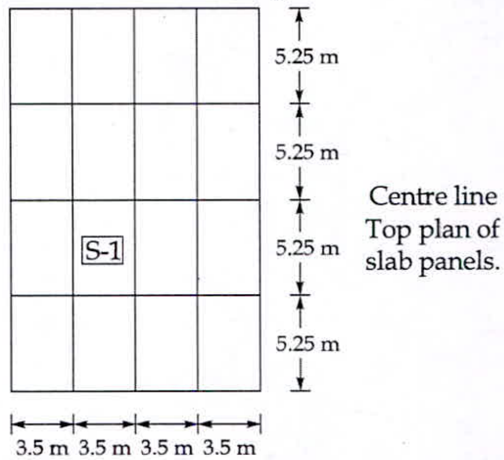
Q.8 (b) A solid interior *RCC* slab panel *S*-1 with effective spans L_x = 3.5 m and L_y = 5.25 m forms part of a floor system as shown in the figure below.



The slab carries a total design load of 25 kN/m^2. Using the Limit State Method as per IS 456: 2000, determine the spacing of all main reinforcements using 10 mm diameter HYSD bars throughout. The effective depth of slab may be assumed as 150 mm. Concrete grade is M25 and steel grade is Fe 415. Check spacing limits and specify the vertical placement of reinforcement. Shear check is not required.

IS 456 : 2000

Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners

(Clauses D-1.1 *and* 24.4.1*)*

Case No.	Type of Panel and Moments Considered	Short Span Coefficients α_x (Values of l_y/l_x)								Long Span Coefficients α_y for All Values of l_y/l_x
		1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	*Interior Panels:*									
	Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032
	Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024
2	*One Short Edge Continuous:*									
	Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037
	Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028
3	*One Long Edge Discontinuous:*									
	Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037
	Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028
4	*Two Adjacent Edges Discontinuous:*									
	Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047
	Positive moment at mid-span	0.035	0.040	0.045	0.049	0.053	0.056	0.063	0.069	0.035
5	*Two Short Edges Discontinuous:*									
	Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	—
	Positive moment at mid-span	0.035	0.037	0.040	0.043	0.044	0.045	0.049	0.052	0.035
6	*Two Long Edges Discontinuous:*									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
	Positive moment at mid-span	0.035	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
7	*Three Edges Discontinuous (One Long Edge Continuous):*									
	Negative moment at continuous edge	0.057	0.064	0.071	0.076	0.080	0.084	0.091	0.097	—
	Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.064	0.069	0.073	0.043
8	*Three Edges Discontinuous (One Short Edge Continuous):*									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.057
	Positive moment at mid-span	0.043	0.051	0.059	0.065	0.071	0.076	0.087	0.096	0.043
9	*Four Edges Discontinuous:*									
	Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056

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TABLE 3 FLEXURE — REINFORCEMENT PERCENTAGE, p_t FOR SINGLY REINFORCED SECTIONS

f_{ck} = 25 N/mm²

M_u/bd^2, N/mm²	f_y, N/mm² 240	250	415	480	500
0·30	0·146	0·140	0·084	0·073	0·070
0·35	0·171	0·164	0·099	0·085	0·082
0·40	0·195	0·188	0·113	0·098	0·094
0·45	0·220	0·211	0·127	0·110	0·106
0·50	0·245	0·236	0·142	0·123	0·118
0·55	0·271	0·260	0·156	0·135	0·130
0·60	0·296	0·284	0·171	0·148	0·142
0·65	0·321	0·309	0·186	0·161	0·154
0·70	0·347	0·333	0·201	0·174	0·167
0·75	0·373	0·358	0·216	0·186	0·179
0·80	0·399	0·383	0·231	0·199	0·191
0·85	0·425	0·408	0·246	0·212	0·204
0·90	0·451	0·433	0·261	0·225	0·216
0·95	0·477	0·458	0·276	0·239	0·229
1·00	0·504	0·483	0·291	0·252	0·242
1·05	0·530	0·509	0·307	0·265	0·255
1·10	0·557	0·535	0·322	0·279	0·267
1·15	0·584	0·561	0·338	0·292	0·280
1·20	0·611	0·587	0·353	0·306	0·293
1·25	0·638	0·613	0·369	0·319	0·306
1·30	0·666	0·639	0·385	0·333	0·320
1·35	0·693	0·666	0·401	0·347	0·333
1·40	0·721	0·692	0·417	0·360	0·346
1·45	0·749	0·719	0·433	0·374	0·359
1·50	0·777	0·746	0·449	0·388	0·373
1·35	0·805	0·773	0·466	0·403	0·387
1·60	0·834	0·800	0·482	0·417	0·400
1·65	0·862	0·828	0·499	0·431	0·414
1·70	0·891	0·856	0·515	0·446	0·428
1·75	0·920	0·883	0·532	0·460	0·442
1·80	0·949	0·911	0·549	0·475	0·456
1·85	0·979	0·940	0·566	0·489	0·470
1·90	1·009	0·968	0·583	0·504	0·484
1·95	1·038	0·997	0·601	0·519	0·498
2·00	1·068	1·026	0·618	0·534	0·513
2·05	1·099	1·055	0·635	0·549	0·527
2·10	1·129	1·084	0·653	0·565	0·542
2·15	1·160	1·114	0·671	0·580	0·557
2·20	1·191	1·143	0·689	0·596	0·572
2·25	1·222	1·173	0·707	0·611	0·587
2·30	1·254	1·204	0·725	0·627	0·602
2·35	1·285	1·234	0·743	0·643	0.617
2·40	1·317	1·265	0·762	0·659	0·632
2·45	1·350	1·296	0·781	0·675	0·648
2·50	1·382	1·327	0·799	0·691	0·663

M_u/bd^2, N/mm²	f_y, N/mm² 240	250	415	480	500
2·55	1·415	1·358	0·818	0·708	0·679
2·60	1·448	1·390	0·837	0·724	0·695
2·65	1·482	1·422	0·857	0·741	0·711
2·70	1·515	1·455	0·876	0·758	0·727
2·75	1·549	1·487	0·896	0·775	0·744
2·80	1·584	1·520	0·916	0·792	0·760
2·85	1·618	1·554	0·936	0·809	0·777
2·90	1·653	1·587	0·956	0·827	0·794
2·95	1·689	1·621	0·977	0·844	0·811
3·00	1·724	1·655	0·997	0·862	0·828
3·05	1·760	1·690	1·018	0·880	0·845
3·10	1·797	1·725	1·039	0·898	0·863
3·15	1·834	1·760	1·061	0·917	0·880
3·20	1·871	1·796	1·082	0·936	0·898
3·25	1·909	1·832	1·104	0·954	0·916
3·30	1·947	1·869	1·126	0·973	0·935
3·32	1·962	1·884	1·135	0·981	0·942
3·34	1·978	1·899	1·144	0·989	
3·36	1·993	1·914	1·153		
3·38	2·009	1·929	1·162		
3·40	2·025	1·944	1·171		
3·42	2·040	1·959	1·180		
3·44	2·056	1·974	1·189		
3·46	2·072	1·989			
3·48	2·088	2·005			
3·50	2·104	2·020			
3·52	2·120	2·036			
3·54	2·137	2·051			
3·56	2·153	2·067			
3·58	2·170	2·083			
3·60	2·186	2·099			
3·62	2·203	2·115			
3·64	2·219	2·131			
3·66	2·236	2·147			
3·68	2·253	2·163			
3·70	2·270	2·179			
3·72	2·287	2·196			
3·74	2·304				

NOTE — Blanks indicate inadmissible reinforcement percentage (*see* Table E).

[20 marks]

Sol^n

$L_{ex} = 3.5$ $\quad$ $W_u = 25$ kN/m²

$L_{ey} = 5.25$ $\quad$ $d = 150$ mm

① Calculate Aspect ratio

$$AR = \frac{5.25}{3.5} = 1.5$$

② Bending moment coefficients

$\alpha_x^+ = 0.041$ $\quad$ $\alpha_y^+ = 0.024$

$\alpha_x^- = 0.053$ $\quad$ $\alpha_y^- = 0.032$

③ Calculate Bending moments

$M_{ux}^{(+)} = \alpha_x^+ w_{u0} L_{ex}^2 = 12.556$ kN-m

$M_{ux}^{(-)} = \alpha_y^- w_{u0} L_{ex}^2 = 16.231$ kN-m

Similarly

$M_{uy}^+ = 7.35$ kN-m

$M_{uy}^- = 9.8$ kN-m

④ Calculate Area of steel (use $\phi = 10$mm)

	Ast (mm²)	Spacing	
$M_{ux}^{(+)}$	240	300mm	
$M_{ux}^{(-)}$	312.75	250mm	
$M_{uy}^{(+)}$	180 mm²	300mm	
$M_{y}^{(-)}$	185mm²	300mm	

$\rightarrow \frac{M_{ux}^{(+)}}{Bd^2} = \frac{12.556 \times 10^6}{1000 \times 150^2} = 0.558$

(from table)

$P_t(\%) = 0.16$

$A_{st} = \frac{0.16}{100} \times 1000 \times 150 =$

$\rightarrow \frac{M_{uy}^{(+)}}{Bd^2} = 0.3266 \rightarrow A_{st}(\%) = 0.0917 < A_{st\,min}$

Provide Ast min,

i.e.

$A_{st\,min} = \frac{0.12}{100} \times 1000 \times 150 = 180$ mm2

Do not write in this margin

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$$S = \frac{1000 \times \frac{\pi}{4} \times 10^2}{A_{st}}$$

$$S = \frac{1000 \times \frac{\pi}{4} \times 10^2}{240} = 327mm \not> 300mm$$

Provide spacing = 300mm.

(similarly for others)

elaborate steps and calculation details

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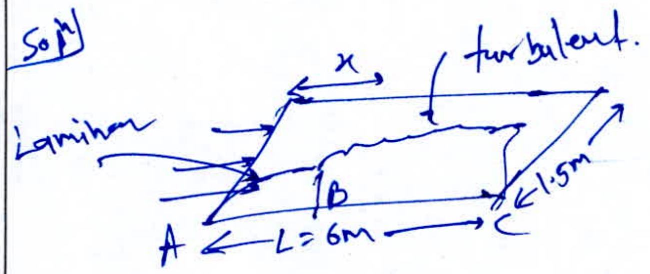
Q.8 (c) Air flows over a flat plate of 6 m length and 1.5 m width at a free-stream velocity of 6 m/s. The density of air is 1.205 kg/m^3 and the dynamic viscosity is 1.81×10^{-5} Pa·s. Assume The flow undergoes transition to turbulent flow at a critical Reynolds number of 5×10^5. Determine the total drag force acting on one side of the plate. Assume the flow occurs along the length of the plate.

Take, coefficient of drag, $C_D = \begin{cases} \dfrac{1.328}{(R_e)^{0.5}} & \text{(For laminar flow)} \\ \dfrac{0.074}{(R_e)^{0.2}} & \text{(For turbulent flow)} \end{cases}$

[20 marks]

Soln



$\rho = 1.205$ kg/m^3

$\mu = 1.81 \times 10^{-5}$

$(Re)_{cr} = 5 \times 10^5$

Calculate transition point at which flow behaviour changes

$$5 \times 10^5 = \frac{1.205 \times 6 \times x}{1.81 \times 10^{-5}}$$

$$x = 1.2517 \text{ m}$$ (from leading Edge)

$$F_D = [F_{AB}]_{Laminar} + \left[[F_{AC}]_{turb} - [F_{AB}]_{turb} \right]$$

$$= \frac{1.328}{(5 \times 10^5)^{0.5}} \times \frac{1}{2} \times 1.205 \times 1.2517 \times 6^2 \times 1.5 +$$

$$\left[\frac{0.074}{\left(\frac{1.205 \times 6 \times 6}{1.81 \times 10^{-5}}\right)^{1/5}} \times 0.5 \times 1.205 \times 6 \times 1.5 \times 6^2 - \frac{0.074}{(5 \times 10^5)^{1/5}} \times 0.5 \times 1.205 \times 1.2517 \times 1.5 \times 6^2 \right]$$

$F_D = 0.6233\ N$

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OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work