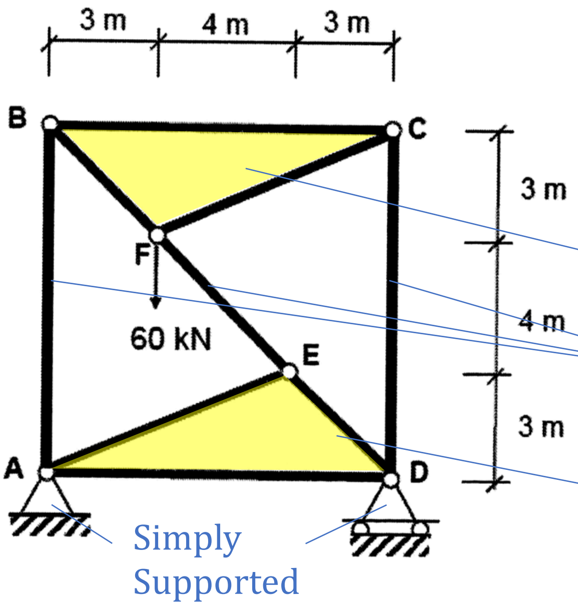
CV2011 – Structural Analysis I, Semester 2 2022-2023 by Owen

1. (a)



Joints: 6, Members: 9, Reactions: 3, 2(6)=9+3. No concurrent/parallel reactions, no collapse mechanism. Overall, statically determinate, stable. <u>**Ans.**</u>

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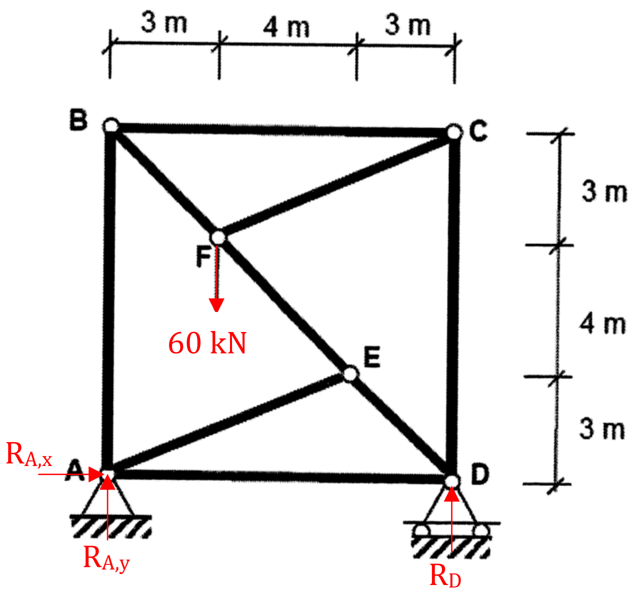
1. (b)



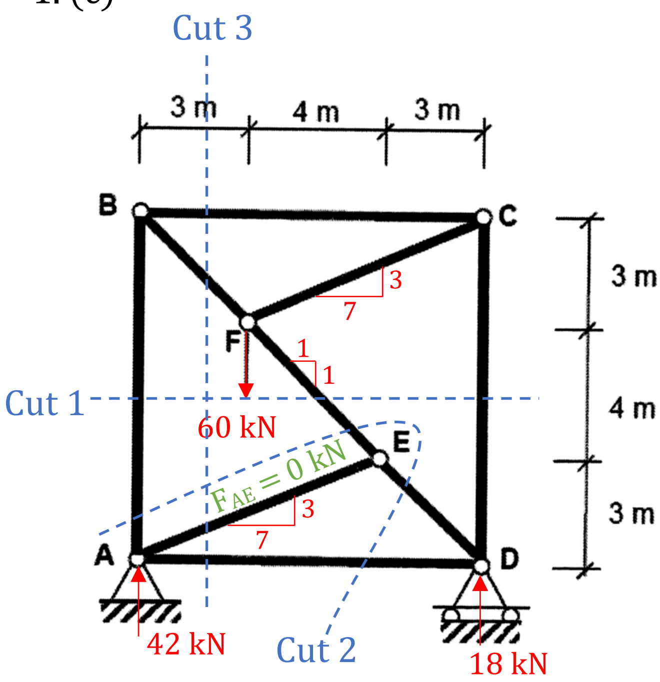
<u>Solving reactions:</u>

$\rightarrow +$, $\Sigma F_x = 0$:
$R_{Ax} = 0$ kN <u>**Ans.**</u>

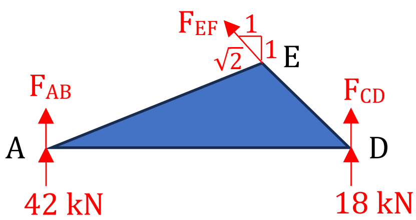
⟲+, $\Sigma M_D = 0$:
$60*7 - R_{Ay}*10 = 0$
$R_{Ay} = 42$kN (upwards) <u>**Ans.**</u>

$\uparrow +$, $\Sigma F_y = 0$:
$R_{Ay} + R_D - 60 = 0$
$R_D = 18$kN (upwards) <u>**Ans.**</u>

1. (c)



Section ADE (Cut 1):



$\rightarrow+,\ \Sigma F_x = 0$:

$-\frac{1}{\sqrt{2}} F_{EF} = 0$

$F_{EF} = 0$ kN **Ans.**

$⟲+,\ \Sigma M_D = 0$:

$-F_{AB} - 42 = 0$

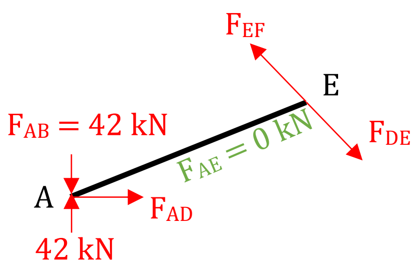
$F_{EF} = -42$ kN (compression) **Ans.**

$\uparrow+,\ \Sigma F_y = 0$:

$42 + 18 + F_{AB} + F_{CD} + \frac{1}{\sqrt{2}} F_{EF} = 0$

$F_{CD} = -18$ kN (compression) **Ans.**

Section AE (Cut 2):



$⟲+,\ \Sigma M_E = 0$:

$42*7 - 42*7 + F_{AD}*3 = 0$

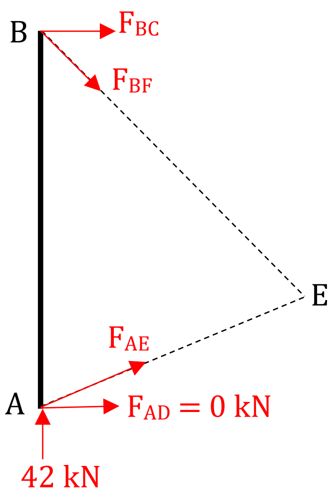
$F_{AD} = 0$ kN **Ans.**

Or since $F_{AE} = 0$,

$\Sigma F_x = 0$ at joint A:

$F_{AD} = 0$ kN **Ans.**

Section AB (Cut 3):

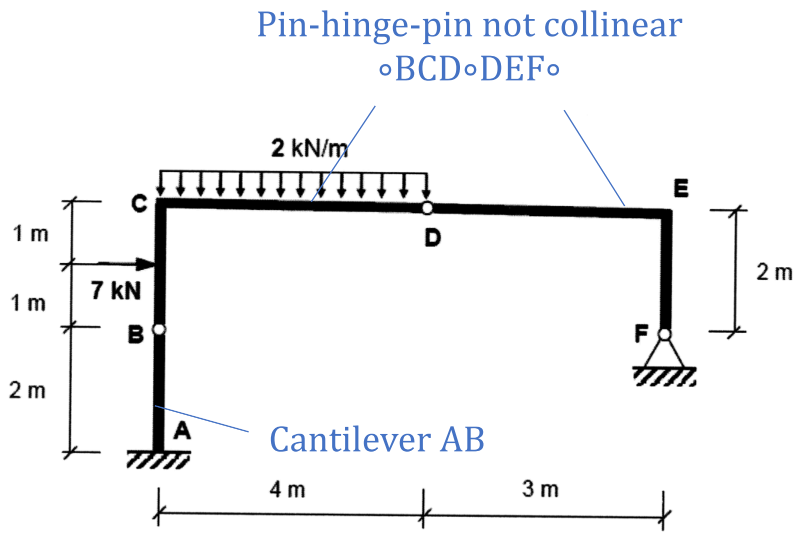


$⟲+,\ \Sigma M_E = 0$:

$F_{BC}*7 + 42*7 = 0$

$F_{BC} = -42$ kN (compression) **Ans.**

2. (a)



Members: 3, Reactions: 3(fixed)+2(pin)+2*2(2 hinge)=9, 3(3)=9. No concurrent/parallel reactions, no collapse mechanism. Overall, statically determinate, stable. **Ans.**

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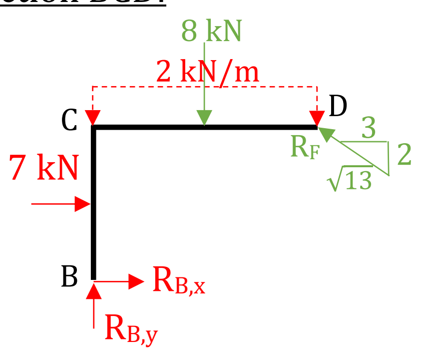
2. (b)

Section BCD:



⟲+, $\Sigma M_B = 0$:

$$-7*1 - 8*2 + \frac{3}{\sqrt{13}} R_F*2 + \frac{2}{\sqrt{13}} R_F*4 = 0$$

$R_F = \frac{23\sqrt{13}}{14}$ kN (correct direction)

$R_{F,y} = \frac{2}{\sqrt{13}} \frac{23\sqrt{13}}{14} = 3.29$ kN (upwards) **Ans.**

$R_{F,x} = \frac{3}{\sqrt{13}} \frac{23\sqrt{13}}{14} = 4.93$ kN (leftwards) **Ans.**

$\rightarrow +, \Sigma F_x = 0$:

$7 + R_{B,x} - R_{F,x} = 0$

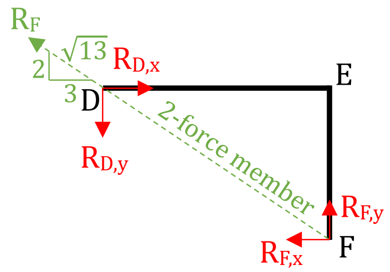
$R_{B,x} = -2.07$ kN (opposite direction)

$\uparrow +, \Sigma F_y = 0$:

$R_{A,y} + R_{F,y} - 8 = 0$

$R_{B,y} = 4.71$ kN (correct direction)

Section DEF:



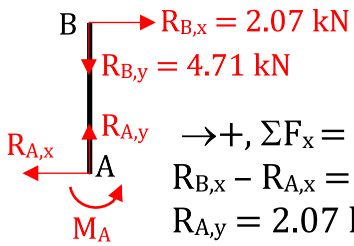
$\rightarrow +, \Sigma F_x = 0$:

$R_{D,x} - R_{F,x} = 0$

$\uparrow +, \Sigma F_y = 0$:

$R_{F,y} - R_{D,y} = 0$

Section AB:



$\rightarrow +, \Sigma F_x = 0$:

$R_{B,x} - R_{A,x} = 0$

$R_{A,y} = 2.07$ kN (leftwards) **Ans.**

$\uparrow +, \Sigma F_y = 0$:

$R_{A,y} - R_{B,y} = 0$

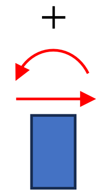
$R_{A,y} = 4.71$ kN (upwards) **Ans.**

⟲+, $\Sigma M_A = 0$:

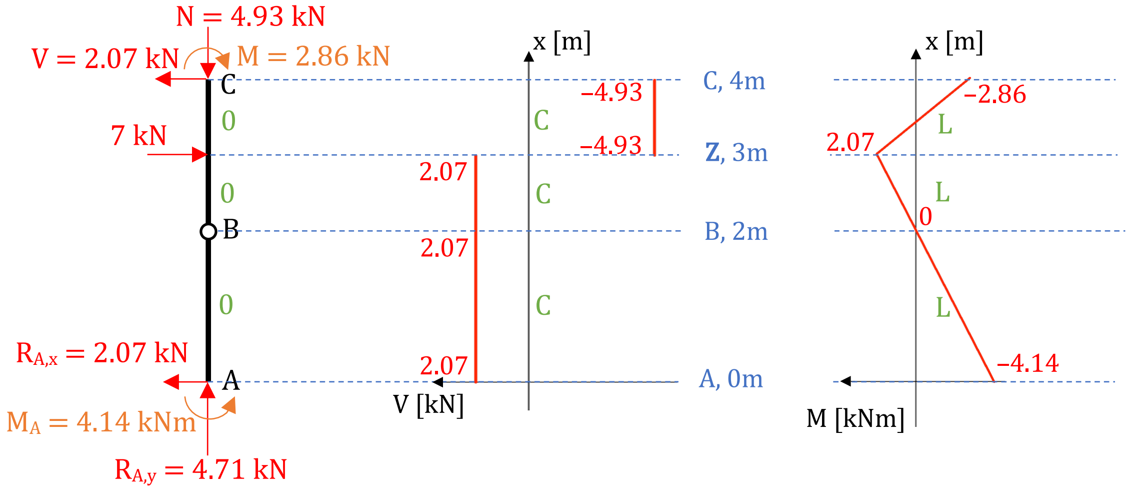
$M_A - 2.07*2 = 0$

$M_A = 4.14$ kNm (anti-clockwise) **Ans.**

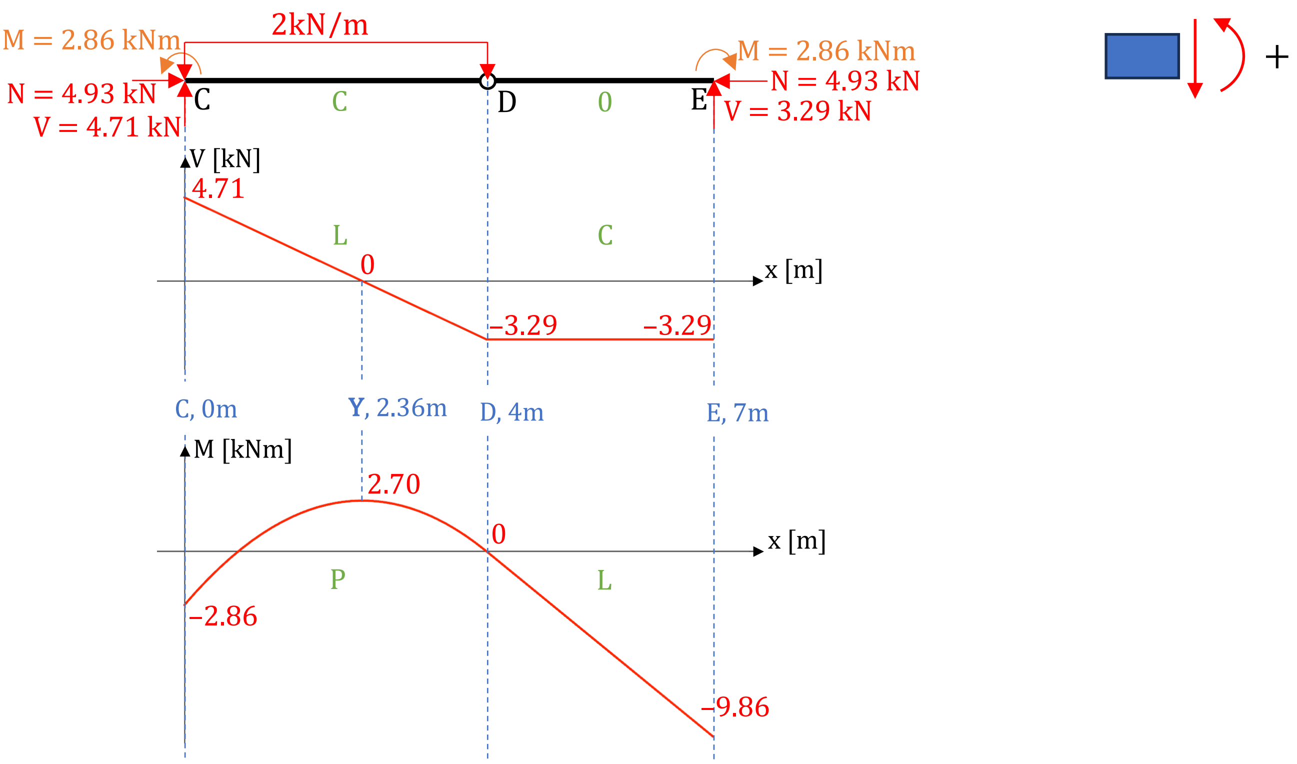
2. (c) **Ans.** 0 – zero, C – constant, L – linear(sloped), P – Parabola(x^2)



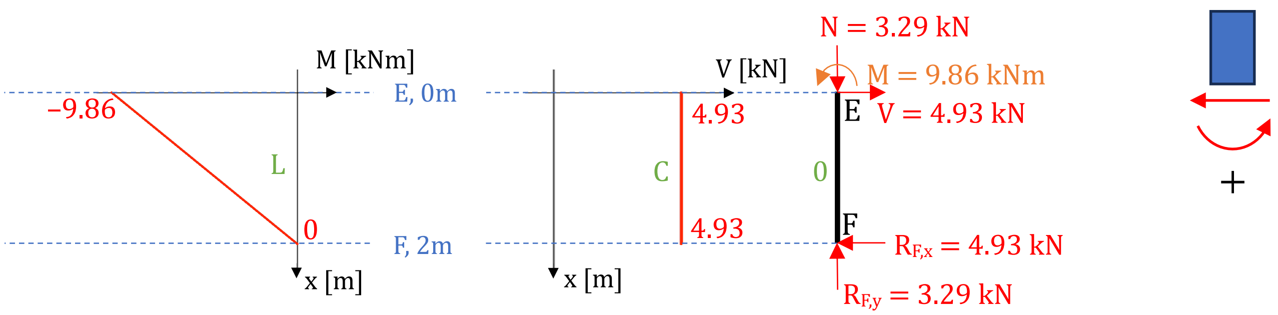
Section ABC:



Section CDE:



Section EF:



2. (c) Calculations

Section ABC:

Shear force:

A: 2.07kN

B: 2.07kN

Z: 2.07kN – 7 kN = –4.93kN

C: –4.93kN

Bending moment:

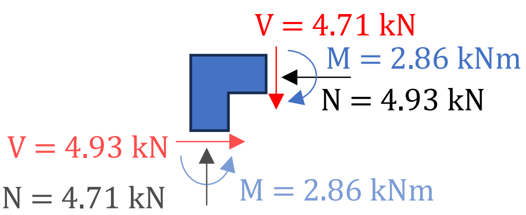
A: –4.14kNm

B: $-4.14\text{kNm} + \int_0^2 V\,dx = -4.14\text{kNm} + (2.07\text{kN} * 2\text{m}) = 0\text{kNm}$ (hinge)

Z: $-4.14\text{kNm} + \int_0^3 V\,dx = -4.14\text{kNm} + (2.07\text{kN} * 2\text{m}) = 2.07\text{kNm}$

C: $2.07\text{kNm} + \int_3^4 V\,dx = 2.07\text{kNm} + (-4.93\text{kN} * 1\text{m}) = -2.86\text{kNm}$

At C:



Section CDE:

Shear force:

C: 4.71kN

Y: 0kN
Distance: $4.71\text{kN} + \int_0^d w\,dx = 4.71\text{kN} + (-2\text{kN/m} * \text{d}) = 0\text{kN}$
$\text{d} = 2.36\text{m}$, $\text{x} = 0\text{m} + \text{d} = 2.36\text{m}$

D: $4.71\text{kN} + \int_0^4 w\,dx = 4.71\text{kN} + (-2\text{kN/m} * 4\text{m}) = -3.29\text{kN}$

E: –3.29kN

2. (c) Calculations

Section CDE:

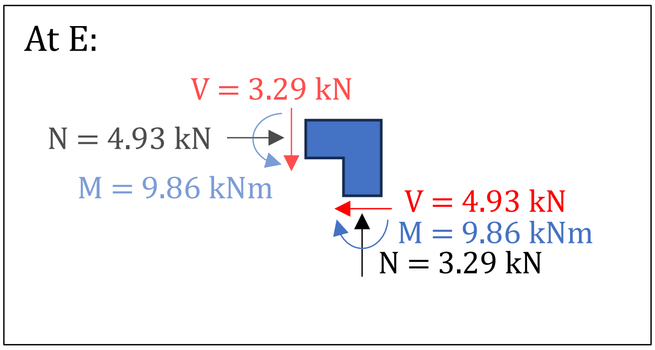
Bending moment:

C: −2.86kNm

Y: $-2.86\text{kNm} + \int_0^{2.36} V\,dx = -2.86\text{kNm} + (0.5 * 4.71\text{kN} * 2.36\text{m}) = 2.70\text{kNm}$

D: $-2.86\text{kNm} + \int_0^{4} V\,dx = 0\text{kNm}$ (hinge)

E: $0\text{kNm} + \int_4^{7} V\,dx = 0\text{kNm} + (-3.29\text{kN} * 3\text{m}) = -9.86\text{kNm}$



Section EF:

Shear force:

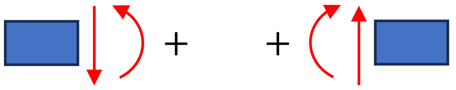
E: 4.93kN

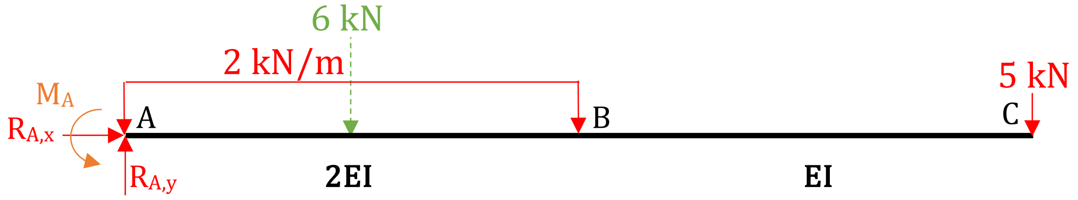
F: 4.93kN

Bending moment:

E: −9.86kNm

F: $-9.86\text{kNm} + \int_0^{2} V\,dx = -9.86\text{kNm} + (4.93\text{kN} * 2\text{m}) = 0\text{kNm}$

3. (a) 



Solving reactions:

$\rightarrow +$, $\Sigma F_x = 0$:
$R_{A,x} = 0$ kN

$\uparrow +$, $\Sigma F_y = 0$:
$R_{A,y} - 6 - 5 = 0$
$R_{A,y} = 11$ kN (upwards)

$\circlearrowleft +$, $\Sigma M_A = 0$:
$M_A - 6*1.5 - 5*6 = 0$
$M_A = 39$ kNm (anti-clockwise)

Integration:

$0 \leq x \leq 3$:

$w_1(x) = -2$

$V_1(x) = -2x + A_1$
$V_1(0) = -2(0) + A_1 = 11$
$A_1 = 11$
$V_1(x) = -2x + 11$

$M_1(x) = -\frac{2}{2}x^2 + 11x + B_1$
$M_1(0) = -\frac{2}{2}(0)^2 + 11(0) + B_1 = -39$
$B_1 = -39$
$M_1(x) = -\frac{2}{2}x^2 + 11x - 39$

$2EI\ v_1'(x) = -\frac{2}{6}x^3 + \frac{11}{2}x^2 - 39x + C_1$

$2EI\ v_1(x) = -\frac{2}{24}x^4 + \frac{11}{6}x^3 - \frac{39}{2}x^2 + C_1x + D_1$

$3 \leq x \leq 6$:

$w_2(x) = 0$

$V_2(x) = A_2$
$V_2(6) = A_2 = 5$
$A_2 = 5$
$V_2(x) = 5$

$M_2(x) = 5x + B_2$
$M_2(6) = 5(6) + B_2 = 0$
$B_2 = -30$
$M_2(x) = 5x - 30$

$EI\ v_2'(x) = \frac{5}{2}x^2 - 30x + C_2$

$EI\ v_2(x) = \frac{5}{6}x^3 - \frac{30}{2}x^2 + C_2x + D_2$

3. (a)

Boundary conditions:

$v_1'(0) = 0$:

$-\frac{2}{6}(0)^3 + \frac{11}{2}(0)^2 - 39(0) + C_1 = 0$

$C_1 = 0$

$v_1(0) = 0$:

$-\frac{2}{24}(0)^4 + \frac{11}{6}(0)^3 - \frac{39}{2}(0)^2 + 0(0) + D_1 = 0$

$D_1 = 0$

Continuity conditions:

$v_1'(3) = v_2'(3)$:

$\frac{1}{2}\left(-\frac{2}{6}(3)^3 + \frac{11}{2}(3)^2 - 39(3) + 0\right) = \frac{5}{2}(3)^2 - 30(3) + C_2$

$C_2 = 29.25$

$v_1(3) = v_2(3)$:

$\frac{1}{2}\left(-\frac{2}{24}(3)^4 + \frac{11}{6}(3)^3 - \frac{39}{2}(3)^2 + 0(3) + 0\right) = \frac{5}{6}(3)^3 - \frac{30}{2}(3)^2 + 29.25(3) + D_2$

$D_2 = -41.625$

Slope equations [$kN{\cdot}m^2/(EI)$]:

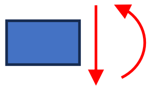
$v_1'(x) = \frac{1}{2EI}\left(-\frac{2}{6}x^3 + \frac{11}{2}x^2 - 39x\right)$ for $0 \le x \le 3$

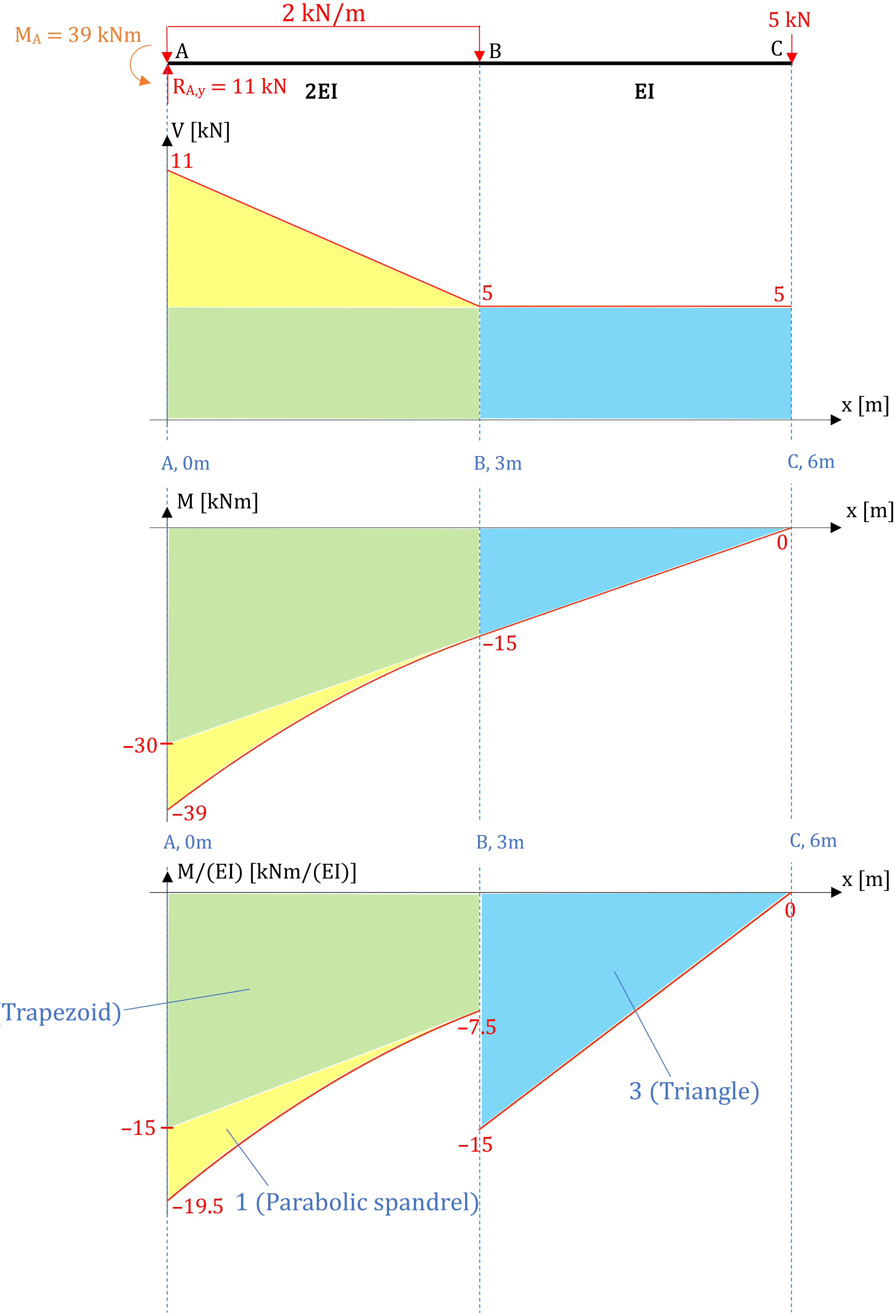
$v_2'(x) = \frac{1}{EI}\left(\frac{5}{2}x^2 - 30x + 29.25\right)$ for $3 \le x \le 6$

Deflection equations [$kN{\cdot}m^3/(EI)$]:

$v_1(x) = \frac{1}{2EI}\left(-\frac{2}{24}x^4 + \frac{11}{6}x^3 - \frac{39}{2}x^2\right)$ for $0 \le x \le 3$ **Ans.**

$v_2(x) = \frac{1}{EI}\left(\frac{5}{6}x^3 - \frac{30}{2}x^2 + 29.25x - 41.625\right)$ for $3 \le x \le 6$ **Ans.**

3. (b)  +



2 kN/m
5 kN
$M_A = 39$ kNm
A
B
C
$R_{A,y} = 11$ kN
2EI
EI
V [kN]
11
5
5
x [m]
A, 0m
B, 3m
C, 6m
M [kNm]
x [m]
0
−15
−30
−39
A, 0m
B, 3m
C, 6m
M/(EI) [kNm/(EI)]
x [m]
0
2 (Trapezoid)
−7.5
3 (Triangle)
−15
−15
−19.5
1 (Parabolic spandrel)

3. (b)

Area Index, i	Area, A_i [kN·m²/(EI)]	Centroid rightwards from point A, x_i [m]	Centroid leftwards from point C, $(x_C - x_i)$ [m]
1	$-\frac{4.5}{EI}$	$\frac{3}{4}$	5.25
2	$-\frac{33.75}{EI}$	$\frac{4}{3}$	$\frac{14}{3}$
3	$-\frac{22.5}{EI}$	4	2

Moment-Area theorems:

$\theta_A = 0$,

$\theta_C = \theta_{C/A} + \theta_A = \sum A_i + 0 = -\frac{60.75\ kN\cdot m^2}{EI}$ (clockwise) **Ans.**

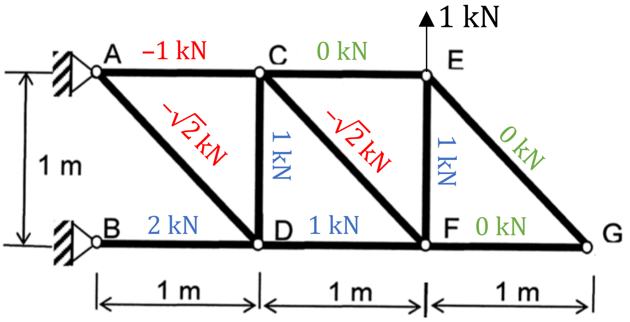
$v_A = 0, \theta_A = 0,$

$t_{C/A} = v_C - v_A - \theta_A(x_C - x_A) = \sum(x_c - x_i)A_i = -\frac{226.125}{EI}$

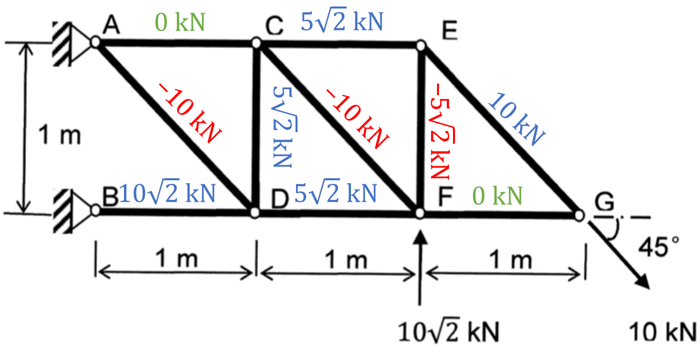
$v_C = -\frac{226.125}{EI} + 0 + 0 = -\frac{226.125\ kN\cdot m^3}{EI}$ (downwards) **Ans.**

4. (a) Blue: Tension, Red: Compression, Green: Zero force member

Virtual forces n:



Real forces N:



Member	n [kN]	N [kN]	L [m]	nNL [$kN^2 \cdot m$]
AC	−1	0	1	0
AD	$-\sqrt{2}$	−10	$\sqrt{2}$	20
BD	2	$10\sqrt{2}$	1	$20\sqrt{2}$
CD	1	$5\sqrt{2}$	1	$5\sqrt{2}$
CE	0	$5\sqrt{2}$	1	0
CF	$-\sqrt{2}$	−10	$\sqrt{2}$	20
DF	1	$5\sqrt{2}$	1	$5\sqrt{2}$
EF	1	$-5\sqrt{2}$	1	$-5\sqrt{2}$
EG	0	10	$\sqrt{2}$	0
FG	0	0	1	0
				$\Sigma = 75.356$

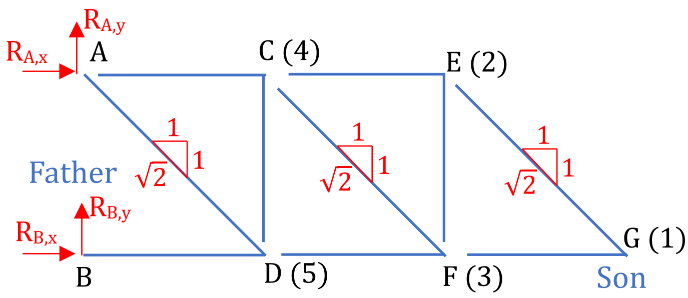
Virtual work equation:

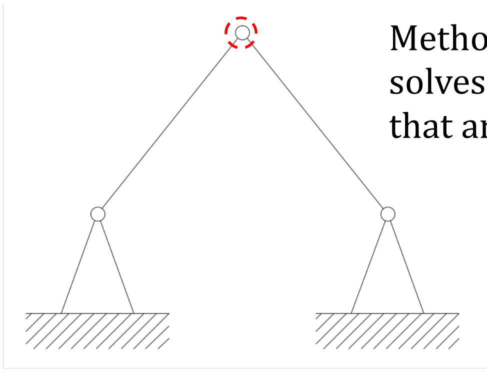
$EA = (200*10^6 \text{ kN/m}^2)(300\ (10^{-3}\text{ m})^2) = 6*10^4 \text{ kN}$

$$1\text{kN} \cdot \Delta_E = \frac{75.356\ kN^2 \cdot m}{6*10^4\ kN} = 1.256*10^{-3} \text{ kNm}$$

$\Delta_E = 1.256*10^{-3}$ m $= 1.256$ mm (up) **Ans.**

4. (a) Calculations





Method of joints solves 2 unknowns that are not collinear.

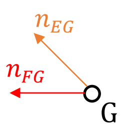
<u>Virtual forces n:</u>

<u>Joint G:</u>

$\uparrow +, \Sigma F_y = 0:$

$\frac{1}{\sqrt{2}} n_{EG} = 0$

$n_{EG} = 0$ kN

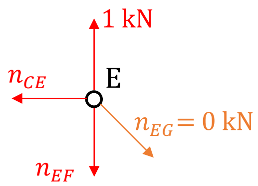


$\rightarrow +, \Sigma F_x = 0:$

$-\frac{1}{\sqrt{2}} n_{EG} - n_{FG} = 0$

$n_{FG} = 0$ kN

<u>Joint E:</u>



$\rightarrow +, \Sigma F_x = 0:$

$-n_{CE} = 0$

$n_{CE} = 0$ kN

$\uparrow +, \Sigma F_y = 0:$

$1 - n_{EF} = 0$

$n_{EF} = 1$ kN (tension)

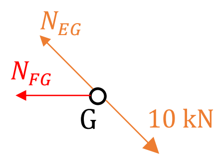
<u>Real forces N:</u>

<u>Joint G:</u>

$\uparrow +, \Sigma F_y = 0:$

$\frac{1}{\sqrt{2}} N_{EG} - \frac{1}{\sqrt{2}} * 10\sqrt{2} = 0$

$N_{EG} = 10$ kN (tension)

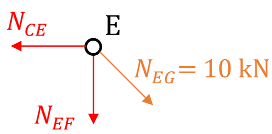


$\rightarrow +, \Sigma F_x = 0:$

$-\frac{1}{\sqrt{2}} N_{EG} - N_{FG} + \frac{1}{\sqrt{2}} * 10 = 0$

$N_{FG} = 0$ kN

<u>Joint E:</u>



$\rightarrow +, \Sigma F_x = 0:$

$-N_{CE} + \frac{1}{\sqrt{2}} * 10 = 0$

$N_{CE} = 5\sqrt{2}$ kN (tension)

$\uparrow +, \Sigma F_y = 0:$

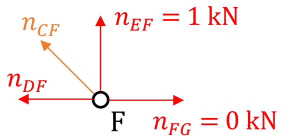
$-\frac{1}{\sqrt{2}} N_{EG} - N_{EF} = 0$

$N_{EF} = -5\sqrt{2}$ kN (compression)

4. (a) Calculations

Virtual forces n:

Joint F:



$\uparrow +$, $\Sigma F_y = 0$:

$$\frac{1}{\sqrt{2}} n_{CF} + n_{EF} = 0$$

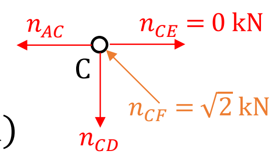
$n_{CF} = -\sqrt{2}$ kN (compression)

$\rightarrow +$, $\Sigma F_x = 0$:

$$-\frac{1}{\sqrt{2}} n_{CF} - n_{DF} = 0$$

$n_{DF} = 1$ kN (tension)

Joint C:



$\rightarrow +$, $\Sigma F_x = 0$:

$$-n_{AC} - \frac{1}{\sqrt{2}} n_{CF} = 0$$

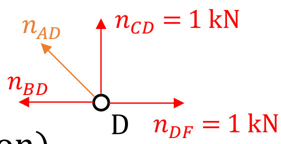
$n_{AC} = -1$ kN (compression)

$\uparrow +$, $\Sigma F_y = 0$:

$$-n_{CD} + \frac{1}{\sqrt{2}} n_{CF} = 0$$

$n_{CD} = 1$ kN (tension)

Joint D:



$\uparrow +$, $\Sigma F_y = 0$:

$$n_{CD} + \frac{1}{\sqrt{2}} n_{AD} = 0$$

$n_{AD} = -\sqrt{2}$ kN (compression)

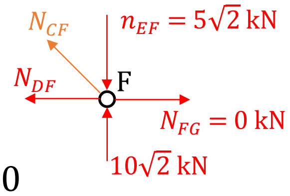
$\rightarrow +$, $\Sigma F_x = 0$:

$$n_{DF} - n_{BD} - \frac{1}{\sqrt{2}} n_{AD} = 0$$

$n_{BD} = 2$ kN (tension)

Real forces N:

Joint F:



$\uparrow +$, $\Sigma F_y = 0$:

$$\frac{1}{\sqrt{2}} N_{CF} + N_{EF} + 10\sqrt{2} = 0$$

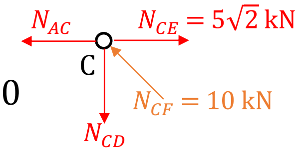
$N_{CF} = -10$ kN (compression)

$\rightarrow +$, $\Sigma F_x = 0$:

$$-\frac{1}{\sqrt{2}} N_{CF} - N_{DF} = 0$$

$N_{DF} = 5\sqrt{2}$ kN (tension)

Joint C:



$\rightarrow +$, $\Sigma F_x = 0$:

$$-N_{AC} - \frac{1}{\sqrt{2}} N_{CF} + N_{CE} = 0$$

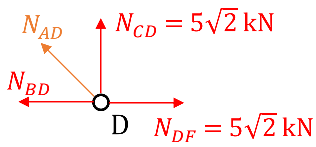
$N_{AC} = 0$ kN

$\uparrow +$, $\Sigma F_y = 0$:

$$-N_{CD} + \frac{1}{\sqrt{2}} N_{CF} = 0$$

$N_{CD} = 5\sqrt{2}$ kN (tension)

Joint D:



$\uparrow +$, $\Sigma F_y = 0$:

$$N_{CD} + \frac{1}{\sqrt{2}} N_{AD} = 0$$

$N_{AD} = -10$ kN (compression)

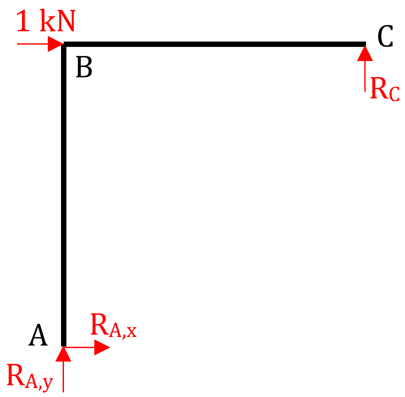
$\rightarrow +$, $\Sigma F_x = 0$:

$$N_{DF} - N_{BD} - \frac{1}{\sqrt{2}} N_{AD} = 0$$

$N_{BD} = 10\sqrt{2}$ kN (tension)

4. (b) (i)

Virtual horizontal force:



Solving reactions:

⟲+, $\Sigma M_A = 0$:
$R_C*4 - 1*4 = 0$
$R_C = 1$ kN (upwards)

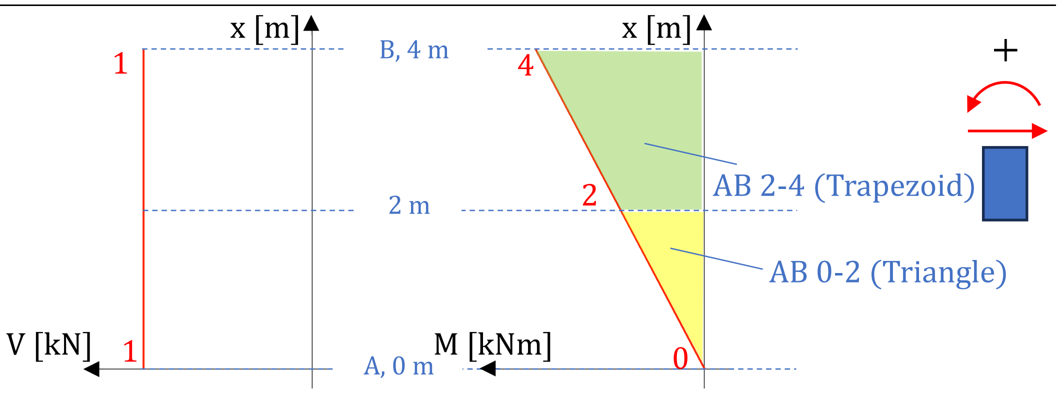
↑+, $\Sigma F_y = 0$:
$R_C + R_{A,y} = 0$
$R_{A,y} = -1$ kN (downwards)

→+, $\Sigma F_x = 0$:
$R_{A,x} + 1 = 0$
$R_{A,x} = -1$ kN (leftwards)

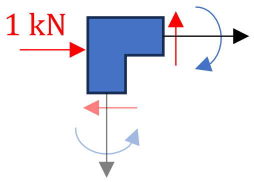
Section AB:

$V_1(x) = 1$ for $0 \le x \le 2$
$M_1(x) = x$ for $0 \le x \le 2$

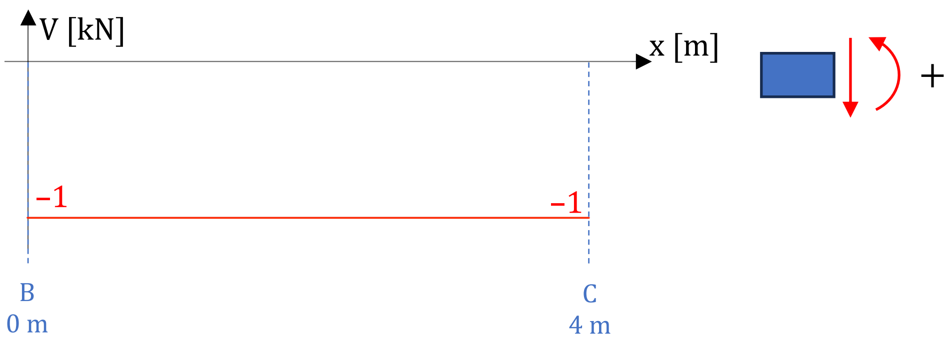
$V_1(x) = 1$ for $2 \le x \le 4$
$M_2(x) = x$ for $2 \le x \le 4$



At B:

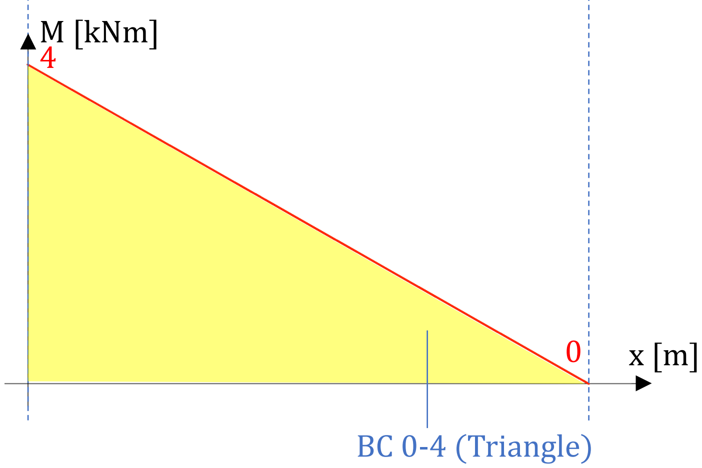


V = −1 kN
M = 4 kNm
N = 0 kN



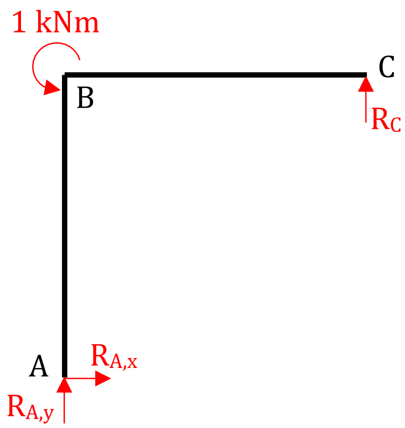
Section BC:

$V_3(x) = -1$ for $0 \le x \le 4$
$M_3(x) = -x + 4$ for $0 \le x \le 4$



4. (b) (i)

Virtual moment:



Solving reactions:

⟲+, $\Sigma M_A = 0$:
$R_C*4 + 1 = 0$
$R_C = -0.25$ kN (downwards)

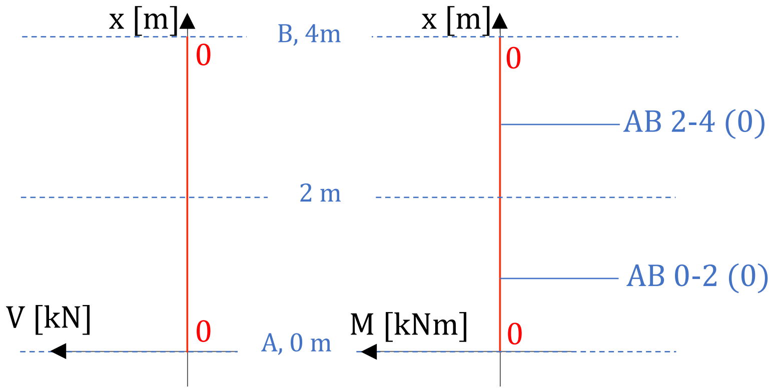
↑+, $\Sigma F_y = 0$:
$R_C + R_{A,y} = 0$
$R_{A,y} = 0.25$ kN (upwards)

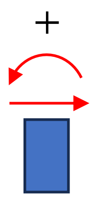
→+, $\Sigma F_x = 0$:
$R_{A,x} = 0$ kN

Section AB:

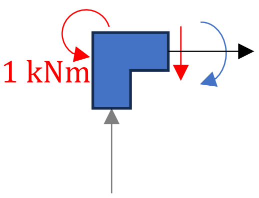
$V_1(x) = 0$ for $0 \leq x \leq 2$
$M_1(x) = 0$ for $0 \leq x \leq 2$

$V_2(x) = 0$ for $2 \leq x \leq 4$
$M_1(x) = 0$ for $2 \leq x \leq 4$

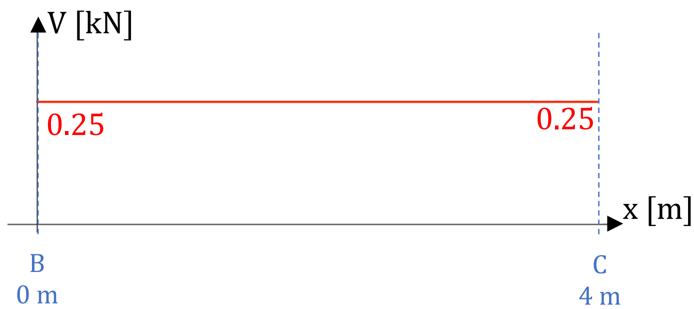


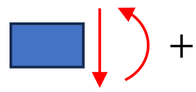


At B:



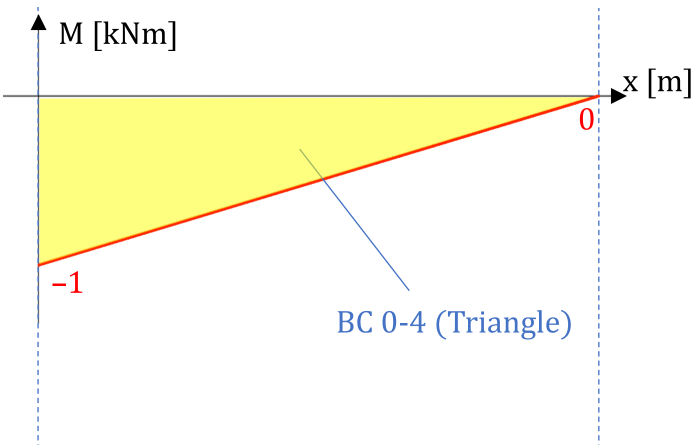
V = 0.25 kN
M = –1 kNm
N = 0 kN





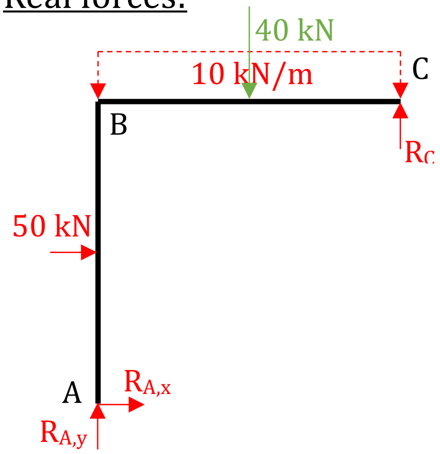
Section BC:

$V_3(x) = 0.25$ for $0 \leq x \leq 4$
$M_3(x) = 0.25x - 1$ for $0 \leq x \leq 4$



4. (b) (i)

Real forces:



Solving reactions:

⟲+, $\Sigma M_A = 0$:
$R_C*4 - 30*2 - 20*4 = 0$
$R_C = 45$ kN (upwards)

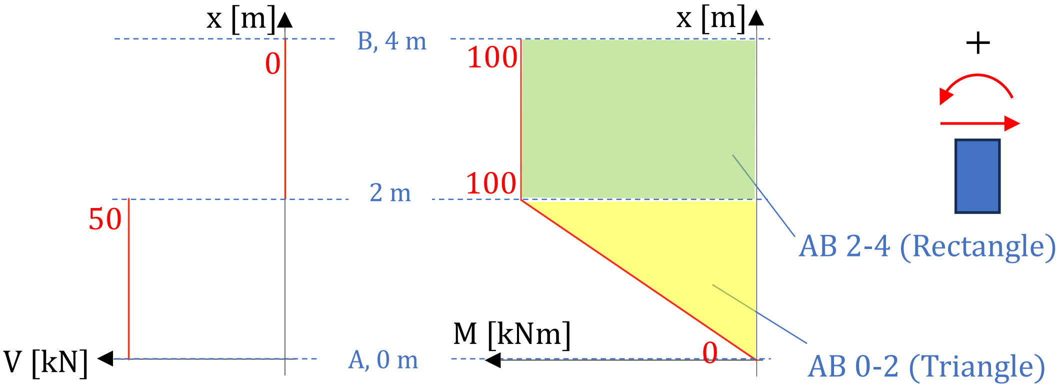
↑+, $\Sigma F_y = 0$:
$R_C + R_{A,y} - 40 = 0$
$R_{A,y} = -5$ kN (downwards)

→+, $\Sigma F_x = 0$:
$R_{A,x} + 50 = 0$
$R_{A,x} = -50$ kN (leftwards)

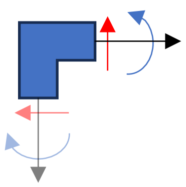
Section AB:

$V_1(x) = 50$ for $0 \leq x \leq 2$
$M_1(x) = 50x$ for $0 \leq x \leq 2$

$V_2(x) = 0$ for $2 \leq x \leq 4$
$M_2(x) = 100$ for $2 \leq x \leq 4$



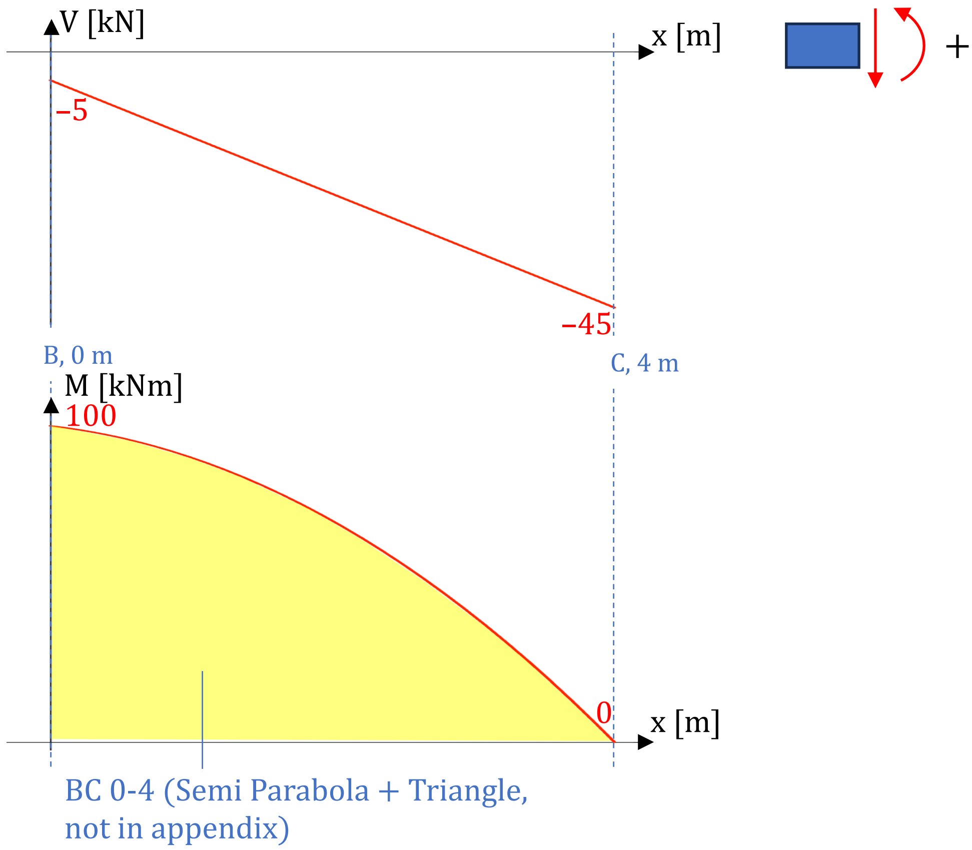
At B:



V = −5 kN
M = 80 kNm
N = 20 kN

Section BC:

$V_3(x) = -10x - 5$ for $0 \leq x \leq 4$
$M_3(x) = -5x^2 - 5x + 100$
for $0 \leq x \leq 4$



4. (b) (i)

$EI = (200\ \text{GPa})(235*10^{6}\ (\text{mm})^{4}) = (200*10^{9}\ \text{N/m}^{2})(235*10^{6}\ (10^{-3}\ \text{m})^{4}) = 4.7*10^{4}\ \text{kN}\cdot\text{m}^{2}$

<u>Virtual work equation:</u>

<u>Horizontal deflection:</u>

$$1\ \text{kN}\cdot\Delta_B = \underbrace{\int_0^2 \frac{(x)(50x)}{EI}dx}_{133.333/(EI)} + \underbrace{\int_2^4 \frac{(x)(100)}{EI}dx}_{600/(EI)} + \underbrace{\int_0^4 \frac{(-x+4)(-5x^2-5x+100)}{EI}dx}_{640/(EI)}$$

$$= 2.922*10^{-2}\,\frac{(kNm)^2}{kN\cdot m^2}\cdot m = 2.922*10^{-2}\ \text{kNm}$$

$\Delta_B = 2.922*10^{-2}$ m = 29.22 mm (rightwards) **<u>Ans.</u>**

<u>Rotation:</u>

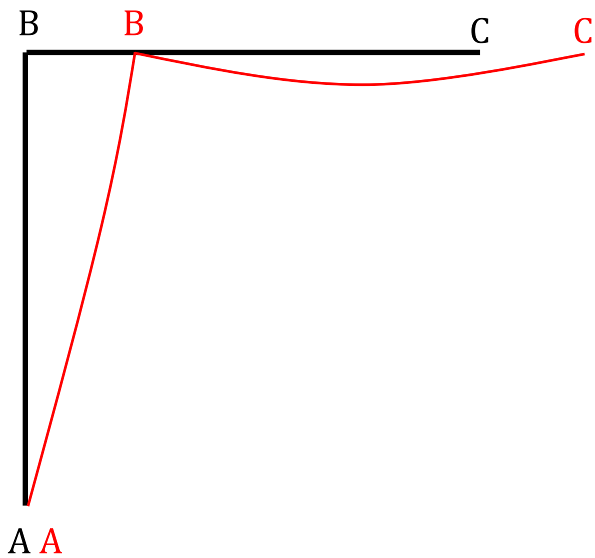
$$1\ \text{kNm}\cdot\theta_B = \underbrace{\int_0^2 \frac{(0)(50x)}{EI}dx}_{0/(EI)} + \underbrace{\int_2^4 \frac{(0)(100)}{EI}dx}_{0/(EI)} + \underbrace{\int_0^4 \frac{(0.25x-1)(-5x^2-5x+100)}{EI}dx}_{-160/(EI)}$$

$$= -3.404*10^{-3}\,\frac{(kNm)^2}{kN\cdot m^2}\cdot m = -3.404*10^{-3}\ \text{kNm}$$

$\theta_B = -3.404*10^{-3} = -0.003404$ rad (clockwise) **<u>Ans.</u>**

---

4. (b) (ii) **<u>Ans.</u>**



B moves right and rotates clockwise

NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2022-2023

CV2011 – STRUCTURAL ANALYSIS I

April / May 2023 **Time Allowed: 2 hours**

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** pages.
2. Answer **ALL** questions.
3. All questions carry equal marks.
4. An Appendix of **TWO (2)** pages is attached to the Question Paper.
5. This is a Restricted Open-Book Examination. You are allowed to bring into the examination hall **ONE (1)** double-sided A4-size reference sheet with texts handwritten or typed on the A4 paper (no sticky notes/post-it notes on the reference sheet).
6. All answers must be written in the Answer Book provided. Answer each question beginning on a **FRESH** page of the Answer Book.
7. Avoid illegible handwriting. Your writing must be **CLEAR** and **READABLE**.

---

1. A pin-jointed truss is subjected to a point load at *F* as shown in Figure Q1. The truss is pinned at *A* and supported by a roller at *D*.

   (a) Determine its determinacy and stability.

   (3 Marks)

   (b) Calculate all the reactions.

   (6 Marks)

   (c) Calculate the internal forces for members of *AB*, *BC*, *CD*, *AD* and *FE*.

   (16 Marks)

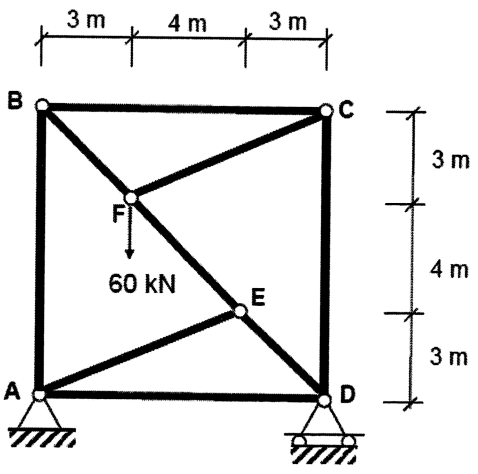


Figure Q1

2. Frame *ABCDEF* shown in Figure Q2 is fixed at *A* and pin-supported at *F*. One uniformly distributed load of 2 *kN/m* is applied at segment *CD*. One point force of 7 *kN* is applied at mid-point of segment *BC*.

(a) Prove that the frame is statically determinate.

(3 Marks)

(b) Calculate the reactions at the supports *A* and *F*.

(8 Marks)

(c) Draw the bending moment and shear force diagrams of the frame, indicating all the critical values.

(14 Marks)

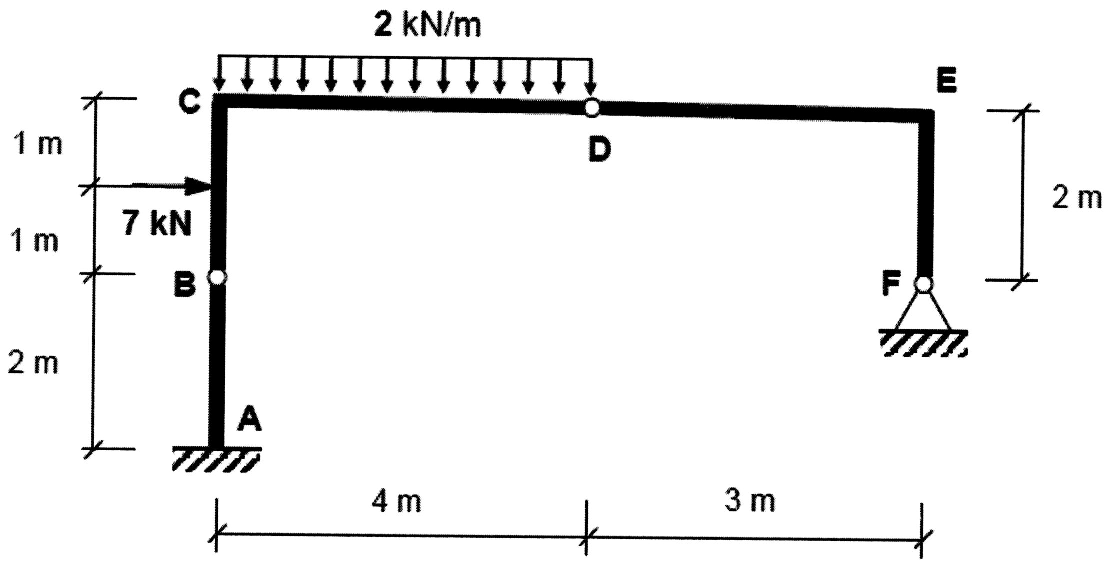


Figure Q2

3. The cantilever beam *ABC* is loaded as shown in Figure Q3. Support *A* is a fixed end. A uniformly distributed load of 2 *kN/m* is applied over the segment *AB*, and a point load of 5 *kN* is applied at the free end *C*. The beam has a flexural rigidity of 2*EI* in the segment *AB* and *EI* in the segment *BC*.

(a) Determine the deflection curve of the cantilever beam in terms of *EI* using the **direct integration method**.

(12 Marks)

(b) Determine the vertical displacement and slope at *C* using the **moment area method**.

(13 Marks)

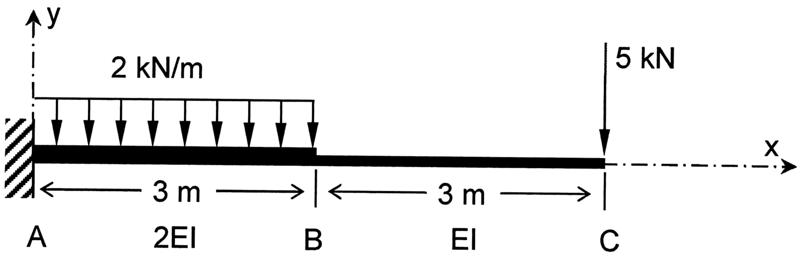


Figure Q3

4. (a) As shown in Figure Q4(a), a truss *ABCDEFG* is supported by two pined ends at *A* and *B*. One point load of 10 *kN* is applied at joint *G* with an angle of 45° as shown. Another point load of $10\sqrt{2}$ *kN* is applied at joint *F* vertically. Each truss member has the same Young's modulus of $E = 200$ *GPa* and the same cross-sectional area of $A = 300$ mm^2. By using the **principle of virtual work**, determine the vertical displacement at joint *E*.

(12 Marks)

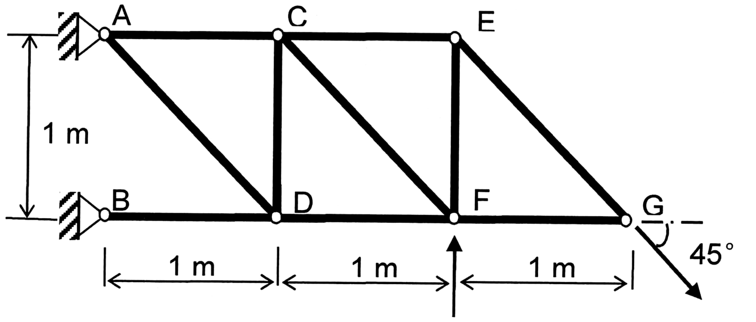


Figure Q4(a)

(b) The frame *ABC* is loaded and supported as shown in Figure Q4(b). Each member has the same Young's modulus of $E = 200$ *GPa* and same moment of inertia of $I = 235 \times 10^6$ mm^4.

(i) By using the **principle of virtual work**, determine the horizontal displacement and rotation at joint *B*.

(11 Marks)

(ii) Based on the results in part (b)(i), draw the deformed shape of the frame in a qualitative manner.

(2 Marks)

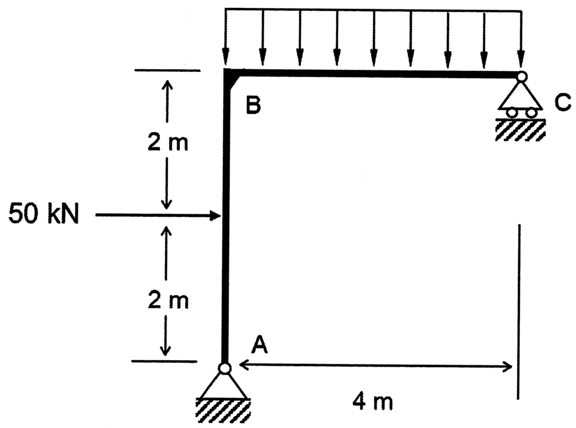
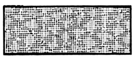
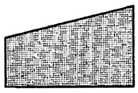
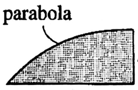
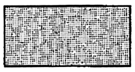
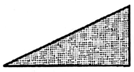
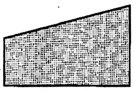
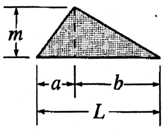
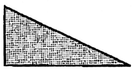


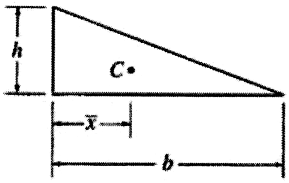
Figure Q4(b)

END OF PAPER

Appendix: Values of Product Integrals $\int_0^L mm'dx$

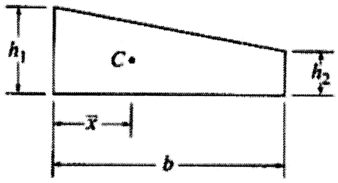
$\int_0^L m\,m'\,dx$				
	$mm'L$	$\frac{1}{2}mm'L$	$\frac{1}{2}m(m'_1 + m'_2)L$	$\frac{2}{3}mm'L$
	$\frac{1}{2}mm'L$	$\frac{1}{3}mm'L$	$\frac{1}{6}m(m'_1 + 2m'_2)L$	$\frac{5}{12}mm'L$
	$\frac{1}{2}m'(m_1 + m_2)L$	$\frac{1}{6}m'(m_1 + 2m_2)L$	$\frac{1}{6}[m'_1(2m_1 + m_2) + m'_2(m_1 + 2m_2)]L$	$\frac{1}{12}[m'(3m_1 + 5m_2)]L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'(L + a)$	$\frac{1}{6}m_1[m'_1(L + b) + m_2(L + a)]$	$\frac{1}{12}mm'\left(3 + \frac{3a}{L} - \frac{a^2}{L^2}\right)L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'L$	$\frac{1}{6}m(2m'_1 + m'_2)L$	$\frac{1}{4}mm'L$

Appendix: Geometric Properties of Areas



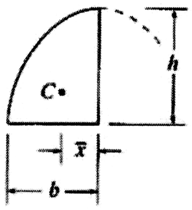
$$A = \frac{1}{2}bh$$
$$\bar{x} = \frac{1}{3}b$$

Triangle



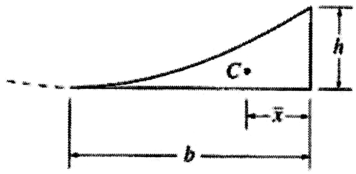
$$A = \frac{1}{2}b\,(h_1 + h_2)$$
$$\bar{x} = \frac{b\,(2h_2 + h_1)}{3\,(h_1 + h_2)}$$

Trapezoid



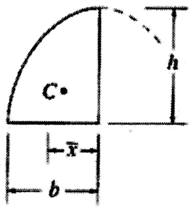
$$A = \frac{2}{3}bh$$
$$\bar{x} = \frac{3}{8}b$$

Semi Parabola



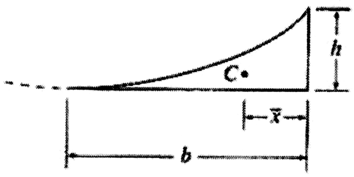
$$A = \frac{1}{3}bh$$
$$\bar{x} = \frac{1}{4}b$$

Parabolic spandrel



$$A = bh\,\left(\frac{n}{n+1}\right)$$
$$\bar{x} = \frac{b\,(n+1)}{2\,(n+2)}$$

Semi-segment of *n*th degree curve



$$A = bh\,\left(\frac{1}{n+1}\right)$$
$$\bar{x} = \frac{b}{(n+2)}$$

Spandrel of *n*th degree curve

CV2011 STRUCTURAL ANALYSIS I

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.