

Lancer avec frottement fluide laminaire

On prépare les vecteurs

$tt := \text{Array}(1..101, \text{datatype} = \text{float}[8])$

$$\left[\begin{array}{l} 1..101 \text{ Array} \\ \text{Data Type: float}_8 \\ \text{Storage: rectangular} \\ \text{Order: Fortran_order} \end{array} \right] \quad (1)$$

$xx := \text{Array}(1..101, \text{datatype} = \text{float}[8])$

$$\left[\begin{array}{l} 1..101 \text{ Array} \\ \text{Data Type: float}_8 \\ \text{Storage: rectangular} \\ \text{Order: Fortran_order} \end{array} \right] \quad (2)$$

$zz := \text{Array}(1..101, \text{datatype} = \text{float}[8])$

$$\left[\begin{array}{l} 1..101 \text{ Array} \\ \text{Data Type: float}_8 \\ \text{Storage: rectangular} \\ \text{Order: Fortran_order} \end{array} \right] \quad (3)$$

On pose $\kappa = k/m$

$$\text{equax} := \frac{d}{dt} \left(\frac{d}{dt} x(t) \right) + \kappa \frac{d}{dt} x(t) = 0$$

$$\frac{d^2}{dt^2} x(t) + \kappa \left(\frac{d}{dt} x(t) \right) = 0 \quad (4)$$

$$\text{equaz} := \frac{d}{dt} \left(\frac{d}{dt} z(t) \right) + \kappa \frac{d}{dt} z(t) = -g$$

$$\frac{d^2}{dt^2} z(t) + \kappa \left(\frac{d}{dt} z(t) \right) = -g \quad (5)$$

$\text{sysEqua} := \text{equax}, \text{equaz}$

$$\frac{d^2}{dt^2} x(t) + \kappa \left(\frac{d}{dt} x(t) \right) = 0, \frac{d^2}{dt^2} z(t) + \kappa \left(\frac{d}{dt} z(t) \right) = -g \quad (6)$$

$$v0x := v0 \cos(\alpha)$$

$$v0 \cos(\alpha) \quad (7)$$

$$v0z := v0 \sin(\alpha)$$

$$v0 \sin(\alpha) \quad (8)$$

$$g := 9.81 \qquad \qquad \qquad 9.81 \qquad \qquad \qquad (9)$$

$$v0 := 10 \qquad \qquad \qquad 10 \qquad \qquad \qquad (10)$$

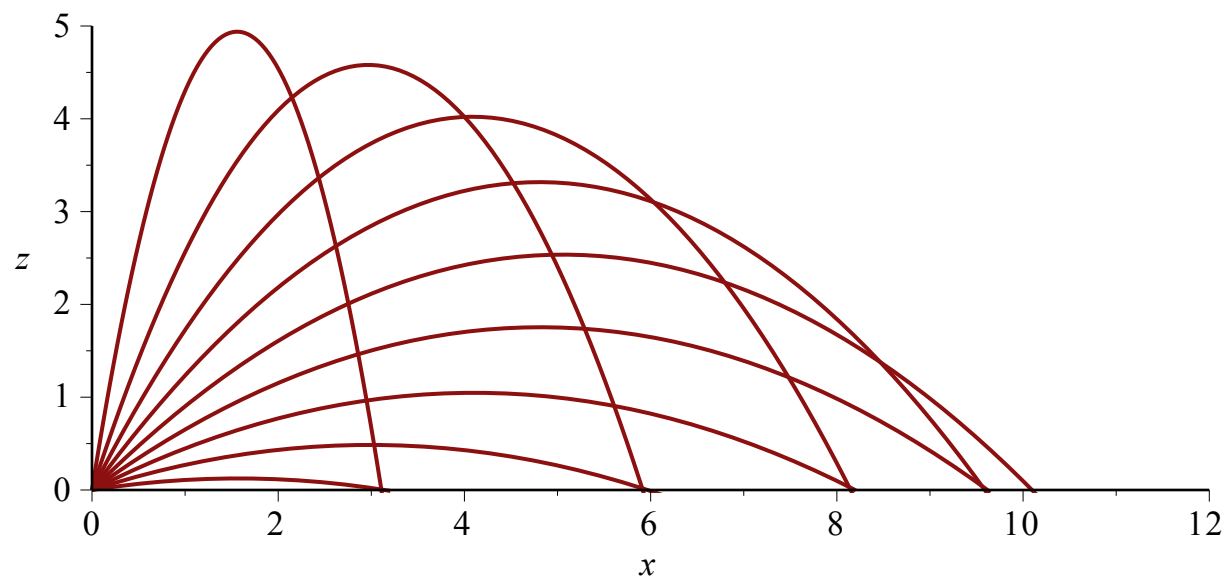
$$\kappa := 30.0 \qquad \qquad \qquad 30.0 \qquad \qquad \qquad (11)$$

$$plts := [] \qquad \qquad \qquad [] \qquad \qquad \qquad (12)$$

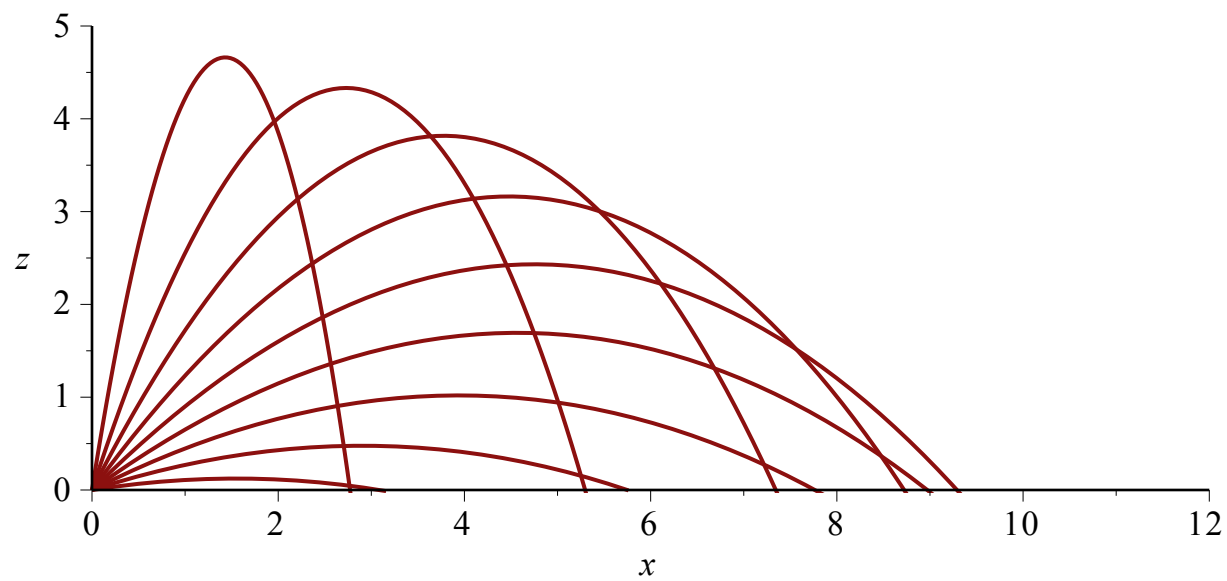
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for kk from 1 to 9 do
   $\alpha := evalf\left(\frac{kk \cdot \pi}{20}\right);$ 
  icond := x(0) = 0, z(0) = 0, D(x)(0) = v0 cos( $\alpha$ ), D(z)(0) = v0 sin( $\alpha$ );
  posit := dsolve([sysEqua, icond], numeric);
  for nn from 1 to 101 do
    tt := 0.025 · (nn − 1);
    tt[nn] := tt;
    ppp := posit(tt);
    xx[nn] := rhs(ppp[2]);
    zz[nn] := rhs(ppp[4]);
  end do;
  plts := [op(plts), plot(xx, zz, x = 0 .. 0.5, z = 0 .. 0.4)];
end do;
plots[display](plts, scaling = constrained)    #  $\kappa=0.01$ 

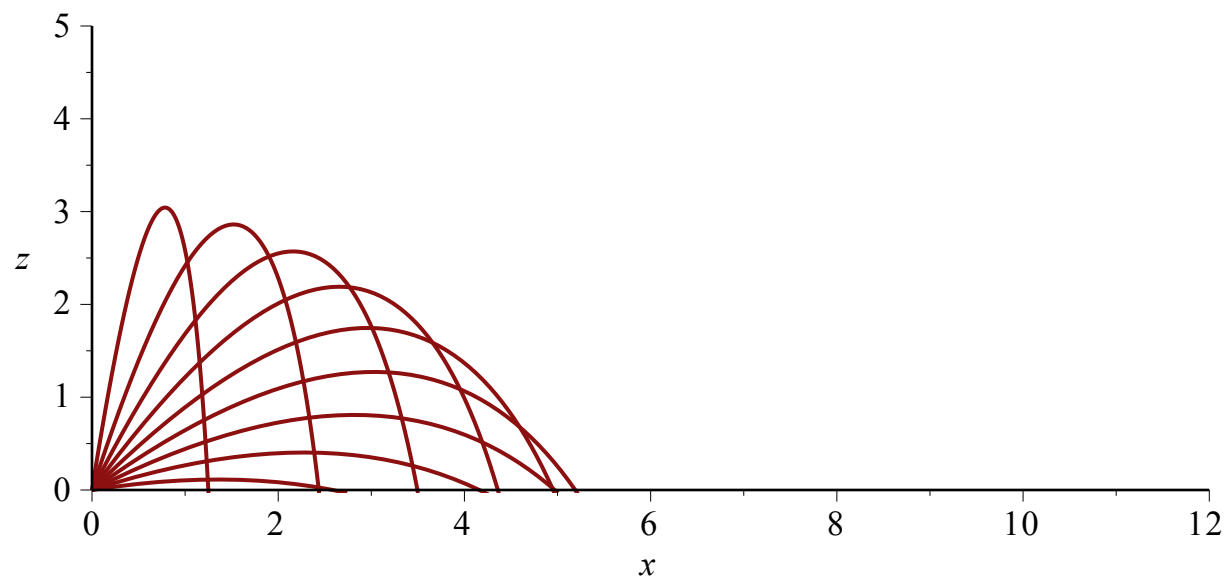
```



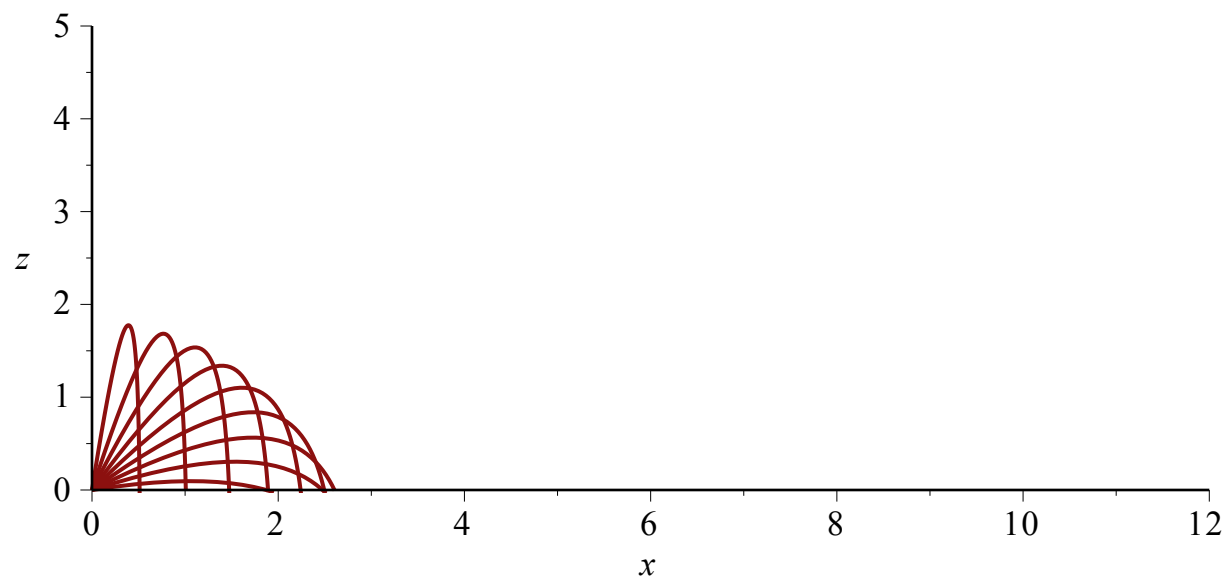
plots[display](plts, scaling = constrained) # $\kappa=0.1$



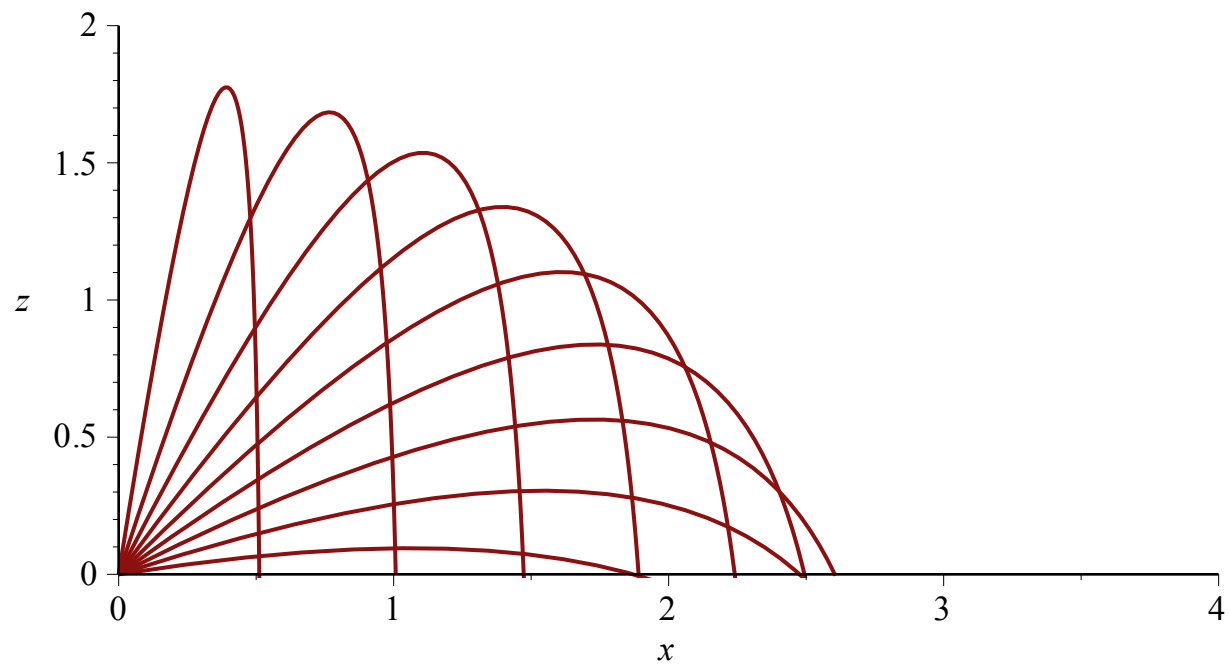
plots[display](plts, scaling = constrained) # $\kappa=1.0$



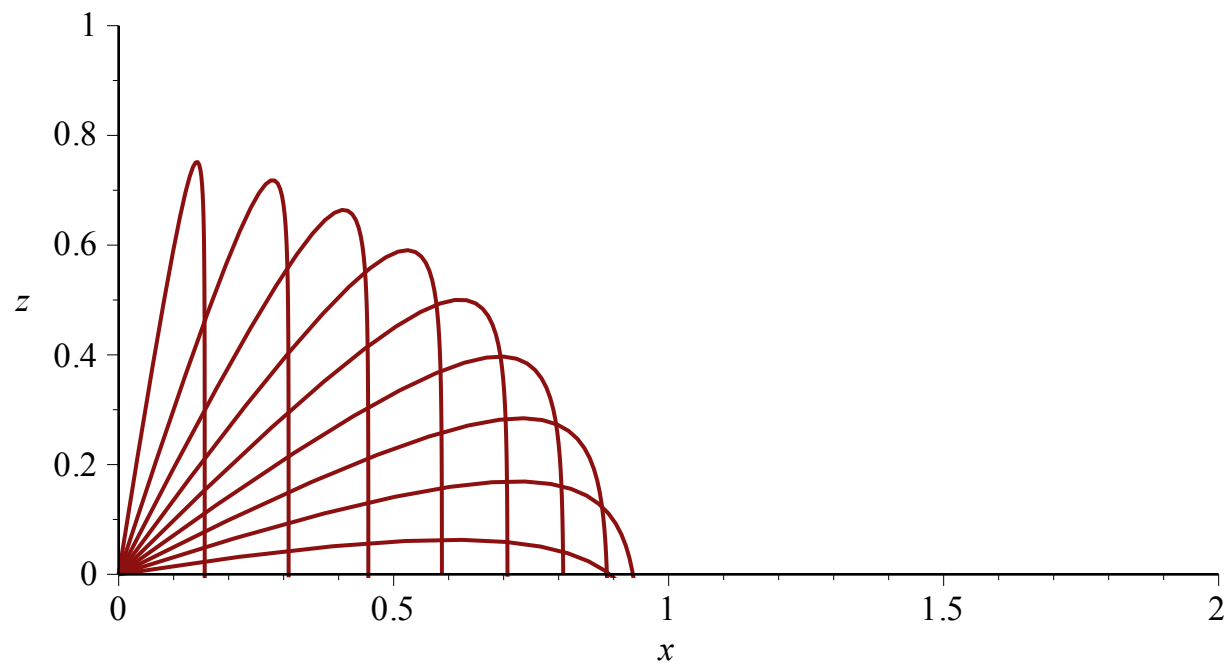
`plots[display](plts, scaling = constrained)` `# κ=3.0`



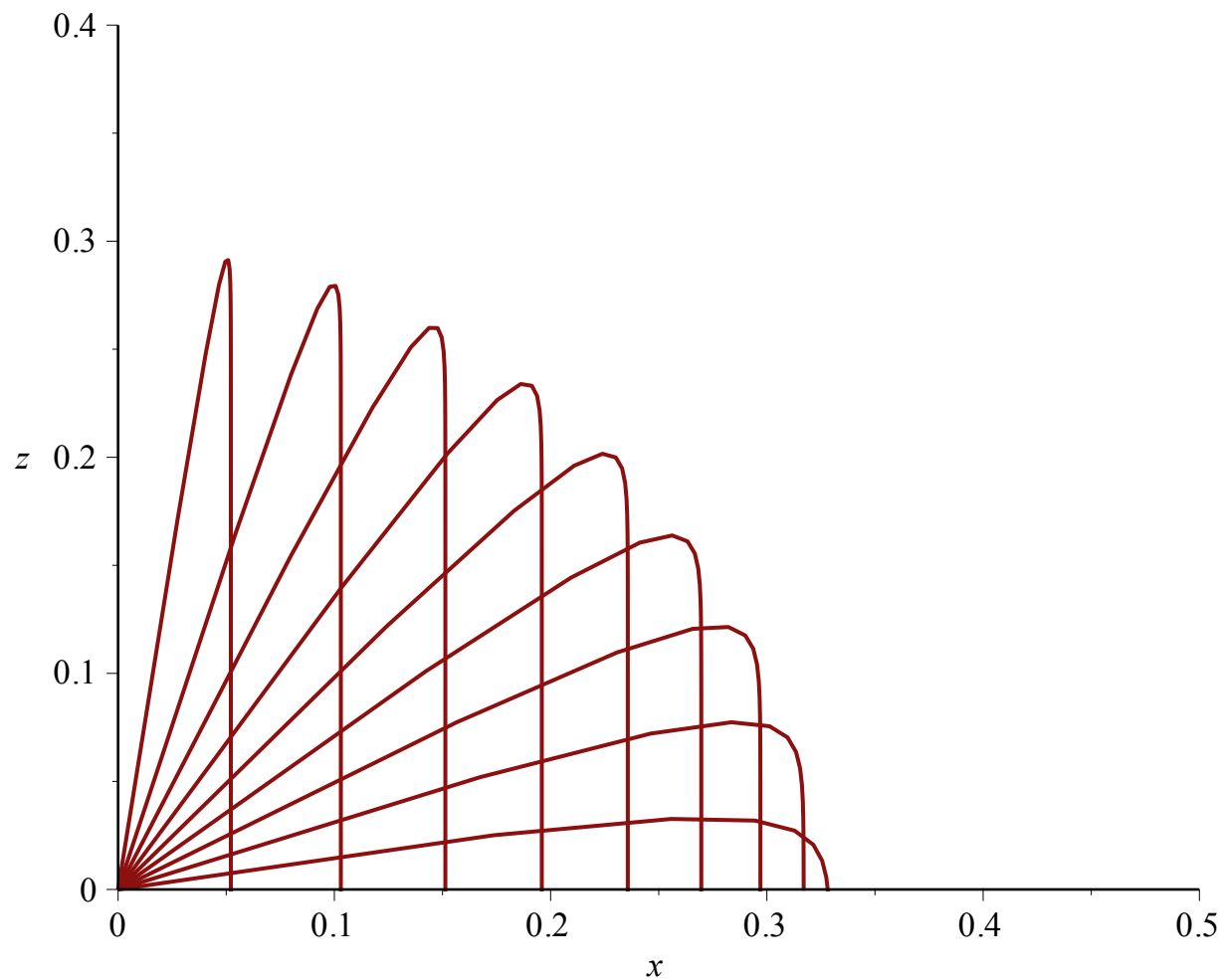
`plots[display](plts, scaling = constrained) # $\kappa=3.0$ (zoom)`



`plots[display](plts, scaling = constrained) # $\kappa=10.0$ (zoom)`



`plots[display](plts, scaling = constrained)` $\# \kappa=30.0$ (zoom)



Plus le frottement est important :

- plus les distances atteintes sont faibles ;
- plus la portée limite est approchée avec un angle de lancer faible ;
- plus le mouvement semble se séparer en deux étapes : mouvement rectiligne ralenti, puis chute libre verticale ;
- plus la courbe de sureté se rapproche d'un cercle.