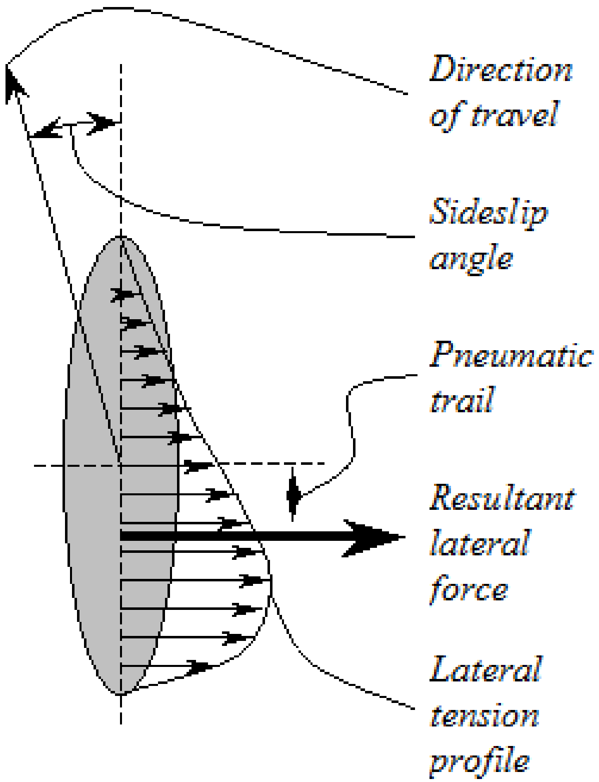
Pneu 145/60 R13 66 T

Spécification pneu:	145	/	60	R	13	66	T
Spécification jante	13	"					
Diamètre jante	330.2	mm					
Hauteur de flanc de pneu	87	mm					
Diamètre du pneu	504.2	mm					
Rayon du pneu	252.1	mm					
Lareur du pneu	145	mm					

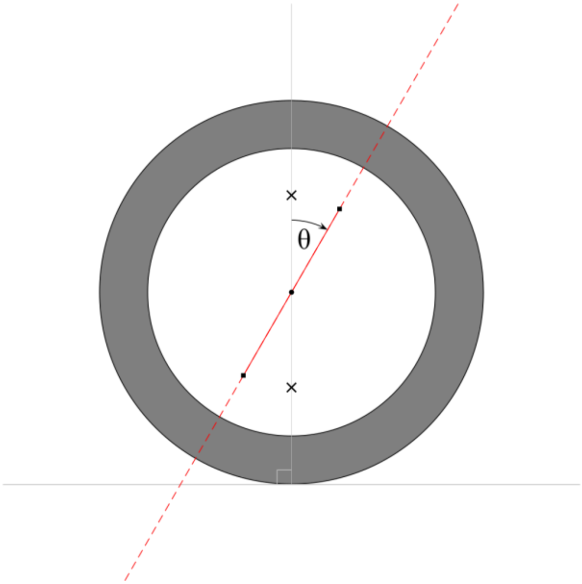
Tire contact patch length: méthode décrite dans papier.
Valeur à la louche: 0.10 m

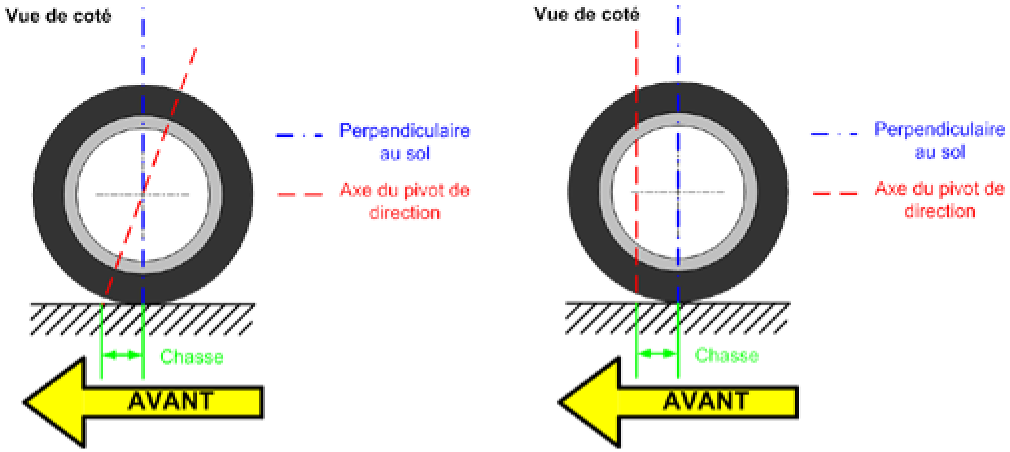
Pneumatic Trail:

Valeurs typique entre 0.01 et 0.03
Valeur considérée: 0.02



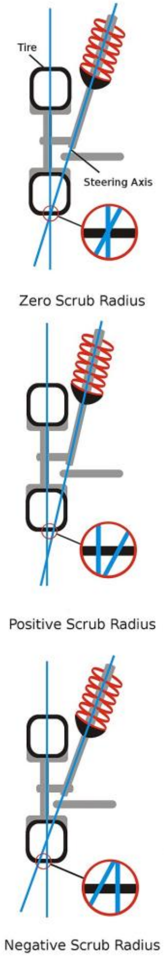
Caster angle (angle de chasse) : Valeur prise : 5 degré





https://en.wikipedia.org/wiki/Caster_angle

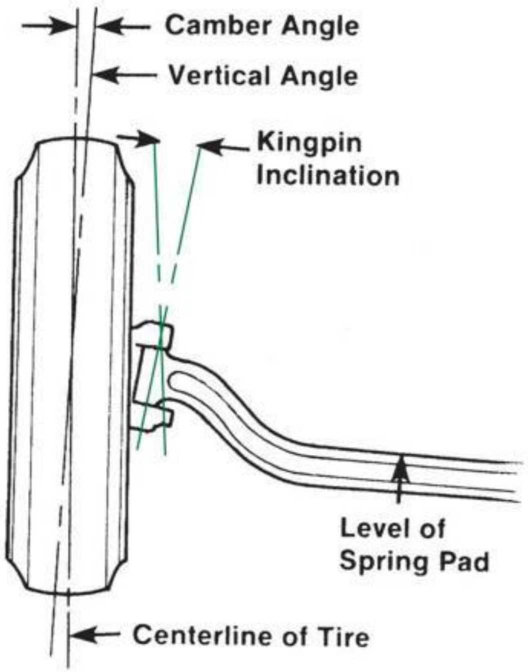
Scrub radius: valeur prise +0.015 mm



https://en.wikipedia.org/wiki/Scrub_radius

Kingpin inclination – road Camber

Kingpin Inclination



Kingpin = 7 degrés
Road camber = 0 degrés

Steering ratio:

Steering wheel angle: center to end stop : 600 degrees

Wheel angle: centerline to max: 30 degrees

Steering ratio: 20

Mechanical advantage:

Help from motorized assistance. Here no
assistance => 1.0

Script python pour évaluer le moment sur la roue, sur le gearbox et sur le volant:
git@gitlab.com:evectors/05-analysis.git

3.10 King pin steering moment

A left wheel with an arbitrary king pin orientation is shown in figure 3.41 which defines the characteristic values of the wheel orientation, the wheel hub geometry, the tyre forces and self aligning moment. Note that all distances are defined in the horizontal plane. This means that the applied longitudinal and lateral forces generate a moment around the vertical world axis.

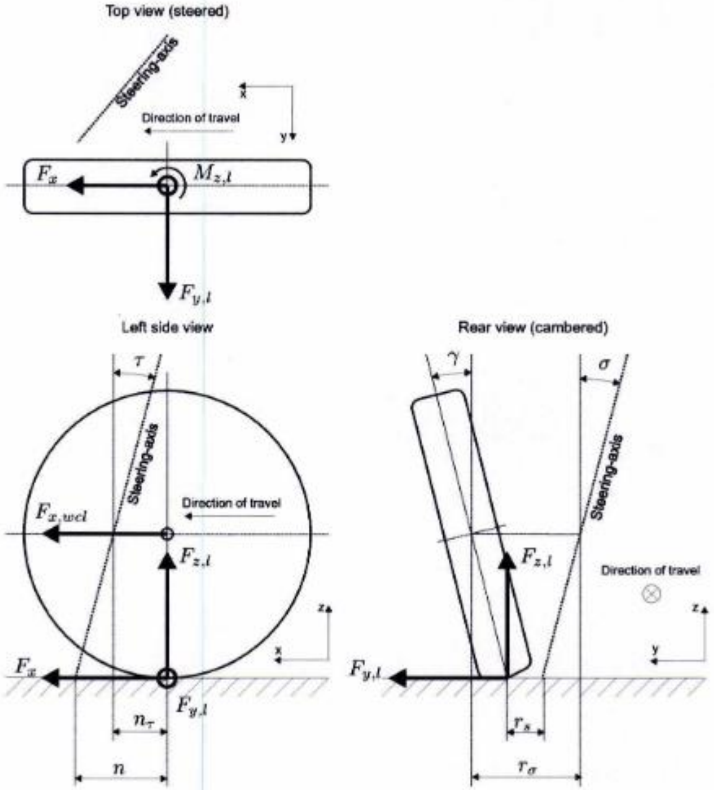


Figure 3.41: Relevant tyre forces and the self aligning moment in relation to the steering-axis orientation.

$$M_{r_s,l} = -cos(\lambda) \cdot F_{x,l} \cdot r_s$$
$$M_{r_\sigma,l} = -cos(\lambda) \cdot F_{x,wcl} \cdot r_\sigma$$
$$M_{n,l} = -cos(\lambda) \cdot F_{y,l} \cdot n$$
$$M_{p,l} = -F_{z,l} \cdot p$$
$$M_{M_z,l} = cos(\lambda) \cdot M_z$$

$$M_z = -C_{M\alpha} \cdot \alpha + C_{M\gamma} \cdot \gamma$$

Mrs,l : kingpin steering moment resulting from the scrub radius (left)
Mro,l : kingpin steering moment resulting from the wheel center offset (left)
Mn,l : kingpin steering moment resulting from the mecanical trail (left)
Mp,l : kingpin steering moment resulting from the wheel load lever arm (left)
Mmz,l : kingpin steering moment resulting from the self aligning moment (left)

Lambda : total king pin tilt angle (tho et theta)
Fx,l : longitudinal force at left wheel contact point
Fx,wcl : longitudinal force at left wheel centre
Fy,l : lateral force at left wheel contact point

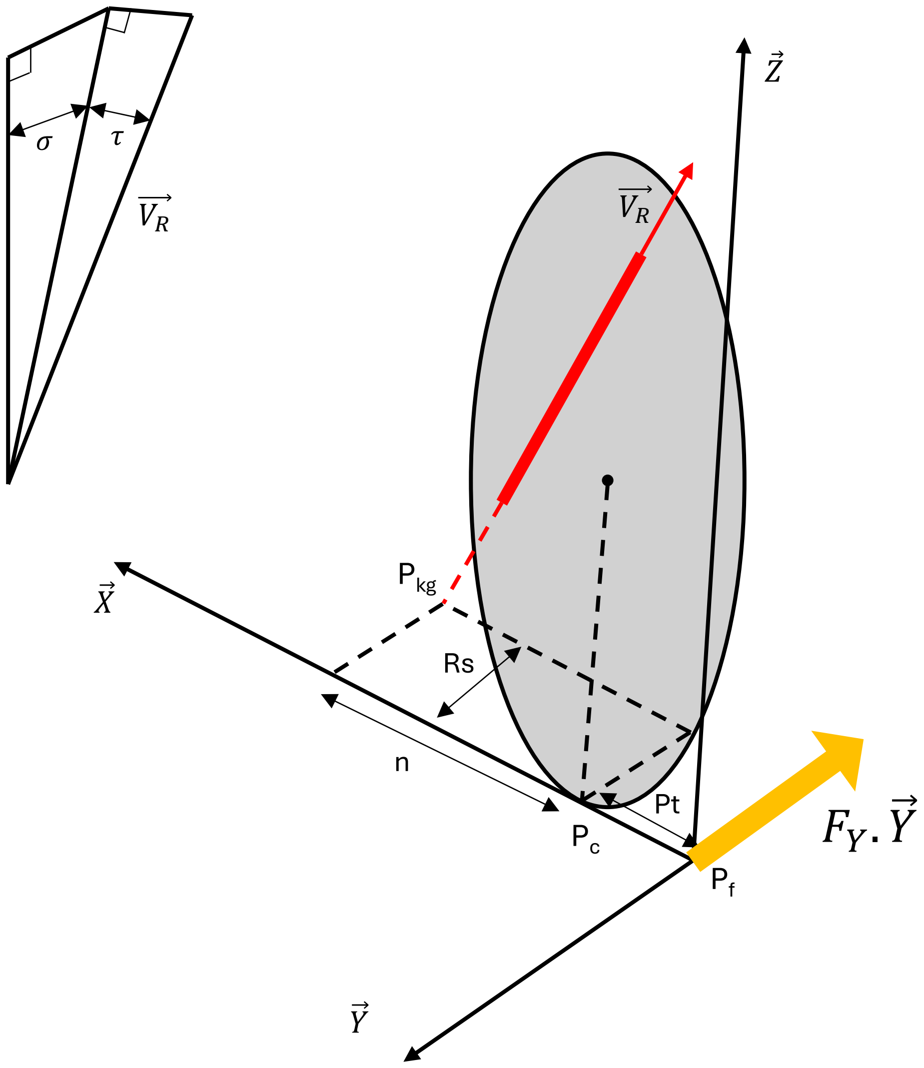
Rs = scrub radius
Rtheta = wheel centre offset
n = mecanical trail
p = wheel load lever arm
Mz = tyre self aligning moment (Fy * pneumatic trail)

$C_{M\alpha}$	Nm/°	Self aligning moment stiffness
$C_{M\gamma}$	Nm/°	Camber stiffness for self aligning moment

Truck in a straight line (rigid axle) :
https://pure.tue.nl/ws/portalfiles/portal/207121785/D_C_2011.030.pdf

$$M_{kp,l} = M_{n,l} + M_{r_\sigma,l} + M_{p,l} + M_{M_z,l}$$

Mkp,l : left kingpin steering moment



Grey : left wheel
Red : steering axis

P_f : lateral force application point
P_C : contact point tire/road
P_{Kg} : intersection point steering axis, ground plane
P_t : pneumatic trail
n : mecanical trail / caster offset
R_s : scrub radius
$\overrightarrow{V_R}$: steering axis unit vector
σ : kingpin inclination angle
τ : caster angle

If the vehicle is turning right, the steering moment coming from the steering wheel is negative
And we have the following efforts on the tire ($F_{X,Y,Z} > 0$) :

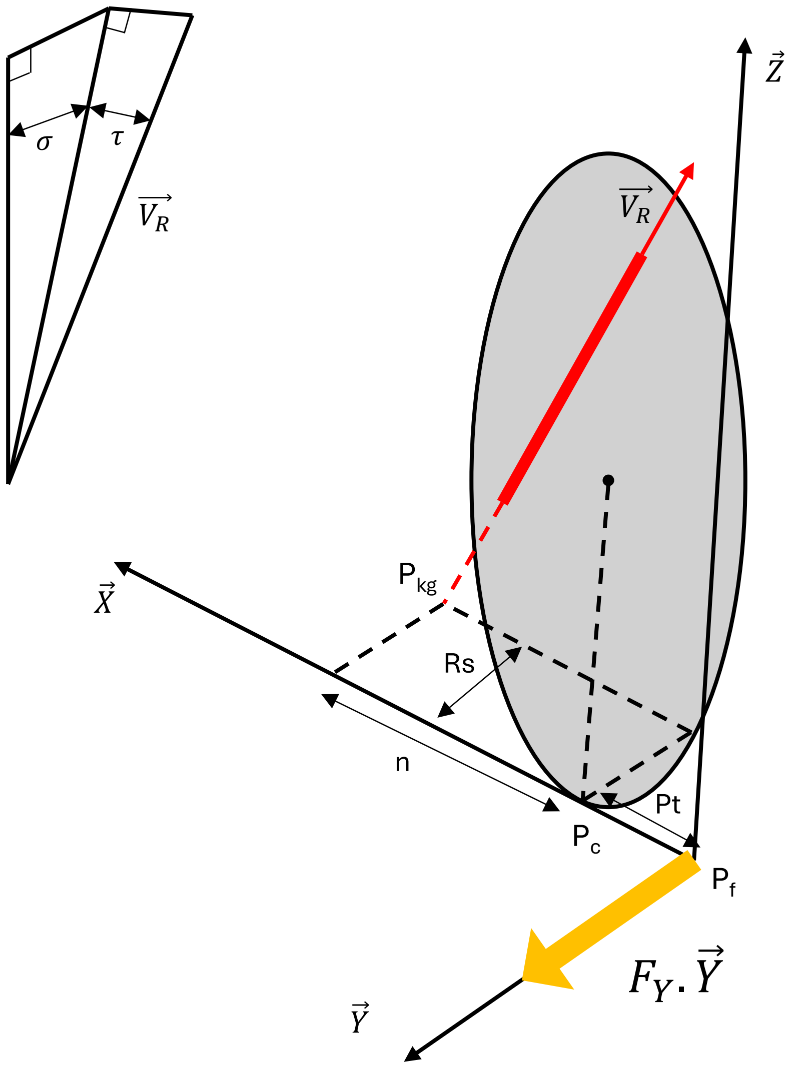
- $F_X.\vec{X}$ applied on P_c
- $-F_Y.\vec{Y}$ applied on P_f
- $F_Z.\vec{Z}$ applied on P_c

We define :

- $\vec{R} = F_X.\vec{X} + F_Z.\vec{Z}$
- $\overrightarrow{R_Y} = -F_Y.\vec{Y}$

$$\overrightarrow{M_R(P_{Kg})} = \overrightarrow{P_{Kg}P_C} \wedge \vec{R} = \begin{cases} R_S.F_Z \\ n.F_Z \\ -R_S.F_X \end{cases}$$

$$\overrightarrow{M_{RY}(P_{Kg})} = \overrightarrow{P_{Kg}P_F} \wedge \overrightarrow{R_Y} = \begin{cases} 0 \\ 0 \\ F_Y.(n + P_t) \end{cases}$$



Grey : left wheel
Red : steering axis

P_f : lateral force application point
P_C : contact point tire/road
P_{Kg} : intersection point steering axis, ground plane
P_t : pneumatic trail
n : mecanical trail / caster offset
R_s : scrub radius
$\overrightarrow{V_R}$: steering axis unit vector
σ : kingpin inclination angle
τ : caster angle

If the vehicle is turning left, the steering moment coming from the steering wheel is positive
And we have the following efforts on the tire ($F_{X,Y,Z} > 0$) :

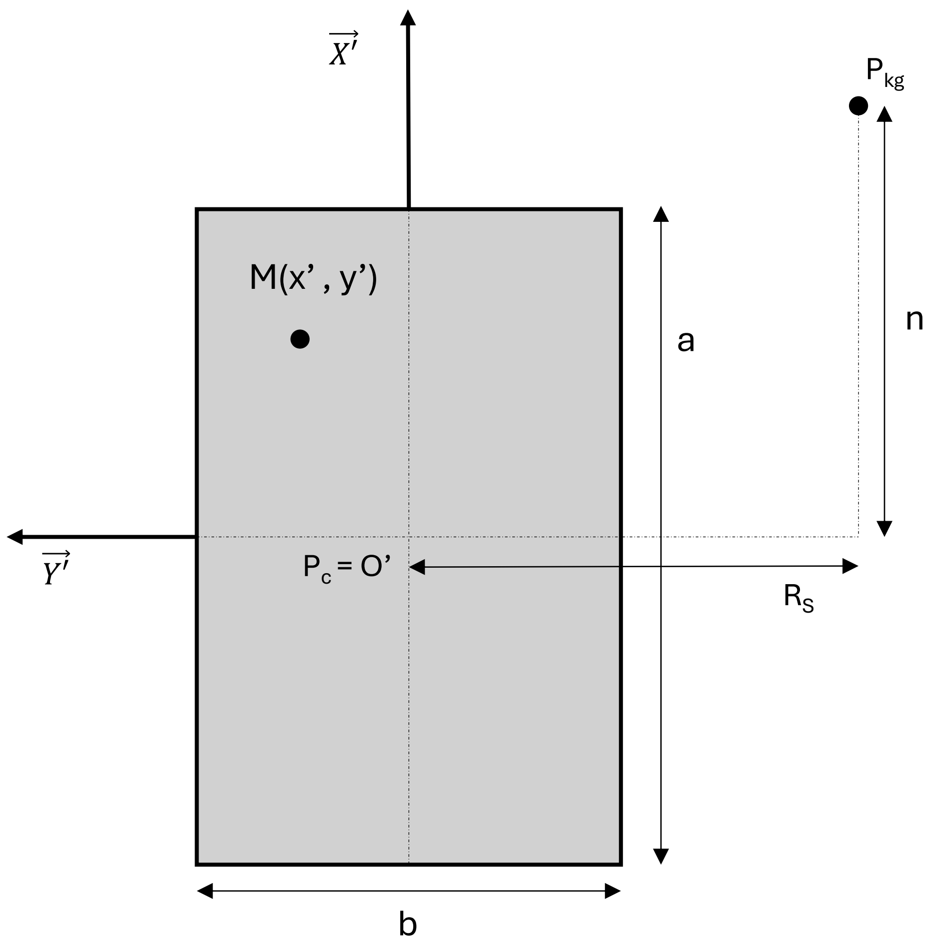
- $F_X.\vec{X}$ applied on P_c
- $F_Y.\vec{Y}$ applied on P_f
- $F_Z.\vec{Z}$ applied on P_c

We define :

- $\vec{R} = F_X.\vec{X} + F_Z.\vec{Z}$
- $\overrightarrow{R_Y} = F_Y.\vec{Y}$

$$\overrightarrow{M_R(P_{Kg})} = \overrightarrow{P_{Kg}P_C} \wedge \vec{R} = \begin{cases} R_S.F_Z \\ n.F_Z \\ -R_S.F_X \end{cases}$$

$$\overrightarrow{M_{RY}(P_{Kg})} = \overrightarrow{P_{Kg}P_F} \wedge \overrightarrow{R_Y} = \begin{cases} 0 \\ 0 \\ -F_Y.(n + P_t) \end{cases}$$



Friction moment :

Grey : tire contact patch

Pressure distribution in the contact patch :

$$p(M) = \frac{6.F_Z}{a^3.b}.\left(\frac{a}{2} - x'\right).\left(\frac{a}{2} + x'\right)$$

When steering, the contact patch rotates around P_{kg} and a friction force normal to $\overrightarrow{P_{Kg}M}$ appears in M :

$$dF_f = \mu.p(M).dx.dy$$

μ is the friction coefficient and depends on u the vehicle speed :

$$\mu = 0{,}4511.e^{-0{,}4603.u} + 0{,}2376$$

This force creates a torque in P_{kg} :

$$dT_f(P_{Kg}) = \mu.p(M).\left\|\overrightarrow{P_{Kg}M}\right\|.dx.dy$$

$$\left\|\overrightarrow{P_{Kg}M}\right\| = \sqrt{(-n + x')^2 + (R_S + y')^2}$$

We can then calculate the friction moment in P_{kg} :

$$M_f(P_{Kg}) = \int_{-\frac{b}{2}}^{\frac{b}{2}} \int_{-\frac{a}{2}}^{\frac{a}{2}} dT_f(P_{Kg})$$

We just have to put the right sign on the friction moment.

Cao, D., Tang, B., Jiang, H., Yin, C., Zhang, D., & Huang, Y. (2019). Study on Low-Speed Steering Resistance Torque of Vehicles Considering Friction between Tire and Pavement. *Applied Sciences*, *9*(5), 1015. https://doi.org/10.3390/app9051015

Ma, B., Yang, Y., Liu, Y., Ji, X., & Zheng, H. (2016). Analysis of vehicle static steering torque based on tire–road contact patch sliding model and variable transmission ratio. *Advances in Mechanical Engineering*, *8*(9), 1687814016668765. https://doi.org/10.1177/1687814016668765