ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO

Introdução aos Elementos de Máquinas

PMR 3320 - A03

Esforços e Diagramas de esforços

2020.2

Cronograma de aulas

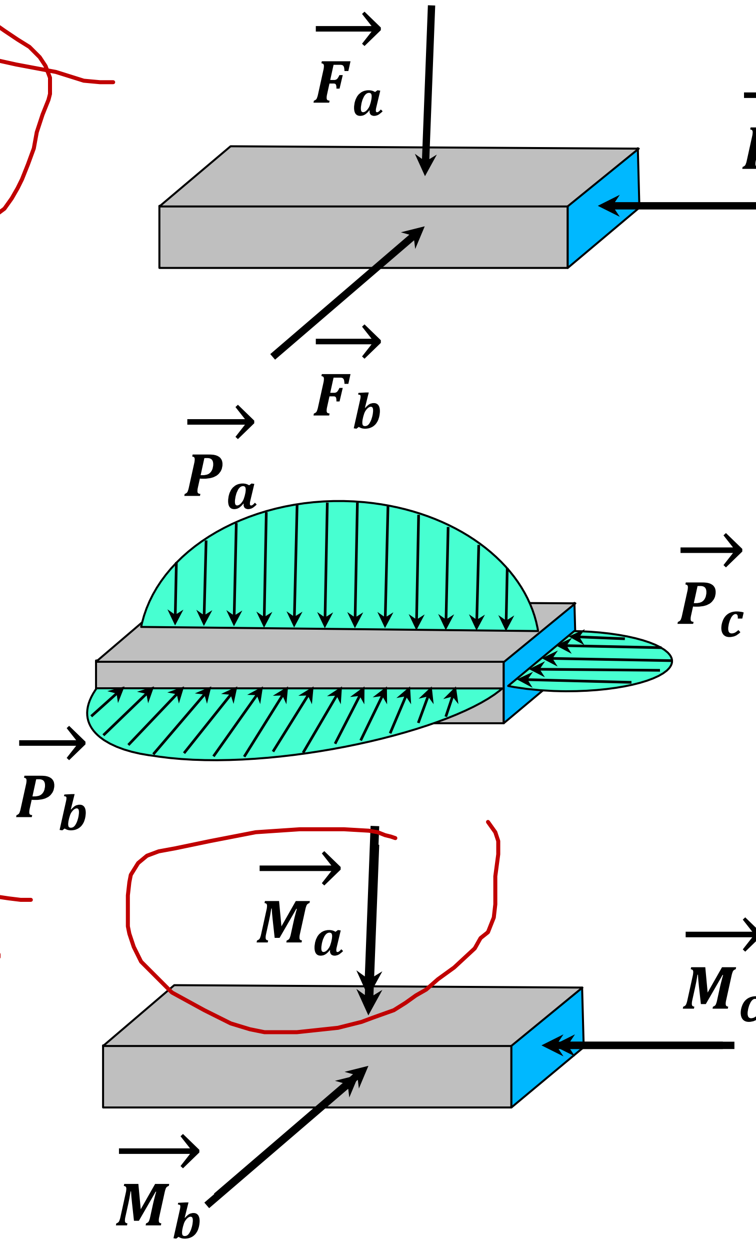
Dia	S	Aula	Tópico	Prof.
17.08	2ª	A1	**Introdução a disciplina** Modelagem, carregamento e equilíbrio	RS
24.08	2ª	A2	Composição de tensões Estado plano de tensões – Círculo de Mohr	RS
31.08	2ª	A3	Composição de tensões Diagramas de esforços	RS
07.09	2ª	---	**Feriado – Independência do Brasil**	
14.09	2ª	A4	Teorias de Falha: 2) Falha por deformação permanente: von Mises, Tresca, Coulomb-Mohr	RS
21.09	2ª	A5	Teorias de Falha: 3) Falha por fadiga	RS
28.09	2ª	A6	Fixações cubo-eixo	NG
05.10	2ª	A7	Dimensionamento de Eixos	NG
12.10	2ª	---	**Feriado – Dia da Criança**	
19.10	2ª	A8	Especificação e dimensionamento de elementos de fixação: Rebites	NG
26.10	2ª	A9	Especificação e dimensionamento de elementos de fixação: Parafusos	NG
02.11	2ª	A10	Especificação e dimensionamento de elementos de transmissão: Fusos	NG
09.11	2ª	A11	Análise e dimensionamento de componentes mecânicos: Engrenagens: Parte - 1	RS
16.11	2ª	A12	Análise e dimensionamento de componentes mecânicos: Engrenagens: Parte - 2	RS
23.11	2ª	A13	Análise e dimensionamento de componentes mecânicos: Mancais	RS
30.11	2ª	A17	Análise e dimensionamento de componentes mecânicos: Molas	NG
07.12	2ª	A18	Análise e dimensionamento de componentes mecânicos: Acoplamentos e embreagens	NG
14.12	2ª		**Encerramento do semestre 2020-2**	

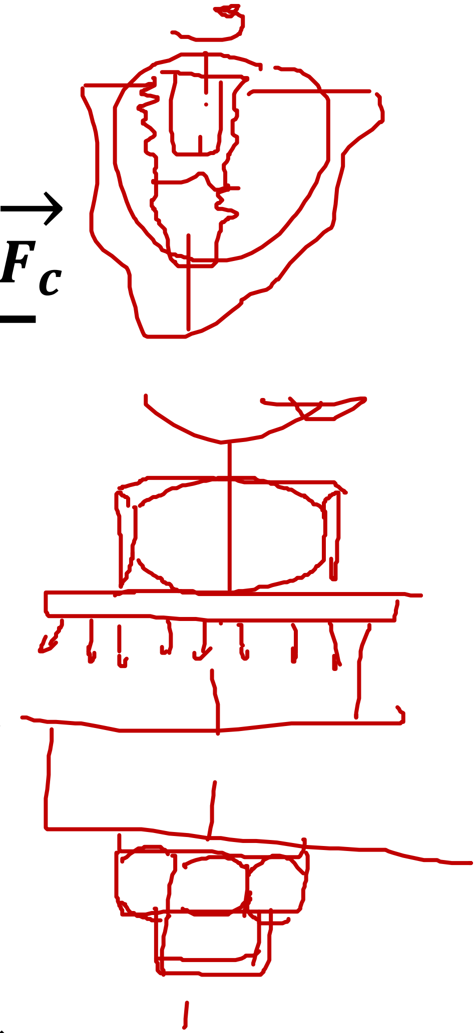
Tópicos

- Composição de tensões
- Método das seções
- Diagramas de esforços e flexão

Carregamentos

- Forças
  - Concentrados
  - Distribuídos
- Momentos



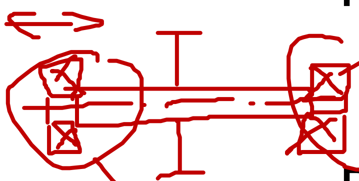


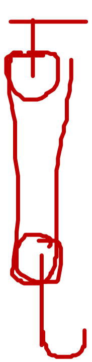
Apoios

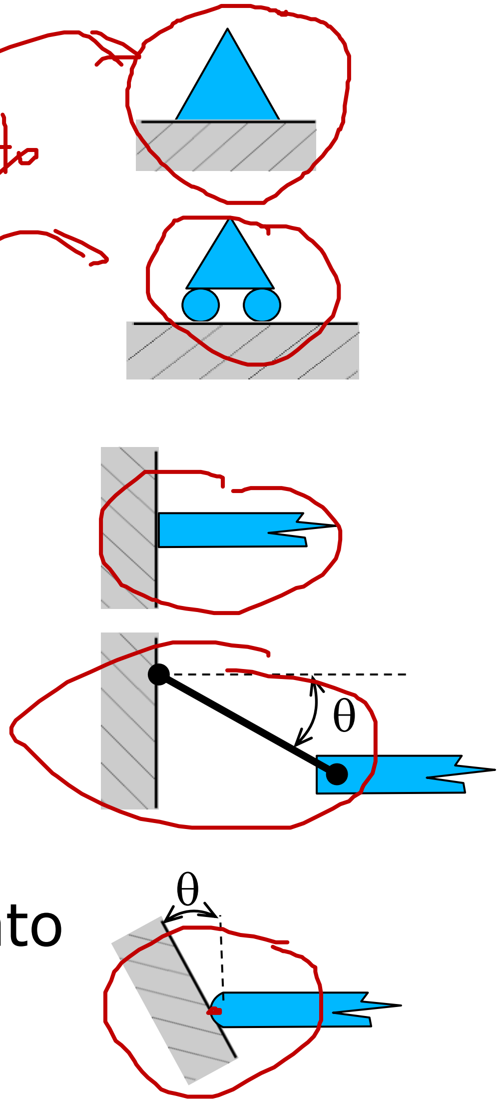
Reações

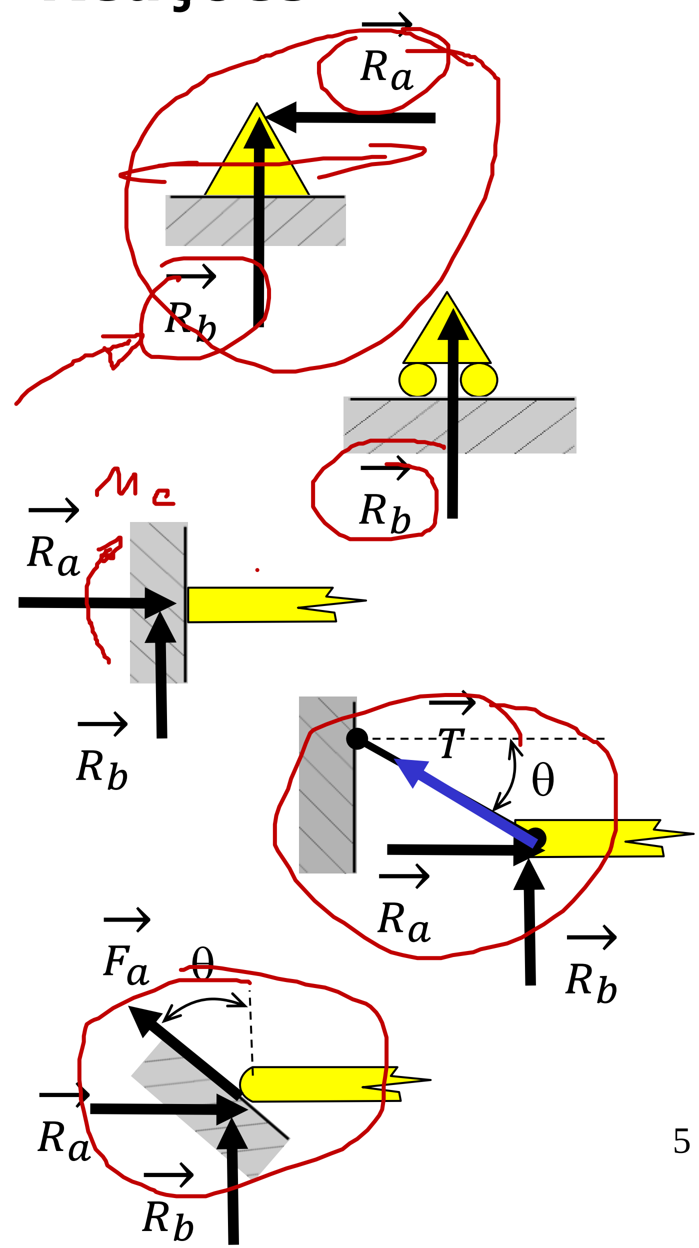
- Fixo
- Deslizante
- Engastado
- Com cabo
- Com contato

Rolamento

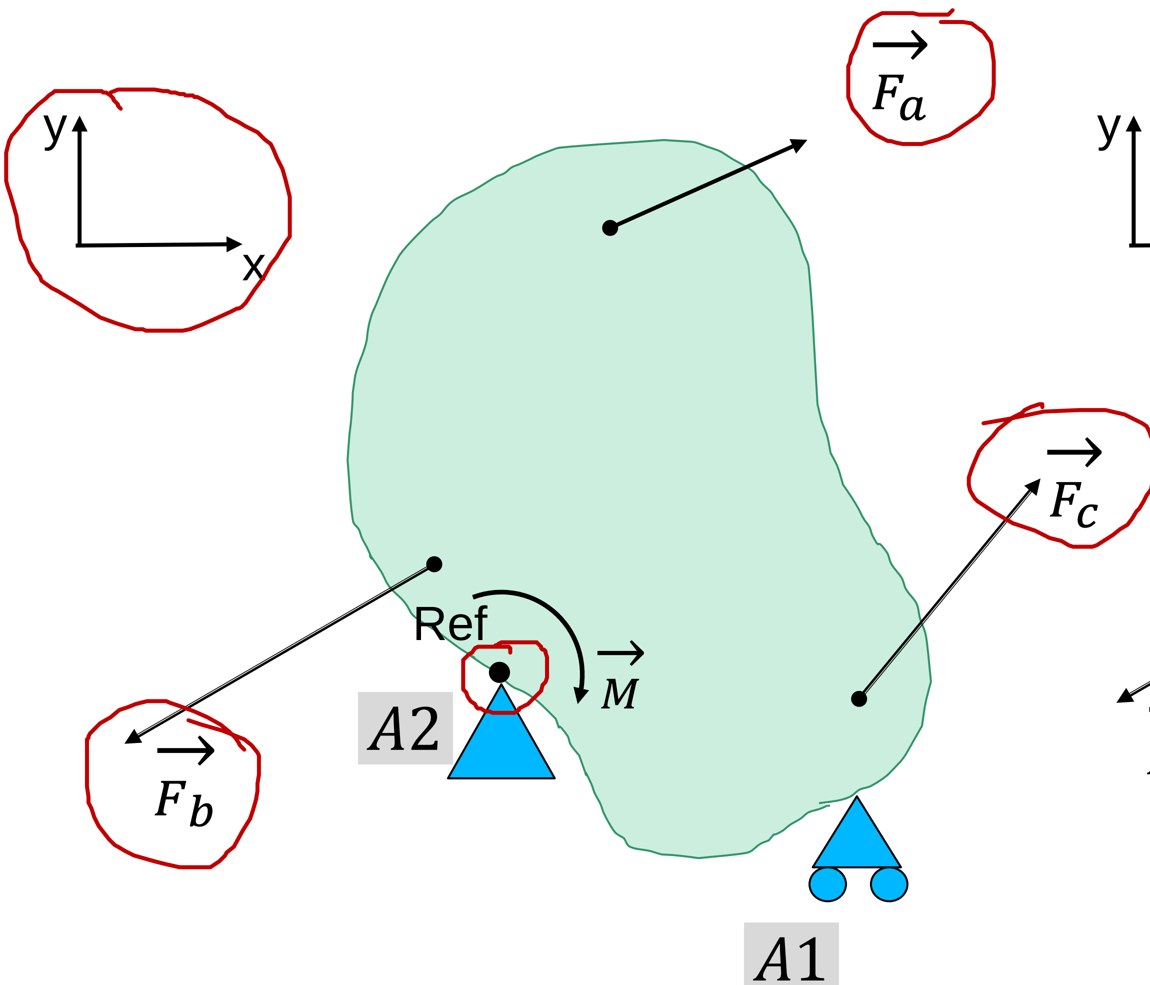


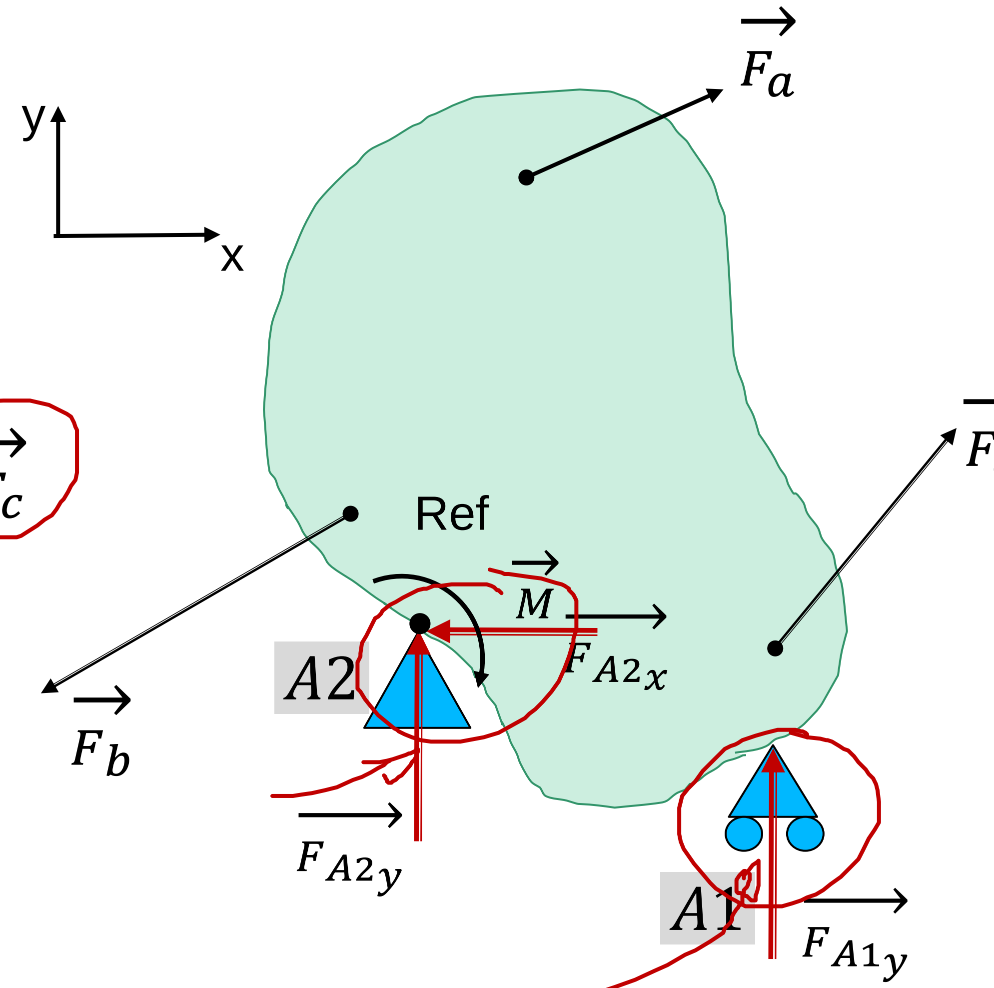




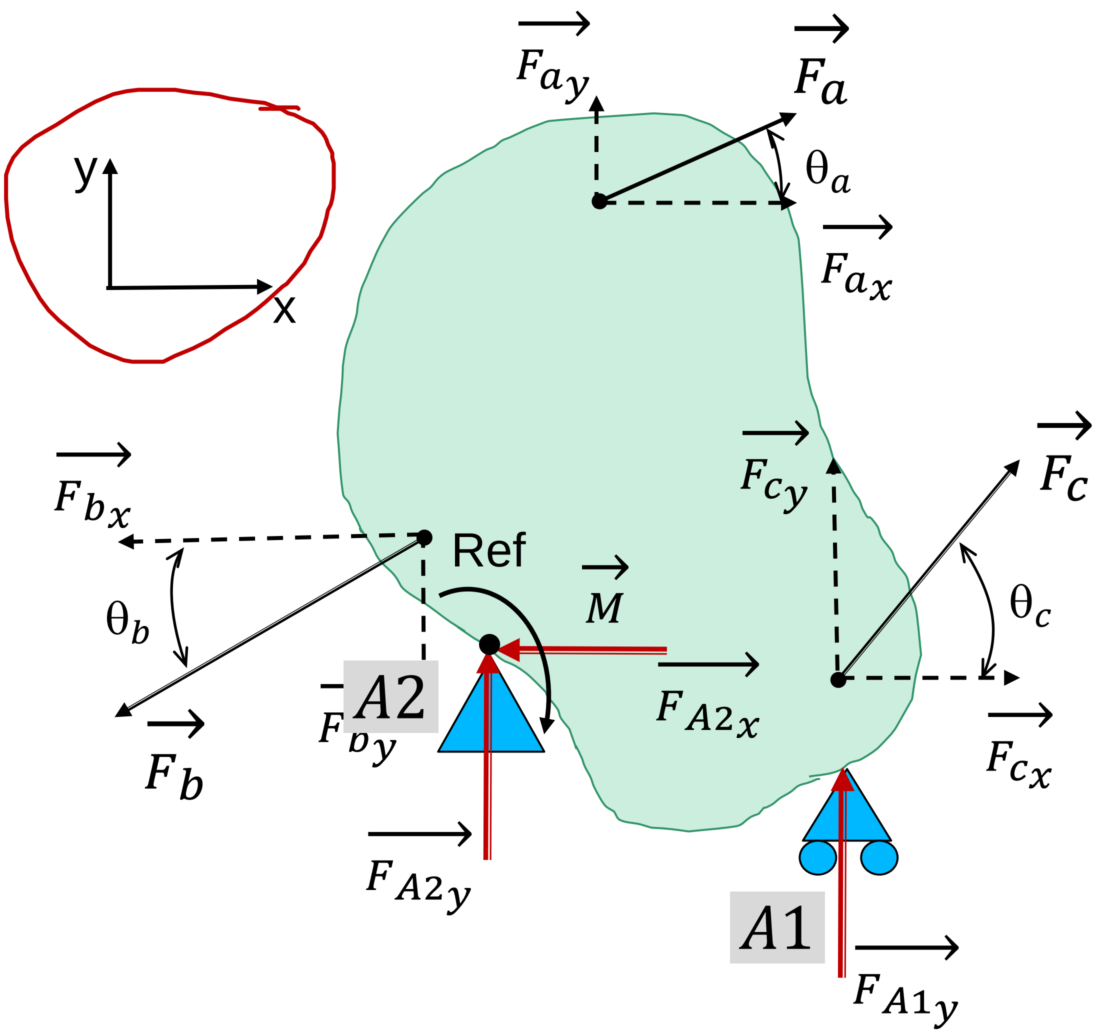


Corpo apoiado sujeito a carregamentos





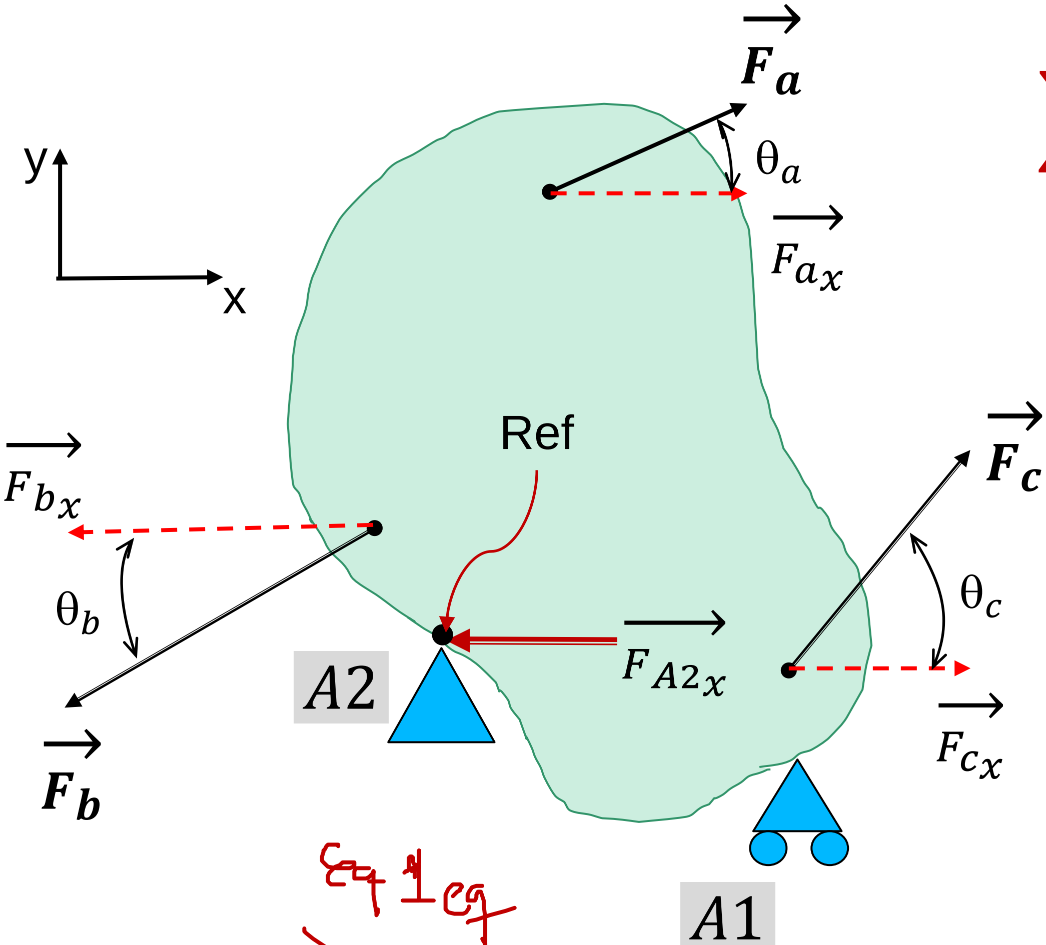
Apoios e reações no equilíbrio



$$\sum_{Ref}\overrightarrow{F_n} = \vec{F} = 0$$

$$\sum_{Ref}\overrightarrow{M_n} = \vec{M} = 0$$

Apoios e reações no equilíbrio



$$\sum \overrightarrow{F_{ref_x}} = 0$$

$$\overrightarrow{F_{a_x}} + \overrightarrow{F_{c_x}} - \overrightarrow{F_{b_x}} + \overrightarrow{F_{A2_x}} = 0$$

$$\overrightarrow{F_{a_x}} = \overrightarrow{F_a}.\cos\theta_a\,,$$

$$\overrightarrow{F_{c_x}} = \overrightarrow{F_c}.\cos\theta_c\,,$$

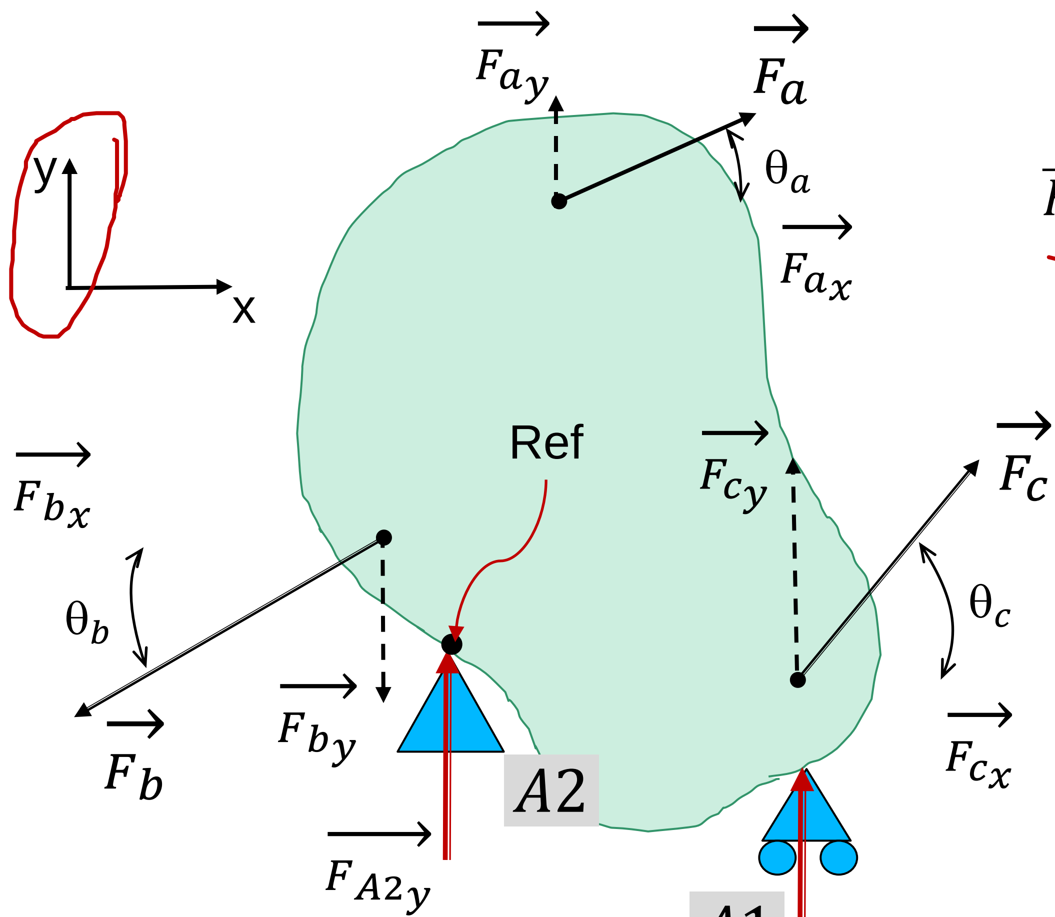
$$-\overrightarrow{F_{b_x}} = \overrightarrow{F_b}.\cos\theta_b\,,$$

$$\overrightarrow{F_{A2_x}}$$

Eq 1 eq

$$\overrightarrow{F_a}.\cos\theta_a + \overrightarrow{F_c}.\cos\theta_c - \overrightarrow{F_b}.\cos\theta_b + \overrightarrow{F_{A2_x}} = 0$$

Apoios e reações no equilíbrio



$$\sum \overrightarrow{F_{ref_y}} = 0$$

$$\overrightarrow{F_{a_y}} + \overrightarrow{F_{c_y}} - \overrightarrow{F_{b_y}} + \overrightarrow{F_{A2_y}} + \overrightarrow{F_{A1_y}} = 0$$

$$\overrightarrow{F_{a_y}} = \overrightarrow{F_a}\,.\sin\theta_a\,,$$

$$-\overrightarrow{F_{b_y}} = \overrightarrow{F_b}\,.\sin\theta_b\,,$$

$$\overrightarrow{F_{c_y}} = \overrightarrow{F_c}\,.\sin\theta_c\,,$$

$$\overrightarrow{F_{A2_y}},$$

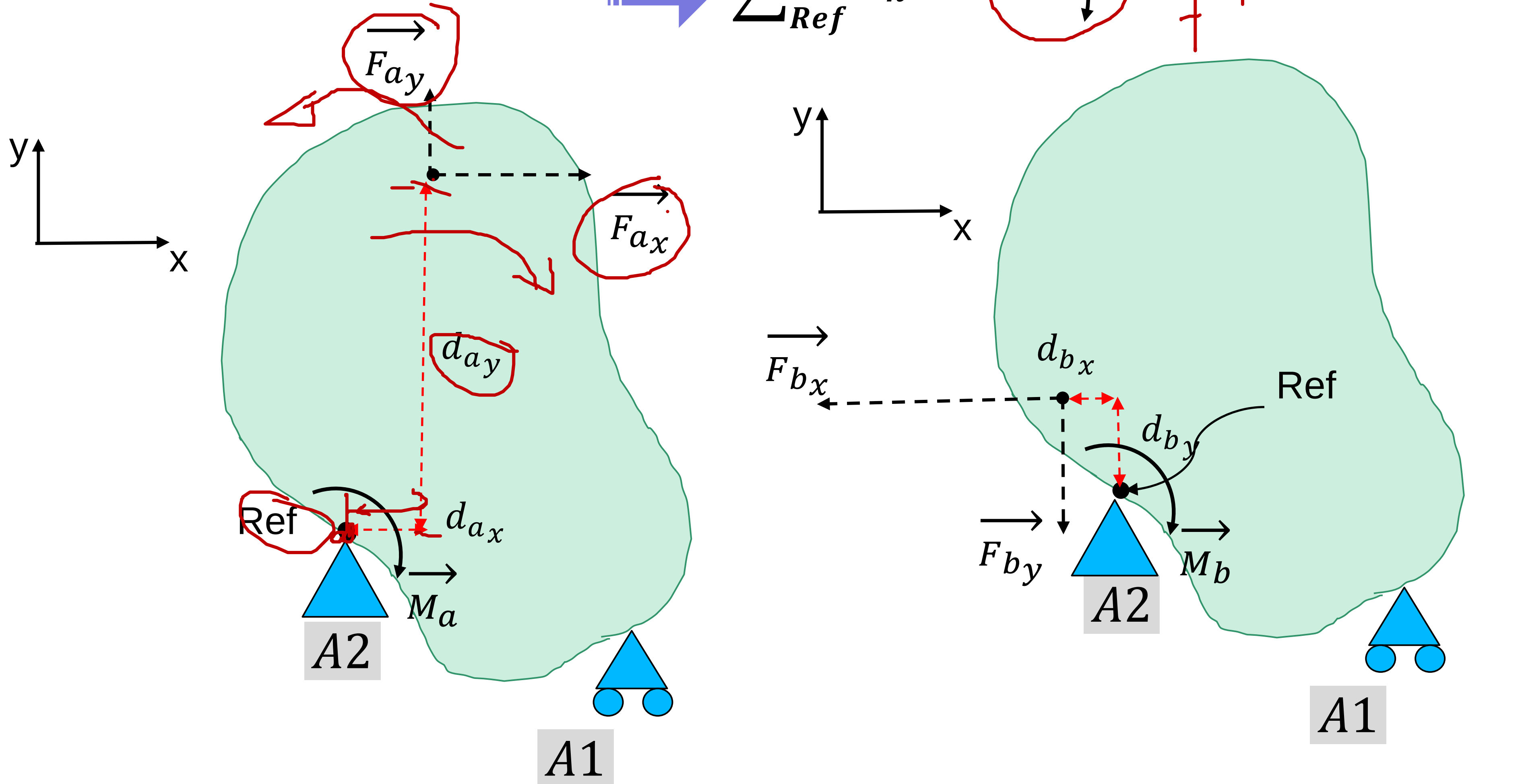
$$\overrightarrow{F_{A1_y}}$$

Eq 2.4

$$\overrightarrow{F_a}\,.\sin\theta_a + \overrightarrow{F_c}\,.\sin\theta_c - \overrightarrow{F_b}\,.\sin\theta_b + \overrightarrow{F_{A2_y}} + \overrightarrow{F_{A1_y}} = 0$$

Apoios e reações no equilíbrio

$$\sum_{Ref} \overrightarrow{M_n} = 0 \quad +$$

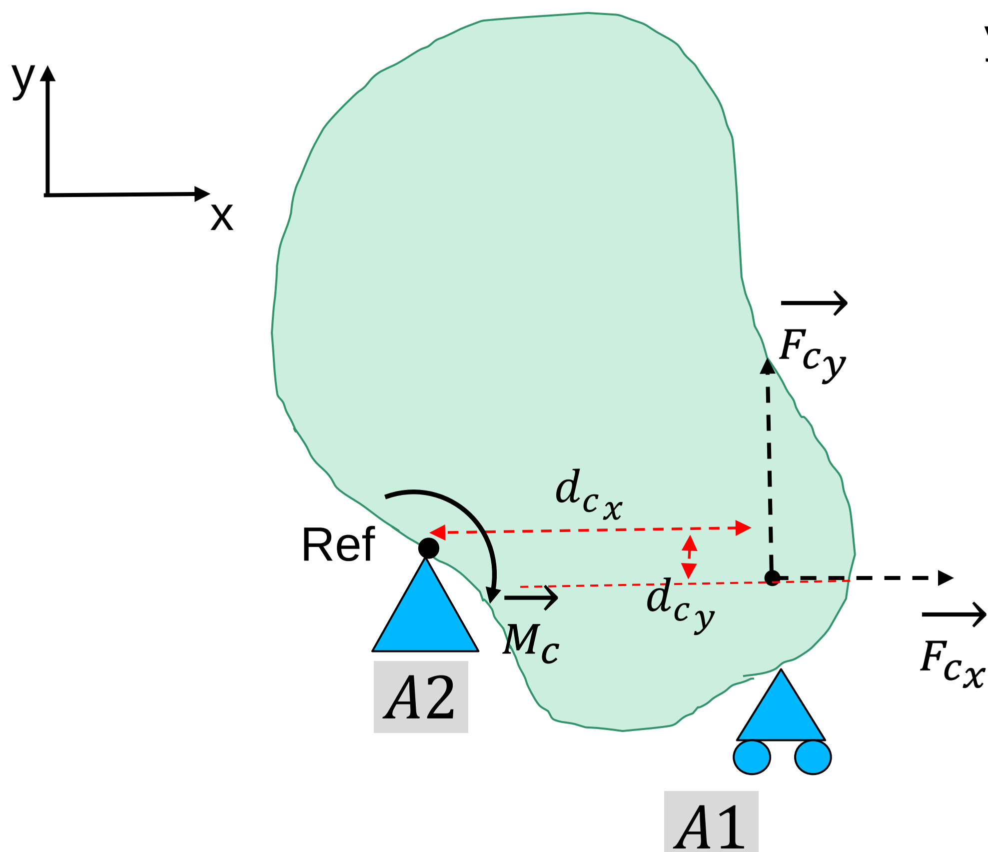


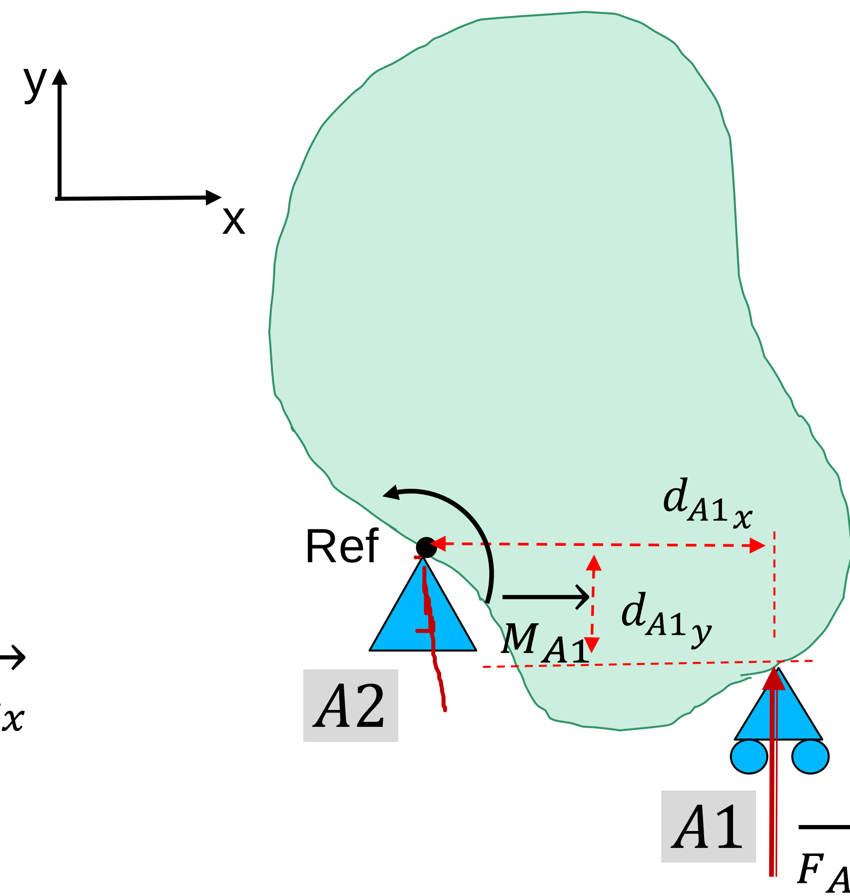
$$\overrightarrow{M_a} = \overrightarrow{F_{a_x}} * d_{a_y} - \overrightarrow{F_{a_y}} * d_{a_x}$$

$$\overrightarrow{M_b} = -\overrightarrow{F_{b_x}} * d_{a_y} - \overrightarrow{F_{b_y}} * d_{a_x}$$

Apoios e reações no equilíbrio

$$\sum_{Ref} \overrightarrow{M_n} = 0 \quad +$$



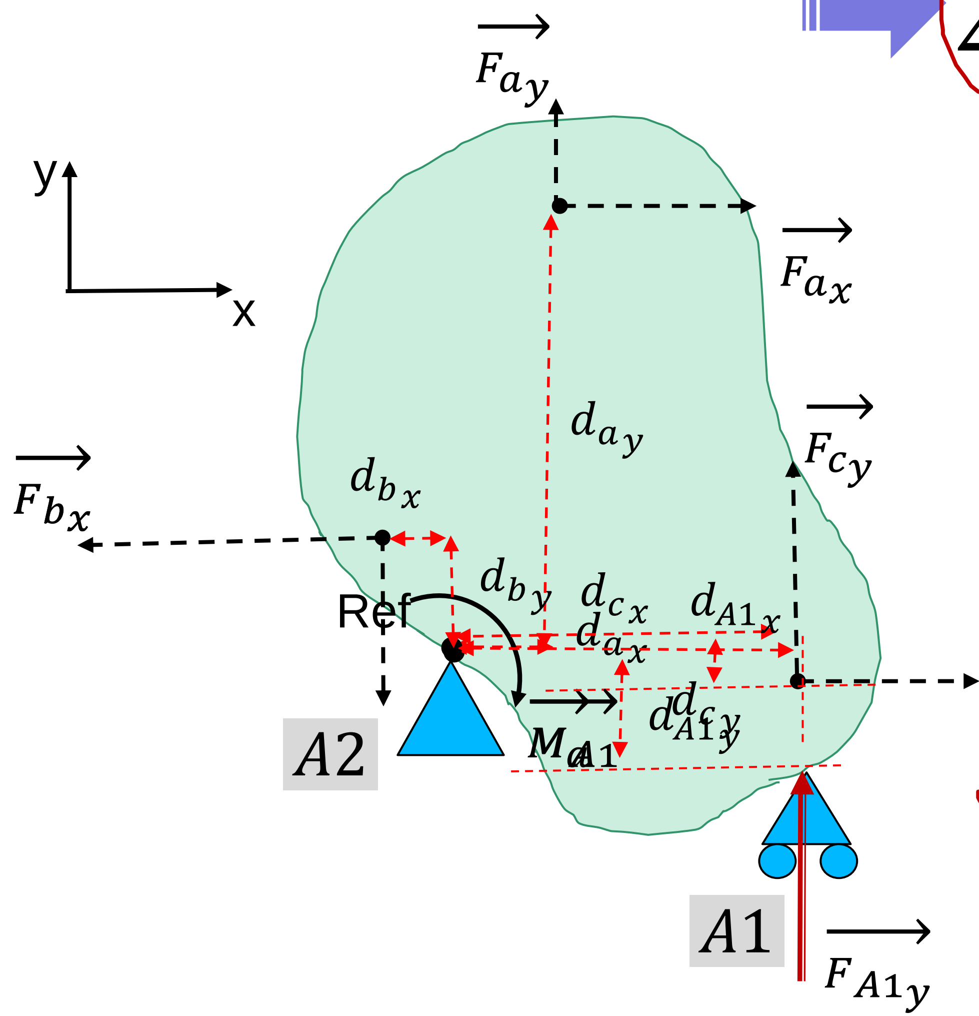


$$\overrightarrow{M_c} = \overrightarrow{-F_{c_x}} * d_{c_y} + \overrightarrow{F_{c_y}} * d_{c_x}$$

$$\overrightarrow{M_{A1}} = \overrightarrow{F_{A1_y}} * d_{A1_x}$$

Apoios e reações no equilíbrio

$$\sum_{Ref} \overrightarrow{M_n} = 0 \quad +$$



$$\overrightarrow{M_a} = \overrightarrow{F_{a_x}} * d_{a_y} - \overrightarrow{F_{a_y}} * d_{a_x}$$

$$\overrightarrow{M_b} = -\overrightarrow{F_{b_x}} * d_{a_y} - \overrightarrow{F_{b_y}} * d_{a_x}$$

$$\overrightarrow{M_c} = \overrightarrow{-F_{c_x}} * d_{c_y} + \overrightarrow{F_{c_y}} * d_{c_x}$$

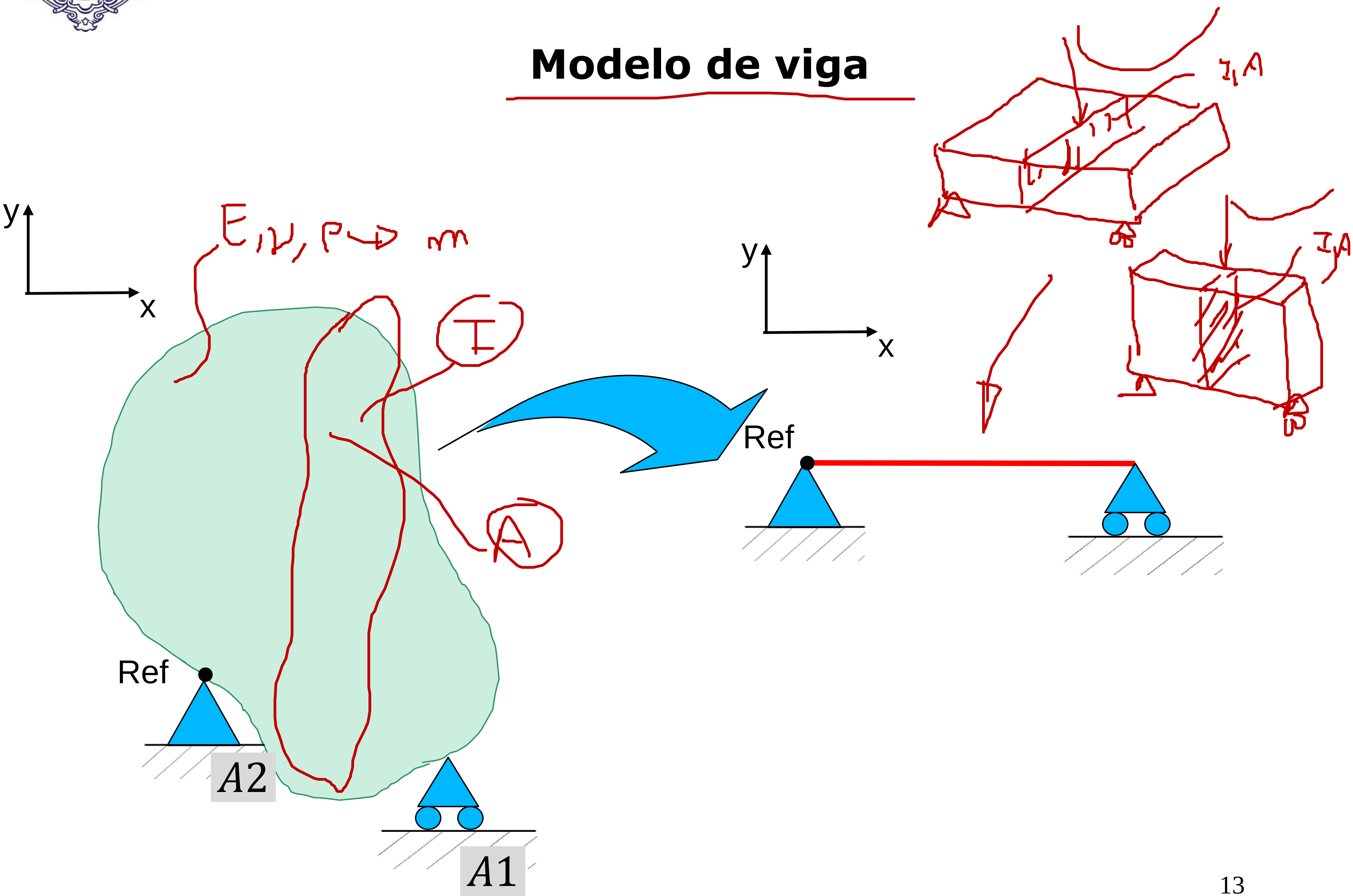
$$\overrightarrow{M_{A1}} = \overrightarrow{F_{A1_y}} * d_{A1_x}$$

Eq 3

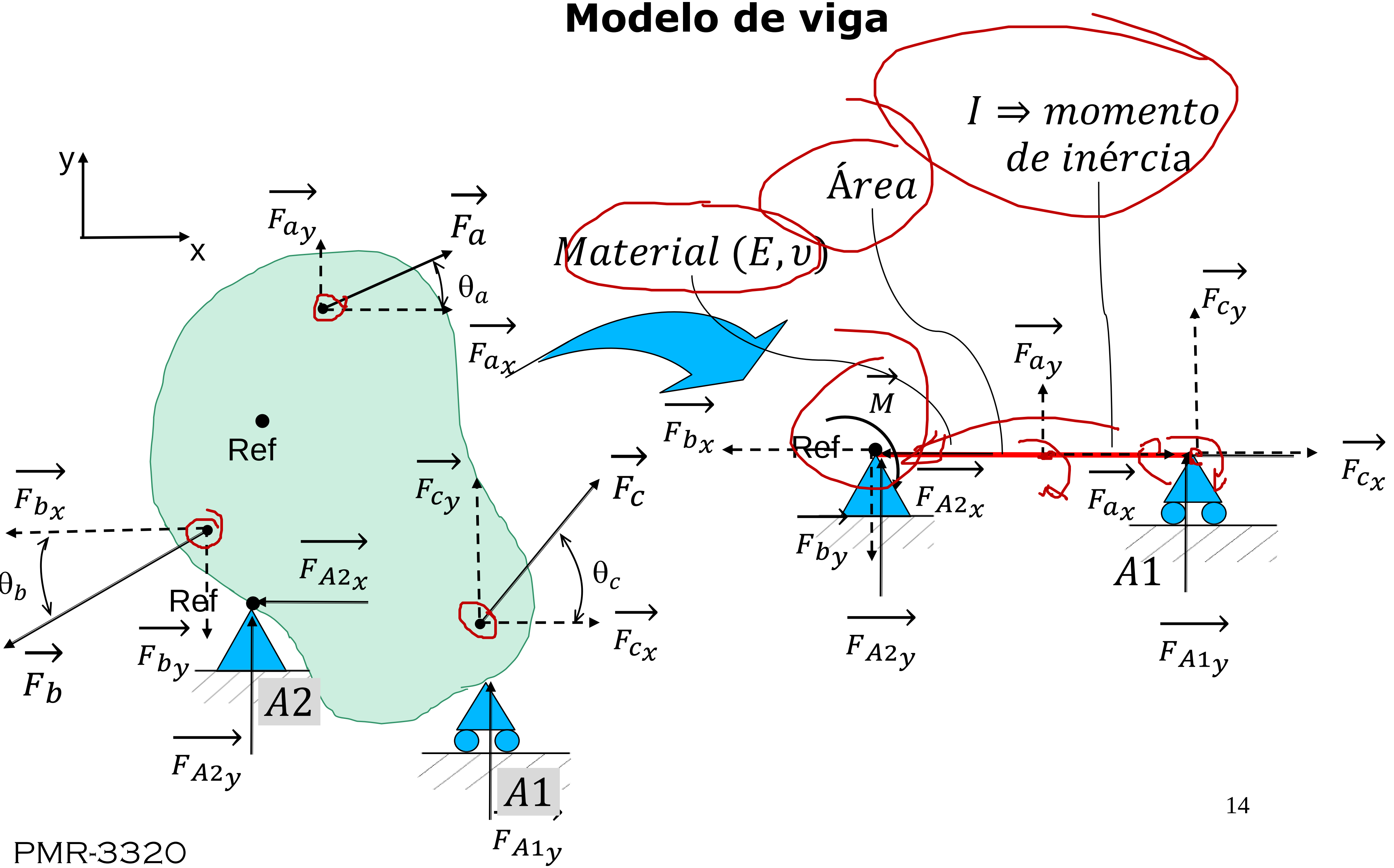
$$\overrightarrow{F_{a_x}} * d_{a_y} - \overrightarrow{F_{a_y}} * d_{a_x} - \overrightarrow{F_{b_x}} * d_{a_y} - \overrightarrow{F_{b_y}} * d_{a_x} \overrightarrow{-F_{c_x}} * d_{c_y} + \overrightarrow{F_{c_y}} * d_{c_x} + \overrightarrow{F_{A1_y}} * d_{A1_x} = 0$$

Eq1, Eq2, Eq3 → RA1, RA2 ⇒

Modelo de viga

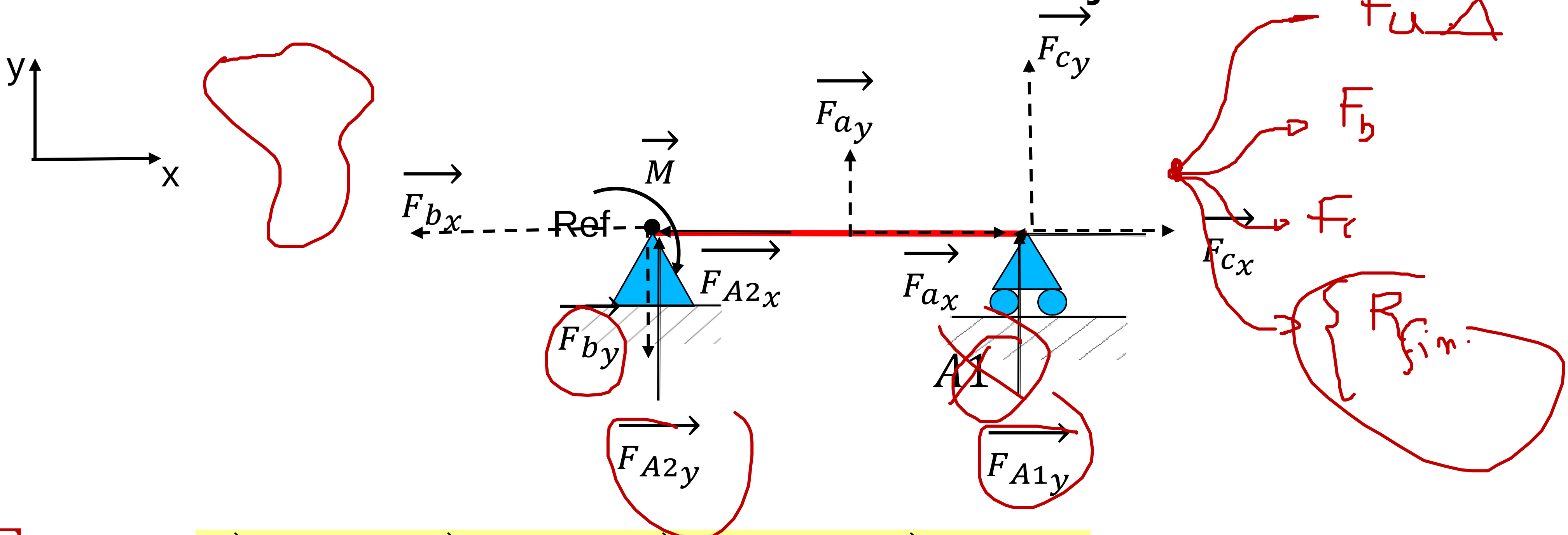


Modelo de viga



Método das seções

1º. Passo - Cálculo das reações



$$\sum \overrightarrow{\boldsymbol{F_{ref}}}_{\boldsymbol{x}} = \mathbf{0} \quad \overrightarrow{F_a}.\cos\theta_a + \overrightarrow{F_c}.\cos\theta_c - \overrightarrow{F_b}.\cos\theta_b + \overrightarrow{F_{A2_x}} = 0$$

$$\sum \overrightarrow{\boldsymbol{F_{ref}}}_{\boldsymbol{y}} = \mathbf{0} \quad \overrightarrow{F_a}.\sin\theta_a + \overrightarrow{F_c}.\sin\theta_c - \overrightarrow{F_b}.\sin\theta_b + \overrightarrow{F_{A2_y}} + \overrightarrow{F_{A1_y}} = 0$$

$$\sum_{\boldsymbol{Ref}} \overrightarrow{\boldsymbol{M_n}} = \mathbf{0} \quad \overrightarrow{F_{a_x}} * d_{a_y} - \overrightarrow{F_{a_y}} * d_{a_x} - \overrightarrow{F_{b_x}} * d_{a_y} - \overrightarrow{F_{b_y}} * d_{a_x} - \overrightarrow{F_{c_x}} * d_{c_y} + \overrightarrow{F_{c_y}} * d_{c_x} + \overrightarrow{F_{A1_y}} * d_{A1_x} = 0$$

$$\overrightarrow{F_a}.\cos\theta_a * d_{a_y} - \overrightarrow{F_a}.\sin\theta_a * d_{a_x} - \cdots + \overrightarrow{F_{A1_y}} * d_{A1_x} = 0$$

Modelo de viga

$$\sum \overrightarrow{F_{ref}}_x = \mathbf{0} \quad \overrightarrow{F_a}.\cos\theta_a + \overrightarrow{F_c}.\cos\theta_c - \overrightarrow{F_b}.\cos\theta_b + \overrightarrow{F_{A2_x}} = 0$$

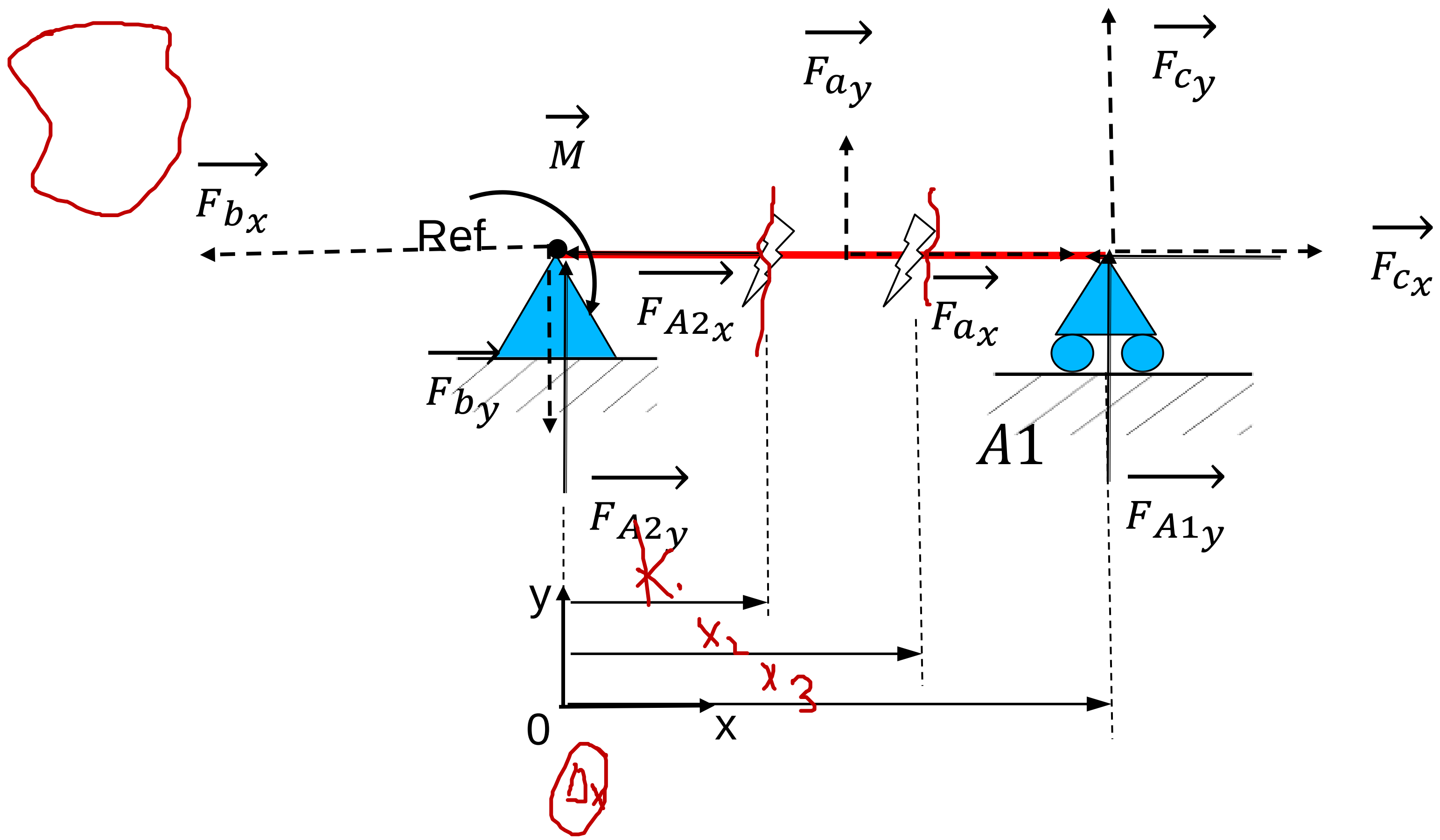
$$\sum \overrightarrow{F_{ref}}_y = \mathbf{0} \quad \overrightarrow{F_a}.\sin\theta_a + \overrightarrow{F_c}.\sin\theta_c - \overrightarrow{F_b}.\sin\theta_b + \overrightarrow{F_{A2_y}} + \overrightarrow{F_{A1_y}} = 0$$

$$\sum_{Ref} \overrightarrow{M_n} = \mathbf{0} \quad \overrightarrow{F_{a_x}} * d_{a_y} - \overrightarrow{F_{a_y}} * d_{a_x} - \overrightarrow{F_{b_x}} * d_{a_y} - \overrightarrow{F_{b_y}} * d_{a_x} - \overrightarrow{F_{c_x}} * d_{c_y} + \overrightarrow{F_{c_y}} * d_{c_x} + \overrightarrow{F_{A1_y}} * d_{A1_x} = 0$$

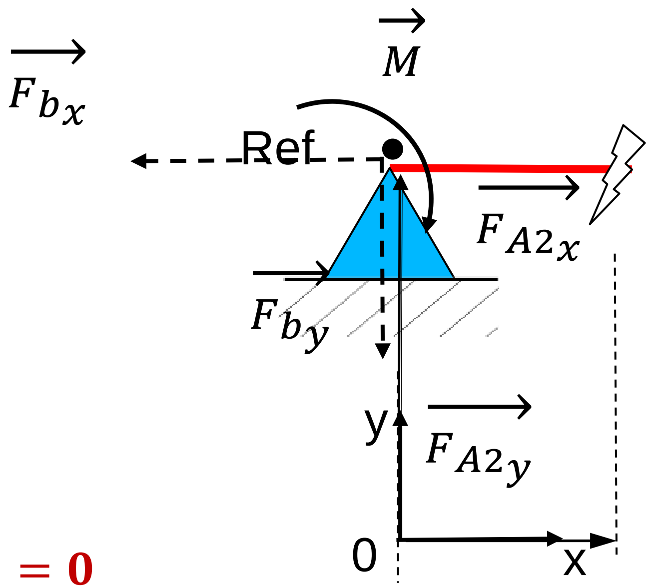
$$\overrightarrow{F_a}.\cos\theta_a * d_{a_y} - \overrightarrow{F_a}.\sin\theta_a * d_{a_x} - \cdots + \overrightarrow{F_{A1_y}} * d_{A1_x} = 0$$

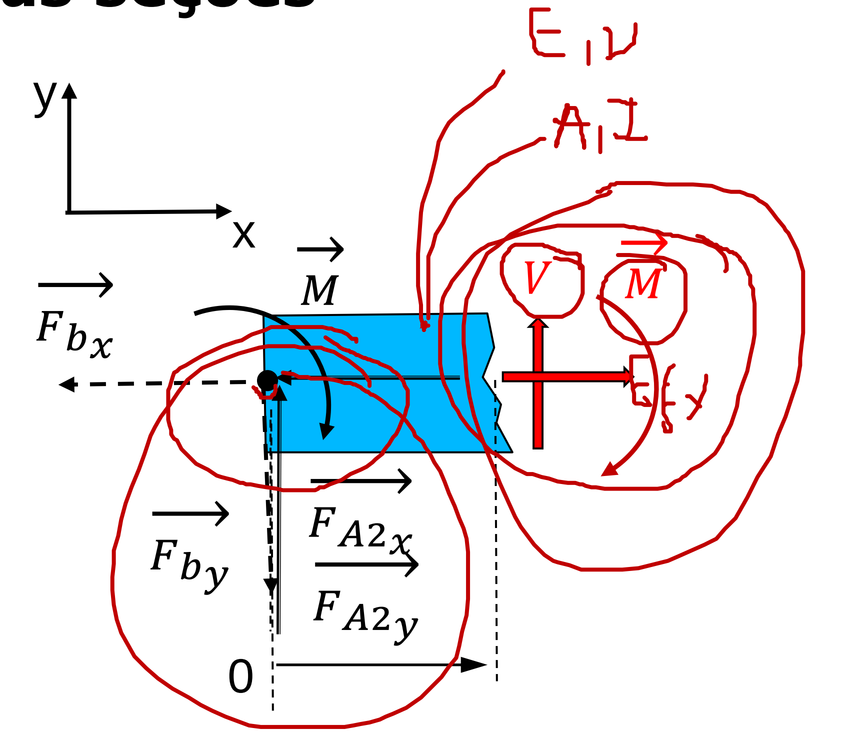
$$\boldsymbol{F_{A1_y}}, \boldsymbol{F_{A2_y}}, \boldsymbol{F_{A2_x}}$$

Método das seções

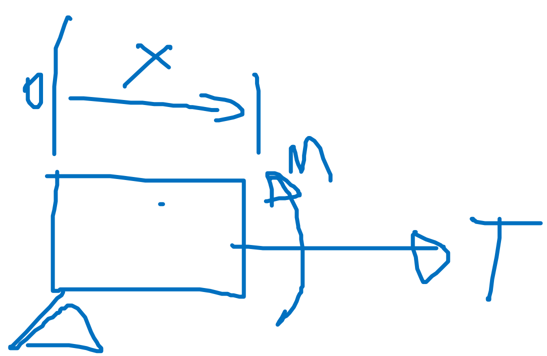


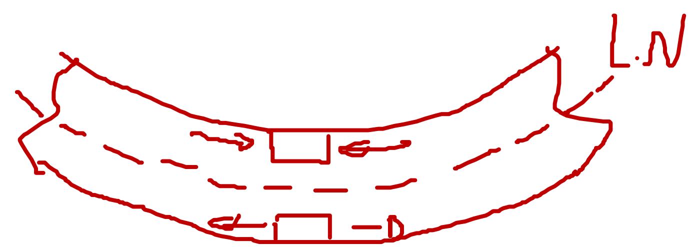
Método das seções



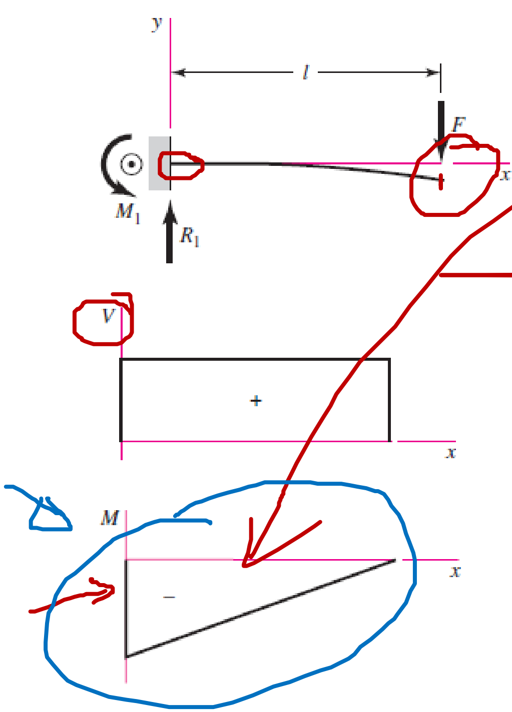


$$
\left\{
\begin{array}{l}
\sum \overrightarrow{F_{ref_x}} = 0 \\
\sum \overrightarrow{F_{ref_y}} = 0 \\
\sum_{Ref} \overrightarrow{M_n} = 0
\end{array}
\right.
$$





1 Cantilever—end load



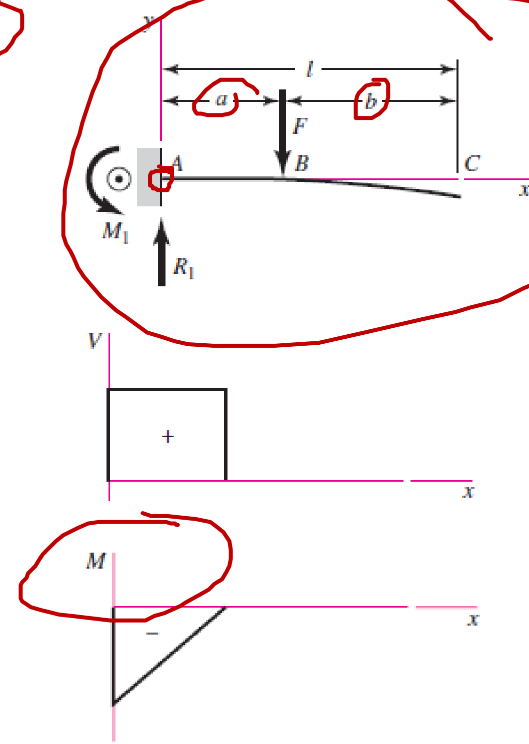
$$R_1 = V = F \qquad M_1 = Fl$$

$$M = F(x - l)$$

$$y = \frac{Fx^2}{6EI}(x - 3l)$$

$$y_{max} = -\frac{Fl^3}{3EI}$$

2 Cantilever—intermediate load



$$R_1 = V = F \qquad M_1 = Fa$$

$$M_{AB} = F(x - a) \qquad M_{BC} = 0$$

$$y_{AB} = \frac{Fx^2}{6EI}(x - 3a)$$

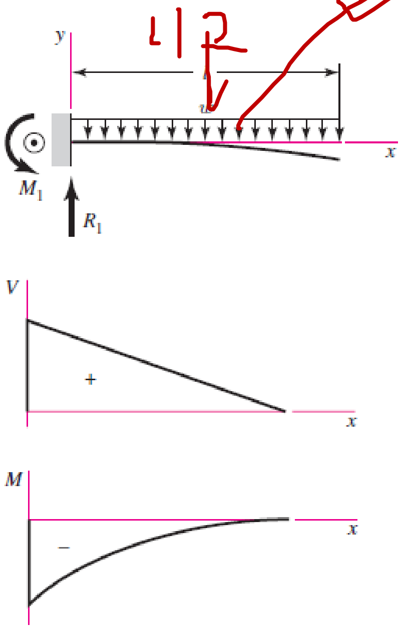
$$y_{BC} = \frac{Fa^2}{6EI}(a - 3x)$$

$$y_{max} = \frac{Fa^2}{6EI}(a - 3l)$$

Shigley's Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

F ~ A

3 Cantilever—uniform load



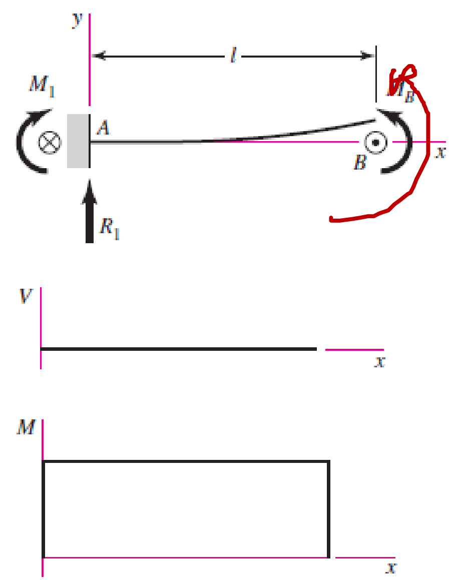
$$R_1 = wl \qquad M_1 = \frac{wl^2}{2}$$

$$V = w(l - x) \qquad M = -\frac{w}{2}(l - x)^2$$

$$y = \frac{wx^2}{24EI}(4lx - x^2 - 6l^2)$$

$$y_{max} = -\frac{wl^4}{8EI}$$

4 Cantilever—moment load

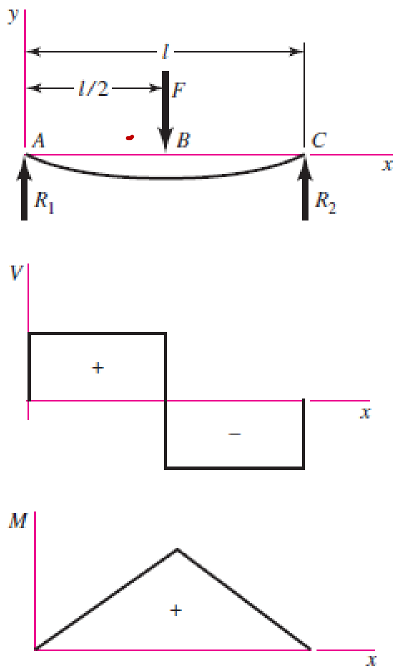


$$R_1 = V = 0 \qquad M_1 = M = M_B$$

$$y = \frac{M_B x^2}{2EI} \qquad y_{max} = \frac{M_B l^2}{2EI}$$

Shigley's Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

5 Simple supports—center load



$$R_1 = R_2 = \frac{F}{2}$$

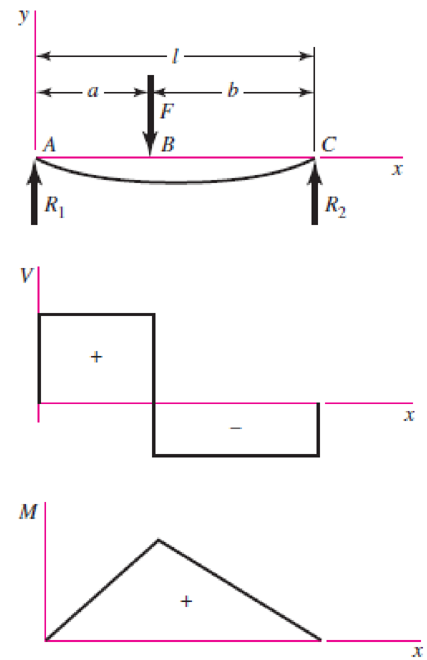
$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

$$M_{AB} = \frac{Fx}{2} \qquad M_{BC} = \frac{F}{2}(l - x)$$

$$y_{AB} = \frac{Fx}{48EI}(4x^2 - 3l^2)$$

$$y_{max} = -\frac{Fl^3}{48EI}$$

6 Simple supports—intermediate load



$$R_1 = \frac{Fb}{l} \qquad R_2 = \frac{Fa}{l}$$

$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

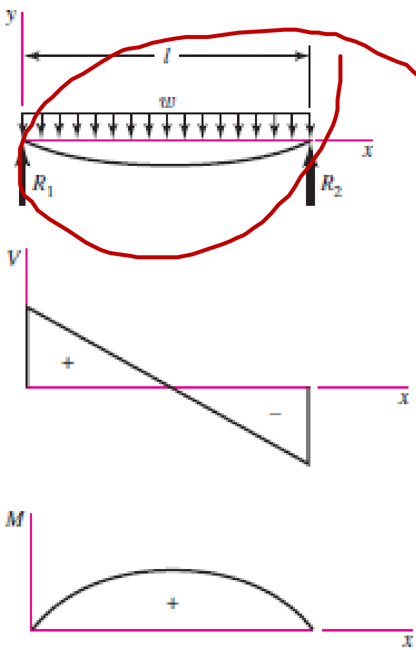
$$M_{AB} = \frac{Fbx}{l} \qquad M_{BC} = \frac{Fa}{l}(l - x)$$

$$y_{AB} = \frac{Fbx}{6EIl}(x^2 + b^2 - l^2)$$

$$y_{BC} = \frac{Fa(l - x)}{6EIl}(x^2 + a^2 - 2lx)$$

Shigley's Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

7 Simple supports—uniform load



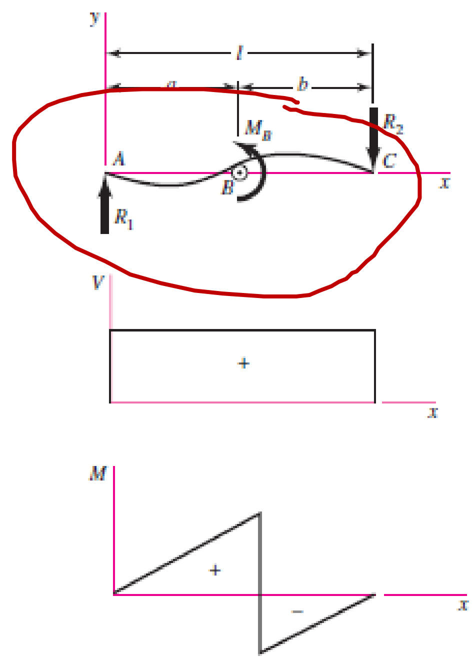
$$R_1 = R_2 = \frac{wl}{2} \qquad V = \frac{wl}{2} - wx$$

$$M = \frac{wx}{2}(l - x)$$

$$y = \frac{wx}{24EI}(2lx^2 - x^3 - l^3)$$

$$y_{max} = -\frac{5wl^4}{384EI}$$

8 Simple supports—moment load



$$R_1 = R_2 = \frac{M_B}{l} \qquad V = \frac{M_B}{l}$$

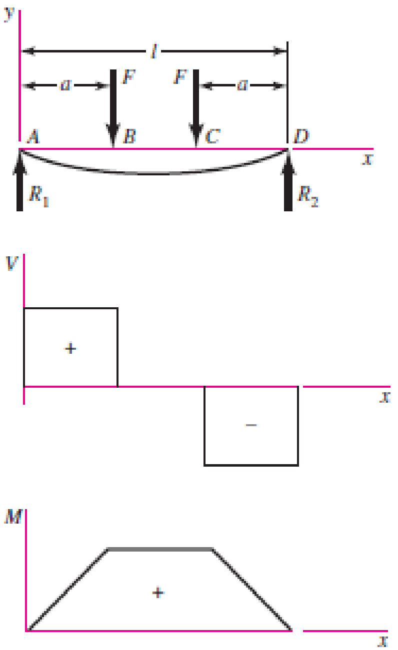
$$M_{AB} = \frac{M_B x}{l} \qquad M_{BC} = \frac{M_B}{l}(x - l)$$

$$y_{AB} = \frac{M_B x}{6EIl}(x^2 + 3a^2 - 6al + 2l^2)$$

$$y_{BC} = \frac{M_B}{6EIl}[x^3 - 3lx^2 + x(2l^2 + 3a^2) - 3a^2 l]$$

Shigley's Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

9 Simple supports—twin loads



$$R_1 = R_2 = F \qquad V_{AB} = F \qquad V_{BC} = 0$$

$$V_{CD} = -F$$

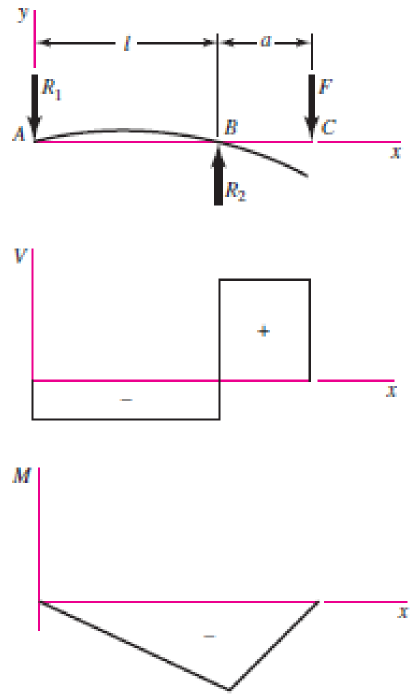
$$M_{AB} = Fx \qquad M_{BC} = Fa \qquad M_{CD} = F(l - x)$$

$$y_{AB} = \frac{Fx}{6EI}(x^2 + 3a^2 - 3la)$$

$$y_{BC} = \frac{Fa}{6EI}(3x^2 + a^2 - 3lx)$$

$$y_{max} = \frac{Fa}{24EI}(4a^2 - 3l^2)$$

10 Simple supports—overhanging load



$$R_1 = \frac{Fa}{l} \qquad R_2 = \frac{F}{l}(l + a)$$

$$V_{AB} = -\frac{Fa}{l} \qquad V_{BC} = F$$

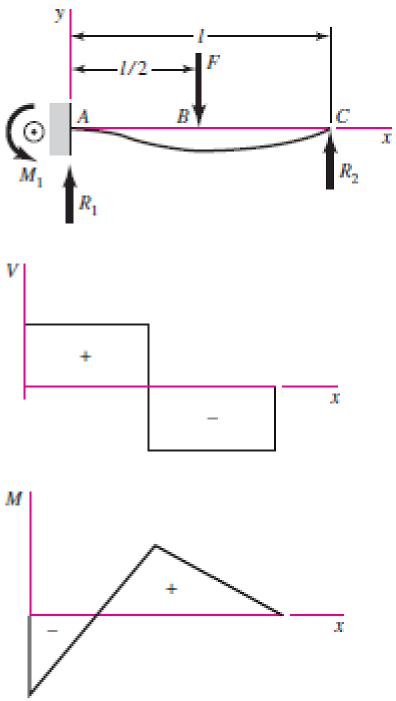
$$M_{AB} = -\frac{Fax}{l} \qquad M_{BC} = F(x - l - a)$$

$$y_{AB} = \frac{Fax}{6EIl}(l^2 - x^2)$$

$$y_{BC} = \frac{F(x - l)}{6EI}[(x - l)^2 - a(3x - l)]$$

$$y_c = -\frac{Fa^2}{3EI}(l + a)$$

11 One fixed and one simple support—center load



$$R_1 = \frac{11F}{16} \qquad R_2 = \frac{5F}{16} \qquad M_1 = \frac{3Fl}{16}$$

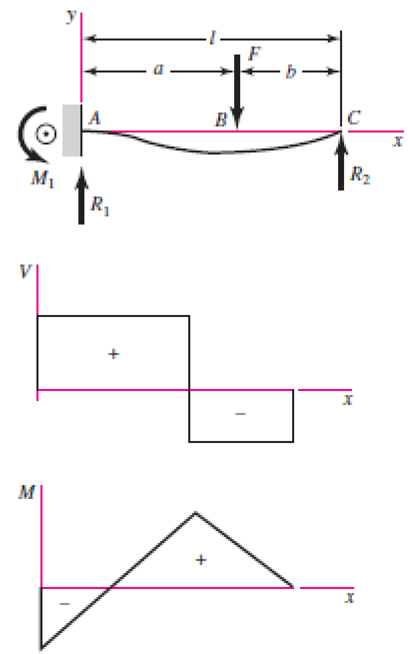
$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

$$M_{AB} = \frac{F}{16}(11x - 3l) \qquad M_{BC} = \frac{5F}{16}(l - x)$$

$$y_{AB} = \frac{Fx^2}{96EI}(11x - 9l)$$

$$y_{BC} = \frac{F(l-x)}{96EI}(5x^2 + 2l^2 - 10lx)$$

12 One fixed and one simple support—intermediate load



$$R_1 = \frac{Fb}{2l^3}(3l^2 - b^2) \qquad R_2 = \frac{Fa^2}{2l^3}(3l - a)$$

$$M_1 = \frac{Fb}{2l^2}(l^2 - b^2)$$

$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

$$M_{AB} = \frac{Fb}{2l^3}[b^2 l - l^3 + x(3l^2 - b^2)]$$

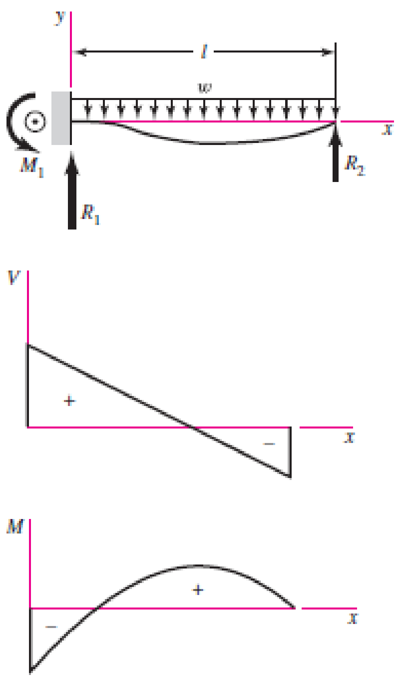
$$M_{BC} = \frac{Fa^2}{2l^3}(3l^2 - 3lx - al + ax)$$

$$y_{AB} = \frac{Fbx^2}{12EIl^3}[3l(b^2 - l^2) + x(3l^2 - b^2)]$$

$$y_{BC} = y_{AB} - \frac{F(x-a)^3}{6EI}$$

Shigley's Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

13 One fixed and one simple support—uniform load



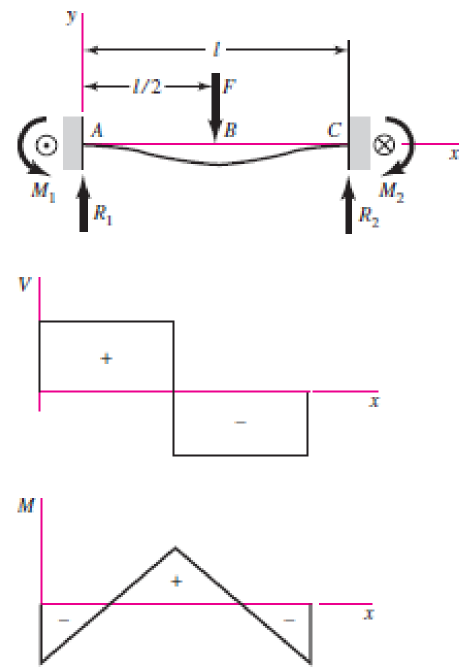
$$R_1 = \frac{5wl}{8} \qquad R_2 = \frac{3wl}{8} \qquad M_1 = \frac{wl^2}{8}$$

$$V = \frac{5wl}{8} - wx$$

$$M = -\frac{w}{8}(4x^2 - 5lx + l^2)$$

$$y = \frac{wx^2}{48EI}(l - x)(2x - 3l)$$

14 Fixed supports—center load



$$R_1 = R_2 = \frac{F}{2} \qquad M_1 = M_2 = \frac{Fl}{8}$$

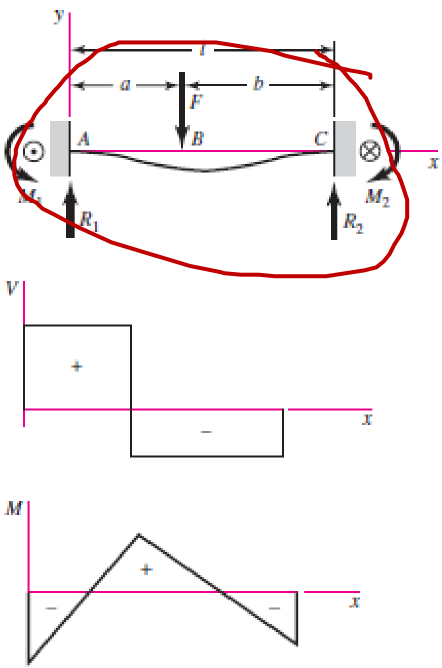
$$V_{AB} = -V_{BC} = \frac{F}{2}$$

$$M_{AB} = \frac{F}{8}(4x - l) \qquad M_{BC} = \frac{F}{8}(3l - 4x)$$

$$y_{AB} = \frac{Fx^2}{48EI}(4x - 3l)$$

$$y_{\max} = -\frac{Fl^3}{192EI}$$

15 Fixed supports—intermediate load



$$R_1 = \frac{Fb^2}{l^3}(3a+b) \qquad R_2 = \frac{Fa^2}{l^3}(3b+a)$$

$$M_1 = \frac{Fab^2}{l^2} \qquad M_2 = \frac{Fa^2b}{l^2}$$

$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

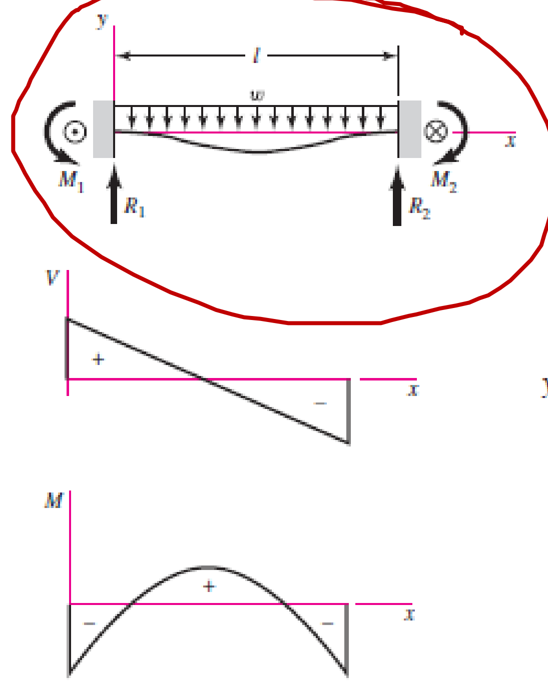
$$M_{AB} = \frac{Fb^2}{l^3}[x(3a+b) - al]$$

$$M_{BC} = M_{AB} - F(x-a)$$

$$y_{AB} = \frac{Fb^2x^2}{6EIl^3}[x(3a+b) - 3al]$$

$$y_{BC} = \frac{Fa^2(l-x)^2}{6EIl^3}[(l-x)(3b+a) - 3bl]$$

16 Fixed supports—uniform load



$$R_1 = R_2 = \frac{wl}{2} \qquad M_1 = M_2 = \frac{wl^2}{12}$$

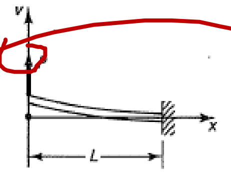
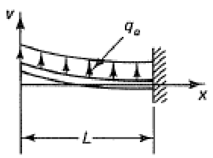
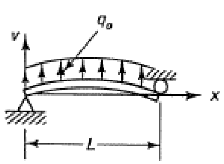
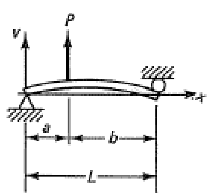
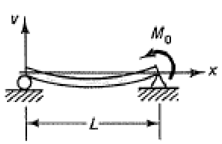
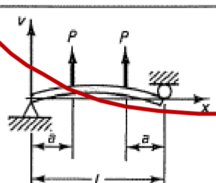
$$V = \frac{w}{2}(l - 2x)$$

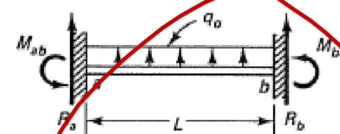
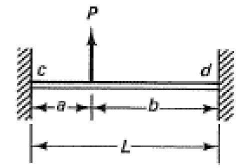
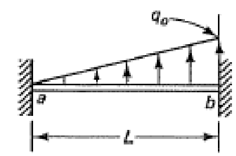
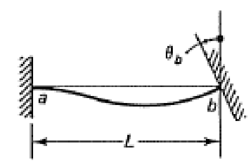
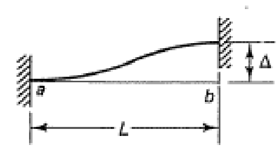
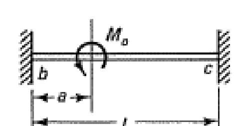
$$M = \frac{w}{12}(6lx - 6x^2 - l^2)$$

$$y = -\frac{wx^2}{24EI}(l-x)^2$$

$$y_{max} = -\frac{wl^4}{384EI}$$

Shigley’s Mechanical Engineering Design, McGraw–Hill, Eighth Edition, 2006

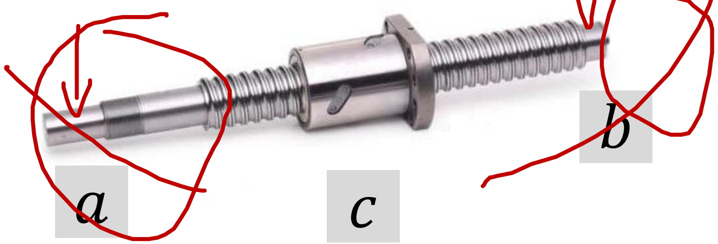
	$v = \frac{P}{6EI}(2L^3 - 3L^2x + x^3)$ $v_{max} = v(0) = -\frac{PL^3}{3EI}$	$\theta(0) = -\frac{PL^2}{2EI}$
	$v = \frac{q_o}{24EI}(x^4 - 4L^3x + 3L^4)$ $v_{max} = v(0) = \frac{q_oL^4}{8EI}$	$\theta(0) = -\frac{q_oL^3}{6EI}$
	$v = \frac{q_o x}{24EI}(L^3 - 2Lx^2 + x^3)$ $v_{max} = v(L/2) = \frac{5q_oL^4}{384EI}$	See Example 10-3. $\theta(0) = -\theta(L) = \frac{q_oL^3}{24EI}$
	When $0 \le x \le a$, then $v = \frac{Pbx}{6EIL}(L^2 - b^2 - x^2)$ When $a = b = \frac{L}{2}$, then $v = \frac{Px}{48EI}(3L^2 - 4x^2)$ $v_{max} = v(L/2) = \frac{PL^3}{48EI}$	See Example 10-6. $\left(0 \le x \le \frac{L}{2}\right)$ $\theta(0) = -\theta(L) = \frac{PL^2}{16EI}$
	$v = -\frac{M_o x}{6EIL}(L^2 - x^2)$ $v_{max} = v(L/\sqrt{3}) = -\frac{M_oL^2}{9\sqrt{3}\,EI}$	See Example 13-1. $\theta(0) = -\frac{\theta(L)}{2} = -\frac{M_oL}{6EI}$
	$v_a = v(a) = \frac{Pa^2}{6EI}(3L - 4a)$ $v_{max} = v(L/2) = \frac{Pa}{24EI}(3L^2 - 4a^2)$	$\theta(0) = \frac{Pa}{2EI}(L - a)$

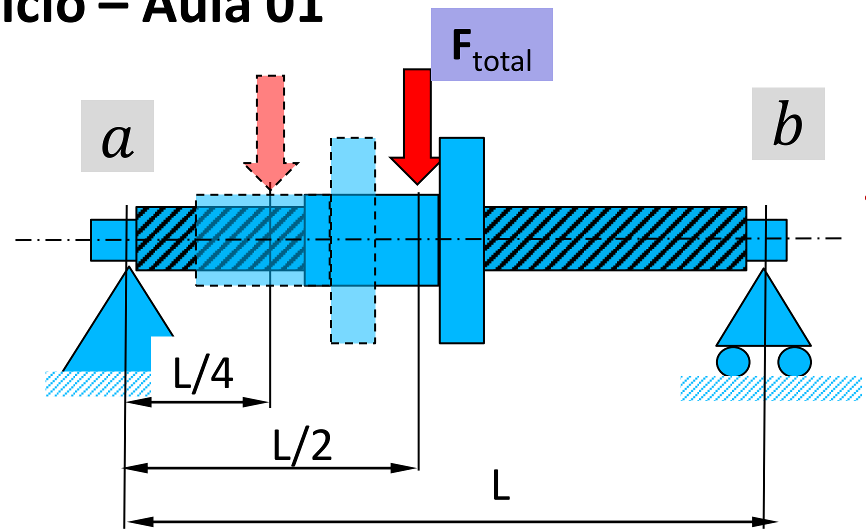
	$M_{ab} = -M_{ba} = -\frac{q_oL^2}{12}$	$R_a = R_b = -\frac{q_oL}{2}$
	$M_{cd} = -\frac{Pab^2}{L^2}$ $M_{dc} = \frac{Pba^2}{L^2}$	$R_c = -\frac{Pb^2}{L^3}(3a + b)$ $R_d = -\frac{Pa^2}{L^3}(a + 3b)$
	$M_{ab} = -\frac{q_oL^2}{30}$ $M_{ba} = \frac{q_oL^2}{20}$	$R_a = -\frac{3q_oL}{20}$ $R_b = -\frac{7q_oL}{20}$
	$M_{ab} = \frac{2EI}{L}\theta_b$ $M_{ba} = \frac{4EI}{L}\theta_b$	$R_a = \frac{6EI}{L^2}\theta_b$ $R_b = -\frac{6EI}{L^2}\theta_b$
	$M_{ab} = -\frac{6EI}{L^2}\Delta$ $M_{ba} = -\frac{6EI}{L^2}\Delta$	$R_a = -\frac{12EI}{L^3}\Delta$ $R_b = \frac{12EI}{L^3}\Delta$
	$M_{bc} = M_o\left(-1 + 4\frac{a}{L} - \frac{3a^2}{L^2}\right)$ $M_{cb} = \frac{M_oa}{L}\left(2 - 3\frac{a}{L}\right)$	$R_b = \frac{6M_oa}{L^2}\left(1 - \frac{a}{L}\right)$ $R_c = -\frac{6M_oa}{L^2}\left(1 - \frac{a}{L}\right)$

Popov, E. P. Introdução a mecânica dos sólidos, Edgard Bluecher, 13° reimpressão, 2016

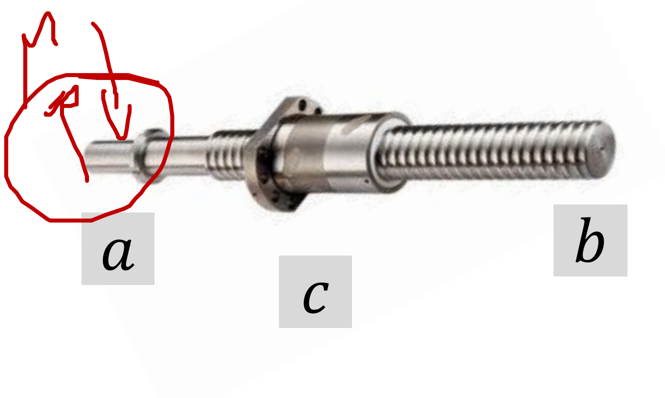
Exercício – Aula 01

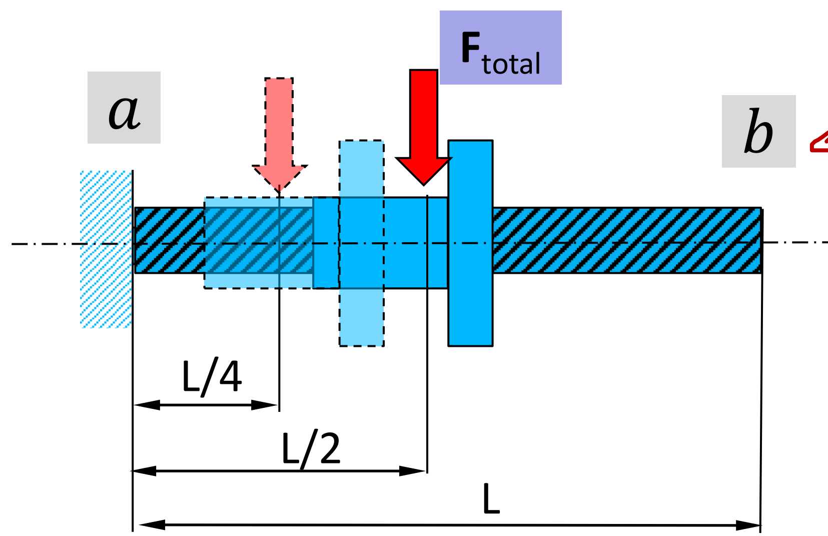
Fuso bi –apoiado,





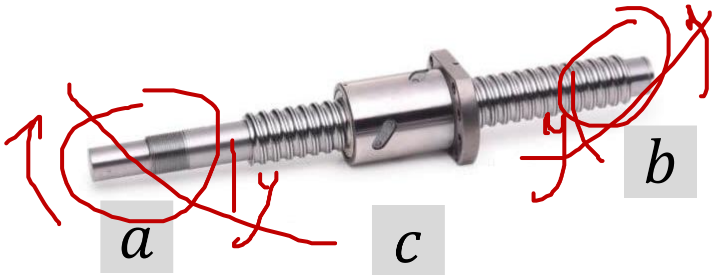
Fuso em balanço

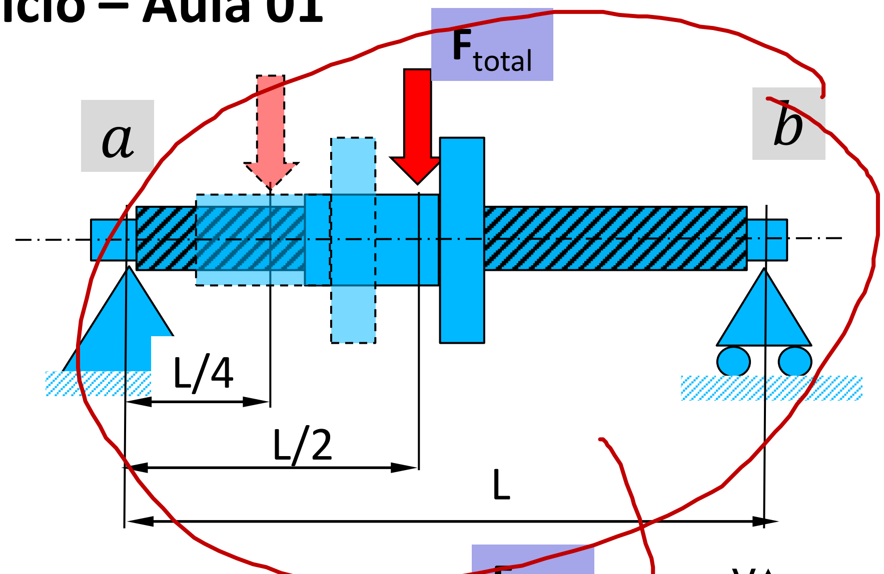




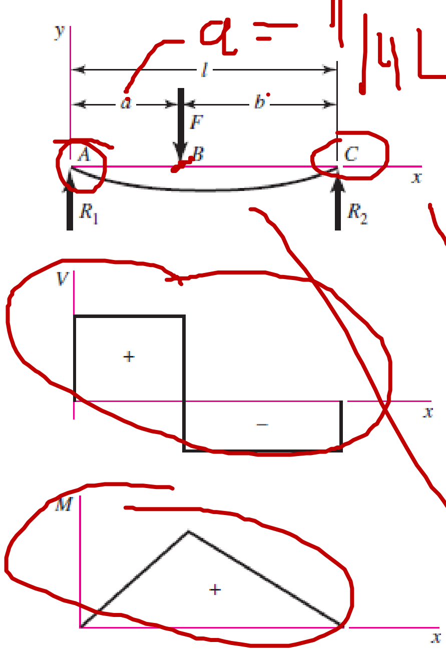
Exercício – Aula 01

Fuso bi –apoiado,





6 Simple supports—intermediate load



$a = 1/4L$

$$R_1 = \frac{Fb}{l} \qquad R_2 = \frac{Fa}{l}$$

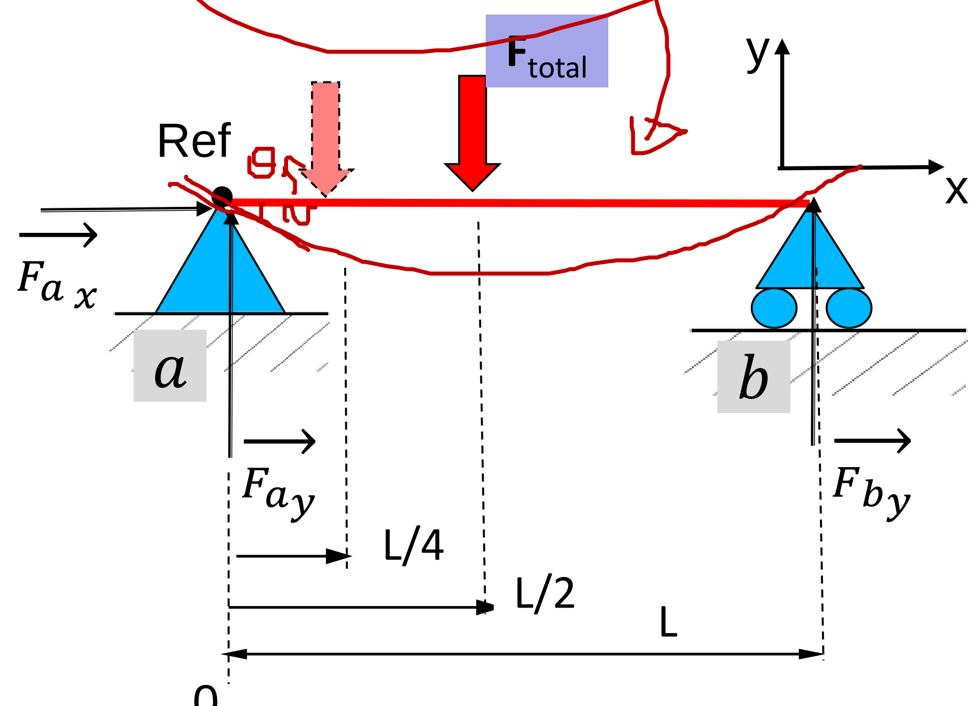
$$V_{AB} = R_1 \qquad V_{BC} = -R_2$$

$$M_{AB} = \frac{Fbx}{l} \qquad M_{BC} = \frac{Fa}{l}(l-x)$$

$$y_{AB} = \frac{Fbx}{6EIl}(x^2 + b^2 - l^2)$$

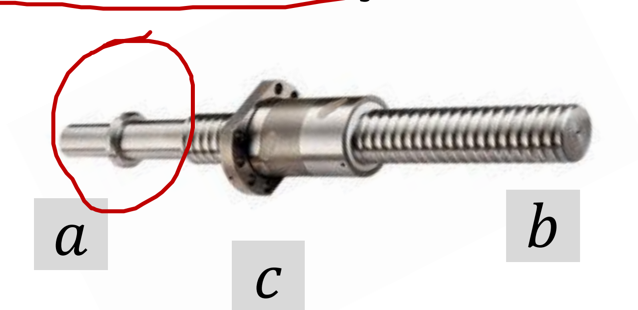
$$y_{BC} = \frac{Fa(l-x)}{6EIl}(x^2 + a^2 - 2lx)$$

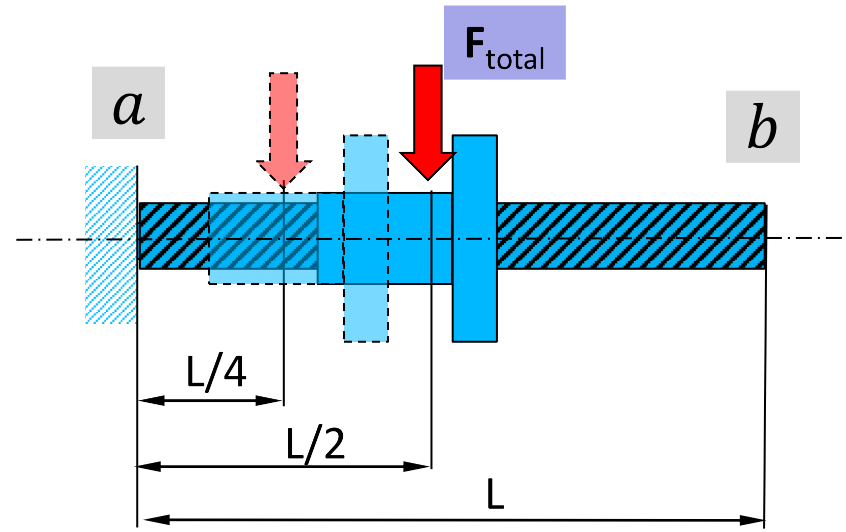
$a = b = 1/2 L$



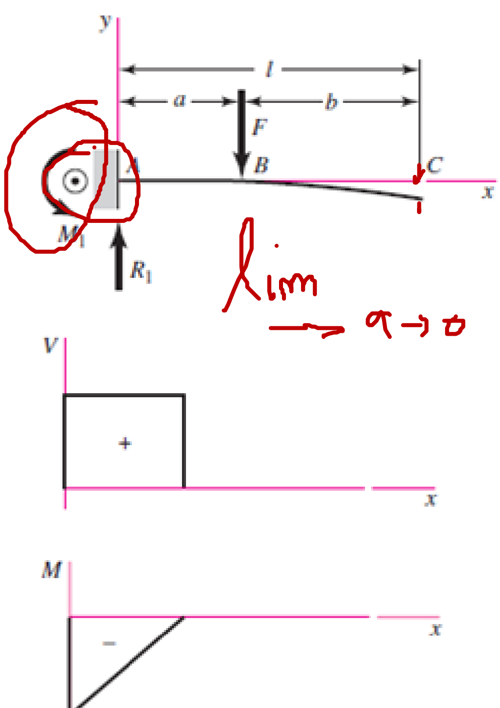
Exercício – Aula 01

Fuso em balanço





2 Cantilever—intermediate load



$$R_1 = V = F \qquad M_1 = Fa$$

$$M_{AB} = F(x-a) \qquad M_{BC} = 0$$

$$y_{AB} = \frac{Fx^2}{6EI}(x-3a)$$

$$y_{BC} = \frac{Fa^2}{6EI}(a-3x)$$

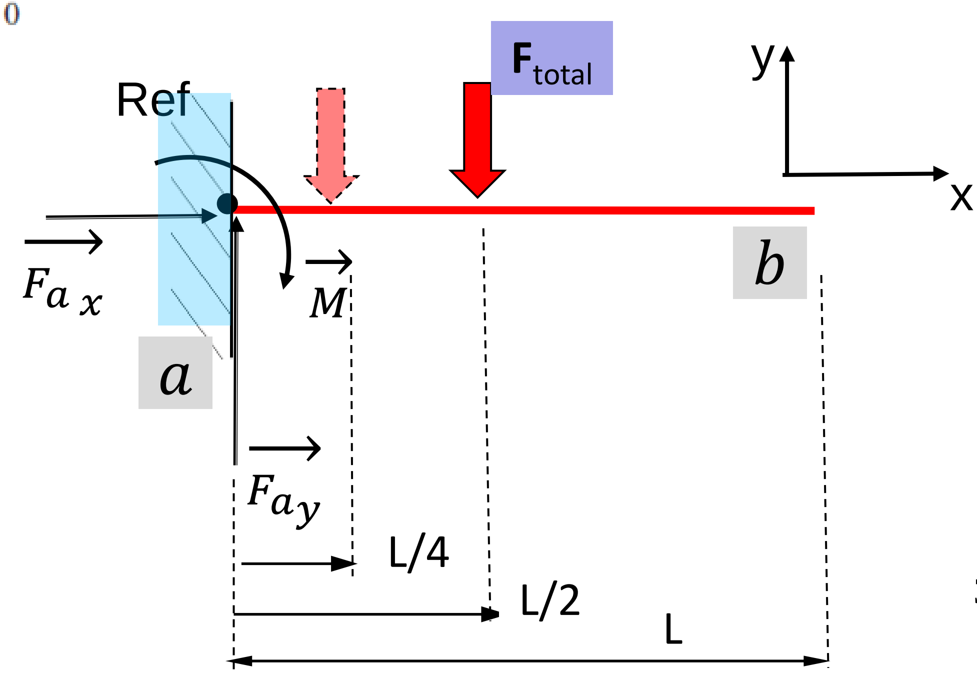
$$y_{max} = \frac{Fa^2}{6EI}(a-3l)$$

lim

→ a → 0

a = 1/4 L

a = 1/2 L



FIM DA AULA