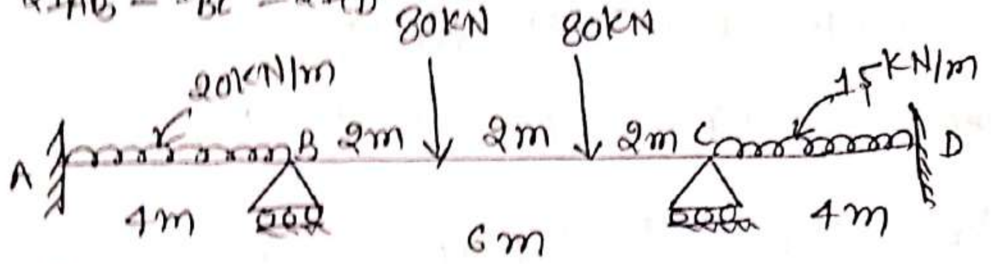
Ans 2 ⇒ $2I_{AB} = I_{BC} = 2I_{CD} = 2I$

2(b) ⇒



$I_{AB} = I_{CD} = I$, $I_{BC} = 2I$, $\theta_A = \theta_D = 0$ (A & D are fixed)

Fixed end moment ⇒

$$\overline{M}_{AB} = -\frac{wl^2}{12} = -\frac{20\times 4^2}{12} = -26.67\ KNm$$

$$\overline{M}_{BA} = +\frac{wl^2}{12} = \frac{20\times 4^2}{12} = 26.67\ KNm$$

$$\overline{M}_{BC} = -\left[\frac{Wa_1 b_1^2}{l^2} + \frac{Wa_2 b_2^2}{l^2}\right] = -\left[\frac{80\times 2\times 4^2}{6^2} + \frac{80\times 4\times 2^2}{6^2}\right]$$

$$= -106.67\ KNm$$

$$\overline{M}_{CB} = \left[\frac{Wa_1^2 b_1}{l^2} + \frac{Wa_2^2 b_2}{l^2}\right] = \left[\frac{80\times 2^2\times 4}{6^2} + \frac{80\times 4^2\times 2}{6^2}\right]$$

$$= 106.67\ KNm$$

$$\overline{M}_{CD} = -\frac{wl^2}{12} = -\frac{15\times 4^2}{12} = -20\ KNm$$

$$\overline{M}_{DC} = \frac{wl^2}{12} = \frac{15\times 4^2}{12} = 20\ KNm$$

$$M_{AB} = \overline{M}_{AB} + \frac{2EI}{l}\left[2\theta_A + \theta_B - \frac{3\delta}{l}\right]$$

$$= -26.67 + \frac{2EI}{l}\left[0 + \theta_B + 0\right]$$

$$= -26.67 + \frac{2EI\theta_B}{4} = -26.67 + 0.5EI\theta_B \quad -(1)$$

$$M_{BA} = \overline{M}_{BA} + \frac{2EI}{l}\left(2\theta_B + \theta_A - \frac{3\delta}{l}\right)$$

$$= 26.67 + \frac{2EI}{4}(2\theta_B + 0 - 0) = 26.67 + EI\theta_B \quad -(2)$$

$$M_{BC} = \overline{M}_{BC} + \frac{2EI}{l}\left(2\theta_B + \theta_C - \frac{3\delta}{l}\right)$$

$$= -106.67 + \frac{2E \times 2I}{6}(2\theta_B + \theta_C - 0)$$

$$M_{BC} = -106.67 + EI(1.333\theta_B + 0.666\theta_C) \quad \text{— (3)}$$

$$M_{CB} = \overline{M}_{CB} + \frac{2EI}{l}\left(2\theta_C + \theta_B - \frac{3\delta}{l}\right)$$

$$= 106.67 + \frac{2E \times 2I}{6}(2\theta_C + \theta_B)$$

$$M_{CB} = 106.67 + EI(1.333\theta_C + 0.666\theta_B) \quad \text{— (4)}$$

$$M_{CD} = \overline{M}_{CD} + \frac{2EI}{l}\left(2\theta_C + \theta_D - \frac{3\delta}{l}\right)$$

$$= -20 + \frac{2EI}{4}(2\theta_C + 0 - 0)$$

$$= -20 + EI\theta_C \quad \text{— (5)}$$

$$M_{DC} = \overline{M}_{DC} + \frac{2EI}{4}\left(\theta_C + 2\theta_D - 3\delta/l\right)$$

$$= +20 + 0.5EI\theta_C \quad \text{— (6)}$$

$$M_{BA} + M_{BC} = 0$$

$$M_{CB} + M_{CD} = 0$$

$$26.67 + EI\theta_B - 106.67 + EI(1.333\theta_B + 0.666\theta_C) = 0$$

$$2.333\theta_B + 0.666\theta_C = \frac{80}{EI} \quad \text{— (7)}$$

$$106.67 + EI(0.666\theta_B + 1.333\theta_C) - 20 + EI\theta_C = 0$$

$$0.666\theta_B + 2.333\theta_C = \frac{-86.67}{EI} \quad \text{— (8)}$$

Solving eqn —

$$\boxed{\theta_B = \frac{48.88}{EI}} \quad \boxed{\theta_C = -\frac{51.11}{EI}}$$

Scanned by CamScanner

$$M_{AB} = -26.67 + 0.5EI\left(\frac{48.88}{EI}\right) = -2.23\ KNm$$

$$M_{BA} = 26.67 + EI \times \left(\frac{48.88}{EI}\right) = 75.55\ KNm$$

$$M_{BC} = -106.67 + EI\left(1.333\theta_B + 0.666\theta_C\right)$$

$$= -106.67 + EI\left(1.333\left(\frac{48.88}{EI}\right) + 0.666\left(-\frac{51.11}{EI}\right)\right)$$

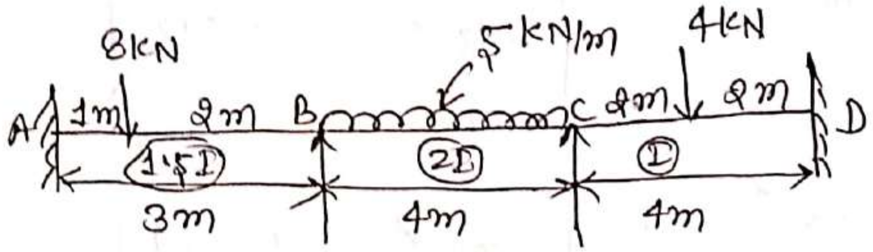
$$= -75.55\ KNm$$

$$M_{CB} = 71.09\ KNm$$

$$M_{CD} = -71.11\ KNm$$

$$M_{DC} = -5.56\ KNm$$

2(a) ⇒



$$\overline{M}_{ab} = -\frac{8\times1\times2^2}{3^2} = -3.56\ KNm, \quad \overline{M}_{ba} = \frac{8\times1^2\times2}{3^2} = +1.78\ KNm$$

$$\overline{M}_{bc} = -\frac{5\times4^2}{12} = -6.67\ KNm, \quad \overline{M}_{cb} = \frac{5\times4^2}{12} = 6.67\ KNm$$

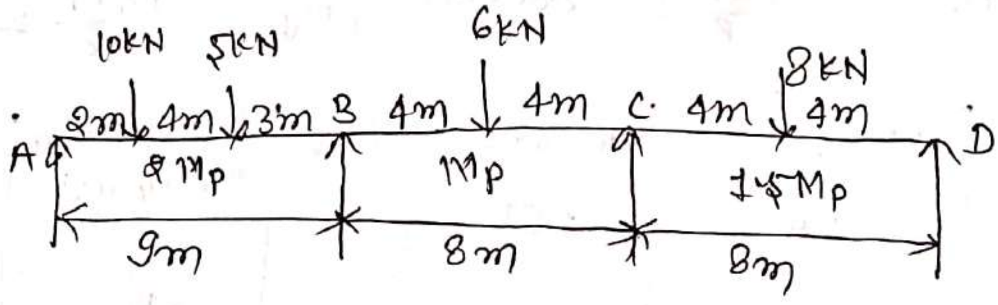
$$\overline{M}_{cb} = -\frac{4\times4}{8} = -2.00\ KNm, \quad \overline{M}_{dc} = +\frac{4\times4}{8} = +2\ KNm$$

Joint	Member	Relative stiffness	Total Relative stiffness	Distribution factors
B	BA	$\frac{1.5I}{3} = \frac{I}{2}$	$\frac{2I}{2}$	$1/2$
	BC	$I/2$		$1/2$
C	CB	$\cancel{\frac{1.5I}{3} = \frac{2I}{4}}$ $\frac{2I}{4}$	$\frac{3I}{4}$	$\frac{2}{3}$
	CD	$I/4$		$1/3$

Scanned by CamScanner

	1/2	1/2	2/3	1/3	
-3.56	1.78	-6.67	6.67	-2	+2
			-3.11	-1.56	
	2.44	2.45			
+1.22		-1.56	1.23		-0.78
	0.78	0.78	-0.82	-0.41	
0.39		-0.41	0.39		-0.20
	+0.20	+0.21	-0.26	-0.13	
0.10		-0.13	0.10		-0.07
	+0.06	+0.07	-0.07	-0.03	
+0.03		-0.04	+0.04		-0.02
	+0.02	+0.02	-0.03	-0.01	
-1.82	+5.28	-5.28	+4.14	-4.14	+0.93

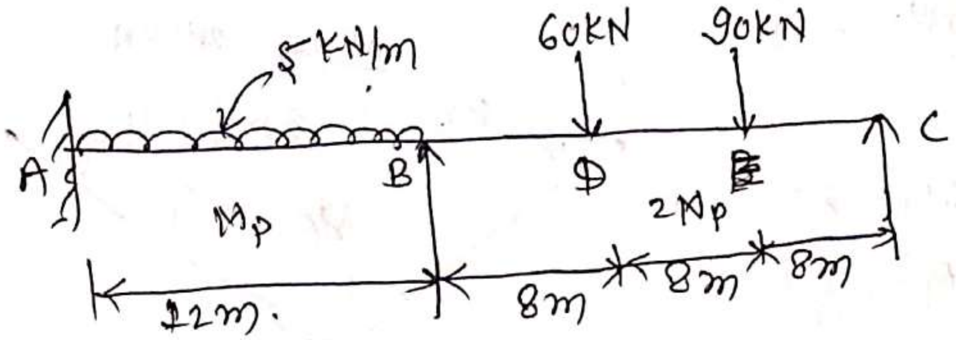
2(c) ⇒



2(d) ⇒

Ans 4 ⇒

(a) →



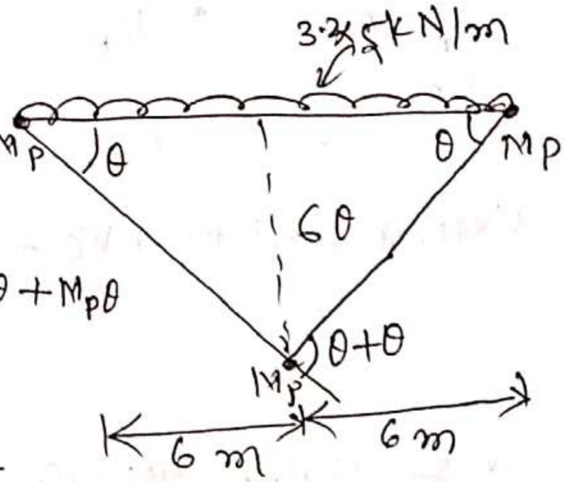
Degree of redundancy, r = ~~5 − 3 = 2~~ $4-2=2$

No. of plastic hinge $= r+1 = 2+1 = 3$

No. of possible hinge $= 5$ (A, B, in AB, D & E)

No. of independent mechanism $= N - r = 5-2 = 3$

Mechanism 1 ⇒



Internal work done

$W_i = M_p\theta + 2M_p\theta + M_p\theta$

$= 4M_p\theta$

External work done −

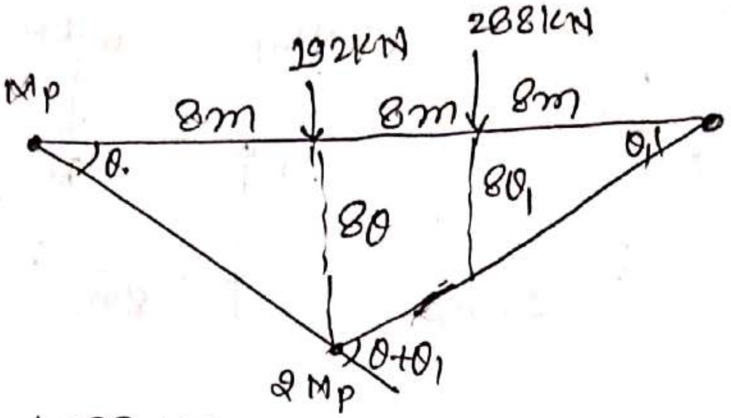
$W_e = \frac{1}{2} \times \cancel{12}^{6} \times 6\theta \times \cancel{5}6$

$W_i = W_e$

$4M_p\theta = 576\theta$

$$\boxed{M_p = 144 \text{ KNm}}$$

Mechanism 2 ⇒



$16\theta_1 = 8\theta$

$\boxed{\theta_1 = \theta/2}$

$W_e = 192 \times 8\theta + 288 \times 4\theta = 2688\theta$

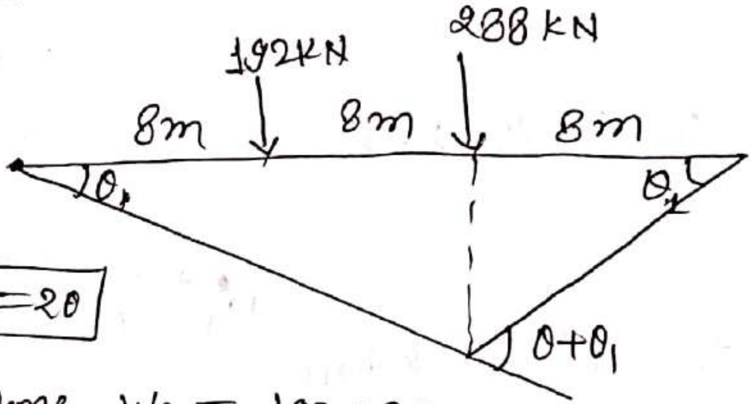
$W_i = M_p + 2M_p(\theta + \theta/2)$

$= 4M_p\theta$

$4M_p\cancel{\theta} = 2688\cancel{\theta}$

$\boxed{M_p = 672 kNm}$

Mechanism 3 -



$8\theta_1 = 16\theta$

$\cancel{\theta_1 = \theta/2}$ $\boxed{\theta_1 = 2\theta}$

External work done, $W_e = 192 \times 8\theta_1 + 288 \times 8\theta_1$

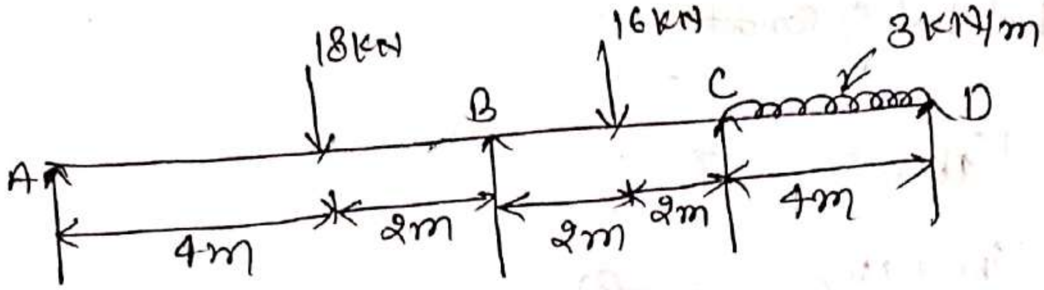
$= \cancel{192}\ 6144$

$W_i = M_p \times \theta_1 + 2M_p(\theta+\theta_1) = 7M_p$

~~= 4Mpθ~~ $M_p = \frac{6144}{7} = 877.71$ kNm

$\boxed{M_p = 877.71 kNm}$

(b) →



F.E.M ⇒

$$\overline{M}_{ab} = -\frac{wab^2}{l^2} = -\frac{18\times4\times2^2}{6^2} = -8\text{ kNm}$$

$$\overline{M}_{ba} = +\frac{wa^2b}{l^2} = \frac{18\times2\times4^2}{6^2} = 16\text{ kNm}$$

$$\overline{M}_{bc} = -\frac{PL}{8} = -\frac{16\times4}{8} = -8\text{ kNm}$$

$$\overline{M}_{cb} = +\frac{PL}{8} = \frac{16\times4}{8} = +8\text{ kNm}$$

$$\overline{M}_{cD} = -\frac{wl^2}{12} = -\frac{3\times4^2}{12} = -4\text{ kNm}$$

$$\overline{M}_{Dc} = +\frac{wl^2}{12} = +\frac{3\times4^2}{12} = 4\text{ kNm}$$

$$M_{ab} = \overline{M}_{ab} + \frac{2EI}{l}\left[2\theta_A+\theta_B-\frac{3\delta}{l}\right]$$

$$= -8+\frac{2EI}{6}(2\theta_A+\theta_B) = -8+0.667EI\theta_A+0.333EI\theta_B \quad -①$$

$$M_{ba} = \overline{M}_{ba} + \frac{2EI}{l}\left[2\theta_B+\theta_A-\frac{3\delta}{L}\right]$$

$$= 16+\frac{2EI}{6}(2\theta_B+\theta_A) = 16+0.666EI\theta_B+0.333EI\theta_A \quad -②$$

$$M_{bc} = -8+\frac{2EI}{4}(2\theta_B+\theta_c-0) = -8+EI\theta_B+0.5EI\theta_c \quad -③$$

$$M_{cb} = +8+\frac{2EI}{4}(\theta_B+2\theta_c) = +8+EI\theta_c+0.5EI\theta_B \quad -④$$

$$M_{cD} = -4+\frac{2EI}{4}(2\theta_c+\theta_D) = -4+EI\theta_c+0.5EI\theta_D \quad -⑤$$

$$M_{Dc} = +4+0.5EI\theta_c+EI\theta_D \quad -⑥$$

Scanned by CamScanner

Compatibility condition $\Rightarrow$

$M_{ab} = 0$ — (7)

$M_{ba} + M_{bc} = 0$ — (8)

$M_{cb} + M_{cD} = 0$ — (9)

$M_{DC} = 0$ — (10)

$-8 + 0.666 EI\theta_A + 0.333 EI\theta_B = 0$

$\cancel{2EI\theta_A + EI\theta_B = 8 - (7)}$

$0.666 EI\theta_A + 0.333 EI\theta_B = 8$ — (7)

$16 + 0.333 EI\theta_A + 0.666 EI\theta_B - 8 + EI\theta_B + 0.5 EI\theta_C = 0$

$0.333 EI\theta_A + 1.666 EI\theta_B + 0.5 EI\theta_C = -8$ — (8)

$8 + EI\theta_C + 0.5 EI\theta_B - 4 + EI\theta_C + 0.5 EI\theta_D = 0$

$0.5 EI\theta_B + 2EI\theta_C + 0.5 EI\theta_D = -4$ — (9)

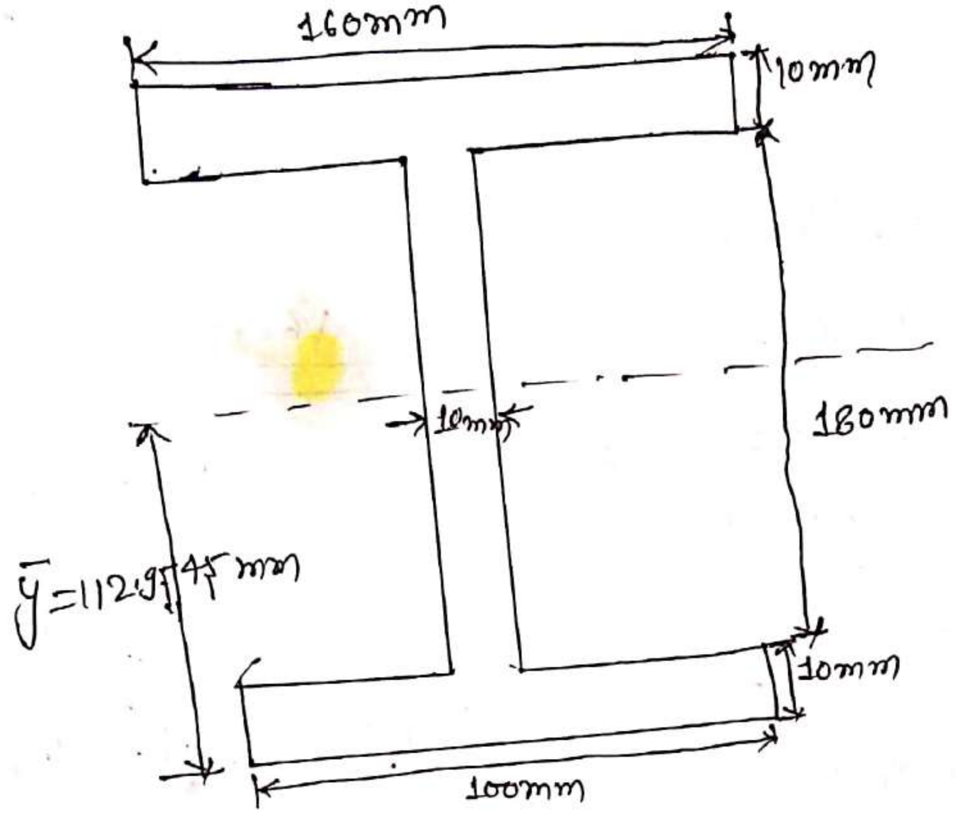
$+4 + 0.5 EI\theta_C + EI\theta_D = 0$

$0.5 EI\theta_C + EI\theta_D = -4$ — (10)

Scanned by CamScanner

Q3 ⇒

3(a) ⇒



find shape factor = ?

$$S = \frac{Z_p}{Z}$$

Location of Centroidal axis -

$$\bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1+A_2+A_3} = \frac{100\times10\times5 + 180\times10\times100 + 160\times10\times(200-5)}{100\times10+180\times10+160\times10}$$

$$= \frac{5000 + 180000 + 312000}{4400}$$

$$\boxed{\bar{y} = 112.9545\,mm}$$

$Z = I/y_{max}$

$$I = \frac{100\times20^3}{12} + 100\times10\times(112.9545-10)^2 + \frac{10\times180^3}{12} + 10\times180\times(112.9545-100)^2 + \frac{160\times10^3}{12} + (160\times10)\times(112.9545-195)^2$$

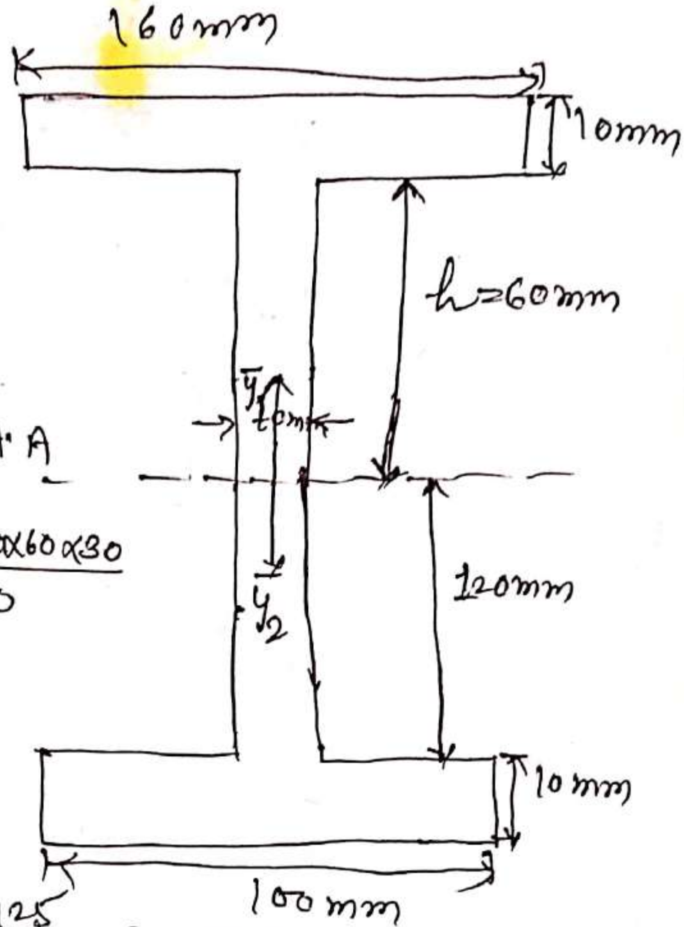
$$= 10607962.4 + 5162074.326 + 10783675.85$$

$$= 26553712.57\,mm^4$$

$Z = I/y_{max} = 235083.2643\ mm^3$

$Z_p = A/_2(\bar{y}_1 + \bar{y}_2)$

Equal area axes –



$160 \times 10 + 10 \times h = \frac{4400}{2}$

$10h = 2200 - 1600$

$10h = 600$

$\boxed{h = 60mm}$

$\bar{y}_1 = \frac{A_1y_1 + A_2y_2}{A_1 + A_2} = \frac{1600 \times 65 + 10 \times 60 \times 30}{2200}$

$= \frac{18000 + 104000}{2200}$

$\bar{y}_1 = 55.4545\ mm$

$\bar{y}_2 = \frac{120 \times 60 \times 10 + 100 \times 10 \times 125}{2200} = 89.5454\ mm$

$Z_p = \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$

$= \frac{4400}{2}(55.4545 + 89.5454 = 318999.78\ mm^3$

$\boxed{S = \frac{Z_p}{Z} = 1.35}$

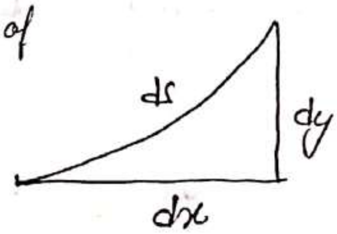
Ans 3 ⇒

3(b) ⇒ **Cable ⇒** cable is a flexible member which have zero moment at any point in the cable.

The maximum sag or dip of the cable varies from $\frac{l}{10}$ to $\frac{l}{15}$ where l is the horizontal span.

Length of cable ⇒

Consider an elementary length ds of the cable.



length of this cable = ds

Parabola eqn —

$y = kx^2$

at $x = l/2$ $y = d$, $d = k\frac{l^2}{4}$ $k = \frac{4d}{l^2}$

$$y = \frac{4d}{l^2}x^2$$

$$\frac{dy}{dx} = \frac{4d}{l^2} \times 2x = \frac{8dx}{l^2}$$

$$ds = \sqrt{dy^2 + dx^2}$$

$$= dx\sqrt{1 + \left(\frac{dy}{dx}\right)^2} = dx\sqrt{1 + \frac{64d^2x^2}{l^4}}$$

$$S = 2\int_0^{l/2} dx\left[1 + \frac{64d^2x^2}{l^4}\right]^{1/2}$$

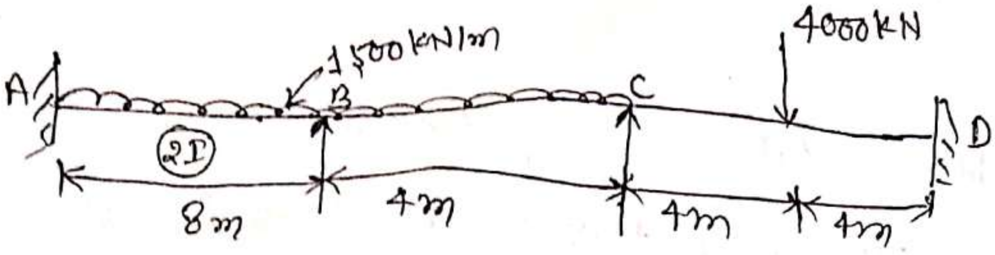
$$S = 2\int_0^{l/2}\left(1 + \frac{1}{2}\times\frac{64d^2x^2}{l^4}\right)dx$$ By Binomial theorem

$$= 2\left(x + \frac{1}{2}\times\frac{64d^2}{l^4}\cdot\frac{x^3}{3}\right)_0^{l/2} = 2\left(\frac{l}{2} + \frac{1}{2}\times\frac{64}{l^4}d^2\times\frac{l^3}{8\times3}\right)$$

$$\boxed{S = l + \frac{8}{3}\frac{d^2}{l}}$$

Ans 5 =>

5(b) =>



$$\overline{M}_{ab} = -\frac{wl^2}{12} = -\frac{1500\times 8^2}{12} = -8000\ \text{kNm}$$

$$\overline{M}_{ba} = +\frac{wl^2}{12} = \frac{1500\times 8^2}{12} = 8000\ \text{kNm}$$

$$\overline{M}_{ab} = -\frac{wl^2}{12} - \frac{6EI\delta}{l^2} = -\frac{1500\times 8^2}{12} - \frac{6\times 2\times 10^5\times 2\times 1600\times 10^4\times 10}{8^2\times 10^3\times 10^9}$$

$$= \cancel{7994\ \text{kNm}} = -8006\ \text{kNm}$$

$$\overline{M}_{ba} = +\frac{wl^2}{12} - \frac{6EI\delta}{l^2} = 8000-6 = 7994\ \text{kNm}$$

$$\overline{M}_{bc} = -\frac{wl^2}{12} + \frac{6EI\delta}{l^2} = -\frac{1500\times 4^2}{12} + \frac{6\times 2\times 10^5\times 1600\times 10^4\times 10}{4^2\times 10^3\times 10^9}$$

$$= -1988\ \text{kNm} \quad +12$$

$$\overline{M}_{cb} = +\frac{wl^2}{12} + \frac{6EI\delta}{l^2} = 2000+12 = 2012\ \text{kNm}$$

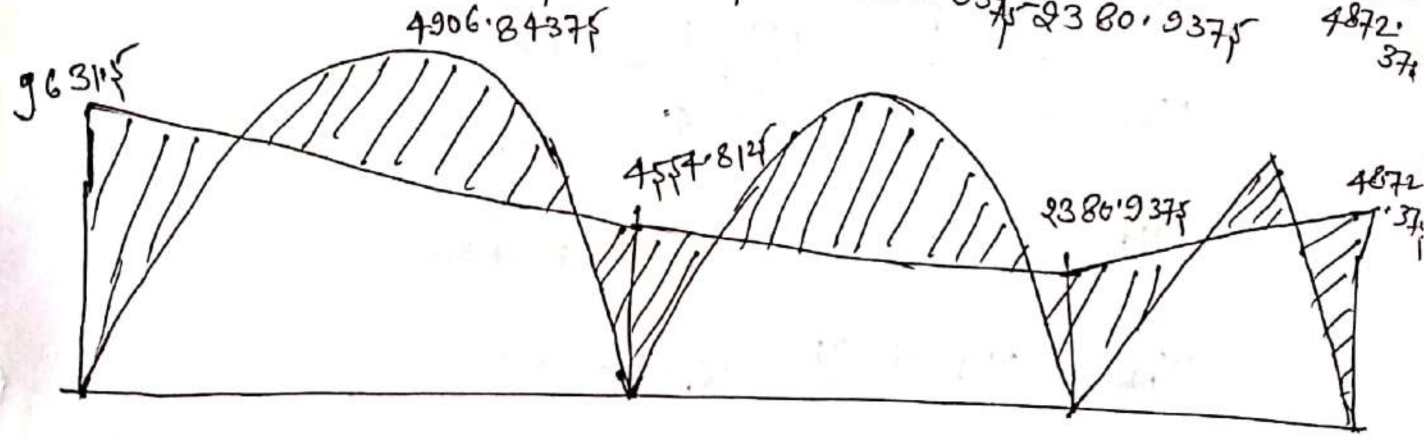
$$\overline{M}_{cd} = -\frac{Pl}{8} = -\frac{4000\times 8}{8} = -4000\ \text{kNm}$$

$$M_{dc} = +\frac{Pl}{8} = \frac{4000\times 8}{8} = 4000\ \text{kNm}$$

Joint	Member	Relative stiffness	Total stiffness	D.F
B	BA	$\frac{2I}{l} = \frac{2I}{8} = \frac{I}{4}$	$I/2$	1/2
	BC	$\frac{I}{4}$		1/2
C	CB	$I/4$	$I/2$	1/2
	CD	$I/4$		1/2

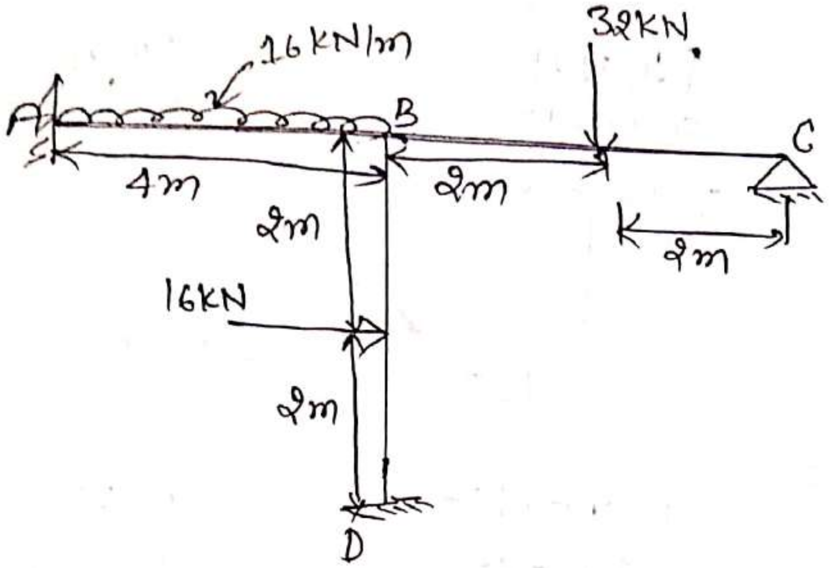
Scanned by CamScanner

	1/2	1/2	1/2	1/2	
-8006	7994	-1988	2012	-4000	4000
	-3003	-3003	994	994	
-1501.5		497	-1501.5		497
-9507.5	4991	-4494	1504.5	-3006	4497
	-248	-248	+750.75	+750.75	
-124		375.375	-124		375.375
-9631.5	4743	-4366.625	2131.25	-2630.625	4872.375
	-188.1875	-188.1875	+249.6875	+249.6875	
-9631.5	4554.8125	-4554.8125	2380.9375	-2380.9375	4872.375



Ans 5 ⇒

5(a) ⇒



F.E.M ⇒

$$\overline{M}_{ab} = -\frac{wl^2}{12} = -\frac{16\times4^2}{12} = -21.33\,KNm$$

$$\overline{M}_{ba} = +\frac{wl^2}{12} = \frac{16\times4^2}{12} = 21.33\,KNm$$

$$\overline{M}_{bc} = -\frac{PL}{8} = -\frac{32\times4}{8} = -16\,KNm$$

$$\overline{M}_{cb} = +\frac{PL}{8} = +\frac{32\times4}{8} = 16\,KNm$$

$$\overline{M}_{BD} = -\frac{PL}{8} = -\frac{16\times4}{8} = -8\,KNm$$

$$\overline{M}_{DB} = +\frac{PL}{8} = \frac{16\times4}{8} = +8\,KNm$$

$$M_{AB} = \overline{M}_{ab} + \frac{2EI}{l}\left[2\theta_A+\theta_B-\frac{3\delta}{l}\right]$$

$$= -21.33 + \frac{2EI}{4}\left[0+\theta_B-0\right]$$

$$= -21.33 + 0.5EI\theta_B \quad -①$$

$$M_{BA} = \overline{M}_{ba} + \frac{2EI}{l}\left[2\theta_B+\theta_A-\frac{3\delta}{l}\right]$$

$$= 21.33 + \frac{2EI}{4}\left[2\theta_B\right]$$

$$= 21.33 + EI\theta_B \quad -②$$

$$M_{bC} = \bar{M}_{bC} + \frac{2EI}{l}\left[2\theta_b + \theta_c - \frac{3\delta}{L}\right]$$

$$= -16 + \frac{2EI}{4}[2\theta_b + \theta_c]$$

$$= -16 + EI\theta_B + 0.5EI\theta_c \quad -③$$

$$M_{CB} = +16 + \frac{2EI}{4}(2\theta_c + \theta_b) = +16 + \frac{2EI}{4}(2\theta_c + \theta_B)$$

$$= 16 + 0.5EI\theta_B + EI\theta_c \quad -④$$

$$M_{BD} = -8 + \frac{2EI}{4}(2\theta_B + \theta_D) = -8 + EI\theta_B \quad -⑤$$

$$M_{DB} = +8 + 0.5EI\theta_B \quad -⑥$$

Campatibility eqn -

$$M_{BA} + M_{BC} + M_{BD} = 0$$

$$21.33 + EI\theta_B \cancel{4} - 16 + EI\theta_B + 0.5EI\theta_c - 8 + EI\theta_B = 0$$

$$3EI\theta_B + 0.5EI\theta_c = 2.67 \quad -⑦$$

$$M_{CB} = 0$$

$$16 + 0.5EI\theta_B + EI\theta_c = 0$$

$$0.5EI\theta_B + EI\theta_c = -16 \quad -⑧$$

$$\boxed{\theta_B = \frac{3.88}{EI}} \qquad \boxed{\theta_c = \frac{-17.94}{EI}}$$

$$\boxed{M_{DB} = 9.94\ kNm} \qquad \boxed{M_{BD} = 4.12\ kNm}$$

$$\boxed{M_{CB} = 0} \qquad \boxed{M_{bc} = -28.85\ kNm}$$

$$\boxed{M_{BA} = 25.21\ kNm} \qquad \boxed{M_{AB} = -19.39\ kNm}$$

Ans1. 1(a) ⇒ Degree of Redundancy ⇒ If any structure solve with the help of only three equilibrium equations is called determinate structure and if any extra equation is required for solving any structure is called Indeterminate structure.

This extra equation is called degree of Redundancy.

1(b) ⇒ Plastic Modulus ⇒ $Z_P = A/2(\bar{y}_1 + \bar{y}_2)$

The plastic modulus of section, Z_P is defined as the sum of first moment of the areas above and below the N.A. or equal area axis.

Section Modulus –

$$\boxed{Z = \frac{I}{y_{max}}}$$

1(c) ⇒ Effect of change in temperature in cable ⇒

When the cable is subjected to change of temperature, there will be a change in the length of the cable. The supporting towers can not undergo any change of span hence there will be a change in the dip of the cable.

1(d) ⇒ Determinate structure ⇒ Determinate structure are those structure which is solve only with the help of equilibrium conditions.

Indeterminate structure => Indeterminate structure are those structure which is ~~sl~~ analyse with equilibrium condition and some extra equation are required.

1(c) => In indeterminate structure, to analyse the structure used some extra condition besides of equilibrium condition.
Thus extra reaction or condition is called compatibility conditions.