1/14

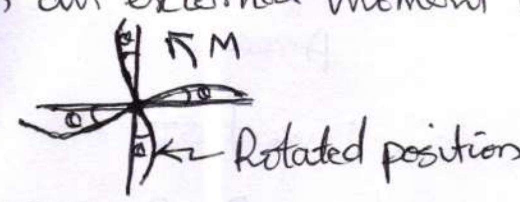
(15) 4014

~~(15) 4014~~

Scoring Indicators

Code : 4014 - THEORY OF STRUCTURES-II

Version:A

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| I | PART-A | | |
| 1) | Column – A long vertical member subjected to axial compressive load. | 1 | |
| | Strut – A member in any position subjected to axial compressive load | 1 | 2 |
| 2) | Core – It is an area around c.G of section, where, if, load is applied, no tension is developed any where on the column. | 2 | 2 |
| 3) | The angle of sloped surface of hipped up material makes with horizontal due to internal friction between particles, is called angle of repose. | 2 | 2 |
| 4) | a) strength criteria and b) stiffness criteria | 1+1 | 2 |
| 5) | It is a joint in which all the members are rotated equally when an external moment is applied.   | 2 | 2 |
| | PART-B | | |
| II 1. | a) short column b) medium column c) Long column | | |
| | a) short column – Column which fails primarly by crushing | 2 | |
| | b) medium column – Column which fails partly due to crushing and partly due to buckling | 2 | 6 marks. |
| | c) Column which fails only due to buckling is long column. | 2 | |
| 2. | method of Joints ÷ In this method, each and every joint is taken separately as a free body in eqlilibrium For taking the joints as free body, care should be taken to see that the joint consists of members having not more than two unknowns member forces developed in it. | | |

## Scoring Indicators

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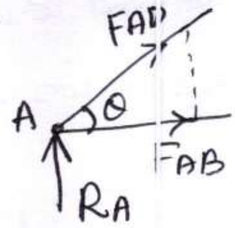
The unknown forces are taken as tensile initially and then determined by equating sum of all vertical forces at the joint to zero and the sum of all horizontal forces at the same joint to zero, — Description 3

ie $\Sigma V = 0$ ; $\Sigma H = 0$ — fig, equations 3 — 6 marks




$\Sigma H = 0 \Rightarrow$

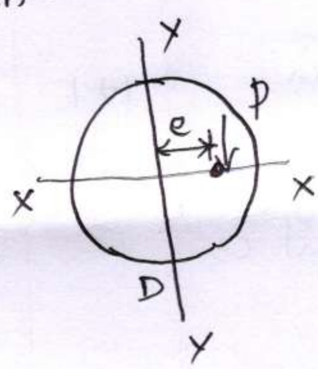
$F_{AB} + F_{AD} \cdot \cos\theta = 0$

Joint A

$\Sigma V = 0 \Rightarrow$

$R_A + F_{AD} \sin\theta = 0$

3.




Dia of column — D

eccentricity — e

Load — P — fig-2

Area of c/s $= \frac{\pi}{4} D^2$

$\sigma_d$ - Direct stress $= \frac{P}{A} = \frac{4P}{\pi D^2}$ — 1

Bending moment $= P \times e$.

Bending stress $\sigma_b = \frac{M}{I} \times y_{max}$.

$= \frac{P \times e \times 64 \times \frac{D}{2}}{\pi D^4} = \frac{32 P \cdot e}{\pi D^3}$ — 1

maximum stress $= \sigma_d + \sigma_b$

$= \frac{4P}{\pi D^2} + \frac{32 \cdot P \cdot e}{\pi D^3}$

$= \frac{4P}{\pi D^2}\left[1 + \frac{8e}{D}\right]$ — 1

minimum stress $= \sigma_d - \sigma_b$

$= \frac{4P}{\pi D^2}\left[1 - \frac{8 \cdot e}{D}\right]$ — 1

6 marks

Scoring Indicators

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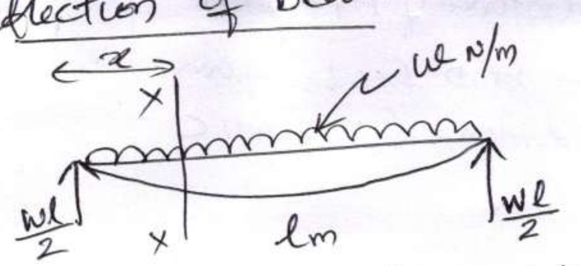
| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| II 4. | Stability Conditions<br>1) Stability against over turning ÷ Resultant thrust should fall within the base area of dam.<br>2) Stability against sliding of dam body ÷ $\mu \cdot W > P$<br>3) Stability against Tension on Dam body. $e \leq \frac{b}{6}$<br>4) Crushing of dam material $\sigma_{max} < \sigma_c$ of dam material.<br>Explanation with the help of fig. and equations | $1\frac{1}{2} \times 4$ | 6 marks |
| 5. | Advantages of indeterminate strs.<br>1) Positive bending moment is reduced considerably.<br>2) Deflection is reduced<br>3) Stability is enhanced.<br>4) material consumption is reduced.<br>5) Due to reduction in c/s Cubical Content of buildg is increased.<br>6) Rotation of members reduced. Any 4 | $4 \times 1\frac{1}{2}$ | 6 marks |
| 6. | Deflection of beam. | | |




Differential eqn — 1

$$EI \cdot \frac{d^2y}{dx^2} = M_x$$

$$E \cdot I \frac{d^2y}{dx^2} = \frac{w \cdot L}{2} \cdot x - \frac{wx^2}{2}$$ Integrating

and applying end conditions $\left(x = \frac{l}{2};\ \frac{dy}{dx} = 0\right)$

$$EI \cdot \frac{dy}{dx} = \frac{wLx^2}{4} - \frac{wx^3}{6} + C_1$$

$$\therefore C_1 = \frac{-wl^3}{24}$$

## Scoring Indicators

Code :

Version:

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| | Put $C_1$ in equation $\frac{dy}{dx} = \frac{wlx^2}{4EI} - \frac{wx^3}{6EI} - \frac{wl^3}{24EI}$<br>To get max slope at support put $x=0$<br>$\theta_{max} = \frac{wl^3}{24EI}$ (or by moment area method) | 3 | |
| | On further integration<br>$y = \frac{wlx^3}{12EI} - \frac{wx^4}{24EI} - \frac{wl^3 x}{24EI} + C_2$<br>at $x=0$ ; $y=0$<br>$\therefore C_2 = 0$<br>$\therefore y = \frac{wlx^3}{12EI} - \frac{wx^4}{24EI} - \frac{wl^3 x}{24EI}$<br>Put $x = l/2$ to get max. deflection<br>$y_{max} = \frac{5wl^4}{384EI}$ (or by moment area method) | 3 | 6 |
| 7. | Theorem of three moments<br>If AB and BC are any two consecutive spans of a continuous beam subjected to loading, the support moments $M_A$, $M_B$, and $M_C$, can be obtained from the relation<br>$M_A \frac{L_1}{I_1} + 2M_B\left[\frac{L_1}{I_1} + \frac{L_2}{I_2}\right] + M_C \cdot \frac{L_2}{I_2} = \frac{-6a_1x_1}{L_1I_1} + \frac{-6a_2x_2}{L_2I_2}$ | 3 | |
| | where,<br>$a_1$ = area of free BMD for $L_1$ span<br>$x_1$ = centroidal distance of $A_1$ from A<br>$a_2$ = area of free BMD for $L_2$ span<br>$x_2$ = centroidal distance of $A_2$ from C | 1 | |
| | Use.<br>This can be used to analyse continuous beam by considering consecutive spans in succession | 2 | 6 marks |

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**Scoring Indicators**

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|---|---|---|---|

Module - I

Part-C

III

a) Limitation of Euler's equation.

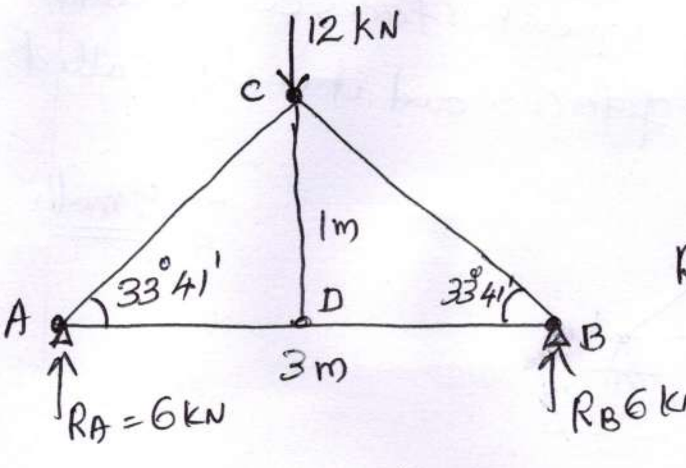
$P_E = \frac{\pi^2 E \cdot I_{min}}{l_{eff}^2}$ for a Column the buckling load depends mainly on effective length or slenderness ratio $\left(\frac{l}{k}\right)$. If the length or ratio is less, which is in the denominator, the buckling load capacity increases sharply due to highvalue of E and I in the numerator. But no material can withstand stress beyond its compressive strength. There for Euler's equation is ideal only for long columns.

Eqn. — 1

Concept. — 4

5 marks.

b) Analysis of truss.

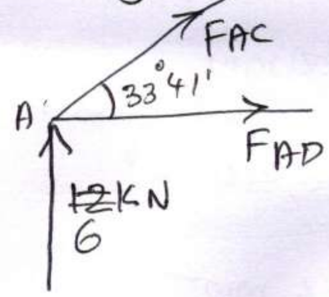



$\tan\theta = \frac{1}{1.5}$

$\therefore \theta = 33°41'$

$R_A = R_B = \frac{12}{2} = 6 kN \rightarrow 2$

Considering Joint A




$\Sigma H = 0$

$F_{AC} \cdot \cos 33°41' + F_{AD} = 0$ — 1

$F_{AC} \times 0.832 + F_{AD} = 0$ — I

$\Sigma V = 0$

$\Sigma V = 0 \Rightarrow 6 + F_{AC} \times \sin 33°41' = 0$

$\therefore F_{AC} = -10.81$ KN (Compressive)

$\therefore F_{AD} = 9$ KN (Tensile).

Consider Joint D — 1


$\Sigma H = 0$

$9 + F_{DB} = 0$

$\therefore F_{DB} = -9$ KN (Compressive)

## Scoring Indicators

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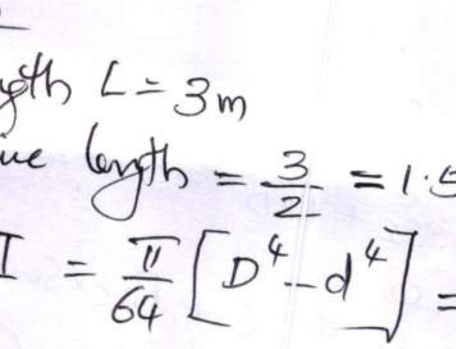
| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| | $\Sigma V = 0 \Rightarrow F_{CD} = 0$ | | |
| | Due to symmetry of truss $F_{BC} = 10.81$ kN (compressive) | 1 | |
| | $F_{AC} = 10.81$ KN Compressive | 1x5 | |
| | $F_{AD} = 9$ KN Tensile | 5 | |
| | $F_{DB} = 9$ KN " | | |
| | $F_{CD} = 0$ KN | | |
| | $F_{BC} = 10.81$ Compressive | | 10 marks |
| IV a) | method of Sections :- In this method a section line is drawn through members, whose forces are to be determined. It should be noted that the section line is always taken not to cut more than three members with unknown forces. Then consider the equilibri of either the left or right of the section line under the action of external forces and the unknown forces induced in the member cut by sections. Some times member forces can be determined only by taking moments of forces and it is also called meth of moments  | 5 marks | |
| b) | Solution<br>Length $L = 3$ m<br>Effective length $= \frac{3}{2} = 1.5$ m $= 1500$ mm<br><br>$I = \frac{\pi}{64}\left[D^4 - d^4\right] = 46,346,400$ mm$^4$<br>Area $= \frac{\pi}{4}\left[D^2 - d^2\right] = 11,304$ mm$^2$<br>$K^2 = \frac{I}{A} = 4100$ mm$^2$ | 2 | |

## Scoring Indicators

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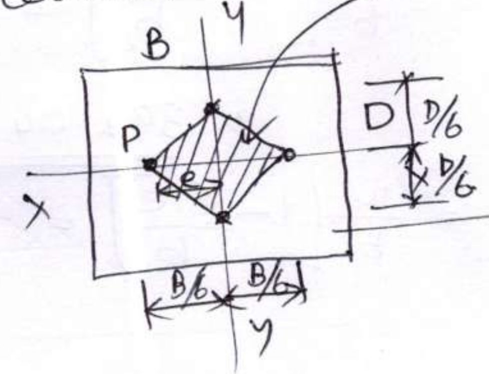
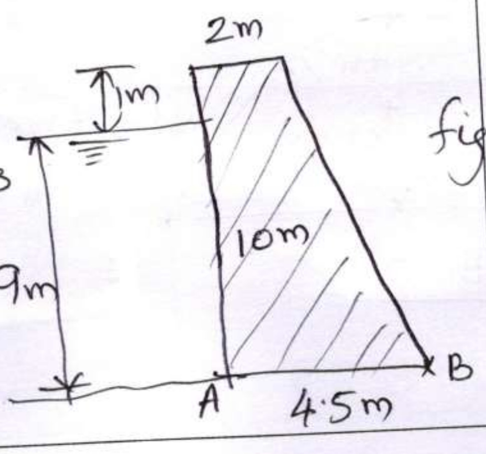
|---|---|---|---|
| | Eulers Buckling Load $= \frac{\pi^2 E I_{min}}{l_{eff}^2}$ | 1 | |
| | $= \frac{3.14^2 \times 1.2 \times 10^5 \times 46,346,400}{(1500)^2} = 24371038\ N$ | | |
| | $= \underline{\underline{24371\ kN}}$ | 3 | |
| | Rankines load $= \frac{\sigma_c \cdot A}{1+\alpha \frac{l_{eff}^2}{K^2}}$ | 1 | |
| | $\alpha = \frac{1}{1600}$ ; $\sigma_c = 500\ N/mm^2$ | | |
| | $= \frac{500 \times 11,304}{1+\frac{1}{1600} \times \frac{1500^2}{4100}} = \frac{5652000}{1.34298}$ | 3 | |
| | $= 4208551\ N$ | 10 | 10marks |
| | $= \underline{\underline{4208.5\ kN}}$ | | |
| V | Core of Rectangular Column | | |
| a) | Core definition | 1 | |
| | For No tension of column | | |
| |  fig 2 | | |
| | $\sigma_b \le \sigma_d$ | | |
| | $\frac{M}{I} \le \frac{P}{A}$ | | |
| | $\frac{\cancel{P} \cdot e}{\frac{\cancel{D} B^{\cancel{2}}}{6}} \le \frac{\cancel{P}}{\cancel{B} \cdot \cancel{D}}$ | 2 | |
| | $e \le \frac{B}{6}$ or $\left[\frac{D}{6}\right.$ in other direction$\left.\right]$ | 5 | 5marks |
| b) | Data given | | |
| | $\gamma = 22\ kN/m^3$ | | |
| | $\gamma_w = 9.81\ kN/m^3$ | | |
| |  fig- 1 | | |

**Scoring Indicators**

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|---|---|---|---|

Total water Pr. for 1m length $= \frac{\gamma \omega \cdot h^2}{2}$

$P = \frac{9.81 \times (9)^2}{2} = \underline{\underline{397.3 \text{ kN}}}$ — ②

weight of dam (1m)

$W = \gamma \cdot \frac{(a+b)}{2} \times H = 22 \times \frac{(2+4.5)}{2} \times 10$

$= \underline{\underline{715 \text{ kN}}}$ — ②

C.G of dam body $x$ from $A = \frac{2^2 + 2\times 4.5 + 4.5^2}{3(2+4.5)}$

$= \underline{1.7 m}$

$x_1 = \frac{P}{W} \times \frac{h}{3} = \frac{397.3}{715} \times \frac{9}{3}$

$= \underline{\underline{1.66 \text{ m}}}$

Eccentricity $e = (1.7 + 1.66) - \frac{4.5}{2} = \underline{\underline{1.11 m}}$ → ①

$\sigma_{max} = \frac{W}{b}\left[1 + \frac{6 \cdot e}{b}\right] = \frac{715}{4.5}\left[1 + \frac{6 \times 1.11}{4.5}\right]$ → ②

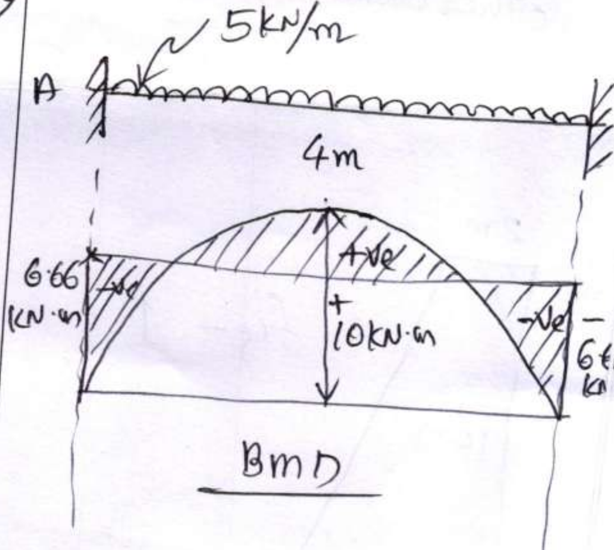
$= \underline{\underline{394.04 \text{ kN/m}^2}}$

$\sigma_{min} = \frac{W}{b}\left[1 - \frac{6 \cdot e}{b}\right] = \underline{\underline{-76.26}} \text{ kN/m}^2$ (Tensile) → ②

10 marks

VI a)

module – II




Free B.m at centre

$= \frac{wl^2}{8} = \frac{5 \times 4^2}{8} = 10 \text{ kN·m}$ — 2

Fixed moments.

$M_A = M_B = \frac{wl^2}{12} = \frac{5 \times 4^2}{12}$

$= \underline{6.66 \text{ kN·m}}$ — 2

fig — 1

5 marks

## Scoring Indicators

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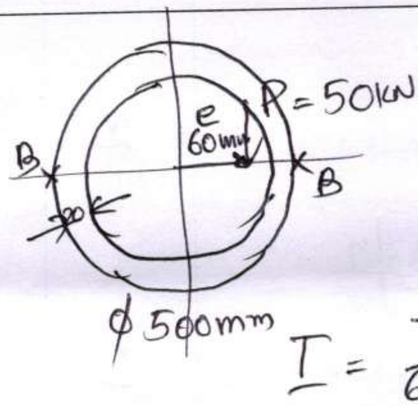
|---|---|---|---|

VI b)




$D = 500\,mm$

$d = 460\,mm$

$Area = \frac{\pi}{4}\left[500^2 - 460^2\right] = \underline{30144\,mm^2}$

$I = \frac{\pi}{64}\left[500^4 - 460^4\right] = 869.65 \times 10^6\,mm^4$ — 2

Direct stress $= \frac{P}{A} = \frac{50 \times 1000}{30144} = \underline{1.658\,N/mm^2}$

Bending stress $= \frac{M}{I} \times y_{max} = \frac{50 \times 1000 \times 60 \times 250}{869.65 \times 10^6}$

$= \underline{0.862\,N/mm^2}$

$\sigma_{max}$ at B $= \sigma_d + \sigma_b = 1.658 + 0.862$

$= \underline{2.52\,N/mm^2}$ — 2

$\sigma_{min}$ at A $= \sigma_d - \sigma_b = 1.658 - 0.862$

$= \underline{0.796\,N/mm^2}$ — 2

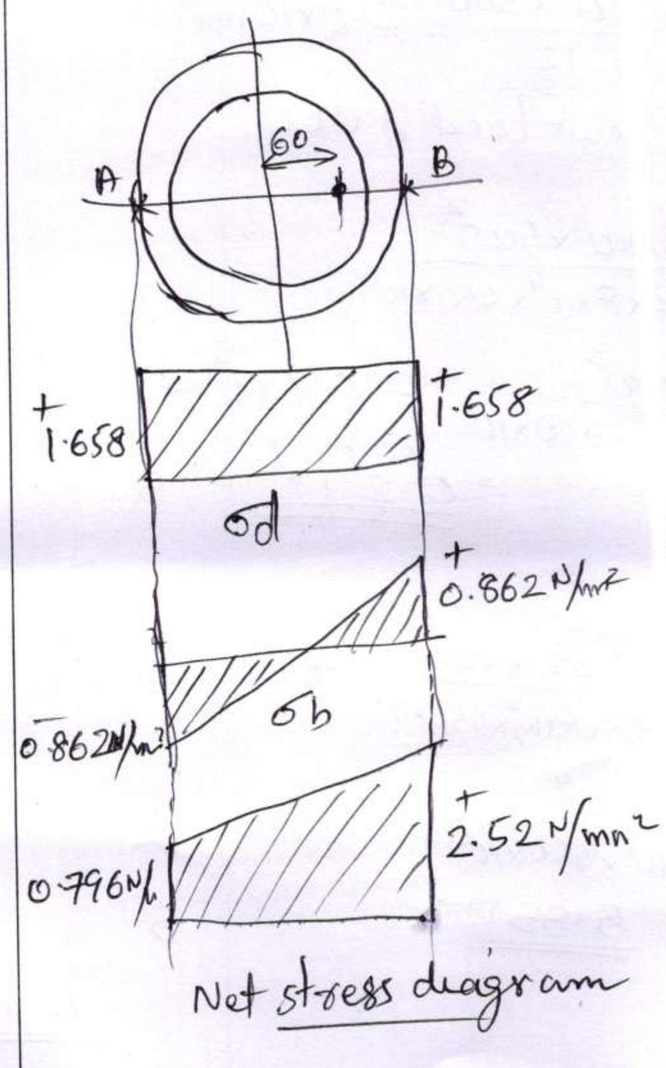


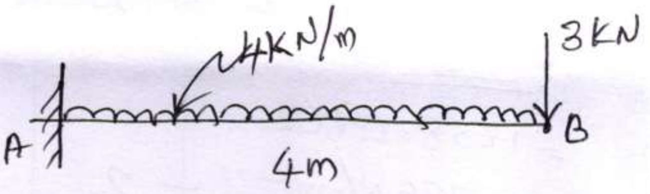

fig-4

Net stress diagram

10 marks

**Scoring Indicators**

**Code : 4014 - THEORY OF STRUCTURES-II** **Version:A**

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| VII a) | The differential eqn. for elastic curve | | |
| | $M = \frac{d^2y}{dx^2} \cdot EI$ | ~~2~~ 1 | |
| | Integrating w.r.t. $x$ $\int m = EI \cdot \frac{dy}{dx}$ | | |
| | using this equation $\frac{dy}{dx}$ or slope canbe determind | 2 | |
| | by integrating once again w.r.t $x$ | | |
| | $\iint m = \int EI \cdot \frac{dy}{dx}$ | | |
| | $\iint m = EI \cdot y$ using this | 2 | |
| | y or deflection canbe determined. | | |
| | | 5 marks | |
| b) |  $E = 8 \times 10^4 N/mm^2$ | | |
| | $I = \frac{200 \times 300^3}{12} = 450 \times 10^6 mm^4$ | | |
| | Slope is max. at B due to point load & UDL | | |
| | $\theta_{max} = \frac{Wl^2}{2EI} + \frac{wl^3}{6EI} = \frac{3 \times 1000 \times 4000^2}{2 \times 8 \times 10^4 \times 450 \times 10^6}$ | | |
| | $+ \frac{4 \times 4000^3}{6 \times 8 \times 10^4 \times 450 \times 10^6} = 6.66 \times 10^{-4} rad.$ | | |
| | $= 0^\circ 2' 17''$ | 5 | |
| | Deflection is max at B | | |
| | $y_{max} = \frac{Wl^3}{3EI} + \frac{wl^4}{8EI} = \frac{3000 \times 4000^3}{3 \times 8 \times 10^4 \times 450 \times 10^6} +$ | | |
| | $\frac{4 \times 4000^4}{8 \times 8 \times 10^4 \times 450 \times 10^6}$ | | |
| | $= \frac{16}{9} + \frac{32}{9} = 5.33 mm.$ | 5 | |
| | | | 10 marks |

## Scoring Indicators

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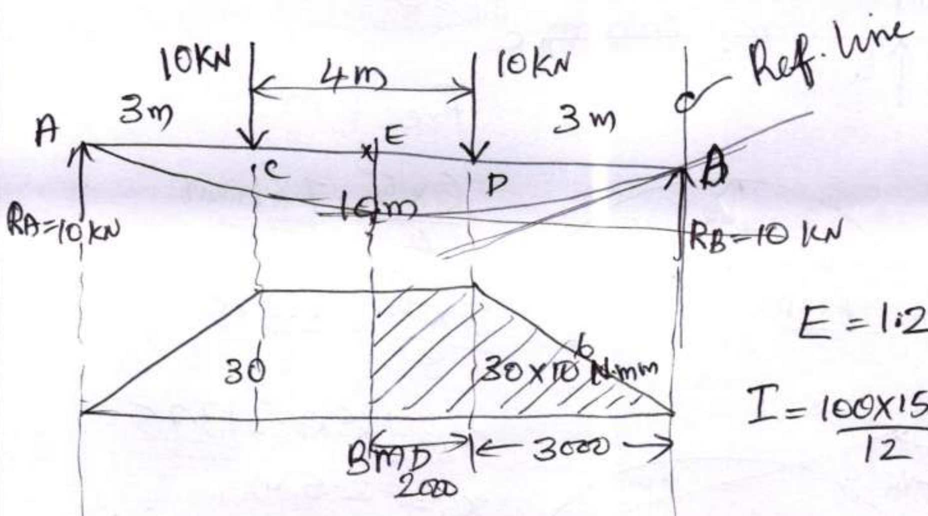
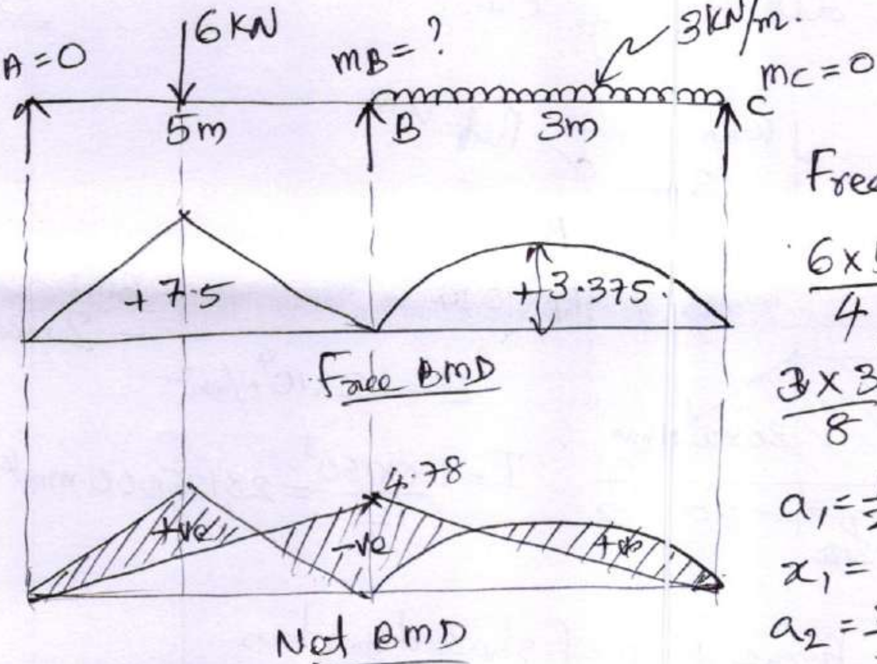
| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| VIII a) | Mohr's theorem 1 ÷ The change in slope between any two points on an elastic curve is equal to the net area of B.M diagram between these two points, divided by E.I. | 2½ | |
| | Mohr's theorem 2 ÷ The intercept taken on a vertical reference line of the tangents at any two points on an elastic curve is equal to the moment of the area of B.M diagram between these two points about the reference line, divided by EI | 2½ | 5 marks |
| b) |  | BMD - 2 marks. | |
| | $E = 1.2\times10^4\ N/mm^2$ <br> $I = \frac{100\times150^3}{12} = 28{,}125{,}000\ mm^4$ | | |
| | Slope $\theta_B = \frac{\text{Area of BMD of shaded portion}}{E.I}$ <br> $= \frac{(2000\times30\times10^6)+\frac{1}{2}3000\times30\times10^6}{1.2\times10^4\times28{,}125{,}000} = \underline{0.311\ rad}$ | | 4 marks |
| | deflection $y_{max} = \frac{\text{moment of area of BMD in shaded colour about Ref. line}}{EI}$ <br> $= \frac{2000\times30\times10^6\times4000+\frac{1}{2}3000\times30\times10^6\times2000}{1.2\times10^4\times28{,}125{,}000} = \underline{977.7}\ mm$ | | 4 marks |
| | (deflection beyond permissible limit) | | 10 marks. |

## Scoring Indicators

**Code** : 4014 **Version:** A

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| IX a) | i) Carryover factor ÷ It is the ratio of moment applied at one end joint of a member to the moment induced at its other end joint. | | 2 |
| | ii) Stiffness ÷ It is the moment required at one end of a member to produce a unit angle of rotation. | | 2 |
| | iii) The ratio of the moment induced in a certain member to the moment applied at the joint is called D.F | | 2 |
| | | | 6 marks |
| IX b) | <br><br>Free B.Ms<br>$\frac{6\times5}{4} = 7.5$ kN.m<br>$\frac{3\times3^2}{8} = 3.375$<br>$a_1 = \frac{1}{2}\times5\times7.5 = 18.75$<br>$x_1 = 2.5$ m<br>$a_2 = \frac{2}{3}\times3\times3.375 = 6.75$<br>$x_2 = 1.5$ m.<br>Applying Clapeyron's theorem.<br>$M_A \cdot L_1 + 2M_B(L_1+L_2) + M_C L_2 = -\frac{6a_1x_1}{L_1} - \frac{6a_2x_2}{L_2}$<br>$0 + 2M_B(5+3) + 0 = -\frac{6\times18.75\times2.5}{5} - \frac{6\times6.75\times1.5}{3}$<br>$16 M_B = -76.5$<br>$M_B = -4.78$ kNm | Free BMD 3 marks<br>Theorem application — 3 marks<br>BMD — 3 | 9 marks |

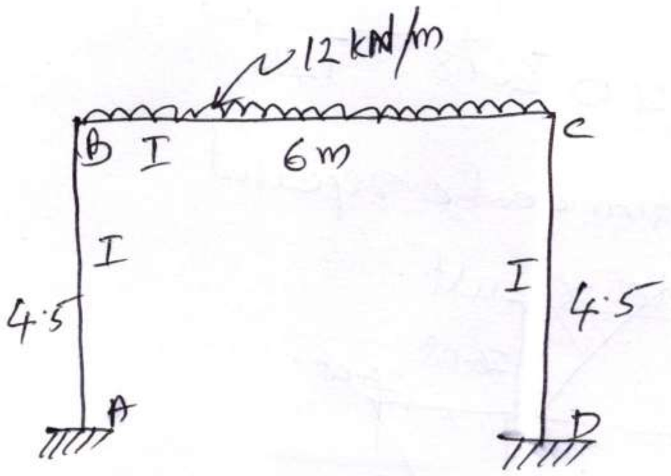
(The problem can be solved using moment area theorem also).

## Scoring Indicators

**Code : 4014 (Theory of structures II)** **Version:A**

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| X a) | Hardy cross method.<br>① Assuming all ends fixed find fixed end moments for all members.<br>② Find stiffness and distribution factors for all members.<br>③ Balance each joint by considering distribution factor.<br>④ The balancing moments are carried over to far ends by considering carryover factor.<br>⑤ This will some times upset the balance of Joint, then balancing is repeated.<br>⑥ This process continues for no: of cycles to get negligible Value for balancing moments.<br>⑦ End moments are added together to get final moments. | 5 marks | |

b)




Free B.M $= \frac{12 \times 6^2}{8} = 54$ kN.m

Fixing moments $FM_{AB} = 0$ ; $FM_{BA} = 0$

$FM_{BC} = \frac{12 \times 6^2}{12} = \bar{3}6$ kN.m

$FM_{CB} = ,, = +36$ kN.m

$FM_{CD} = FM_{DC} = 0$ kN.m.

Stiffness of $K_{BA} = \frac{4 \cdot EI}{4.5} = \underline{0.89} EI$

$K_{BC} = \frac{4 \cdot EI}{6} = \underline{0.67} EI$

2

Distribution factor for BA $= \frac{0.89 EI}{EI(0.89+0.67)} = 0.57$

## Scoring Indicators

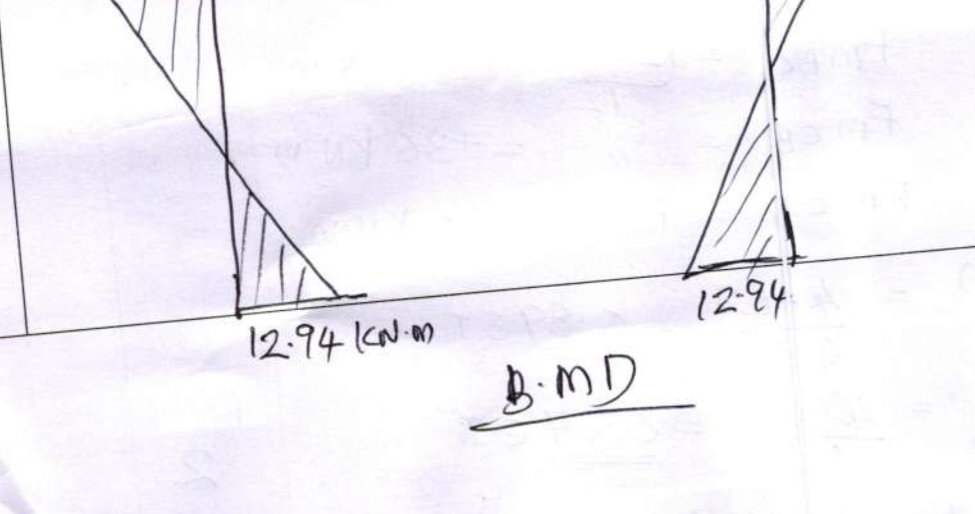
**Code : 4014 (Theory of structures II)** **Version:A**

| Qn. No. | Scoring Indicators | Split score | Total score |
|---|---|---|---|
| | $D.F \text{ for } BC = \dfrac{0.67\,EI}{(0.89+0.67)EI} = \underline{0.43}$ | | |
| | $DF$ for $CB = 0.43$ and $D.F$ for $CD = 0.57$ due to symmetry. | | |

| | A | B (BA) | B (BC) | C (CB) | C (CD) | D |
|---|---|---|---|---|---|---|
| | | 0.57 | 0.43 | 0.43 | 0.57 | |
| | 0 | +0 | −36 | +36 | −0 | +0 |
| | | +20.52 | +15.48 | −15.48 | −20.52 | |
| | +10.26 | | −7.74 | +7.74 | | −10.26 |
| | | +4.41 | +3.33 | −3.33 | −4.41 | |
| | +2.205 | | −1.665 | +1.665 | | −2.205 |
| | | +0.95 | +0.715 | −0.715 | −0.95 | |
| | +0.475 | | −0.357 | +0.357 | | −0.475 |
| | | +0.203 | +0.153 | −0.153 | −0.203 | |
| Final moment | +12.94 | +26.08 | −26.08 | +26.08 | −26.08 | −12.94 |

Tabulation 5

Cycle of operation can be repeated to get accurate results.




B.M.D

fig 3