TD1

Exo 1 : $s \equiv x$; $\vec{t} = \vec{x}$; $\vec{n} = \vec{y}$; $\vec{b} = \vec{z}$ (pb plan)

1/ PFS

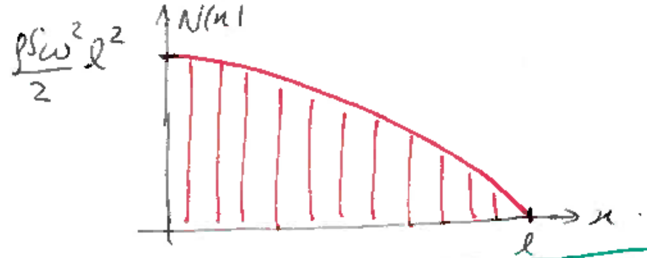
• $\frac{d\vec{R}(x)}{dx} + \vec{f} = \vec{0} \Rightarrow \frac{d\vec{R}(x)}{dx} = -\vec{f} = -\rho S \omega^2 x \vec{x} \Rightarrow \vec{R}(x) = -\rho S\omega^2 \frac{x^2}{2}\vec{x} + \vec{C}$

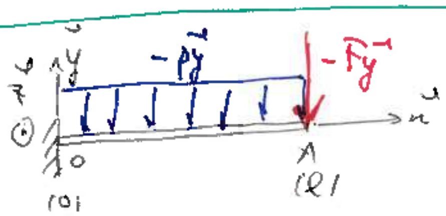
or $\vec{R}(\ell) = \vec{0} \Rightarrow \vec{C} = \rho S \omega^2 \frac{\ell^2}{2}$ soit $\vec{R}(x) = -\frac{\rho S\omega^2}{2}(x^2 - \ell^2)\vec{x} = N(x)\vec{x} + T_y(x)\vec{y}$

$$\boxed{N(x) = -\frac{\rho S\omega^2}{2}(x^2 - \ell^2)} \quad \text{et} \quad \boxed{T_y(x) = 0}$$

• $\frac{d\vec{M}(x)}{dx} + \underbrace{\vec{t}}_{\vec{x}} \wedge \vec{R}(x) + \underbrace{\vec{m}(x)}_{\vec{0}} = \vec{0} \Rightarrow \frac{d}{dx}[M_z(x)\vec{z}] + T_y(x)\vec{z} = \vec{0}$

soit $\frac{dM_z(x)}{dx} = -T_y(x) = 0 \Rightarrow M_z(x) = k = M_z(\ell) = 0 \Rightarrow \boxed{M_z(x) = 0}$





Exo 2 :

1/ Éq^ons d'équilibre locales : $s \equiv x$; $\vec{t} = \vec{x}$; $\vec{n} = \vec{y}$

$$\begin{cases} \bullet\ \frac{d\vec{R}(x)}{dx} + \underbrace{\vec{f}(x)}_{-p\vec{y}} = \vec{0} & (1) \\ \bullet\ \frac{d\vec{M}(x)}{dx} + \vec{x} \wedge \vec{R}(x) + \underbrace{\vec{m}(x)}_{\vec{0}} = \vec{0} \Rightarrow \frac{dM_z(x)}{dx} + T_y(x) = 0. & (2) \end{cases}$$

+ Condit^ons aux extrémités $\begin{cases} \vec{R}(\ell) = -F\vec{y} \\ \vec{M}(\ell) = \vec{0} \end{cases}$ libre effort et $\begin{cases} \vec{R}(0) = -\vec{R_0} \\ \vec{M}(0) = -\vec{M_0} \end{cases}$ efforts liaison dûs encastrem^t

2/ a/ Méthode d'intégrat^o des éq^ons d'équilibre locales :

(1) $\Rightarrow$ • $\frac{d\vec{R}(x)}{dx} = -\vec{f}(x) = +p\vec{y} \Rightarrow \vec{R}(x) = +px\vec{y} + \vec{C}$

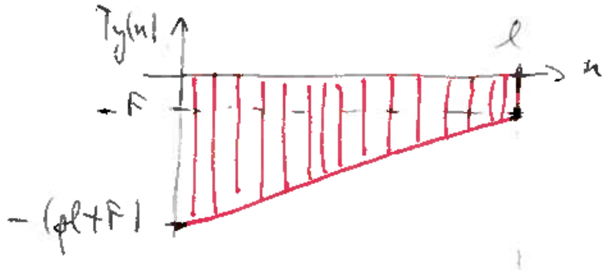
or $\vec{R}(\ell) = -F\vec{y} = +p\ell\vec{y} + \vec{C} \rightarrow \vec{C} = -(p\ell + F)\vec{y}$

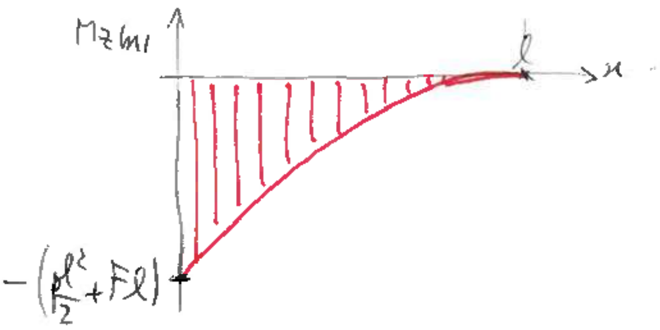
$\vec{R}(x) = +[p(x-\ell) - F]\vec{y} = N(x)\vec{x} + T_y(x)\vec{y} \rightarrow \boxed{\begin{array}{l} N(x) = 0 \\ T_y(x) = +[p(x-\ell) - F] \end{array}}$

(2) $\Rightarrow \frac{dM_z(x)}{dx} = -T_y(x) = -p(x-\ell)+F \Rightarrow M_z(x) = -p\frac{(x-\ell)^2}{2} + F(x-\ell) + k$

or $M_z(\ell) = 0 \Rightarrow k = 0 \Rightarrow \boxed{M_z(x) = -p\frac{(x-\ell)^2}{2} + F(x-\ell)}$

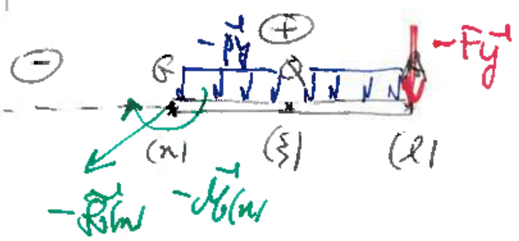
diagramme des efforts de cohésion :





b) Méthode des coupures :

On coupe la poutre [OA] en G d'abscisse x et on applique l'équilibre du tronçon [GA] pour éviter de calculer les efforts de liaison O



ici ⊖ → ⊕ $\Rightarrow -\{\mathcal{T}_{int}\}_F = -\begin{Bmatrix}\vec R(x)\\ \vec M(x)\end{Bmatrix}_G$

Th de la résultante : $-\vec R(x) + \int_x^\ell -p\vec y\, d\xi - F\vec y = \vec 0 \Rightarrow \vec R(x) = -p(\ell-x)\vec y - F\vec y$

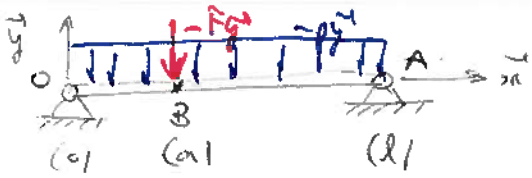
$$\boxed{\vec R(x) = [p(x-\ell)-F]\vec y}$$

Th du m^t en G : $-\vec M(x) + \int_x^\ell \underset{(\xi-x)\vec x}{\underset{\parallel}{\vec{GQ}}} \wedge (-p\vec y)\,d\xi + \underset{(\ell-x)\vec x}{\underset{\parallel}{\vec{GA}}} \wedge (-F\vec y) = \vec 0$

$$\Rightarrow \vec M(x) = \underbrace{\int_x^\ell -p(\xi-x)\,d\xi}_{-p\left[\frac{(\xi-x)^2}{2}\right]_x^\ell = -p\frac{(\ell-x)^2}{2}}\ \vec z + F(x-\ell)\vec z$$

donc $\boxed{\vec M(x) = \left[-\frac{p}{2}(x-\ell)^2 + F(x-\ell)\right]\vec z}$

Exo 3 :



1/ $\begin{cases} \bullet \ \dfrac{d\vec{R}(x)}{dx} + \underset{-p\vec{y}}{\underset{\parallel}{\vec{f}(x)}} = \vec{0} \\ \bullet \ \dfrac{dM_z(x)}{dx} + T_y(x) = 0 \end{cases}$ <u>éq° d'équilibre locales</u>. pour $x \neq a$.

$\begin{cases} [\![\vec{R}]\!](a) - F\vec{y} = \vec{0} \\ [\![\vec{M}_G]\!](a) = \vec{0} \end{cases}$ <u>condit° de saut</u> en $x = a$ car ici force ponctuelle à l'intérieur de $[OA]$ $\Rightarrow$ 2 domaines $\left| \begin{array}{l} ① \equiv [OB] \\ ② \equiv [BA] \end{array} \right.$

$\begin{cases} \vec{R}(l) = R_A\vec{y} \\ \vec{M}_G(l) = \vec{0} \end{cases}$ et $\begin{cases} \vec{R}(0) = -R_0\vec{y} \\ \vec{M}_G(0) = \vec{0} \end{cases}$ $\rightarrow$ <u>condit° aux extrémités</u>

ici pas d'efforts normaux (précision dans l'énoncé...) et condit° d'appuis.

2/ <u>Résolut° via intégrat° des éq° d'équilibre locales</u> :

On a besoin du calcul des efforts de liaison en O et A $\Rightarrow$ équilibre global de $[OA]$.

<u>PFS</u> : $\bullet$ <u>Th de la résultante</u> : $R_0\vec{y} - F\vec{y} + R_A\vec{y} + \int_0^l -p\vec{y}\,dx = \vec{0}$

$\Rightarrow R_0 + R_A = pl + F \quad (*)$

$\bullet$ <u>Th du mt en O</u> : $\underset{a\vec{x}}{\underset{\parallel}{\vec{OB}}} \wedge (-F\vec{y}) + \underset{l\vec{x}}{\underset{\parallel}{\vec{OA}}} \wedge R_A\vec{y} + \int_0^l \underset{x\vec{x}}{\underset{\parallel}{\vec{OG}}} \wedge (-p\vec{y})\,dx = \vec{0}$

$\Rightarrow /\vec{z} \quad -aF + lR_A - \dfrac{pl^2}{2} = 0 \quad (**) \Rightarrow \boxed{R_A = \dfrac{pl}{2} + a\dfrac{F}{l}}$

dans $(*)$ $\Rightarrow R_0 = -\dfrac{pl}{2} - \dfrac{aF}{l} + pl + F = \boxed{\dfrac{pl}{2} + (l-a)\dfrac{F}{l} = R_0}$

$\rightarrow$ soit $G_1 \in [OB]$ $\quad \underline{0 < x < a}$.

$\begin{cases} \dfrac{d\vec{R}^{①}(x)}{dx} - p\vec{y} = \vec{0}. \quad (1) \\ \dfrac{dM_z^{①}(x)}{dx} + T_y^{①}(x) = 0 \quad (2) \end{cases}$ $\Rightarrow \vec{R}^{①}(x) = px\vec{y} + \vec{C_1}$

or $\vec{R}^{①}(0) = -R_0\vec{y} = \vec{C_1}$

$\Rightarrow \vec{R}^{①}(x) = (px - R_0)\vec{y}$

$$\vec{R}^{(1)}(x) = (px - R_O)\,\vec{y} = N^{(1)}(x)\,\vec{x} + T_y^{(1)}(x)\,\vec{y}$$

$$\Rightarrow \boxed{\begin{array}{l} N^{(1)}(x) = 0 \\ T_y^{(1)}(x) = px - R_O = p\left(x - \frac{\ell}{2}\right) - (\ell - a)\frac{F}{\ell} \end{array}}$$

d'après (2) : $\dfrac{dM_z^{(1)}(x)}{dx} = -T_y^{(1)}(x) = -px + R_O \Rightarrow M_z^{(1)}(x) = -\dfrac{px^2}{2} + R_O x + k_1$

or $M_z^{(1)}(0) = 0 \Rightarrow k_1 = 0 \Rightarrow \boxed{M_z^{(1)}(x) = -\dfrac{px^2}{2} + \left[\dfrac{p\ell}{2} + (\ell - a)\dfrac{F}{\ell}\right]x}$

→ soit $G_2 \in [BA]$: $a < x < \ell$

$$\begin{cases} \dfrac{d\vec{R}^{(2)}(x)}{dx} - p\vec{y} = \vec{0} & (\overline{1}) \\ \dfrac{dM_z^{(2)}(x)}{dx} + T_y^{(2)}(x) = 0 & (\overline{2}) \end{cases} \Rightarrow \vec{R}^{(2)}(x) = px\vec{y} + \vec{C}_2$$

$\hat{c}$ $\vec{R}^{(2)}(\ell) = R_A\vec{y} = p\ell\vec{y} + \vec{C}_2 \Rightarrow \vec{C}_2 = (R_A - p\ell)\,\vec{y}$

soit $\vec{R}^{(2)}(x) = [p(x-\ell) + R_A]\,\vec{y} = N^{(2)}(x)\,\vec{x} + T_y^{(2)}(x)\,\vec{y}$

donc $\boxed{\begin{array}{l} N^{(2)}(x) = 0 \\ T_y^{(2)}(x) = p(x-\ell) + R_A = p\left(x - \frac{\ell}{2}\right) + \frac{aF}{\ell} \end{array}}$

d'après $(\overline{2})$: $\dfrac{dM_z^{(2)}(x)}{dx} = -T_y^{(2)}(x) \Rightarrow -p\dfrac{(x-\ell)^2}{2} - R_A(x-\ell) + k_2 = M_z^{(2)}(x)$

or $M_z^{(2)}(\ell) = 0 \Rightarrow k_2 = 0 \Rightarrow \boxed{M_z^{(2)}(x) = -\dfrac{p(x-\ell)^2}{2} - \underbrace{R_A}_{\left(\frac{p\ell}{2} + \frac{aF}{\ell}\right)}(x-\ell)}$

Vérification des conditions de saut en $x = a$:

- $[\![\vec{R}]\!](a) = [T_y^{(2)}(a) - T_y^{(1)}(a)]\,\vec{y} = \{[p(a-\ell) + R_A] - [pa - R_O]\}\,\vec{y}$
$= \{-p\ell + R_A + R_O\}\,\vec{y} \underset{(*)}{=} F\vec{y}$ donc $[\![\vec{R}]\!](a) - F\vec{y} = \vec{0}$ OK

- $[\![\vec{M}_O]\!](a) = [M_z^{(2)}(a) - M_z^{(1)}(a)]\,\vec{z} = \left\{\left[-p\dfrac{(a-\ell)^2}{2} - R_A(a-\ell)\right] - \left[-\dfrac{pa^2}{2} + R_O a\right]\right\}\vec{z}$
$= \left\{-\dfrac{p}{2}(\cancel{a^2} + \ell^2 - 2a\ell) - \left(\dfrac{p\ell}{2} + \dfrac{aF}{\ell}\right)(a-\ell) + \cancel{\dfrac{pa^2}{2}} - \dfrac{p\ell}{2}a - (\ell - a)a\dfrac{F}{\ell}\right\}\vec{z}$

$$= \left\{ -\cancel{\frac{pl^2}{2}} + \cancel{pal} - \cancel{\frac{pal}{2}} + \cancel{\frac{pl^2}{2}} - \frac{a^2F}{l} + aF - \cancel{\frac{pla}{2}} - aF + \frac{a^2F}{l} \right\} \vec{z}$$

$$= \vec{0}$$

$$\Rightarrow \quad [\![\vec{\mathcal{M}}]\!](a) = \vec{0} \quad \underline{\text{OK}}$$

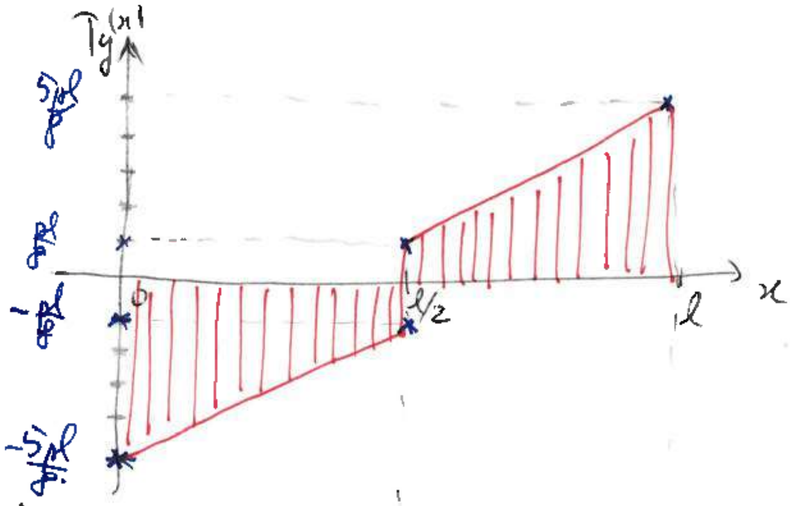
<u>diagrammes des efforts de cohésion :</u>

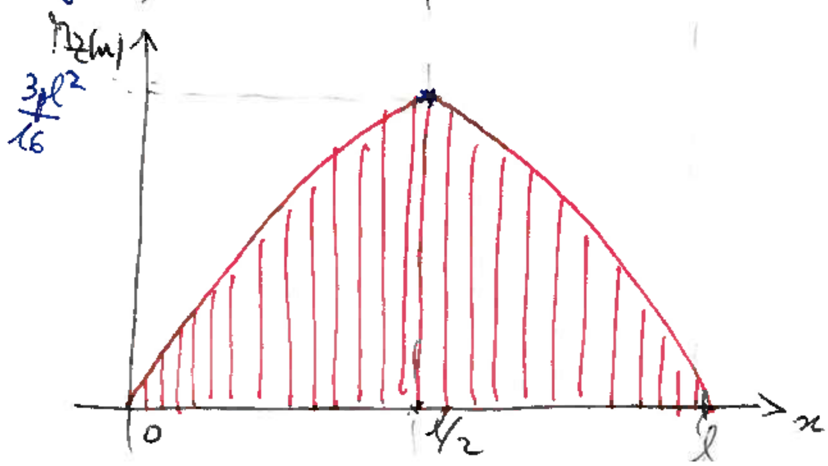
pour voiture de 1500 kg $\Rightarrow$ $F \simeq 15\,kN$ or $pl \sim 60\,kN = 4F$

pour $a = \frac{l}{2}$ et $F = \frac{pl}{4}$ alors $R_0 = R_A = \frac{pl}{2} + \frac{l}{2} \times \frac{p}{4} = \underline{\frac{5pl}{8}}$

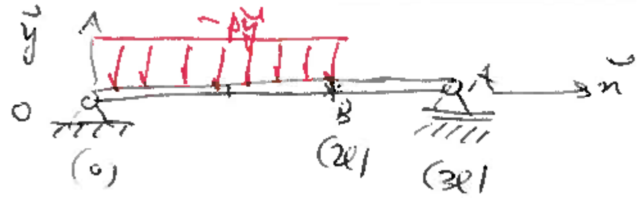
- $T_y^{(1)}(x) = px - R_0 = p\left(x - \frac{5l}{8}\right)$ $\quad T_y^{(1)}(0) = -\frac{5pl}{8}$; $T_y^{(1)}(l/2) = -\frac{pl}{8}$
- $T_y^{(2)}(x) = p(x-l) + R_A = p\left(x - l + \frac{5l}{8}\right) = p\left(x - \frac{3l}{8}\right)$ $\quad T_y^{(2)}\left(\frac{l}{2}\right) = +\frac{pl}{8}$; $T_y^{(2)}(l) = \frac{5pl}{8}$
- $M_z^{(1)}(x) = -p\frac{x^2}{2} + R_0 x = -p\frac{x^2}{2} + \frac{5pl}{8}x = -\frac{p}{2}x\left(x - \frac{5l}{4}\right)$ $\quad M_z^{(1)}(0) = 0$
- $M_z^{(2)}(x) = -\frac{p}{2}(x-l)^2 - \frac{5pl}{8}(x-l) = -\frac{p}{2}(x-l)\left[x - l + \frac{5l}{4}\right] = -\frac{p}{2}(x-l)\left(x + \frac{l}{4}\right)$

$M_z^{(1)}\left(\frac{l}{2}\right) = M_z^{(2)}\left(\frac{l}{2}\right) = -\frac{p}{2}\frac{l}{2}\left(\frac{l}{2} - \frac{5l}{4}\right) = +\frac{3pl^2}{16}$ $\qquad M_z^{(2)}(l) = 0$





Ex04



PFS • $\vec{R_O} + R_A\vec{y} - p(2l)\vec{y} = \vec{0}$ $\Rightarrow$ $R_O + R_A = 2pl$ (*)

• $\vec{M}^{t}$ en O : $\underset{\underset{3l\vec{x}}{\parallel}}{\vec{OA}} \wedge R_A\vec{y} + \int_0^{2l} \underset{\underset{\xi\vec{x}}{\parallel}}{\vec{OM}} \wedge (-p\vec{y})\,d\xi = \vec{0}$ $\Rightarrow 3l R_A = p\left[\frac{\xi^2}{2}\right]_0^{2l}$

$\Rightarrow \boxed{R_A = \frac{2pl}{3}}$

d'ap (*) : $R_O = 2pl - R_A = \frac{4pl}{3}$

Efforts de cohésion :

* partie [OB] ≡ ① ($0<x<2l$) : Eq° d'équilibre locales

• $\frac{d\vec{R}^{(1)}(x)}{dx} - p\vec{y} = \vec{0} \Rightarrow \vec{R}^{(1)}(x) = px\vec{y} + \vec{C}$ or $\vec{R}^{(1)}(0) = -R_O\vec{y} = -\frac{4pl}{3}\vec{y} = \vec{C}$

d'où $\vec{R}^{(1)}(x) = p(x - \frac{4}{3}l)\vec{y}$ $\Rightarrow$ $\boxed{N^{(1)}(x) = 0}$ $\boxed{T_y^{(1)}(x) = p(x - \frac{4l}{3})}$

$T_y^{(1)}(0) = -\frac{4pl}{3}$; $T_y^{(1)}(2l) = \frac{2pl}{3}$

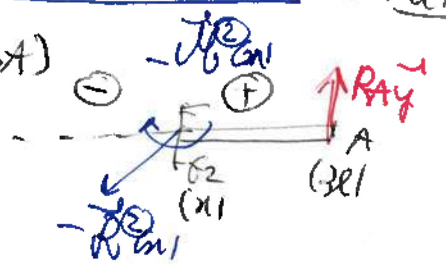
• $\frac{dM_z^{(1)}(x)}{dx} + T_y^{(1)}(x) = 0 \Rightarrow \frac{dM_z^{(1)}}{dx}(x) = -T_y^{(1)}(x) = -p(x - \frac{4l}{3})$

soit $M_z^{(1)}(x) = -p\left(\frac{x^2}{2} - \frac{4l}{3}x\right) + \underset{\underset{0}{\parallel}}{k}$ car $M_z^{(1)}(0) = 0$ $\Rightarrow$ $\boxed{M_z^{(1)}(x) = -\frac{p}{6}x(3x - 8l)}$

$M_z^{(1)}(0) = 0$; $M_z^{(1)}(2l) = \frac{2pl^2}{3}$

* partie [BA] ≡ ② ($2l<x<3l$) : méthode des coupures

soit $G_2 \in [BA]$



⊖ → ⊕ $\Rightarrow$ $-\{\mathcal{T}_{int}\}$

• $-\vec{R}^{(2)}(x) + R_A\vec{y} = \vec{0} \Rightarrow \vec{R}^{(2)}(x) = R_A\vec{y} = \frac{2pl}{3}\vec{y}$ $\Rightarrow$ $\boxed{N^{(2)}(x) = 0}$ $\boxed{T_y^{(2)}(x) = \frac{2pl}{3}}$

• $-\vec{\mathcal{M}}^{(2)}(x) + \underset{\underset{(3l-x)\vec{x}}{\parallel}}{\vec{G_2A}} \wedge R_A\vec{y} = \vec{0}$ $\rightarrow$ $M_z^{(2)}(x) = (3l - x)R_A$ $\Rightarrow$ $\boxed{M_z^{(2)}(x) = -\frac{2pl}{3}(x - 3l)}$

$M_z^{(2)}(2l) = \frac{2pl^2}{3}$

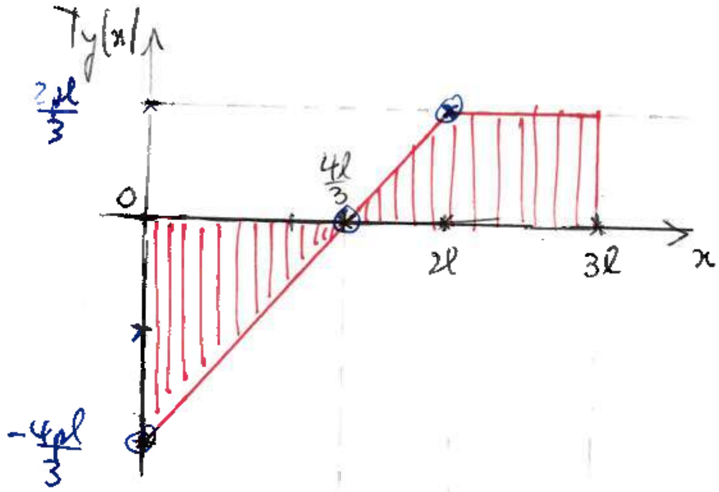
$M_z^{(2)}(0) = 0$

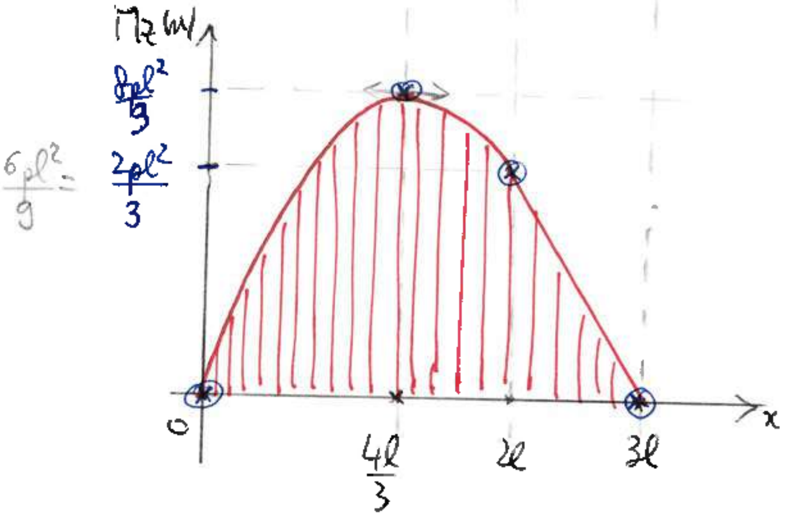
• Diagrammes :

$T_y^{(1)}(x) = p\left(x - \frac{4l}{3}\right) \Rightarrow T_y^{(1)}(x) = 0$ pour $x = \frac{4l}{3}$

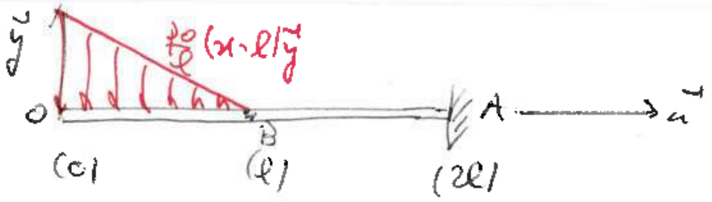
or $\frac{dM_z^{(1)}(x)}{dx} = -T_y^{(1)}(x) \Rightarrow$ en $x = \frac{4l}{3}$ maximum pour $x = \frac{4l}{3}$

$M_z^{(1)}\left(\frac{4l}{3}\right) = -\frac{p}{6} \times \frac{4l}{3} \times \left(3 \times \frac{4l}{3} - 8l\right) = -\frac{2pl}{9}(-4l) = \frac{8pl^2}{9}$





Ex 05 :



$\boxed{0 < x < \ell}$

• $\frac{d\vec{R}^{(1)}}{dx}(x) + \frac{p_0}{\ell}(x-\ell)\vec{y} = \vec{0} \Rightarrow \vec{R}^{(1)}(x) = -\frac{p_0}{\ell}\left(\frac{x^2}{2} - \ell x\right)\vec{y} + \underset{\vec{0}}{\underset{\parallel}{\vec{C}}}$ car $\vec{R}^{(1)}(0) = \vec{0}$

d'où $\boxed{N^{(1)}(x) = 0}$

$\boxed{T_y^{(1)}(x) = -\frac{p_0}{2\ell}x(x-2\ell)}$ $\quad T_y^{(1)}(0) = 0$ et $T_y^{(1)}(\ell) = \frac{p_0\ell}{2}$

• $\frac{dM_z^{(1)}(x)}{dx} + T_y^{(1)}(x) = 0 \Rightarrow \frac{dM_z^{(1)}}{dx}(x) = \frac{p_0 x}{2\ell}(x-2\ell) \Rightarrow M_z^{(1)}(x) = \frac{p_0}{2\ell}\left(\frac{x^3}{3} - x^2\ell\right) + \underset{0}{\underset{\parallel}{k}}$

car $M_z^{(1)}(0) = 0$

$\Rightarrow \boxed{M_z^{(1)}(x) = \frac{p_0}{6\ell}x^2(x-3\ell)}$ $\quad M_z^{(1)}(0) = 0 \; ; \; M_z^{(1)}(\ell) = -\frac{p_0\ell^2}{3}$

$\boxed{\ell < x < 2\ell}$

• $\frac{d\vec{R}^{(2)}}{dx}(x) = \vec{0} \Rightarrow \vec{R}^{(2)}(x) = \vec{C}_2$ or $[\![\vec{R}]\!](\ell) = \vec{0} \Rightarrow \vec{C}_2 = -\frac{p_0}{2\ell}\ell(-\ell)\vec{y} = \frac{p_0\ell}{2}\vec{y}$

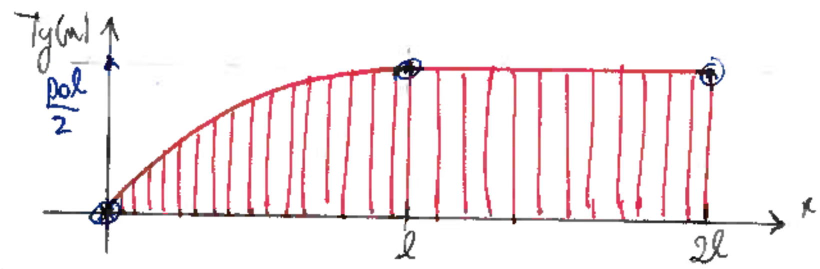
$\Rightarrow \boxed{N^{(2)}(x) = 0}$ et $\boxed{T_y^{(2)}(x) = \frac{p_0\ell}{2}}$

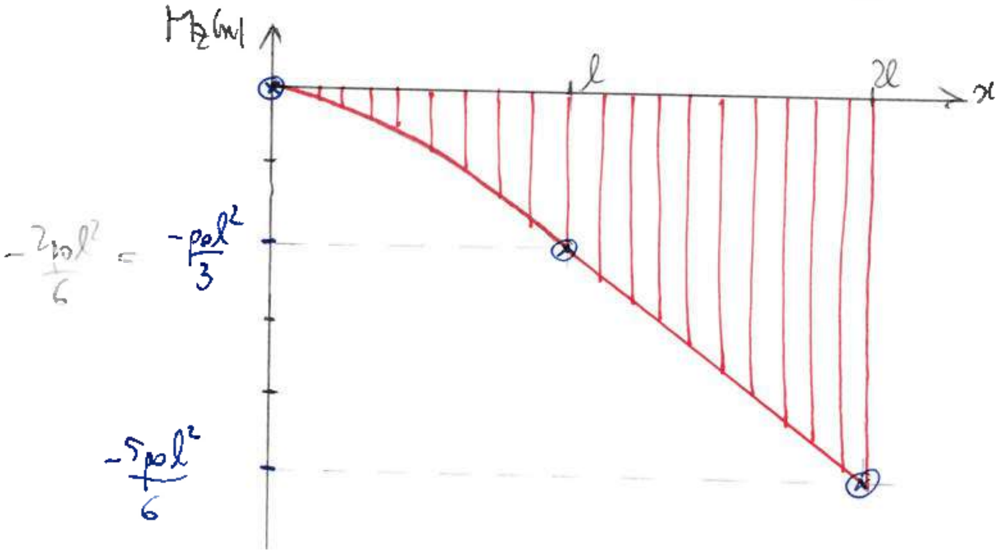
• $\frac{dM_z^{(2)}(x)}{dx} = -T_y^{(2)}(x) = -\frac{p_0\ell}{2} \Rightarrow M_z^{(2)}(x) = -\frac{p_0\ell}{2}x + k_2$

or $[\![M_z]\!](\ell) = 0 \Rightarrow -\frac{p_0\ell}{2}\ell + k_2 = \frac{p_0\ell^2}{6\ell}(\ell - 3\ell) \Rightarrow k_2 = p_0\ell^2\left(\frac{1}{2} - \frac{1}{3}\right) = \frac{p_0\ell^2}{6}$

d'où $\boxed{M_z^{(2)}(x) = -\frac{p_0\ell}{6}(3x-\ell)}$ $\quad M_z^{(2)}(2\ell) = -\frac{5p_0\ell^2}{6}$

diagrammes :





Ex 6 :

Force ponctuelle $-F\vec{y}$ appliquée en C $\Rightarrow$ 2 tronçons à considérer.

$\Rightarrow$ $[BC] \equiv (1)$ $\quad 0<\theta<\pi/2$ $\quad$ et $\quad [CA] \equiv (2)$ $\quad \pi/2<\theta<\pi$

on oriente de B vers A

ici $\vec{t} = +\vec{e_\theta}$; $\vec{n} = -\vec{e_r}$

$(\vec{t}, \vec{n}, \vec{z})$ trièdre direct

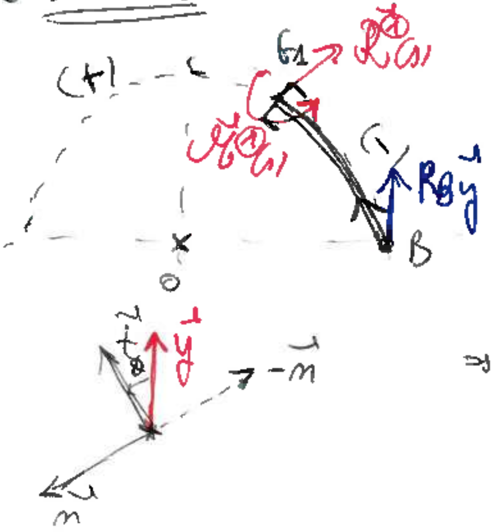
pb plan : $\left\| \begin{array}{l} \vec{R}(s) = N(s)\,\vec{t}(s) + T_n(s)\,\vec{n}(s) \\ \vec{\mathcal{M}}(s) = M_z(s)\,\vec{z} \end{array} \right.$ $\qquad s \equiv R\theta$

PFS : • $\vec{R_A} + R_B\vec{y} - F\vec{y} = \vec{0}$ $\quad \Rightarrow \boxed{R_A + R_B = F}$

• m^t en A : $\underbrace{\vec{AC}}_{R\vec{x}+R\vec{y}} \wedge (-F\vec{y}) + \underbrace{\vec{AB}}_{2R\vec{x}} \wedge R_B\vec{y} = \vec{0}$ $\Rightarrow -FR + 2RR_B = 0 \Rightarrow \boxed{R_B = R_A = \frac{F}{2}}$

Torseur de cohésion : méthode des coupures :

• $G_1 \in [BC]$ $\quad (0<\theta<\pi/2)$



$(+) \to (-) \Rightarrow +$ efforts int $\}$

• $\vec{R}^{(1)}(s) + R_B\vec{y} = \vec{0}$ $\Rightarrow \vec{R}^{(1)}(s) = -R_B\vec{y} = -\frac{F}{2}\vec{y}$

$\Rightarrow \vec{y} = \cos\theta\,\vec{t} - \sin\theta\,\vec{n}$ $\quad \Rightarrow \vec{R}^{(1)}(s) = -\frac{F}{2}(\cos\theta\,\vec{t} - \sin\theta\,\vec{n})$

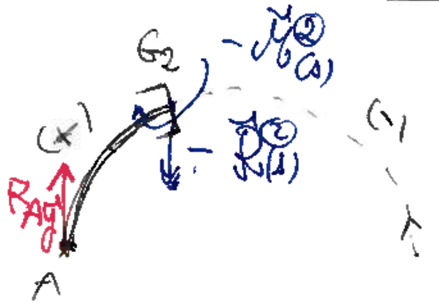
soit $\boxed{\begin{array}{l} N^{(1)}(\theta) = -\frac{F}{2}\cos\theta \\ T_n^{(1)}(\theta) = \frac{F}{2}\sin\theta \end{array}}$

• M^t en G_1 : $\vec{\mathcal{M}}^{(1)}(s) + \vec{G_1B} \wedge R_B\vec{y} = \vec{0}$

$\Rightarrow$ $\vec{G_1B} = \vec{G_1O} + \vec{OB} = -R(\cos\theta\,\vec{x} + \sin\theta\,\vec{y}) + R\vec{x}$

$\Rightarrow \vec{\mathcal{M}}^{(1)}(s) = R(\cos\theta - 1)R_B\,\vec{z}$ $\qquad$ soit $\boxed{M_z^{(1)}(\theta) = \frac{FR}{2}(\cos\theta - 1)}$

• $G_2 \in [CA]$ $\left(\frac{\pi}{2}<\theta<\pi\right)$



$(-) \rightarrow (+) \Rightarrow -\{\mathcal{T}_{int}\}$

• $-\vec{R}^{(2)}(\theta) + R_A\vec{y} = \vec{0} \Rightarrow \vec{R}^{(2)}(\theta) = R_A\vec{y} = \frac{F}{2}\vec{y}$
$= \frac{F}{2}(\cos\theta\,\vec{t} - \sin\theta\,\vec{n})$

$\Rightarrow \boxed{N^{(2)}(\theta) = \frac{F}{2}\cos\theta}$ et $\boxed{T_n^{(2)}(\theta) = -\frac{F}{2}\sin\theta}$

• M^t en G_2 : $-\vec{\mathcal{M}}^{(2)}_G(\theta) + \vec{G_2A} \wedge R_A\vec{y} = \vec{0}$

$\vec{G_2A} = \vec{G_2O} + \vec{OA} = -R(\cos\theta\,\vec{x} + \sin\theta\,\vec{y}) - R\vec{x}$

$\Rightarrow \vec{\mathcal{M}}^{(2)}(\theta) = -R(\cos\theta + 1)\,R_A\,\vec{z}$ donc $\boxed{M_z^{(2)}(\theta) = -\frac{FR}{2}(1+\cos\theta)}$

• diagrammes :