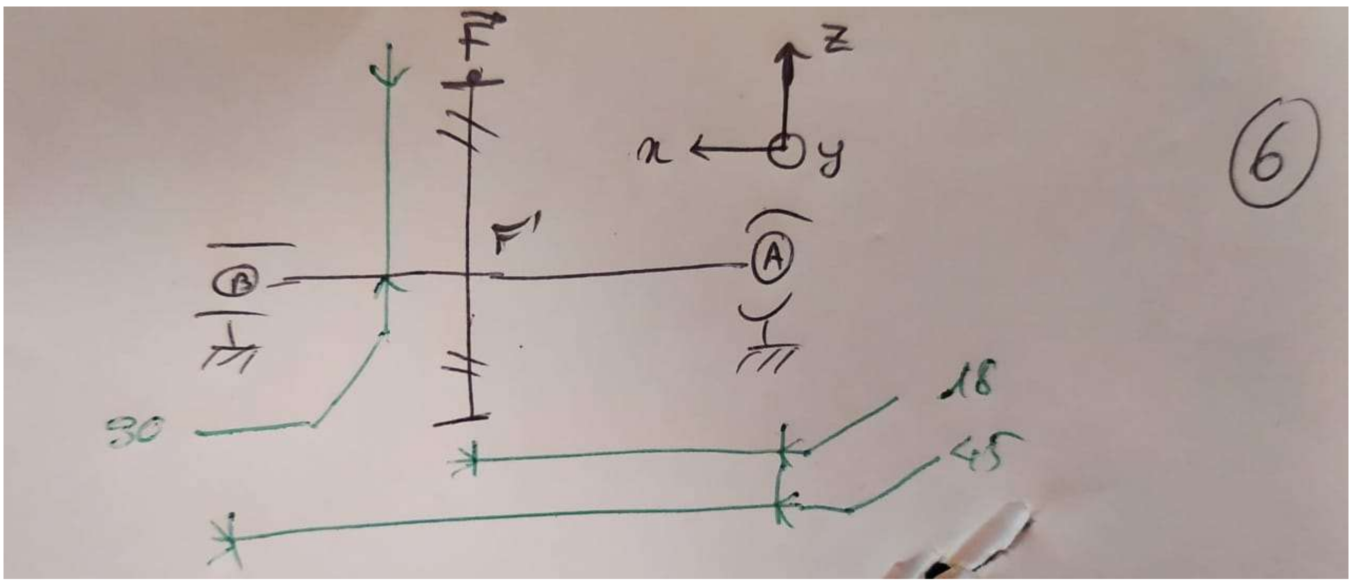
$with(VectorCalculus)$

[&x, `*`, `+`, `-`, `.`, <,>, <|>, About, AddCoordinates, ArcLength, BasisFormat, Binormal, ConvertVector, CrossProduct, Curl, Curvature, D, Del, DirectionalDiff, Divergence, DotProduct, Flux, GetCoordinateParameters, GetCoordinates, GetNames, GetPVDescription, GetRootPoint, GetSpace, Gradient, Hessian, IsPositionVector, IsRootedVector, IsVectorField, Jacobian, Laplacian, LineInt, MapToBasis, ∇, Norm, Normalize, PathInt, PlotPositionVector, PlotVector, PositionVector, PrincipalNormal, RadiusOfCurvature, RootedVector, ScalarPotential, SetCoordinateParameters, SetCoordinates, SpaceCurve, SurfaceInt, TNBFrame, TangentLine, TangentPlane, TangentVector, Torsion, Vector, VectorField, VectorPotential, VectorSpace, Wronskian, diff, eval, evalVF, int, limit, series] **(1)**



$P := 3000$

$$P := 3000 \qquad (2)$$

$we := \frac{2 \cdot \mathrm{Pi} \cdot 1500}{60}$

$$we := 50\,\pi \qquad (3)$$

$r := 30$

$$r := 30 \qquad (4)$$

$C := \frac{P}{we}$

$$C := \frac{60}{\pi} \tag{5}$$

$C := C \cdot 1000$

$$C := \frac{60000}{\pi} \tag{6}$$

Conversion de C en Nmm

$Ft := \frac{C}{r}$

$$Ft := \frac{2000}{\pi} \tag{7}$$

$B := \frac{30 \cdot \mathrm{Pi}}{180}$

$$B := \frac{\pi}{6} \tag{8}$$

$Fa := Ft \cdot \tan(B)$

$$Fa := \frac{2000\sqrt{3}}{3\pi} \tag{9}$$

$An := \frac{20 \cdot \mathrm{Pi}}{180}$

$$An := \frac{\pi}{9} \tag{10}$$

$Fr := \frac{Ft \cdot \tan(An)}{\cos(B)}$

$$Fr := \frac{4000 \tan\left(\frac{\pi}{9}\right)\sqrt{3}}{3\pi} \tag{11}$$

$F := PositionVector([Fa, Ft, Fr])$

$$F := \begin{bmatrix} \frac{2000\sqrt{3}}{3\pi} \\ \frac{2000}{\pi} \\ \frac{4000 \tan\left(\frac{\pi}{9}\right)\sqrt{3}}{3\pi} \end{bmatrix} \tag{12}$$

$Ra := PositionVector([Xa, Ya, Za])$

$$Ra := \begin{bmatrix} Xa \\ Ya \\ Za \end{bmatrix} \tag{13}$$

$Rb := PositionVector([0, Yb, Zb])$

$$Rb := \begin{bmatrix} 0 \\ Yb \\ Zb \end{bmatrix} \tag{14}$$

$AB := PositionVector([45, 0, 0])$

$$AB := \begin{bmatrix} 45 \\ 0 \\ 0 \end{bmatrix} \tag{15}$$

$AF := PositionVector([18, 0, 30])$

$$AF := \begin{bmatrix} 18 \\ 0 \\ 30 \end{bmatrix} \tag{16}$$

$SommeForce := Ra + Rb + F$

$$SommeForce := \begin{bmatrix} Xa + \frac{2000\sqrt{3}}{3\pi} \\ Ya + Yb + \frac{2000}{\pi} \\ Za + Zb + \frac{4000\tan\left(\frac{\pi}{9}\right)\sqrt{3}}{3\pi} \end{bmatrix} \tag{17}$$

$SommeMoment := AF \mathbin{\&x} F + AB \mathbin{\&x} Rb$

$$SommeMoment := \begin{bmatrix} -\frac{60000}{\pi} \\ -\frac{24000\tan\left(\frac{\pi}{9}\right)\sqrt{3}}{\pi} + \frac{20000\sqrt{3}}{\pi} - 45\,Zb \\ \frac{36000}{\pi} + 45\,Yb \end{bmatrix} \tag{18}$$

$PFD := solve(\{SommeForce(1) = 0, SommeForce(2) = 0, SommeForce(3) = 0, SommeMoment(2) = 0, SommeMoment(3) = 0\}, [Xa, Ya, Za, Yb, Zb])$

$$PFD := \left[\left[Xa = -\frac{2000\sqrt{3}}{3\pi}, Ya = -\frac{1200}{\pi}, Za = -\frac{800\sqrt{3}\left(9\tan\left(\frac{\pi}{9}\right) + 5\right)}{9\pi}, Yb = -\frac{800}{\pi}, \right.\right. \tag{19}$$

$$Zb = -\frac{800\sqrt{3}\left(6\tan\left(\frac{\pi}{9}\right)-5\right)}{9\pi}\Bigg]\Bigg]$$

$Ra\_num := PositionVector([fsolve(PFD[1][1]), fsolve(PFD[1][2]), fsolve(PFD[1][3])])$

$$Ra\_num := \begin{bmatrix} -367.5525970 \\ -381.9718633 \\ -405.5689106 \end{bmatrix} \quad \textbf{(20)}$$

$Rb\_num := PositionVector([0, fsolve(PFD[1][4]), fsolve(PFD[1][5])])$

$$Rb\_num := \begin{bmatrix} 0 \\ -254.6479089 \\ 138.0125008 \end{bmatrix} \quad \textbf{(21)}$$

<u>Passons au calcul du torseur de cohesion :</u>

$N\_Ty\_Tz := Ra\_num$

$$N\_Ty\_Tz := \begin{bmatrix} -367.5525970 \\ -381.9718633 \\ -405.5689106 \end{bmatrix} \quad \textbf{(22)}$$

$N\_Ty\_Tz := evalf(N\_Ty\_Tz + F)$

$$N\_Ty\_Tz := \begin{bmatrix} 0. \\ 254.6479089 \\ -138.0125011 \end{bmatrix} \quad \textbf{(23)}$$

$N\_Ty\_Tz := evalf(N\_Ty\_Tz + Rb\_num)$

$$N\_Ty\_Tz := \begin{bmatrix} 0. \\ 0. \\ -3.00000010611257\ 10^{-7} \end{bmatrix} \quad \textbf{(24)}$$

C'est bon on a bien 0 en bout d'arbre.

$Ra\_num := PositionVector([Xa, Ya, Za])$

$$Ra\_num := \begin{bmatrix} Xa \\ Ya \\ Za \end{bmatrix} \quad \textbf{(25)}$$

$F := PositionVector([Faa, Ftt, Frr])$

$$F := \begin{bmatrix} Faa \\ Ftt \\ Frr \end{bmatrix} \quad \textbf{(26)}$$

$Mf\_Mt := PositionVector([-x, 0, 0])\ \&x\ Ra\_num$

$$Mf\_Mt := \begin{bmatrix} 0 \\ Za\, x \\ -Ya\, x \end{bmatrix} \tag{27}$$

$Mf\_Mt := Mf\_Mt + PositionVector([-(x - AFp), 0, FpF])\ \&x\ F$

$$Mf\_Mt := \begin{bmatrix} -FpF\, Ftt \\ Za\, x - (-x + AFp)\, Frr + FpF\, Faa \\ -Ya\, x + (-x + AFp)\, Ftt \end{bmatrix} \tag{28}$$

$\xrightarrow{\text{évaluer à un point}}$

$$\begin{bmatrix} -FpF\, Ftt \\ 45\, Za - (-45 + AFp)\, Frr + FpF\, Faa \\ -45\, Ya + (-45 + AFp)\, Ftt \end{bmatrix} \tag{29}$$

<u>C'est bon notre torseur de cohesion est correct !</u>

<u>On trace maintenant les diagrammes A RENTRER A LA MAIN:</u>

$N := x \rightarrow piecewise(0 < x < 18, -367.5525970, 18 < x < 45, 0.)$

$$N := x \mapsto \begin{cases} -367.5525970 & 0 < x < 18 \\ 0. & 18 < x < 45 \end{cases} \tag{30}$$

$Ty := x \rightarrow piecewise(0 < x < 18, -381.9718633, 18 < x < 45, -405.5689106)$

$$Ty := x \mapsto \begin{cases} -381.9718633 & 0 < x < 18 \\ -405.5689106 & 18 < x < 45 \end{cases} \tag{31}$$

$Tz := x \rightarrow piecewise(0 < x < 18, -405.5689106, 18 < x < 45, -138.0125009)$

$$Tz := x \mapsto \begin{cases} -405.5689106 & 0 < x < 18 \\ -138.0125009 & 18 < x < 45 \end{cases} \tag{32}$$

$Mt := x \rightarrow piecewise(0 < x < 18, 0, 18 < x < 45, -19098.59317)$

$$Mt := x \mapsto \begin{cases} 0 & 0 < x < 18 \\ -19098.59317 & 18 < x < 45 \end{cases} \tag{33}$$

$Mfy := x \rightarrow piecewise(0 < x < 18, -405.5689106\, x, 18 < x < 45, -138.0125009\, x + 6210.562537)$

$$Mfy := x \mapsto \begin{cases} -405.5689106\, x & 0 < x < 18 \\ -138.0125009\, x + 6210.562537 & 18 < x < 45 \end{cases} \tag{34}$$

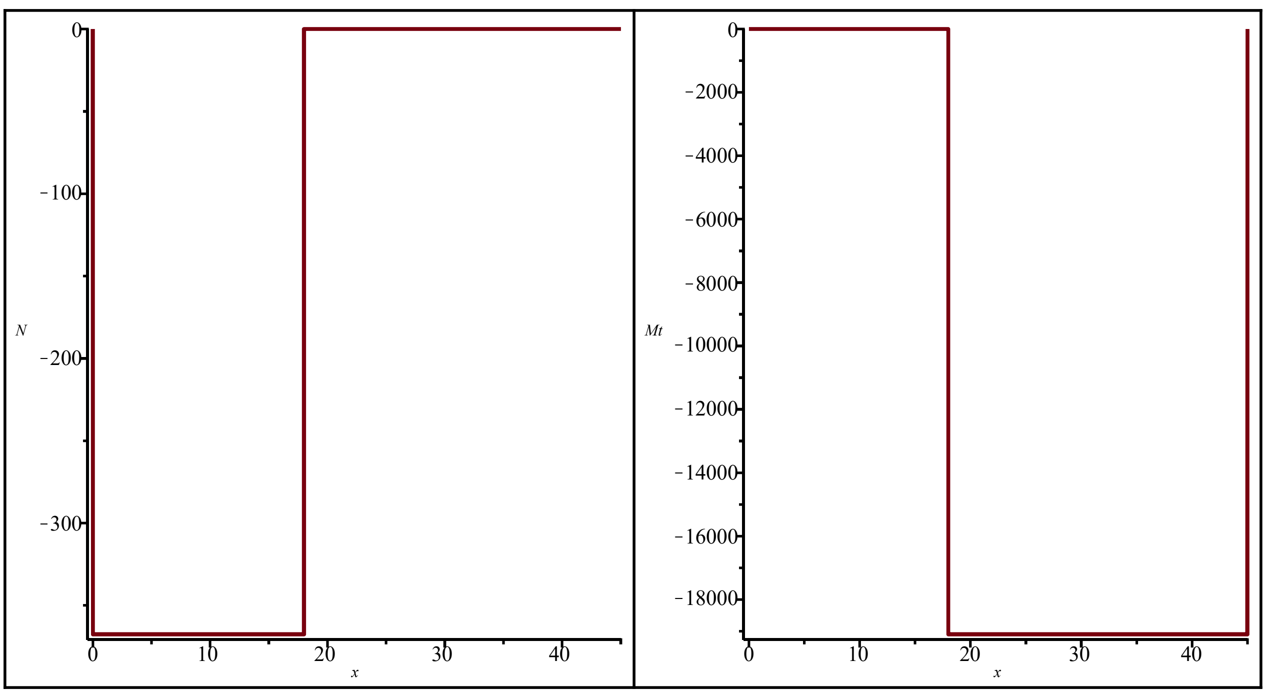
$Mfz := x \rightarrow piecewise(0 < x < 18, 381.9718633\, x, 18 < x < 45, -254.6479089\, x + 11459.15590)$

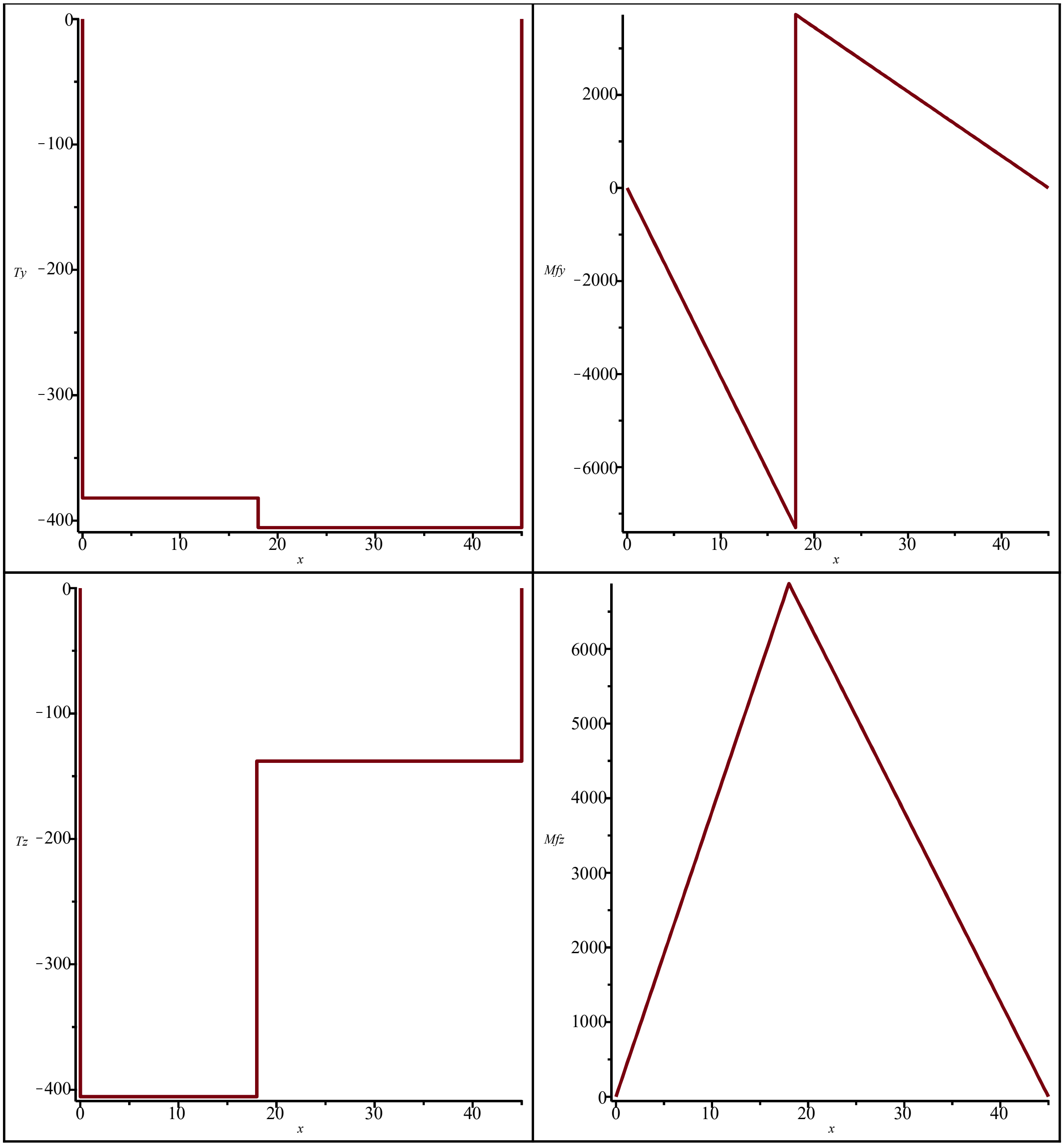
$$Mfz := x \mapsto \begin{cases} 381.9718633\, x & 0 < x < 18 \\ -254.6479089\, x + 11459.15590 & 18 < x < 45 \end{cases} \tag{35}$$

$with(plots)$

$[animate, animate3d, animatecurve, arrow, changecoords, complexplot, complexplot3d, conformal, conformal3d, contourplot, contourplot3d, coordplot, coordplot3d, densityplot, display, dualaxisplot, fieldplot, fieldplot3d, gradplot, gradplot3d, implicitplot, implicitplot3d, inequal, interactive, interactiveparams, intersectplot, listcontplot, listcontplot3d, listdensityplot, listplot, listplot3d, loglogplot, logplot, matrixplot, multiple, odeplot, pareto, plotcompare, pointplot, pointplot3d, polarplot, polygonplot, polygonplot3d, polyhedra\_supported, polyhedraplot, rootlocus, semilogplot, setcolors, setoptions, setoptions3d, shadebetween, spacecurve, sparsematrixplot, surfdata, textplot, textplot3d, tubeplot]$ **(36)**

$Affichage := Array(1..3, 1..2):$
$Affichage[1, 1] := plot(N(x), x = 0..45, axes = framed, labels = [x, 'N']):$
$Affichage[2, 1] := plot(Ty(x), x = 0..45, axes = framed, labels = [x, 'Ty']):$
$Affichage[3, 1] := plot(Tz(x), x = 0..45, axes = framed, labels = [x, 'Tz']):$
$Affichage[1, 2] := plot(Mt(x), x = 0..45, axes = framed, labels = [x, 'Mt']):$
$Affichage[2, 2] := plot(Mfy(x), x = 0..45, axes = framed, labels = [x, 'Mfy']):$
$Affichage[3, 2] := plot(Mfz(x), x = 0..45, axes = framed, labels = [x, 'Mfz']):$
$display(Affichage)$





En normalisé on obtient :

$Affichage \coloneqq Array(1..2, 1..2)$:

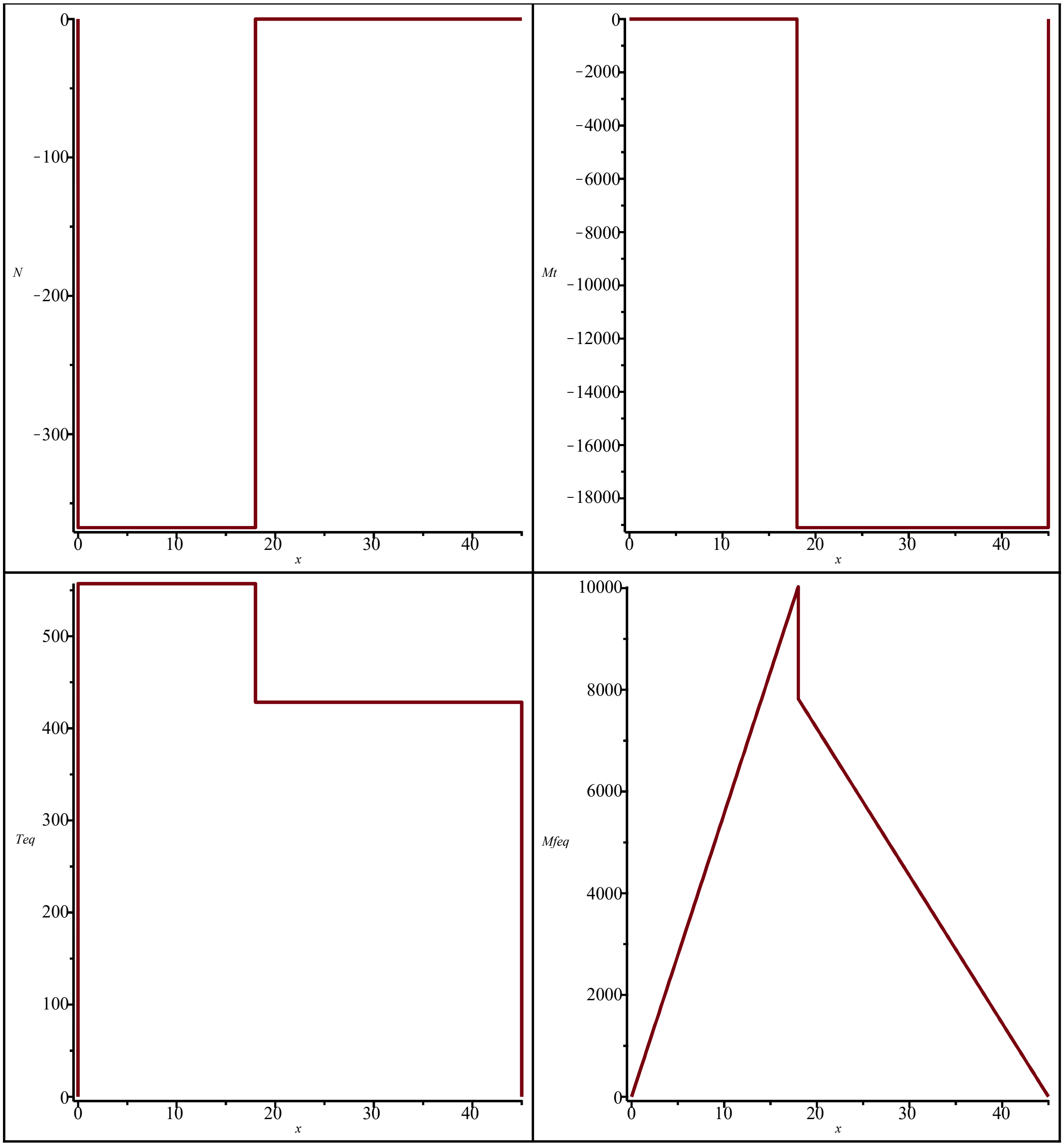
$Affichage[1, 1] \coloneqq plot(N(x), x = 0..45, axes = framed, labels = [x, 'N'])$:

$Affichage[2, 1] \coloneqq plot\left(\sqrt{Ty(x)^2 + Tz(x)^2}, x = 0..45, axes = framed, labels = [x, 'Teq']\right)$:

$Affichage[1, 2] \coloneqq plot(Mt(x), x = 0..45, axes = framed, labels = [x, 'Mt'])$:

$Affichage[2, 2] \coloneqq plot\left(\sqrt{Mfy(x)^2 + Mfz(x)^2}, x = 0..45, axes = framed, labels = [x, 'Mfeq']\right)$:

$display(Affichage)$



On peut maintenant determiner les criteres de resistance mecanique :
$Mf := 10026$

$$Mf := 10026 \quad \textbf{(37)}$$

$\sigma\_max := \left(\frac{32 \cdot Mf}{\mathrm{Pi} \cdot \mathrm{D}^3} \right)$

$$\sigma\_max := \frac{320832}{\pi \, \mathrm{D}^3} \quad \textbf{(38)}$$

$S := \frac{\mathrm{Pi} \cdot \mathrm{D}^2}{4}$

$$S := \frac{\pi D^2}{4} \quad (39)$$

$T := 557$

$$T := 557 \quad (40)$$

$\tau\_max\_cisaill := evalf\left(\frac{4}{3} \cdot \frac{T}{S}\right)$

$$\tau\_max\_cisaill := \frac{945.5925684}{D^2} \quad (41)$$

$Mt := 19100$

$$Mt := 19100 \quad (42)$$

$\tau\_max\_torsion := evalf\left(\frac{16 \cdot Mt}{\mathrm{Pi} \cdot D^3}\right)$

$$\tau\_max\_torsion := \frac{97275.50119}{D^3} \quad (43)$$

On peut effectivement negliger la contrainte de cisaillement vis a vis de la contrainte de torsion.

Critere de Von Mises

$\sigma\_eq := \sqrt{\sigma\_max^2 + 3\ \tau\_max\_torsion^2}$

$$\sigma\_eq := \sqrt{\frac{102933172224}{\pi^2 D^6} + \frac{2.838756940\ 10^{10}}{D^6}} \quad (44)$$

On prend un coefficient de securité S=3 et une limite elastique de l'acier de 225MPa pour du E295

$S := 3$

$$S := 3 \quad (45)$$

$\left(solve\left(\left\{\frac{\sigma\_eq}{S} = 225\right\}, [D], maxsols = 1\right) \text{assuming } D :: positive\right)$

$$[[D = 6.633389724]] \quad (46)$$

Par resistance mecanique on trouve un diametre minimum de 6.6mm

Passons aux criteres de deformation :

Pour la deformation en torsion

$D\_meca := 6.633389724$

$$D\_meca := 6.633389724 \quad (47)$$

$L := 45$

$$L := 45 \quad (48)$$

Arbre court ou arbre long ?

$LsurD := \frac{L}{D\_meca}$

$$LsurD := 6.783861928 \quad (49)$$

On a 5<L/D<7 et aucune information sur s'il s'agit d'un couple regulier ou non, donc dans le doute on choisit θadm=1/4 deg/m

$$\theta adm := \frac{1}{4} \cdot \frac{\mathrm{Pi}}{180}$$

$$\theta adm := \frac{\pi}{720} \tag{50}$$

$$Io := \frac{\mathrm{Pi} \cdot \mathrm{D}^4}{32}$$

$$Io := \frac{\pi \, \mathrm{D}^4}{32} \tag{51}$$

$$E := 190 \cdot 10^3$$

$$E := 190000 \tag{52}$$

$$G := \frac{E}{2 \cdot (1 + 0.3)}$$

$$G := 73076.92307 \tag{53}$$

$$\theta := \frac{Mt}{G \cdot Io}$$

$$\theta := \frac{2.662276875}{\mathrm{D}^4} \tag{54}$$

$$solve(\{\theta = \theta adm\}, [\mathrm{D}], maxsols = 1) \text{ assuming } \mathrm{D} :: positive$$

$$[[\mathrm{D} = 4.970029435]] \tag{55}$$

Il faut un diametre de plus de 4.9mm pour satisfaire le critere de deformation en torsion

Pour la deformation en Flexion :

fleche selon y

Condition limites : f(0)=0 et f(45)=0
Dans le repere principal avec Mfeq

$$Igxy := \frac{\mathrm{Pi} \cdot Df^4}{64}$$

$$Igxy := \frac{\pi \, Df^4}{64} \tag{56}$$

$$ypp := -\frac{Mfy(x)}{E \cdot Igxy}$$

$$ypp := -\frac{4 \left(\begin{cases} -405.5689106\, x & 0 < x < 18 \\ -138.0125009\, x + 6210.562537 & 18 < x < 45 \end{cases} \right)}{11875 \, \pi \, Df^4} \tag{57}$$

$$yp := evalf(int(ypp, x))$$

$$yp := \tag{58}$$

$$-\frac{0.0001072201722\left(\left\{\begin{array}{ll}0. & x\le 0.\\ -202.7844553\,x^2 & x\le 18.\\ -69.00625045\,x^2+6210.562537\,x-155134.2640 & x\le 45.\\ -15396.60703 & 45.<x\end{array}\right.\right)}{Df^4}$$

$-202.7844553\,x^2, -69.00625045\,x^2+6210.562537\,x-155134.2640 \xrightarrow{\text{évaluer à un point}}$
$-65702.16352,\ -65702.16345$

Donc les constantes d'integration sont egales i.e. a=b (cf ligne du dessus + continuité en x=18)

$yp := \frac{0.0001072201722}{Df^4}\cdot piecewise(0<x<18, -202.7844553\,x^2+ay, 18<x<45,$
$-69.00625045\,x^2+6210.562537\,x-155134.2640+ay)$

$$yp := \frac{1}{Df^4}\left(0.0001072201722\left(\left\{\begin{array}{ll}-202.7844553\,x^2+ay & 0<x<18\\ -69.00625045\,x^2+6210.562537\,x-155134.2640+ay & 18<x<45\end{array}\right.\right)\right) \quad \textbf{(59)}$$

$y := int(yp, x)$

$$y := \frac{1}{Df^4}\left(0.0001072201722\left(\left\{\begin{array}{l}0.\\ -67.59481843\,x^3+ay\,x\\ -23.00208348\,x^3+3105.281268\,x^2-155134.2640\,x+ay\,x+1.526240791\,10\\ -1.262671378\,10^6+45.\,ay\end{array}\right.\right)\right)$$

$-67.59481843\,x^3+a\,y\cdot x, -23.00208348\,x^3+3105.281268\,x^2-155134.2640\,x+a\,y\cdot x$
$+1.526240791\,10^6$
$\xrightarrow{\text{évaluer à un point}}$
$-394212.9811+\frac{0.001929963100\,a\,(-394212.9811+18\,ay)}{Df^4},\ -394212.981$

$$+\frac{0.001929963100\,a\,(-394212.9811+18\,ay)}{Df^4}$$

De nouveau les constantes d'integration sont egales c=d. De plus y(0)=0 donc c=0. On determine maintenant a.

$solve\left(\{-23.00208348\,x^3+3105.281268\,x^2-155134.2640\,x+a\,y\cdot x+1.526240791\,10^6=0\},[ay]\right)$

$$\left\{\begin{array}{l} [\,] \\ \left[\left[ay=\frac{1.865320638\,10^{-17}\left(\left(1.150104174\,10^{22}\,x^3-1.552640634\,10^{24}\,x^2+7.756713200\,10^{25}\,x-7.6\right.\right.}{a\,x^2}\right.\right. \\ \left[\left[ay=\frac{7.461282551\,10^{-17}\left(5.75052087\,10^8\,x^3-7.763203170\,10^{10}\,x^2+3.878356600\,10^{12}\,x-3.815601978\right.}{a\,x^2}\right.\right. \\ \left[\left[ay=\frac{8.290313946\,10^{-14}\left(5.750520870\,10^{16}\,x^3\,Df^4-7.763203170\,10^{18}\,x^2\,Df^4+\left(3.878356600\,10^{20}\,Df\right.\right.}{a\,x}\right.\right. \end{array}\right.$$

$$\frac{1}{x}\left(4.000000000\,10^{-8}\left(5.75052087\,10^8\,x^3-7.763203170\,10^{10}\,x^2+3.878356600\,10^{12}\,x-3.815601978\,10^{13}\right)\right)$$

$\xrightarrow{\text{évaluer à un point}}$ 28059.36396

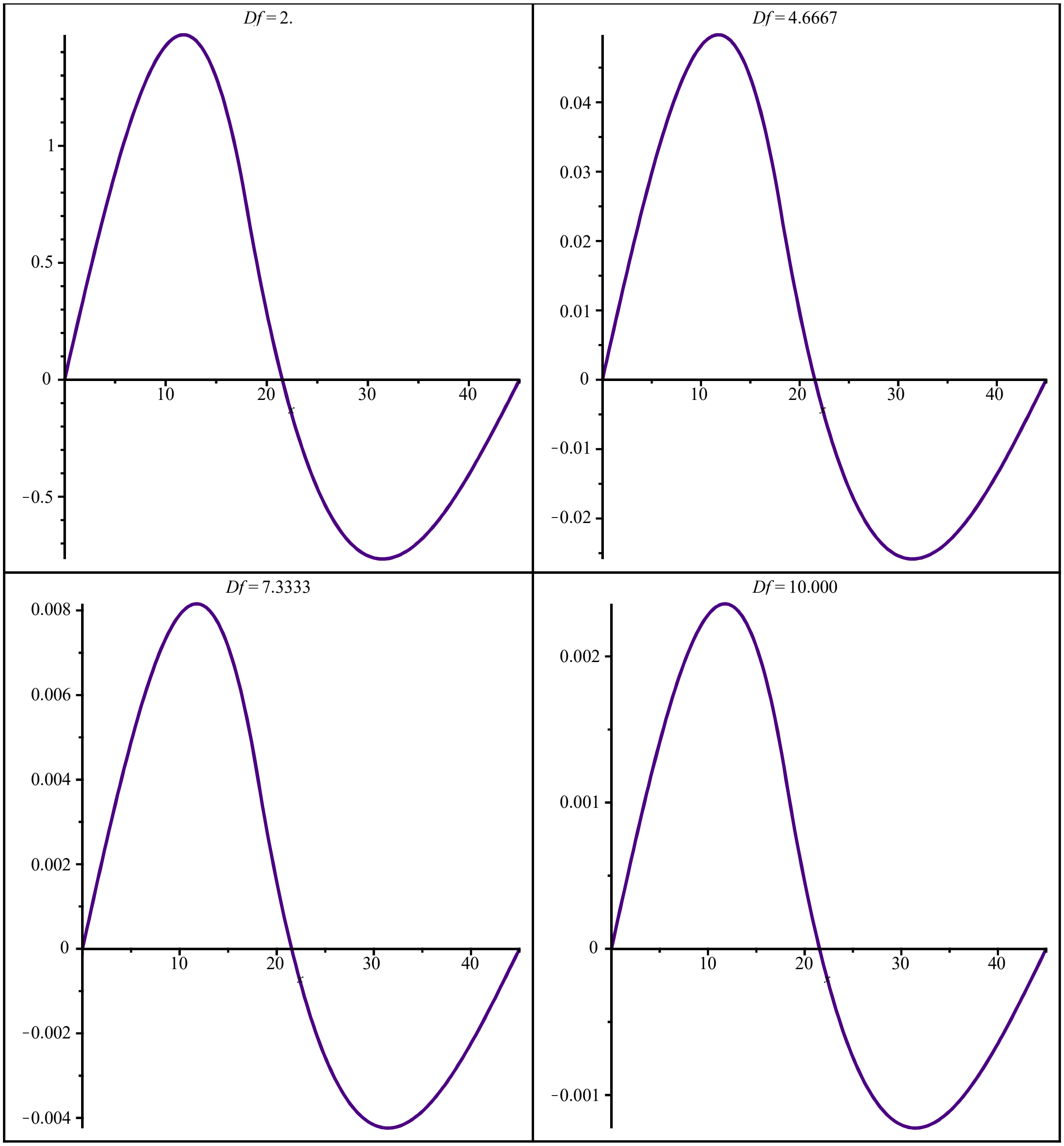
$ay := 28059.36396$

$$ay := 28059.36396 \tag{62}$$

On a alors l'expression de la fleche sur y en fonction de D:

$p := animate(plot, [y, x=0..45, color="Indigo"], Df=2..10, frames=4):$

$display(p)$



<u>Fleche selon z</u>

$$zpp := -\frac{Mfz(x)}{E \cdot Igxy}$$

$$zpp := -\frac{4\left(\begin{cases} 381.9718633\,x & 0 < x < 18 \\ -254.6479089\,x + 11459.15590 & 18 < x < 45 \end{cases}\right)}{11875\,\pi\,Df^4} \qquad \textbf{(63)}$$

$zp := int(zpp, x)$

$zp :=$ **(64)**

$$-\frac{0.0001072201722\left(\begin{cases} 0. & x \le 0. \\ 190.9859316\,x^2 & x \le 18. \\ -127.3239544\,x^2 + 11459.15590\,x - 103132.4031 & x \le 45. \\ 154698.6046 & 45. < x \end{cases}\right)}{Df^4}$$

On verifie la continuité en 18:

$$190.9859316\,x^2, -127.3239544\,x^2 + 11459.15590\,x - 103132.4031 \xrightarrow{\text{évaluer à un point}}$$

61879.44184, 61879.4419

C'est continu donc il faut avoir a=b

$$z := int\left(-\frac{0.0001072201722\left(\begin{cases} 0. + az & x \le 0. \\ 190.9859316\,x^2 + az & x \le 18. \\ -127.3239544\,x^2 + 11459.15590\,x - 103132.4031 + az & x \le 45. \\ 154698.6046 + az & 45. < x \end{cases}\right)}{Df^4}, x\right)$$

$$z :=$$

$$-\frac{1}{Df^4}\left(0.0001072201722\left(\begin{cases} az\,x \\ 63.66197720\,x^3 + az\,x \\ -42.44131813\,x^3 + 5729.577950\,x^2 - 103132.4031\,x + az\,x + 618794.4184 \\ (154698.6046 + az)\,x - 3.248670694\;10^6 \end{cases}\right.\right.$$

$$\Bigg)\Bigg)$$

$63.66197720\,x^3 + az\,x, -42.44131813\,x^3 + 5729.577950\,x^2 - 103132.4031\,x + az\,x + 618794.4184$

$\xrightarrow{\text{évaluer à un point}} 371276.6510 + 18\,az, 371276.6514 + 18\,az$

On a alors c=d et c=0 condition en 0, on trouve maintenant a:

$solve(\{-42.44131813\,x^3 + 5729.577950\,x^2 - 103132.4031\,x + az\,x + 618794.4184\}, [az])$

$$\left[\left[az = \frac{1}{x}\left(1.000000000\ 10^{-8}\left(4.244131813\ 10^{9}\,x^3 - 5.729577950\ 10^{11}\,x^2 + 1.031324031\ 10^{13}\,x - 6.187944184\ 10^{13}\right)\right)\right]\right] \quad \textbf{(66)}$$

$\frac{1}{x}\left(1.000000000\ 10^{-8}\left(4.244131813\ 10^{9}\,x^3 - 5.729577950\ 10^{11}\,x^2 + 1.031324031\ 10^{13}\,x - 6.187944184\ 10^{13}\right)\right)$

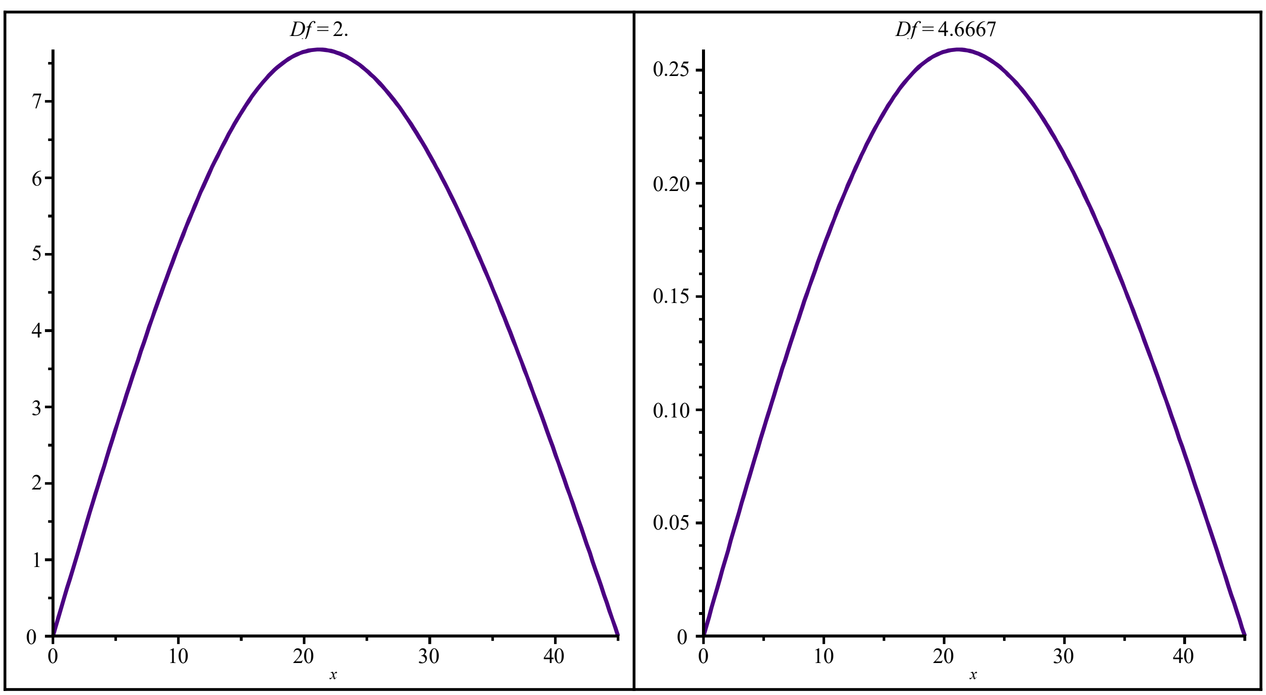
$\xrightarrow{\text{évaluer à un point}} -82505.92251$

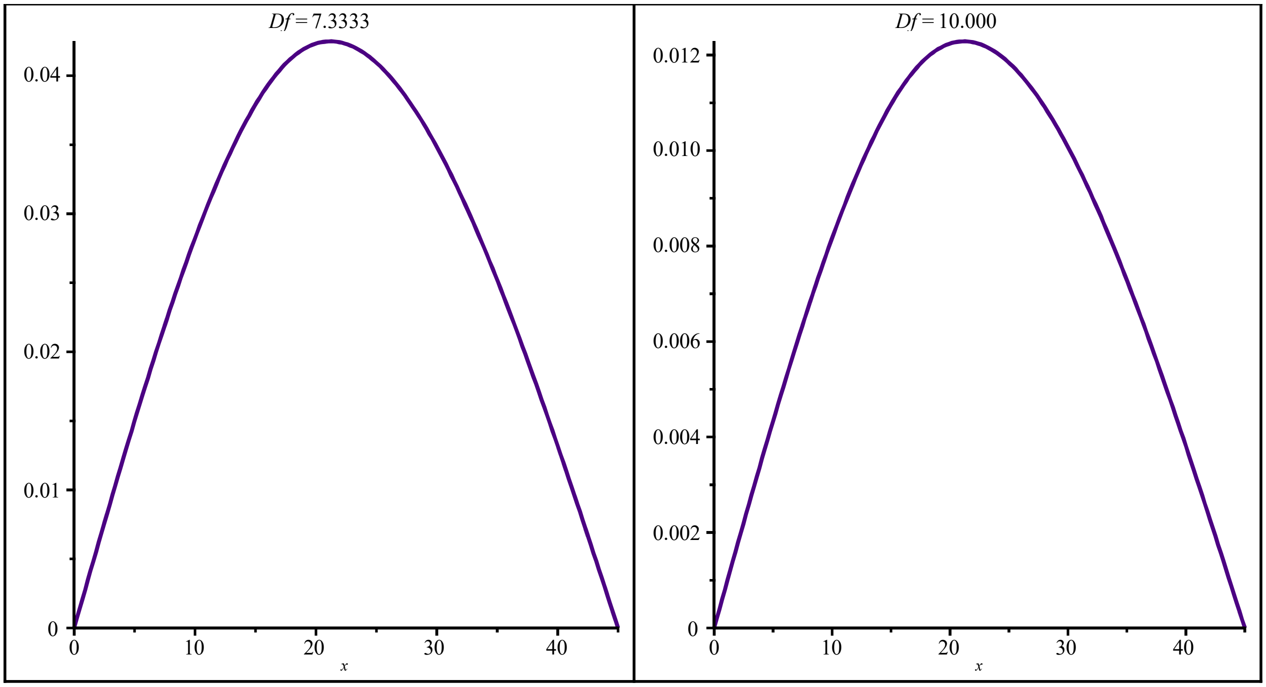
$az := -82505.92251$

$$az := -82505.92251 \quad \textbf{(67)}$$

$p := animate(plot, [z, x = 0..45, color = \text{"Indigo"}], Df = 2..10, frames = 4):$

$display(p)$





On evalue maintenant la fleche globale :

$$fp := \sqrt{yp^2 + zp^2}$$

$$fp := \quad \textbf{(68)}$$

$$\left(\frac{1}{Df^8} \left(1.149616533\ 10^{-8} \right.\right.$$

$$\left(\left(\begin{cases} -202.7844553\,x^2 + 28059.36396 & 0 < x < 18 \\ -69.00625045\,x^2 + 6210.562537\,x - 127074.9000 & 18 < x < 45 \end{cases} \right)^2 \right)$$

$$+ \frac{1}{Df^8} \left(1.149616533\ 10^{-8} \right.$$

$$1/2$$

$$\left. \left(\left(\begin{cases} 0. & x \leq 0. \\ 190.9859316\ x^2 & x \leq 18. \\ -127.3239544\ x^2 + 11459.15590\ x - 103132.4031 & x \leq 45. \\ 154698.6046 & 45. < x \end{cases} \right)^2 \right) \right)$$

$f := \sqrt{y^2 + z^2}$

$$f := \qquad \mathbf{(69)}$$

$$\left(\frac{1}{Df^8} \left(1.149616533\ 10^{-8} \right. \right.$$

$$\left(\left(\begin{cases} 0. & x \leq 0. \\ -67.59481843\ x^3 + 28059.36396\ x & x \leq 18. \\ -23.00208348\ x^3 + 3105.281268\ x^2 - 127074.9000\ x + 1.526240791\ 10^6 & x \leq 45. \\ 0. & 45. < x \end{cases} \right. \right.$$

$$\left. \left. \right)^2 \right)$$

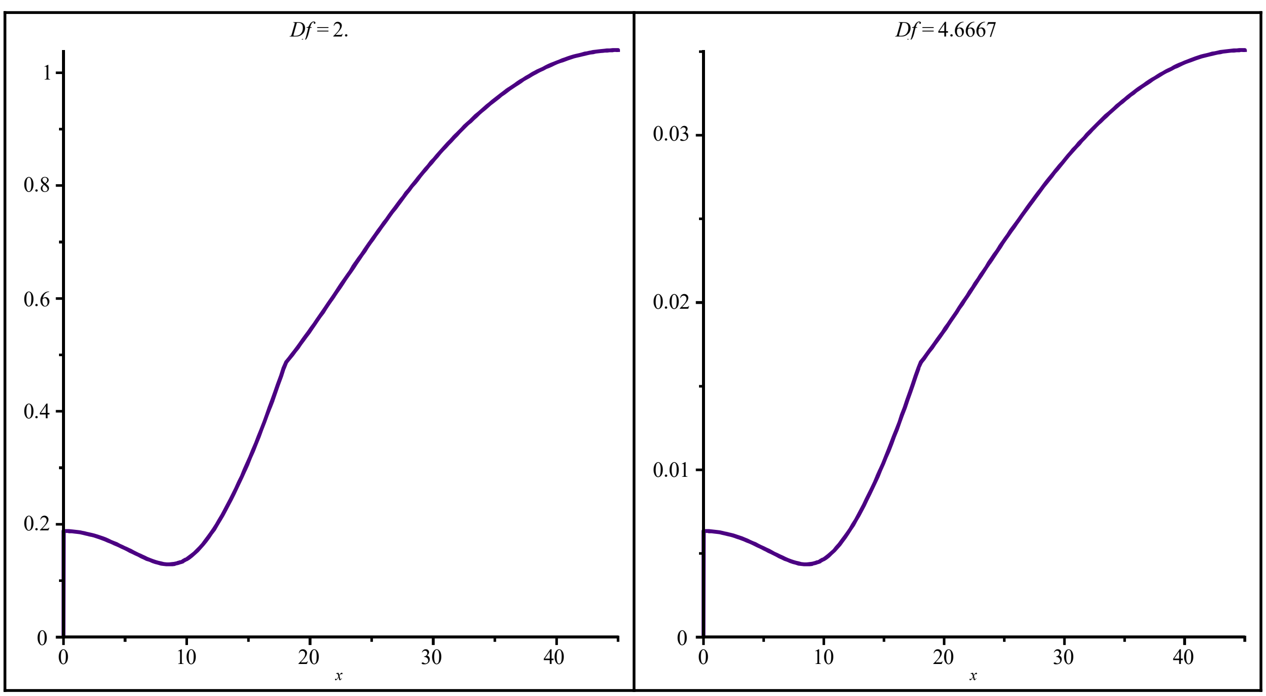
$$+\frac{1}{Df^{8}}\left(1.149616533\ 10^{-8}\right.$$

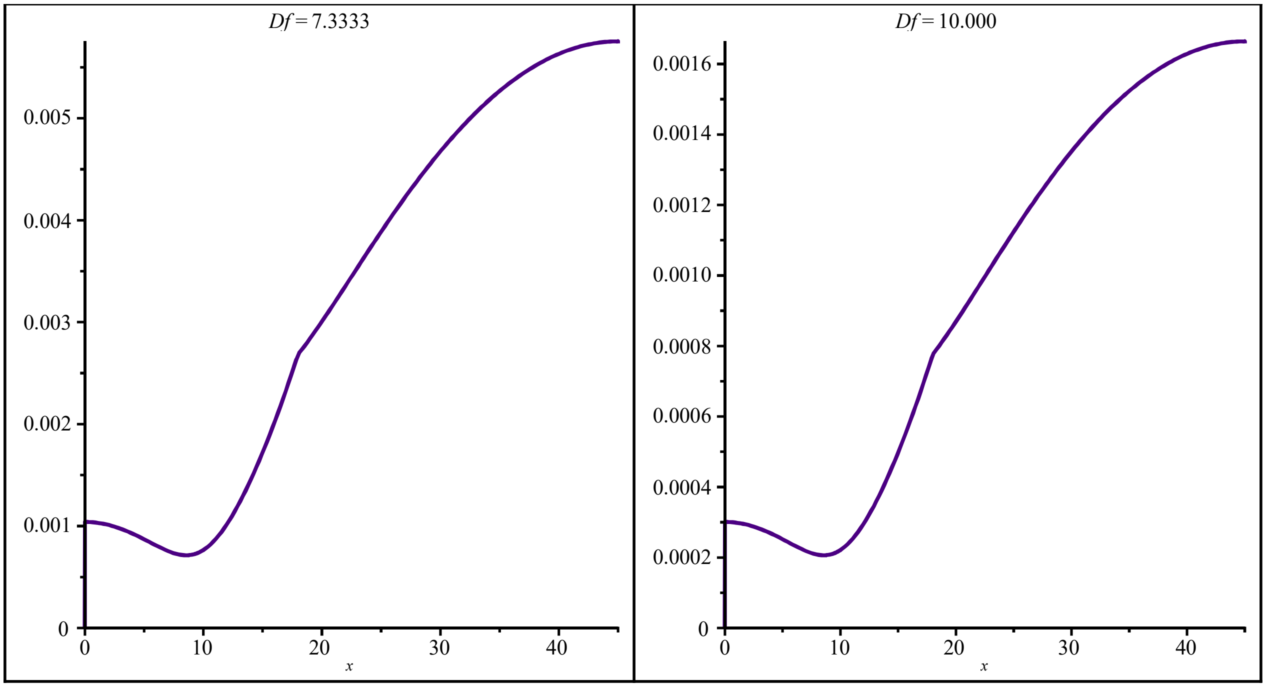
$$\left(\left(\begin{cases} -82505.92251\,x & x \leq 0. \\ 63.66197720\,x^{3} - 82505.92251\,x & x \leq 18. \\ -42.44131813\,x^{3} + 5729.577950\,x^{2} - 185638.3256\,x + 618794.4184 & x \leq 45. \\ 72192.68209\,x - 3.248670694\ 10^{6} & 45. < x \end{cases}\right)^{2}\right)$$

$$1/2$$

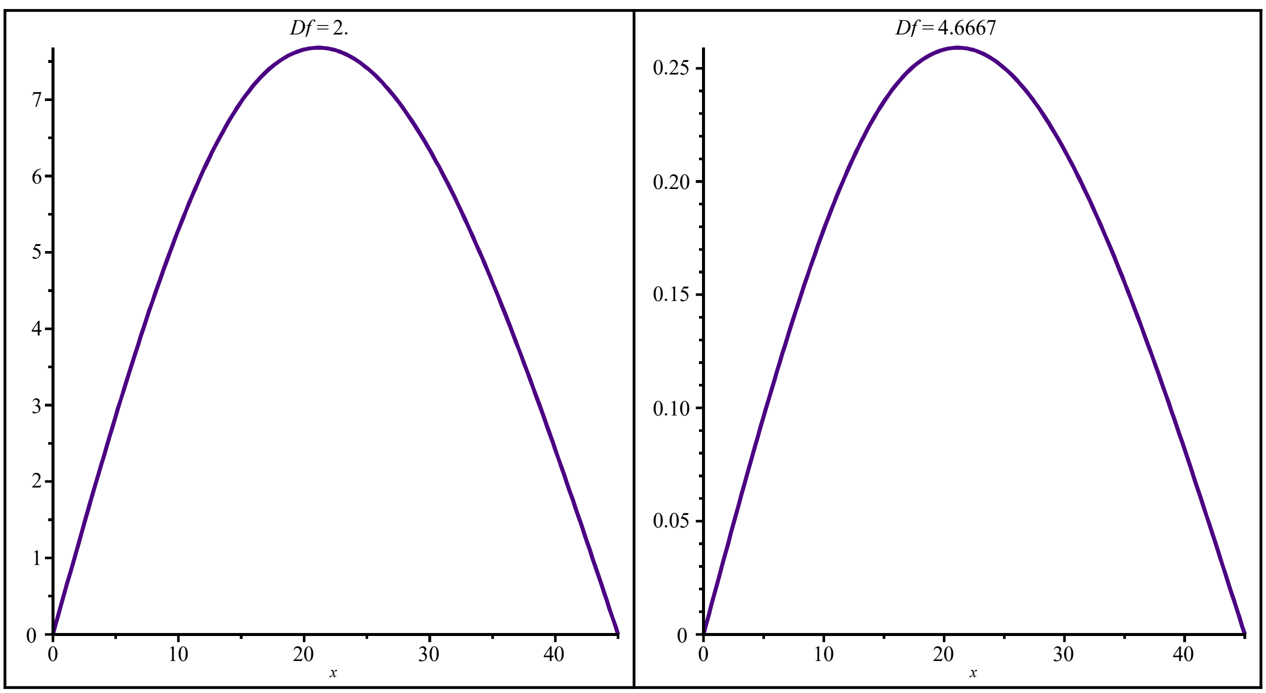
$$\left.\right)$$

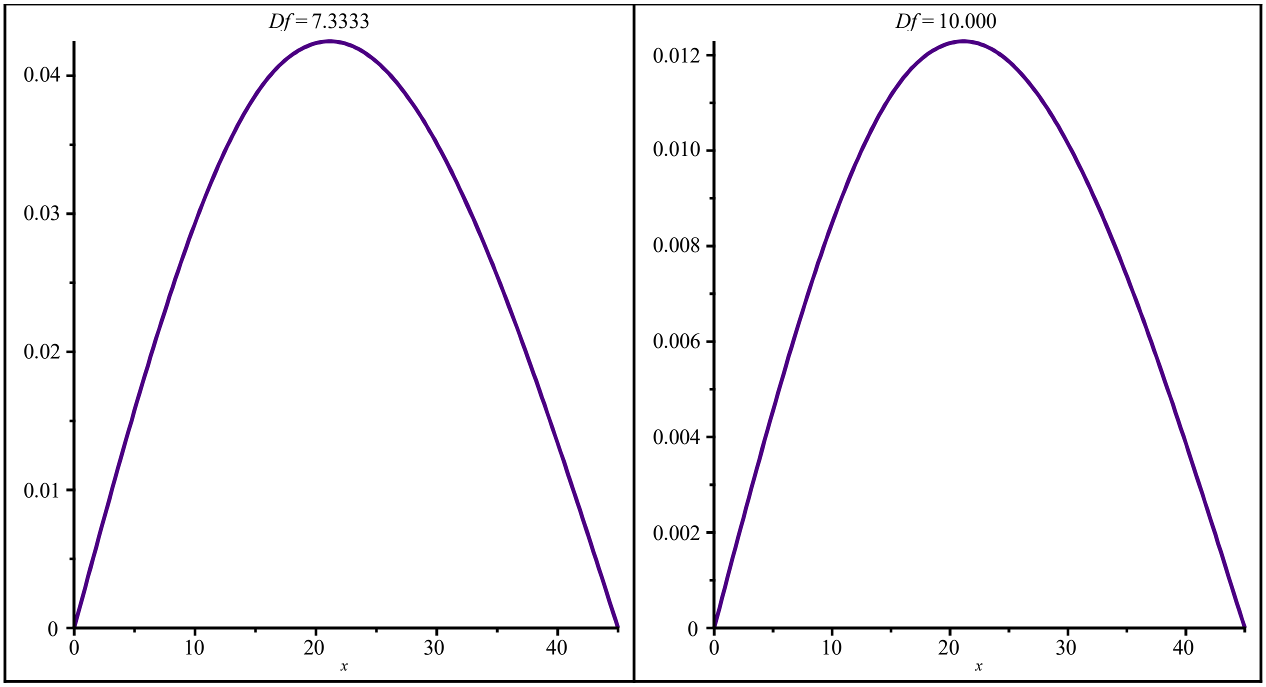
$p := animate(plot, [fp, x = 0 ..45, color = \text{"Indigo"}], Df = 2 ..10, frames = 4) :$
$display(p)$






```
p := animate(plot, [f, x = 0 ..45, color = "Indigo"], Df = 2 ..10, frames = 4) :
display(p)
```





On evalue maintenant le maximum et de la fleche :

$$solve\left(\left\{eval(f, x=21) = \frac{L}{3000}\right\}, [Df], maxsols=1\right) \text{assuming } Df :: positive$$

$$[[Df = 9.513551126]] \tag{70}$$

Pour la fleche max il faut Df >9.5mm

On evalue le max de la pente (1/500 pour roues larges et 1/1500 pour roues etroites --> je pense qu'elles sont large mais pas sur)

$$solve\left(\left\{eval(fp, x=21) = \frac{1}{500}\right\}, [Df], maxsols=1\right) \text{assuming } Df :: positive$$

$$[[Df = 8.234173018]] \tag{71}$$

Il faut Df>8.2mm

On evalue la pente dans les roulements. Il faut un angle inferieur a 3deg (ie f'<tan 3deg =0.05)

$$solve(\{eval(fp, x=0.01) = 0.05\}, [Df], maxsols=1) \text{assuming } Df :: positive$$

$$[[Df = 2.785133398]] \tag{72}$$

<u>On a completement determiné notre arbre</u> !

Le critere le plus limitant est le la fleche max qui impose Df>9.5mm