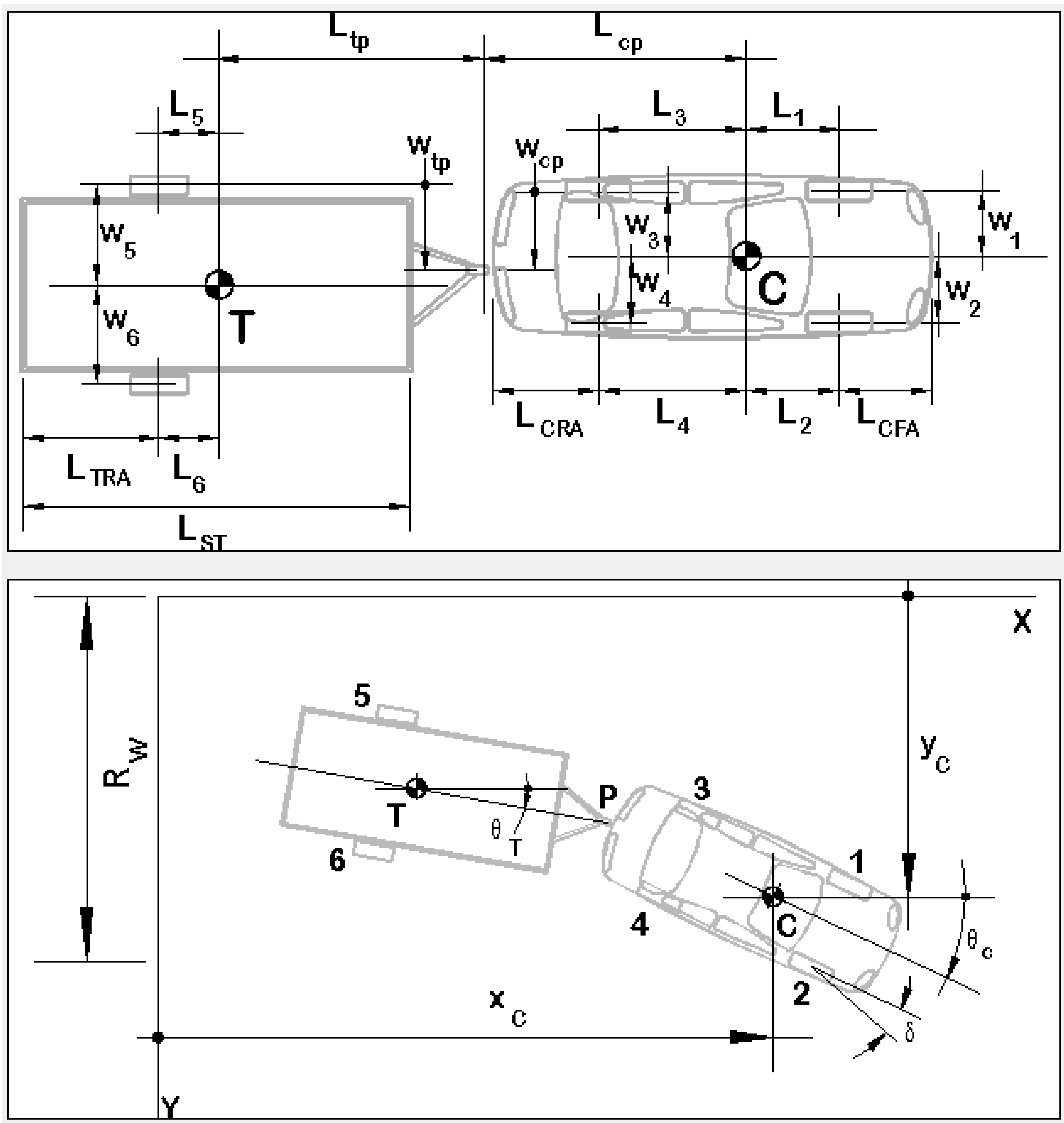
Articulated Vehicle Planar Simulation

Simulate the Planar Motion of an articulated vehicle in time

VXPhysics.com

Layout of Physical Variables



Brach & Brach ***Vehicle Accident Analysis and Reconstruction Methods - Fig.13.1***

Articulated Vehicle Planar Simulation

Input Variables

For Definitions of Variables Refer to Brach & Brach *Vehicle Accident Analysis and Reconstruction Methods,* 13.5 Appendix: Differential Equations of Planar Vehicle Motion

$$\begin{pmatrix} W_c & J_c \\ L_1 & L_2 \\ L_3 & L_4 \\ W_1 & W_2 \\ W_3 & W_4 \\ L_{cp} & W_{cp} \\ h_c & h_{cx} \\ C_{a1} & C_{a2} \\ C_{a3} & C_{a4} \\ C_{s1} & C_{s2} \\ C_{s3} & C_{s4} \\ s_1 & s_2 \\ s_3 & s_4 \\ C_{t1} & C_{t2} \\ C_{t3} & C_{t4} \\ X_{c0} & V_{xc0} \\ Y_{c0} & V_{yc0} \\ \theta_{c0} & \theta_{vc0} \\ \delta & g \end{pmatrix} := \begin{pmatrix} 3000 & 1900 \\ 3.75 & 3.75 \\ 4.58 & 4.58 \\ 2.5 & 2.5 \\ 2.5 & 2.5 \\ 3 & 0 \\ 1 & 0 \\ 8800 & 8800 \\ 8100 & 8100 \\ 10000 & 10000 \\ 10000 & 10000 \\ 0 & 0 \\ 0.007 & 0.007 \\ 0 & 0 \\ 0 & 0 \\ 0 & 73.3 \\ 0 & 0 \\ 0 & 0 \\ 0 & 32.17 \end{pmatrix} \begin{matrix} W.c & J.c \\ L.1 & L.2 \\ L.3 & L.4 \\ W.1 & W.2 \\ W.3 & W.4 \\ L.cp & W.cp \\ h.c & h.cx \\ C.a1 & C.a2 \\ C.a3 & C.a4 \\ C.s1 & C.s2 \\ C.s3 & C.s4 \\ s.1 & s.2 \\ s.3 & s.4 \\ C.t1 & C.t2 \\ C.t3 & C.t4 \\ X.c0 & V.xc0 \\ Y.c0 & V.yc0 \\ \theta.c0 & \theta.vc0 \\ \delta & g \end{matrix}$$

$$\begin{pmatrix} W_t & J_t \\ L_3 & L_4 \\ W_5 & W_6 \\ L_{tp} & W_{tp} \\ h_t & h_{tx} \\ C_{a5} & C_{a6} \\ C_{s5} & C_{s6} \\ s_5 & s_6 \\ C_{t5} & C_{t6} \\ \theta t0 & \theta_{vt0} \end{pmatrix} := \begin{pmatrix} 1900 & 0 \\ 2 & 2 \\ 3.7 & 3.7 \\ 6.5 & 3.7 \\ 0.5 & 0 \\ 9200 & 9200 \\ 10000 & 10000 \\ 0 & 0 \\ 0 & 0 \\ 0 & 40 \end{pmatrix} \begin{matrix} W.t & J.t \\ L.3 & L.4 \\ W.5 & W.6 \\ L.tp & W.tp \\ h.t & h.tx \\ C.a5 & C.a6 \\ C.s5 & C.s6 \\ s.5 & s.6 \\ C.t5 & C.t6 \\ \theta t0 & \theta.vt0 \end{matrix}$$

$m_c := \frac{W_c}{g}$ $\quad m_t := \frac{W_t}{g}$ $\quad F_{cx} := 0$ $\quad F_{xy} := 0$ $\quad f := 0.7$ $\quad F_{xx} := \sum_{n=1}^{6} f_{ix}$

$m_{bar} := \frac{m_c \cdot m_t}{m_c + m_t}$ $\quad m_{ct} := m_c + m_t$

$F_{cx} := f \cdot m_c$ $\quad F_{cy} := 0$

$F_{ty} := 0$ $\quad F_{tx} := f \cdot m_t$

$t_e := 2$ $\quad FRAME := 100$

$t_1 := \frac{t_e}{100} \cdot (FRAME + 1)$ $\quad t_1 = 2.02$

Derivative Symbol Ctrl+F7

Differential Equations of Motion of Vehicles

$R_{cp} := \sqrt{{L_{cp}}^2 + \left(W_3 - W_{cp}\right)^2}$

$R_{tp} := \sqrt{{L_{tp}}^2 + \left(W_{tp} - W_5\right)^2}$

$\theta_{cp}(\theta) := \frac{\pi}{2} - \theta - \operatorname{atan}\left[\frac{\left(W_3 - W_{cp}\right)}{L_{cp}}\right]$

$\theta_{tp}(\theta) := \frac{\pi}{2} - \theta - \operatorname{atan}\left[\frac{\left(W_{tp} - W_5\right)}{L_{tp}}\right]$

$r_{tpx}(\theta) := -L_{tp}\cdot\sin(\theta) - \left(W_{tp} - W_5\right)\cos(\theta)$

$r_{tpy}(\theta) := L_{tp}\cdot\cos(\theta) - \left(W_{tp} - W_5\right)\sin(\theta)$

$r_{cpx}(\theta) := L_{cp}\cdot\sin(\theta) + \left(W_3 - W_{cp}\right)\cos(\theta)$

$r_{tpx}(\theta) := -L_{cp}\cdot\sin(\theta) - \left(W_{tp} - W_5\right)\cos(\theta)$

$r_{cpy}(\theta) := -L_{cp}\cdot\cos(\theta) + \left(W_3 - W_{cp}\right)\cos(\theta)$

Given

$Xc(0) = X_{c0}$ $Xc'(0) = V_{xc0}$ $Yc(0) = Y_{c0}$ $Yc'(0) = V_{yc0}$ $\theta c(0) = \theta_{c0}$ $\theta c'(0) = 0$ $\theta t(0) = ($ $\theta t'(0) = 0$

$$m_{ct}\cdot Xc''(t) = -m_t\cdot\left[-\left(R_{cp}\cdot\theta c''(t)\right)\cos\left(\theta_{cp}(\theta c(t))\right) + R_{cp}\cdot\left(-2\,\theta_{cp}(\theta c(t))\right)\theta c'(t)\sin\left(\theta_{cp}(\theta c(t))\right) + R_{tp}\cdot\theta t''(t)\cos\left(\theta_{tp}(\theta t(t))\right)\right] \ldots$$
$$+ m_t\cdot R_{tp}\cdot 2\,\theta t(t)\,\theta t'(t)\sin\left(\theta_{tp}(\theta t(t))\right) + F_{cx} + F_{tx}$$

$$m_{ct}\cdot Yc''(t) = -m_t\cdot\left(-R_{cp}\cdot\theta c''(t)\sin\left(\theta_{cp}(\theta c(t))\right) + R_{cp}\cdot 2\,\theta c(t)\,\theta c'(t)\cos\left(\theta_{cp}(\theta c(t))\right) - R_{tp}\cdot\theta t''(t)\sin\left(\theta_{tp}(\theta t(t))\right)\right) \ldots$$
$$+ m_t\cdot R_{tp}\cdot 2\,\theta t(t)\,\theta t'(t)\cos\left(\theta_{tp}(\theta t(t))\right) + F_{cy} + F_{ty}$$

$$\left[J_c + m_{bar}\cdot R_{cp}\cdot\left(r_{cpx}(\theta c(t))\cdot\cos\left(\theta_{cp}(\theta c(t))\right) - r_{cpy}(\theta c(t))\cdot\sin\left(\theta_{cp}(\theta c(t))\right)\right)\right]\theta c''(t) = f\cdot m_{bar}$$

$$\left[J_t + m_{bar}\cdot R_{tp}\cdot\left(r_{tpy}(\theta t(t))\cdot\sin\left(\theta_{tp}(\theta t(t))\right) - r_{tpy}(\theta t(t))\cdot\cos\left(\theta_{tp}(\theta t(t))\right)\right)\right]\theta t''(t) = f\cdot m_{bar}$$

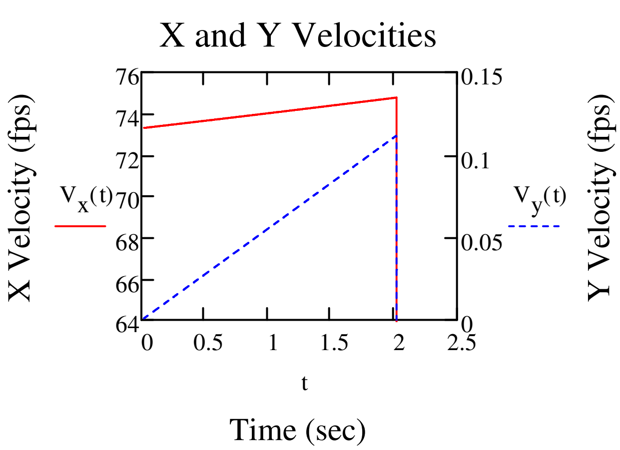
$$\begin{pmatrix} Xc \\ Yc \\ \theta c \\ \theta t \end{pmatrix} := \operatorname{Odesolve}\left[\begin{pmatrix} Xc \\ Yc \\ \theta c \\ \theta t \end{pmatrix}, t, t_1\right]$$

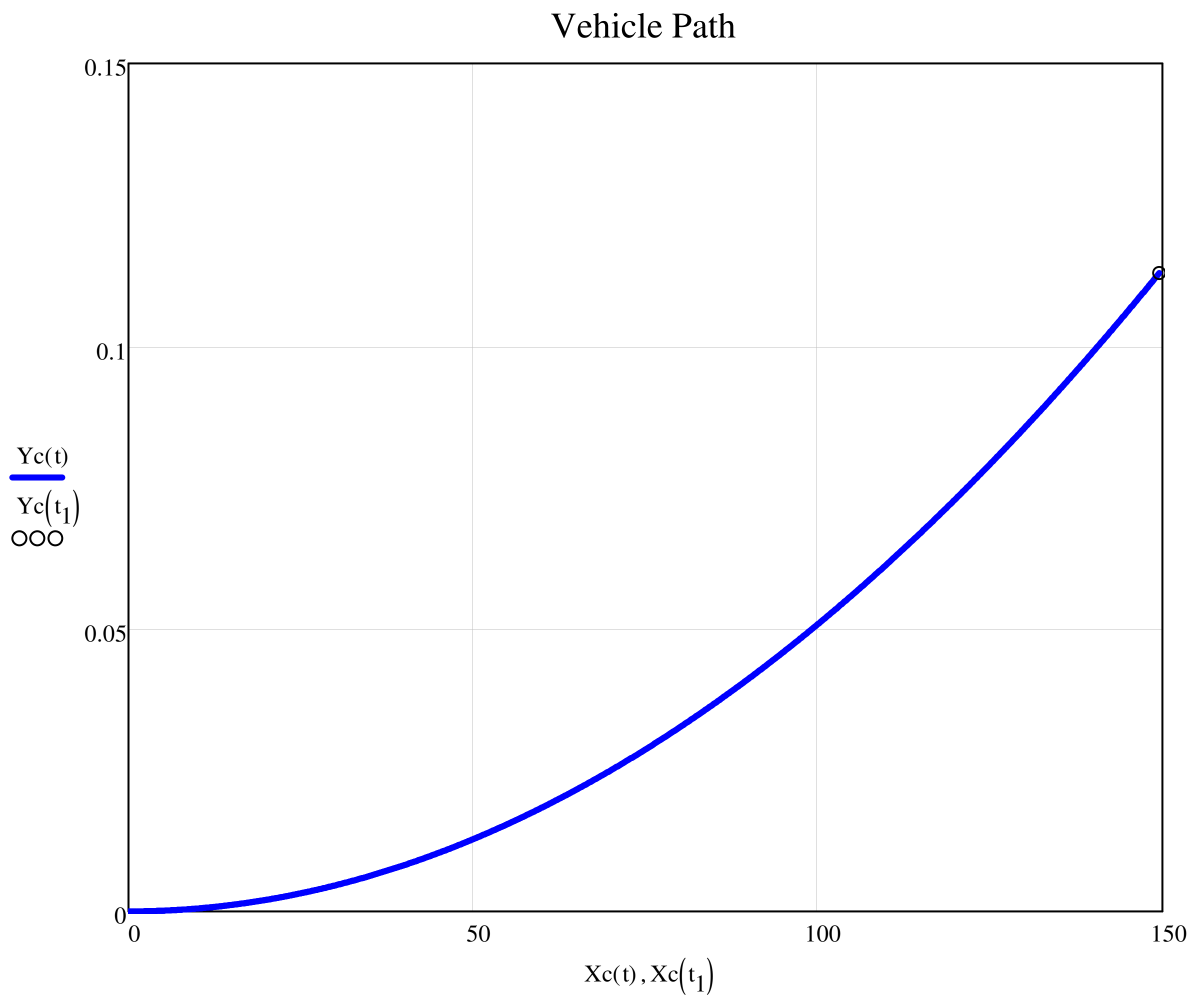
$n := 0..20$ $tt_n := n\cdot 0.1$

$V_x(t) := \frac{d}{dt}Xc(t)$ $V_y(t) := \frac{d}{dt}Yc(t)$ $V_x(1) = 74.023$

$X_n := Xc\left(tt_n\right)$ $Y_n := Yc\left(tt_n\right)$ $V_{yy_n} := V_y\left(tt_n\right)$ $\theta_{c_n} := \theta c\left(tt_n\right)$ $\theta_{t_n} := \theta t\left(tt_n\right)$

$Output := \operatorname{augment}\left(tt, X, [illegible], Y, \theta_c, \theta_t\right)$





Vehicle Path
0.15
0.1
0.05
0
Yc(t)
Yc(t1)
0
50
100
150
Xc(t), Xc(t1)

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