Department of Automotive Technologies –
Vehicle Mechanics Fundamentals

Gábor Sipos

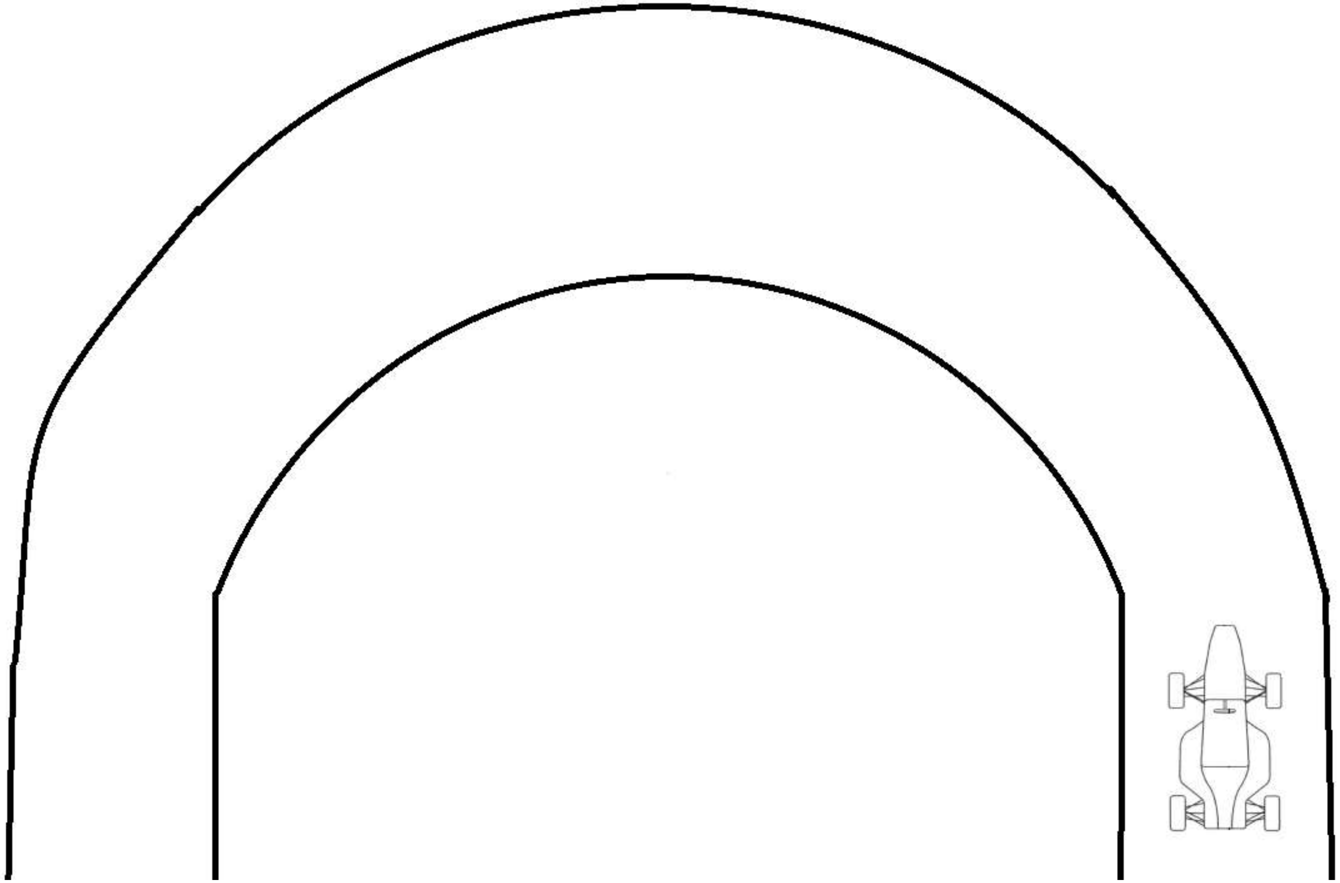
BME
DEPARTMENT OF AUTOMOTIVE TECHNOLOGIES

Lecture 4

Basic information

Week nr.	Date	Lecture (Monday)		Lab (date+1;Tuesday)	
1	12th Feb	1	General information, Tyre, Driving force	1	Lab
2	19th Feb	2	Longitudinal and lateral behaviour		
3	26th Feb	3	Concepts and over/understeer	2	Lab
4	4th Mar	4	Weight transfer		
5	11th Mar	5	Bicycle model	3	Lab
6	18th Mar	T1	Midterm exam I. ONLINE		
7	25th Mar	6	Braking and brakes ONLINE	4	Lab ONLINE
8	1st Apr	-	Break		
9	8th Apr	7	Systems of the vehicle	T1 R	Exam 1 - subsequent
10	15th Apr	8	Quarter vehicle model ONLINE		
11	22th Apr		Break		Break
12	29th Apr	T2	Midterm exam II. ONLINE		
13	6th May	9	Tyre management	T2 R	Exam 2 - subsequent
14	13th May	10	Racecar engineering		

Cornering with different tires



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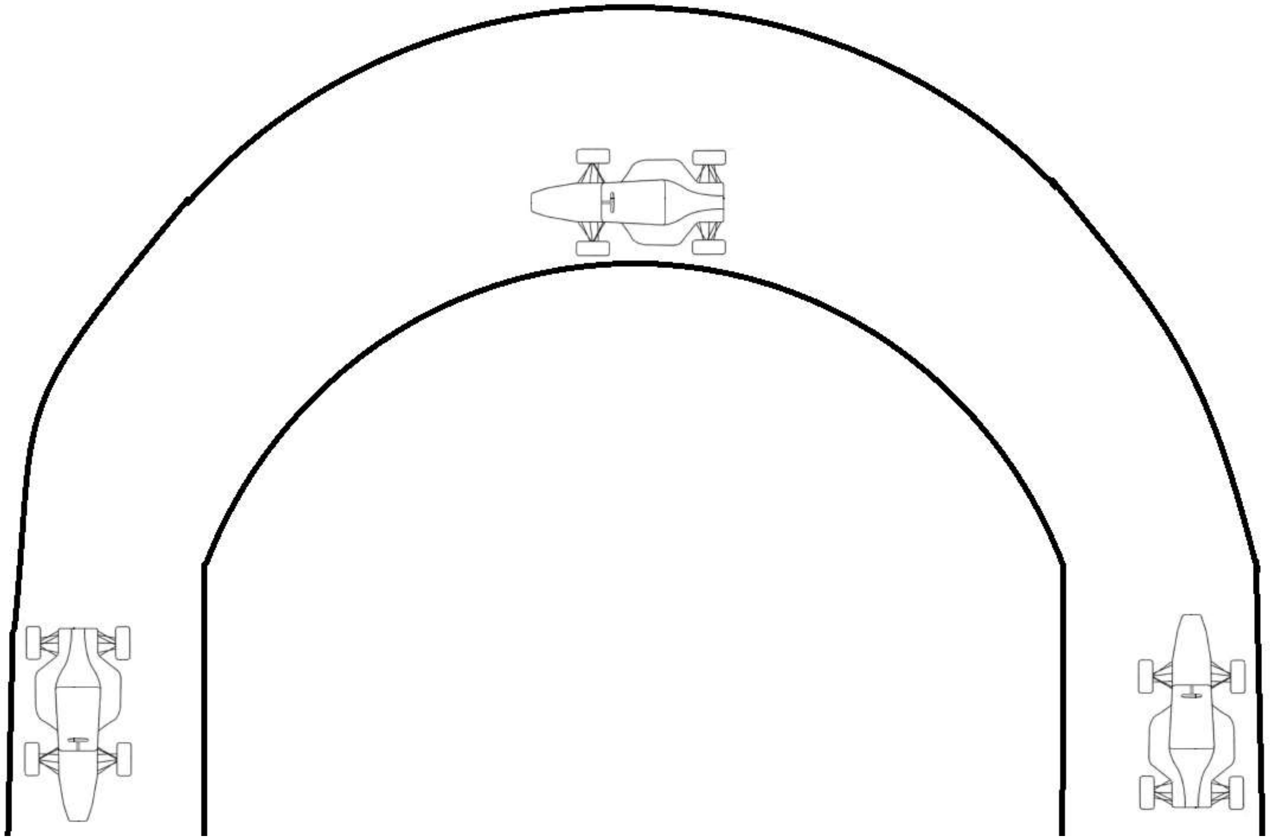

Cornering with different tires

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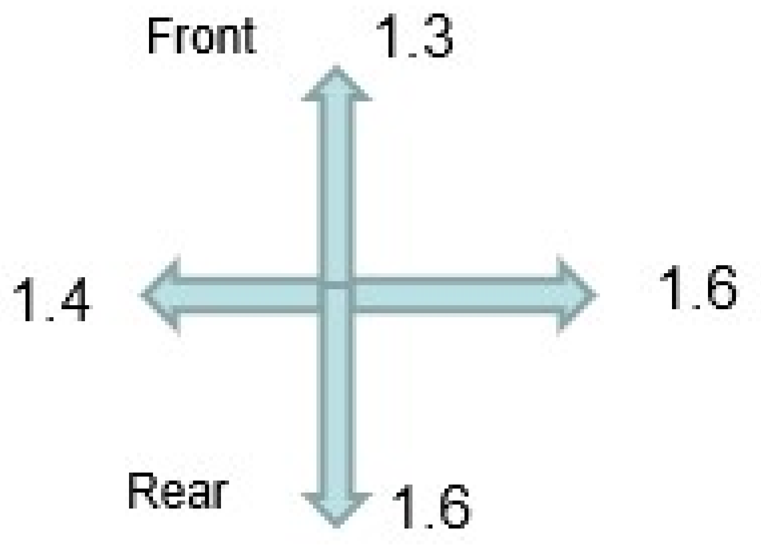
Different Friction Coefficient along Lateral and Longitudinal Axis



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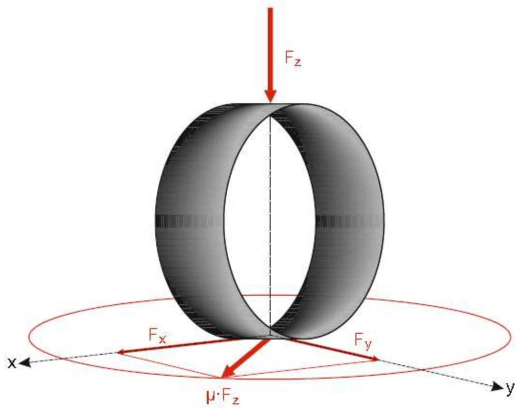

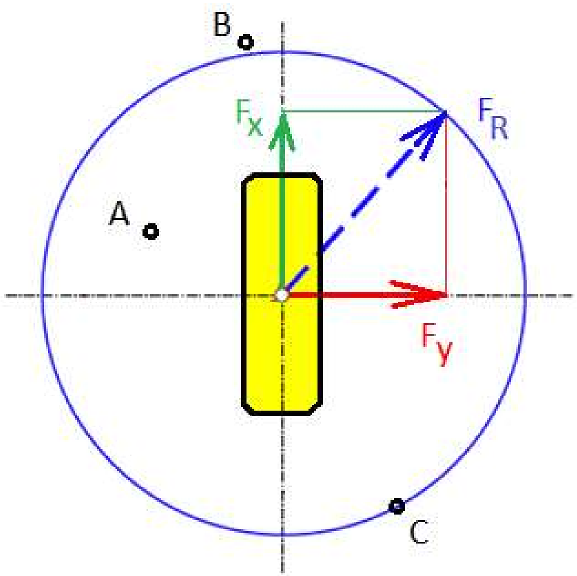

$$F_R = \mu_{max} F_z \geq \sqrt{F_x^2 + F_y^2}$$

- F_x: longitudinal force; F_y: lateral force; F_z: normal force; F_R: resultant horizontal force;
- To which places can resultant horizontal force point?
  - A
  - B
  - C
- The tyre is able to accelerate and corner at the same time. How much of the different components can it use?

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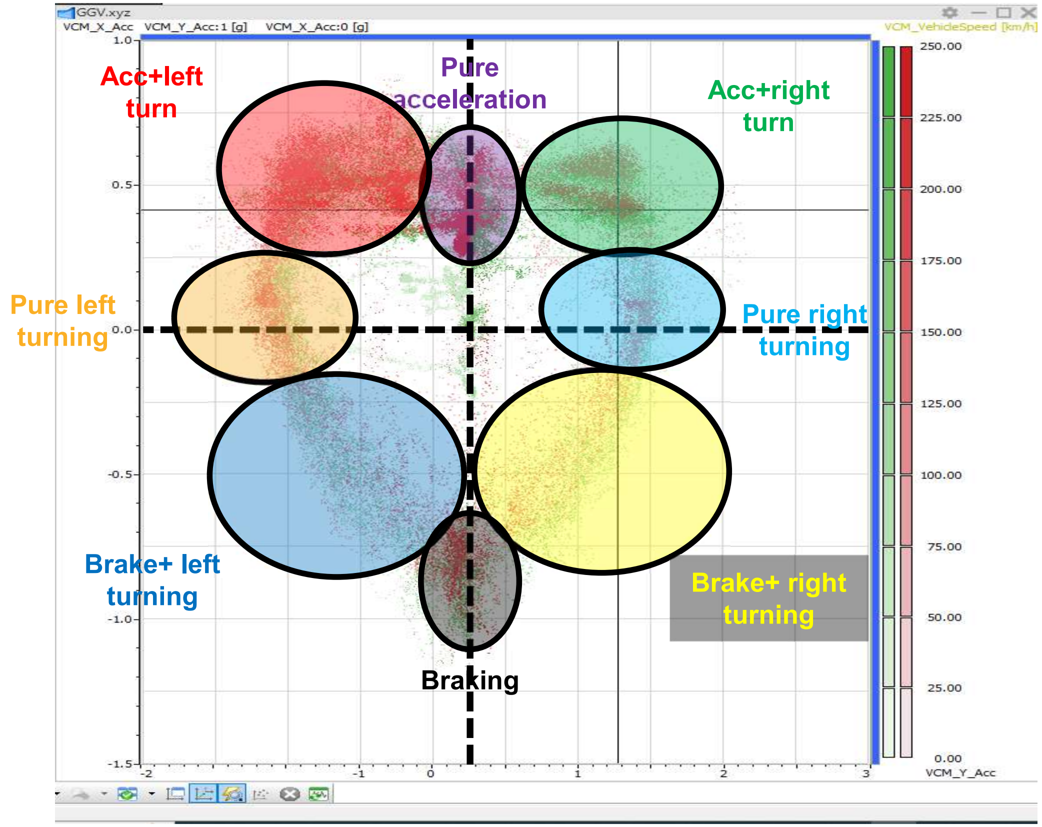
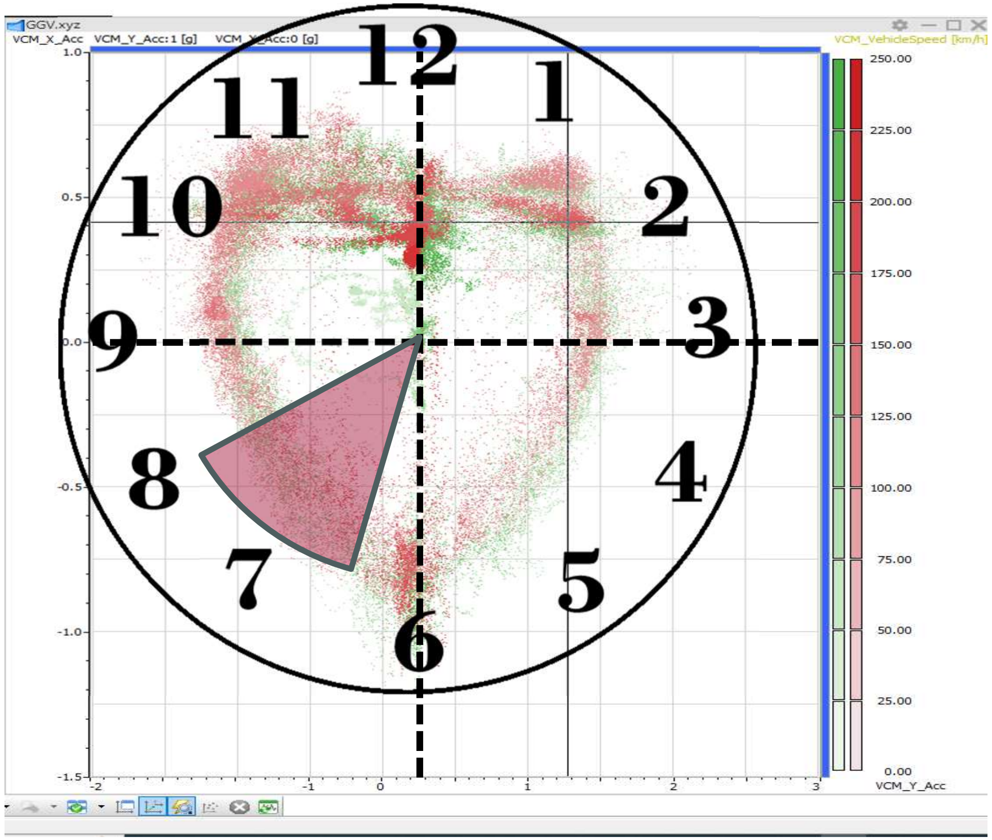
GG diagram



* Zero lat axis sensor calibration issue corr

GG diagram



** Zero lat axis sensor calibration issue corr*

Question

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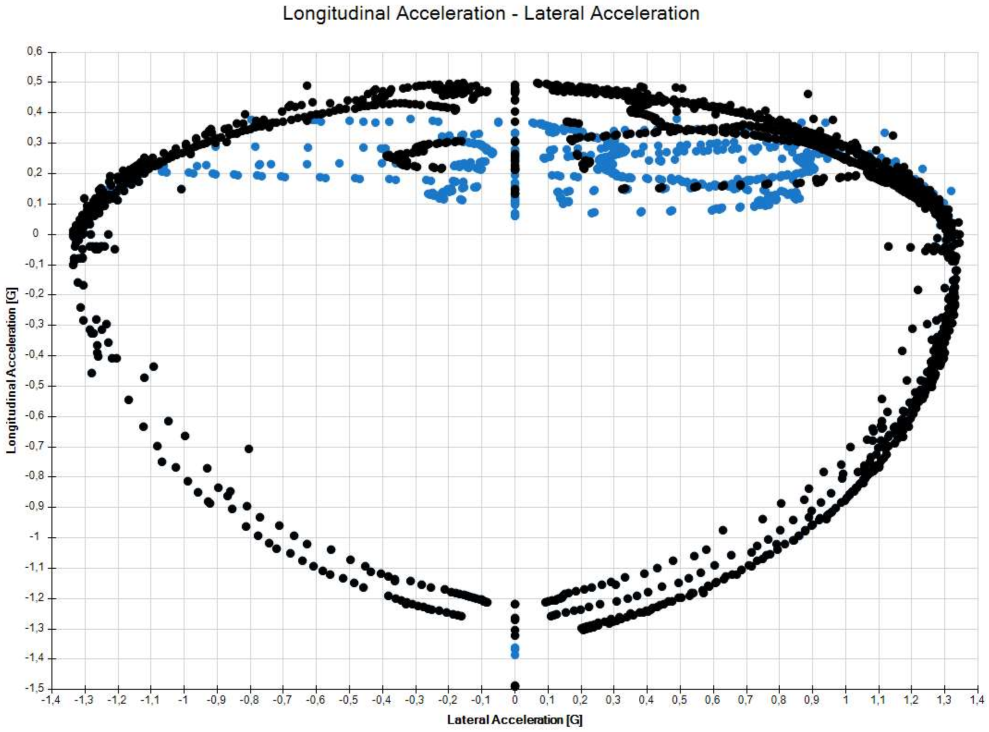
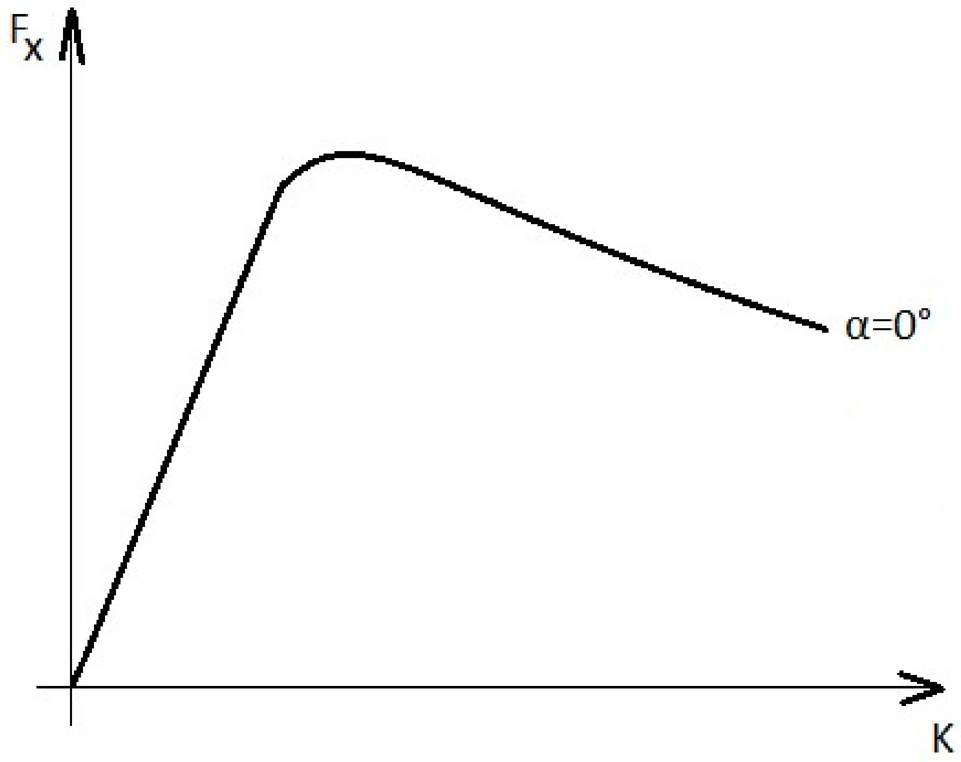
What could be the modification from black (base) to blue electric racecar?

A - changed tyre with more lateral performance
B - electric drivetrain changed to a lower power mode
C - electric drivetrain changed to a higher regenerative braking mode
D – suspension adjusted to reach higher lateral acceleration



Cornering with different tires



Cornering with different tires

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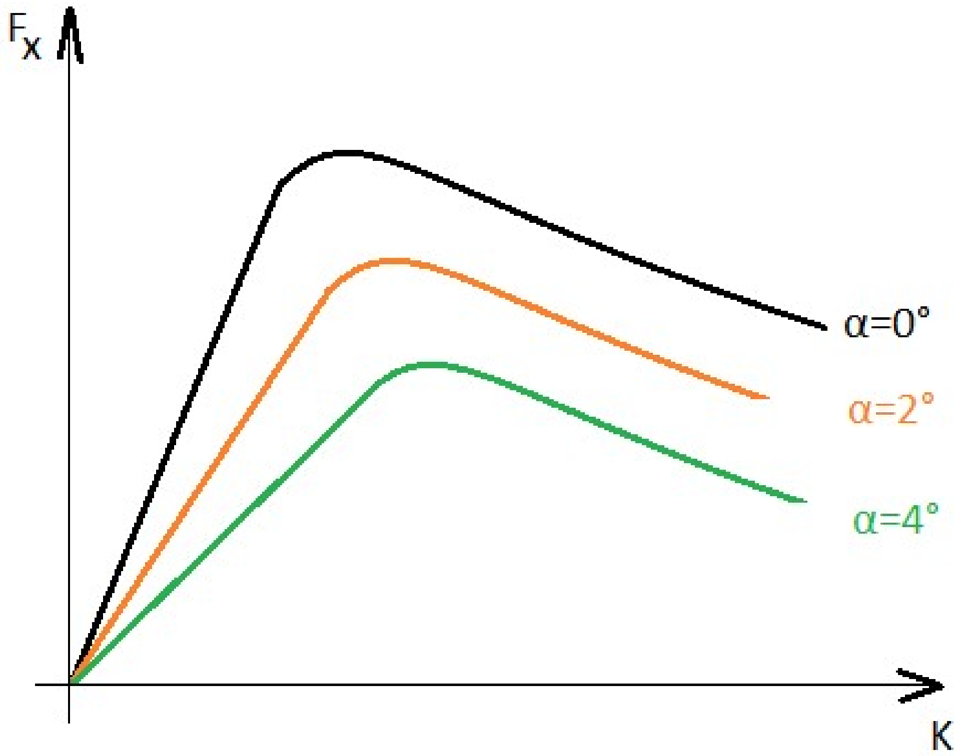

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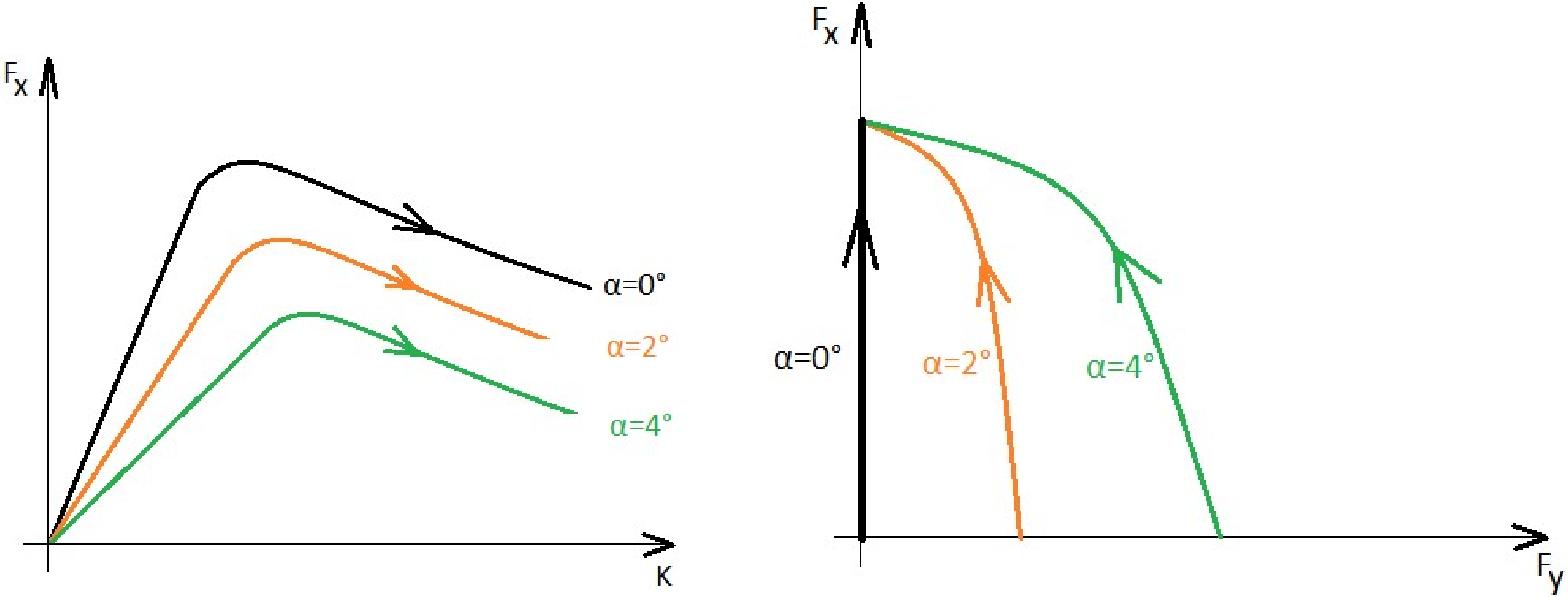

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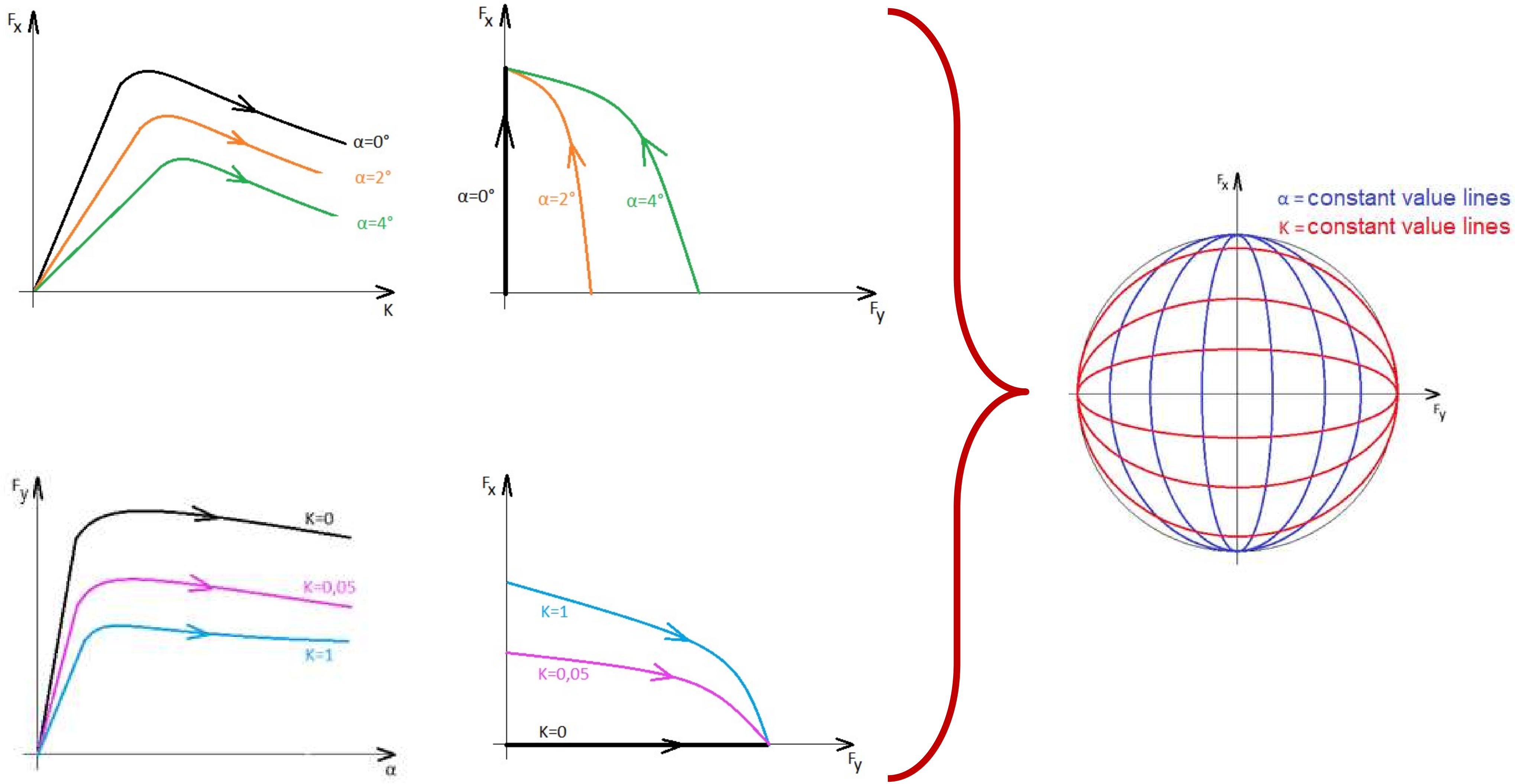
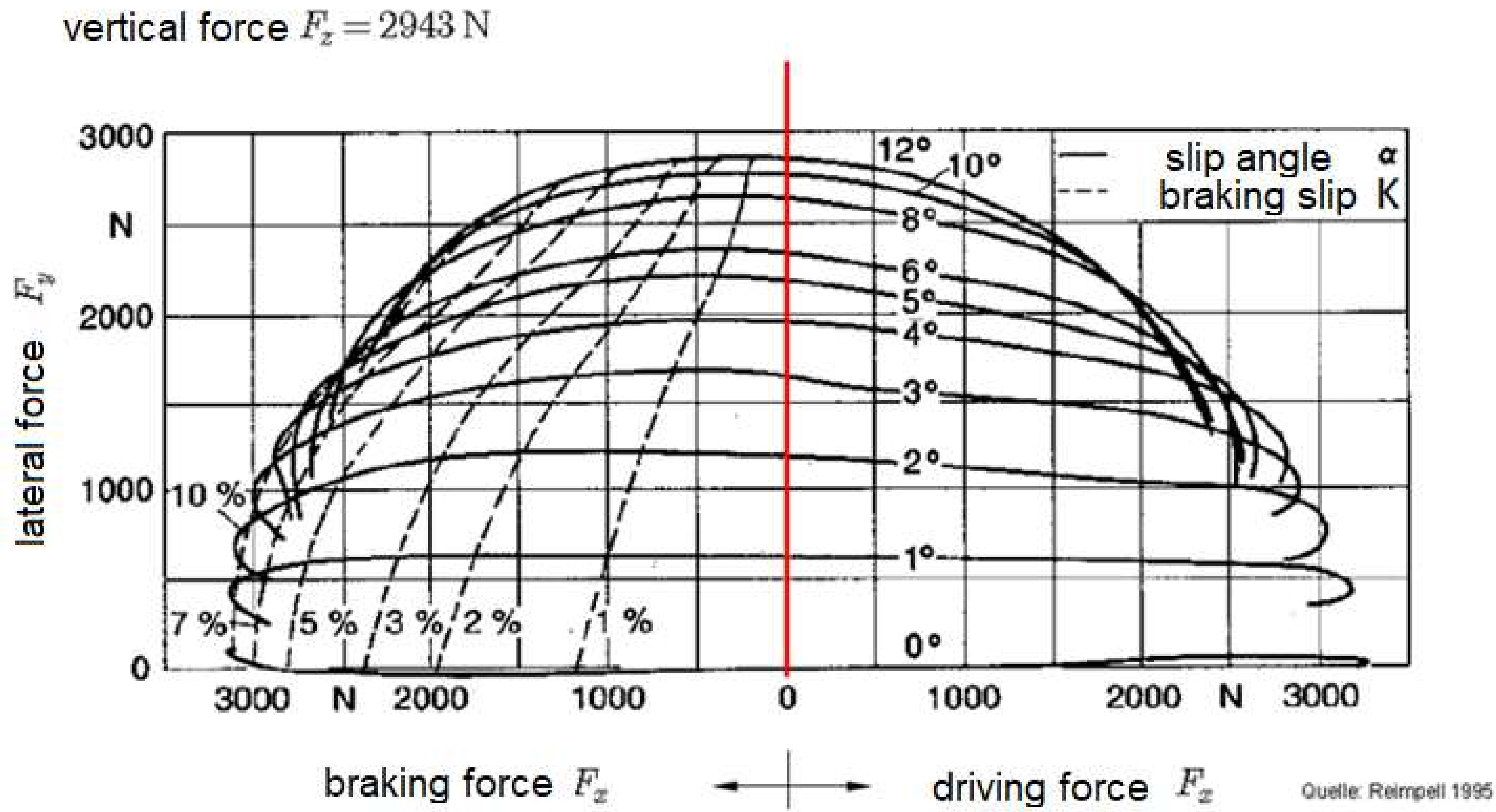
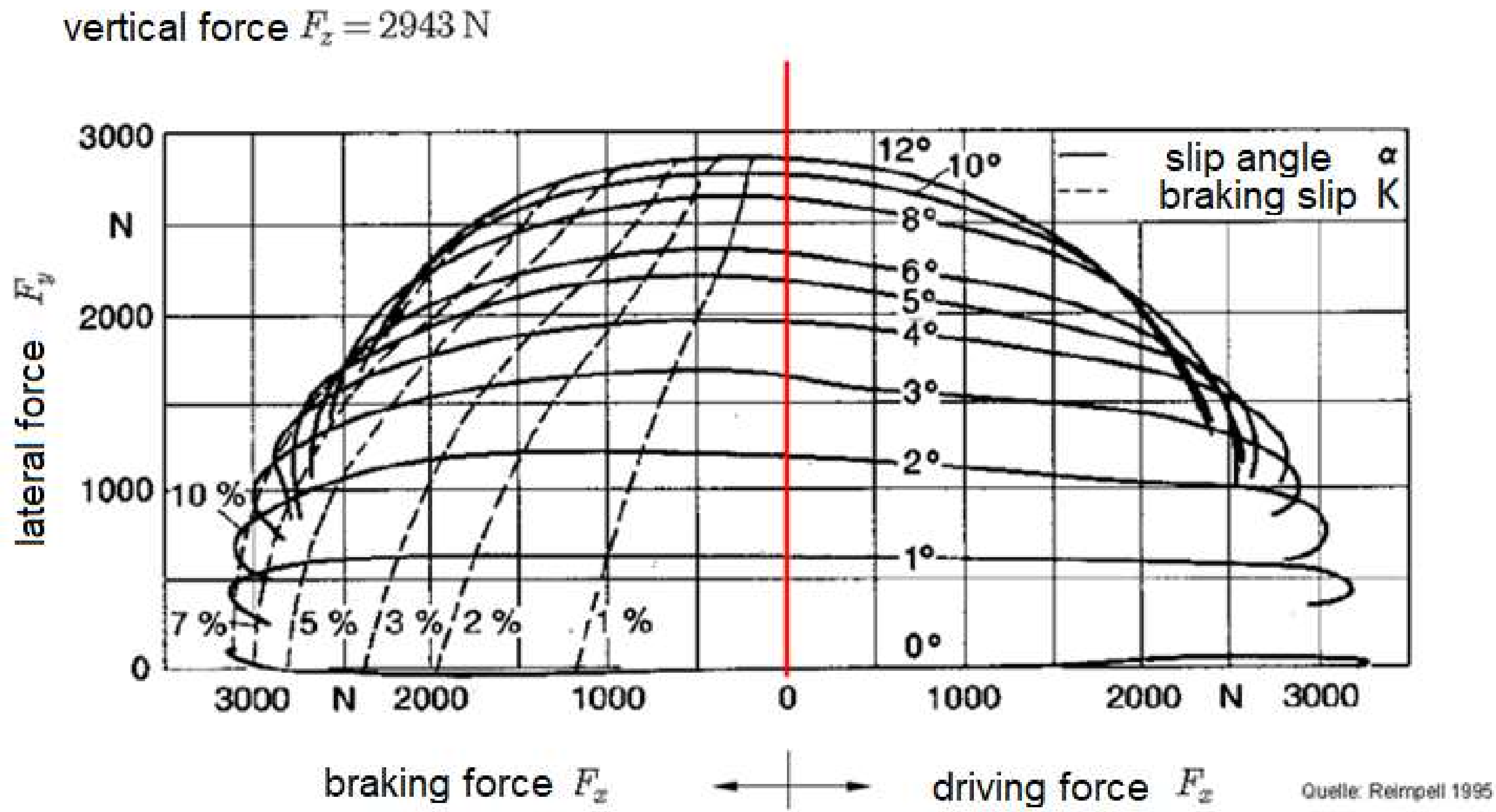


Cornering with different tires



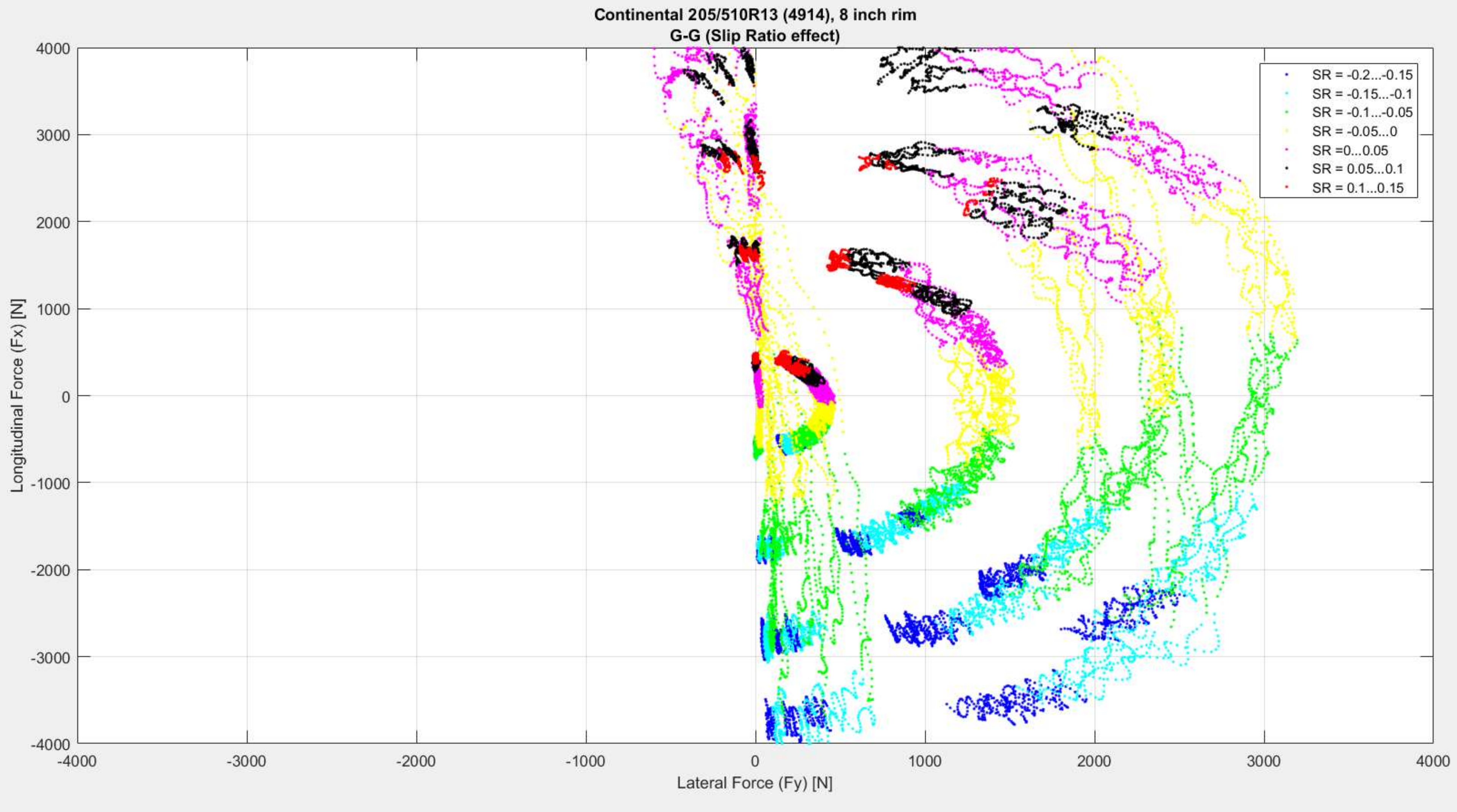
- What is the reason behind the elliptic shape of curves?
- Why the curves are asymmetrical to Fx=0 axis?

Cornering with different tires

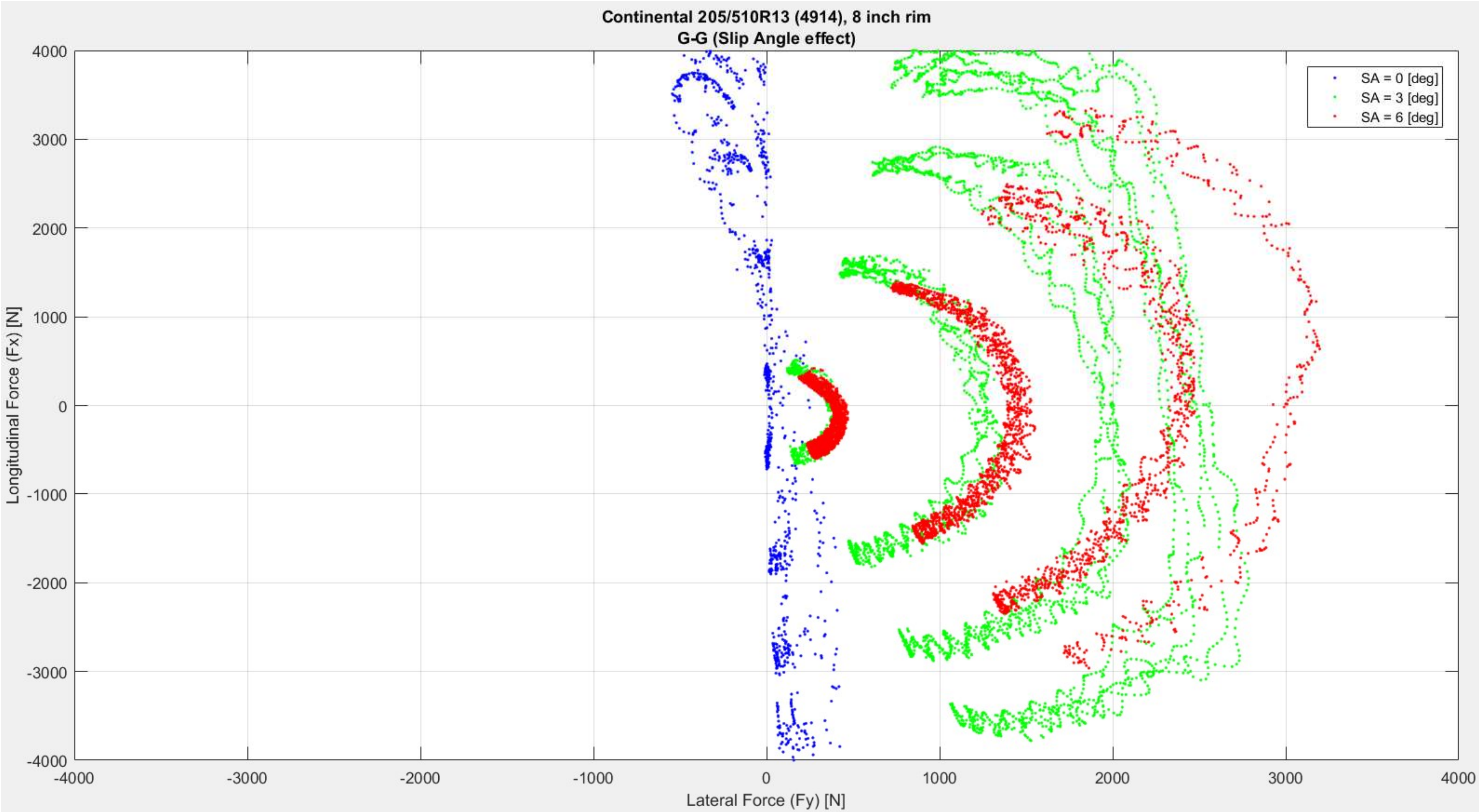


- What is the reason behind the elliptic shape of curves?
  Different values of friction coefficients to different directions.
- Why the curves are asymmetrical to Fx=0 axis?
  Tyre behaviour is different in case of accelerating and braking.

Cornering with different tires



Cornering with different tires

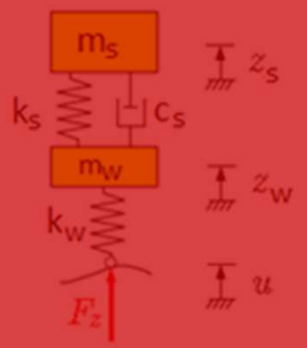
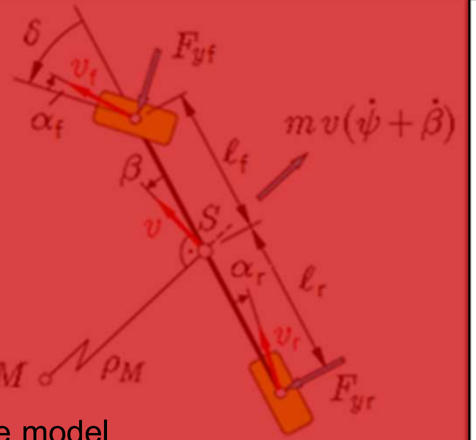
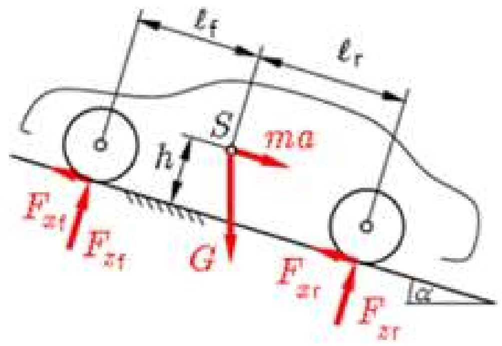


Vertical load in static case

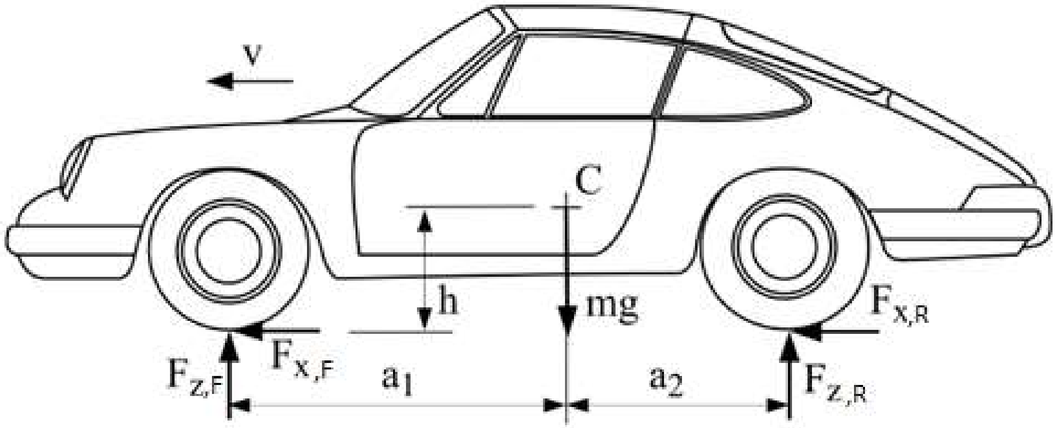
Notation

Vertical load in static case

Dynam

	vertical dynamics	lateral dynamics	longitudinal dynamics
	 Quarter vehicle model	 Bicycle model	 longitudinal model
Features	• Vertical vibration • Wheel loads • comfort	• steering • Lateral acceleration • Self aligning torque • Critical speed	• Acceleration and braking • resistances: tyre,air, uphill – power requirement; • Engine characteristics and gears • Braking and driving forces
Parameters	m_s – structural weight m_w – wheel weight k_t – tyre stiffness k_s – spring stiffness k_d – damping u - movement	l – wheelbase l_f – CoG distance m – weight v – vehicle speed α – slip angle δ – steering angle	h – CoG height G – gravity force F_{xf} – front axle driving force F_{zf} – tyre forces at front

Vertical load in static case



Static load of axles:

$$F_{z,F}^{st} = \mathrm{m} \cdot \mathrm{g} \cdot \frac{\mathrm{a}_2}{\mathrm{w}}$$

$$F_{z,R}^{st} = \mathrm{m} \cdot \mathrm{g} \cdot \frac{\mathrm{a}_1}{\mathrm{w}}$$

static load of tyres:

$$\mathrm{F}_{z,1} = \frac{1}{2} \cdot F_{z,F}$$

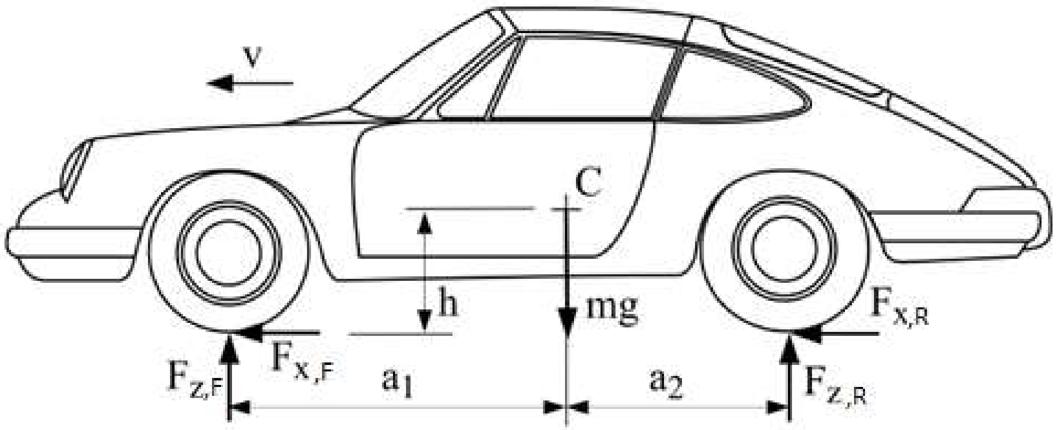
$$\mathrm{F}_{z,3} = \frac{1}{2} \cdot F_{z,R}$$

Longitudinal weight transfer

$\dot{v} \neq 0$

Vertical load in static case

$\dot{v} \neq 0$



Law of motion:

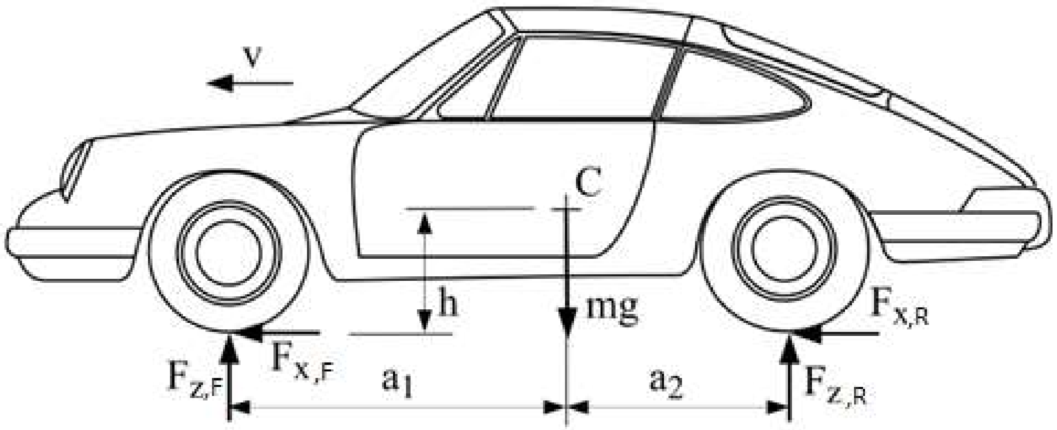
X direction: $$m \cdot \dot{v} = F_{x,F} + F_{x,R}$$

Z direction: $$0 = F_{z,F} + F_{z,R} - m \cdot g$$

Moments: $$0 = -F_{z,F} \cdot a_1 + F_{z,R} \cdot a_2 - (F_{x,F} + F_{x,R}) \cdot h$$

Vertical load in static case

$\dot{v} \neq 0$



Dynamic load of axles:

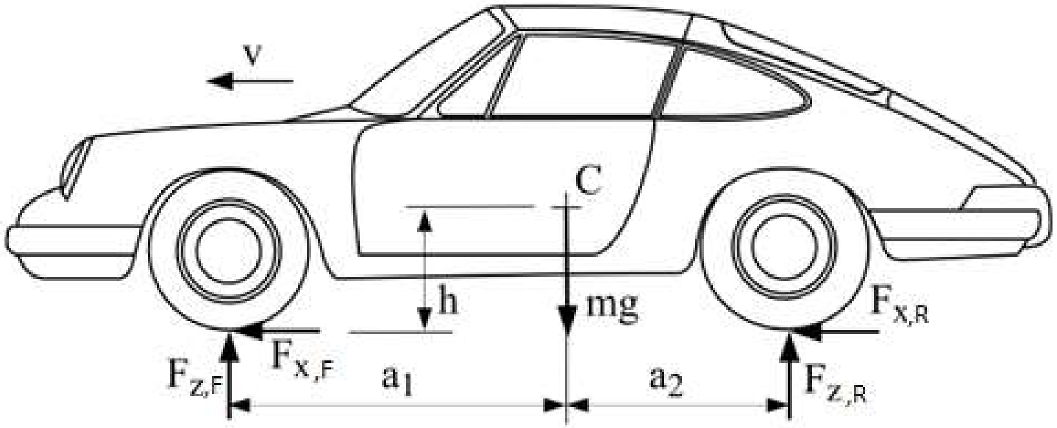
$$F_{z,F} = F_{z,F}^{st} + F_{z,F}^{dyn} \longrightarrow$$

$$F_{z,R} = F_{z,R}^{st} + F_{z,R}^{dyn} \longrightarrow$$

?

Vertical load in static case

$\dot{v} \neq 0$



Dynamic load of axles:

$$F_{z,F} = F_{z,F}^{st} + F_{z,F}^{dyn} \longrightarrow F_{z,F}^{dyn} = -m \cdot \dot{v} \cdot \frac{h}{w}$$

$$F_{z,R} = F_{z,R}^{st} + F_{z,R}^{dyn} \longrightarrow F_{z,R}^{dyn} = m \cdot \dot{v} \cdot \frac{h}{w}$$

Vertical load in static case

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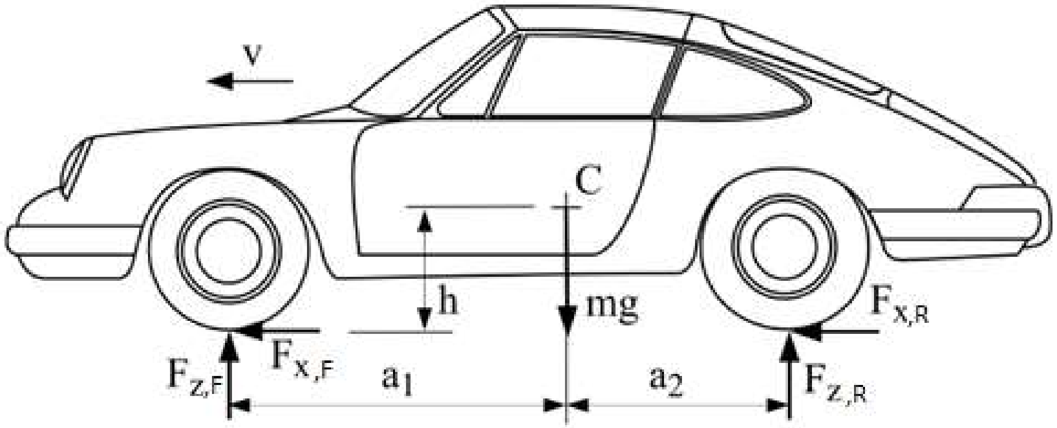

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Dynamic load of tyres:

$$F_{z,1} = \frac{1}{2} \cdot F_{z,F}$$

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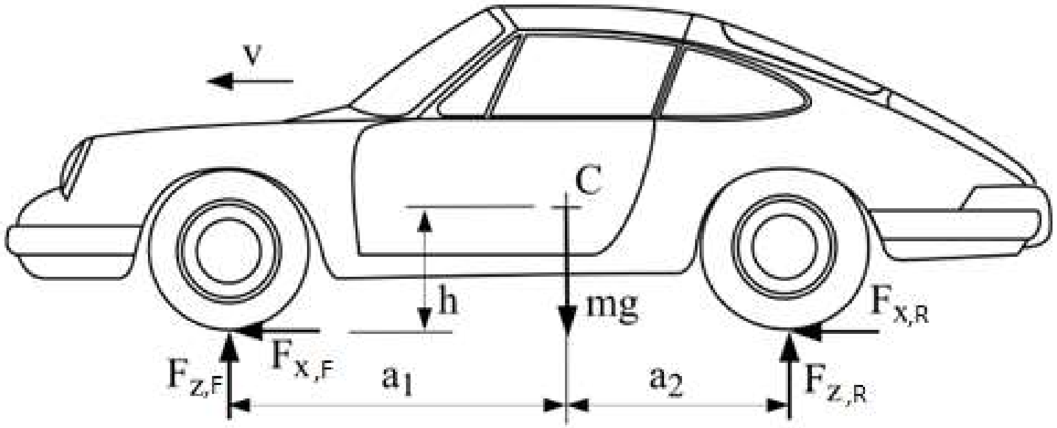

Dynamic load of axles:

$$F_{z,F} = m \cdot g \cdot \frac{a_2}{w} - \frac{h}{w} \cdot m \cdot \dot{v}$$

$$F_{z,R} = m \cdot g \cdot \frac{a_1}{w} + \frac{h}{w} \cdot m \cdot \dot{v}$$

Dynamic load of tyres:

$$F_{z,1} = \frac{1}{2} \cdot F_{z,F}$$

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Longitudinal weight transfer

What does weight transfer depend on?

- CoG height
- weight of car
- amount and direction of acceleration
- wheelbase

$$F_{z,R}^{dyn} = \mathrm{m} \cdot \dot{\mathrm{v}} \cdot \frac{\mathrm{h}}{\mathrm{w}}$$

nothing else!

Longitudinal weight transfer

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$$F_{z,R}^{dyn} = \mathrm{m} \cdot \dot{\mathrm{v}} \cdot \frac{\mathrm{h}}{\mathrm{w}}$$

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With increased wheelbase, the longitudinal weight transfer will be ….

Longitudinal weight transfer

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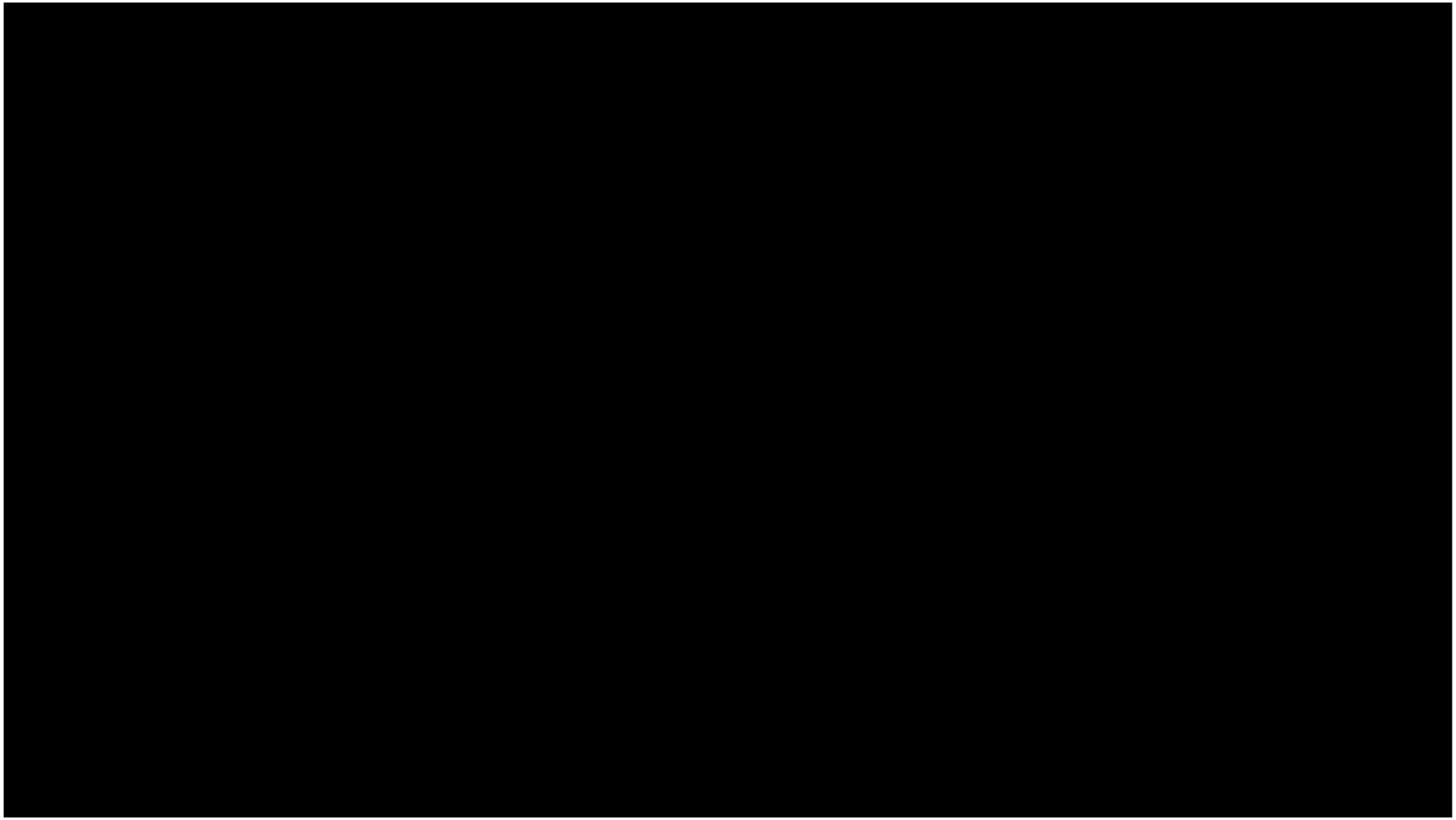
nothing else!

With increased wheelbase, the longitudinal weight transfer will be ….

less

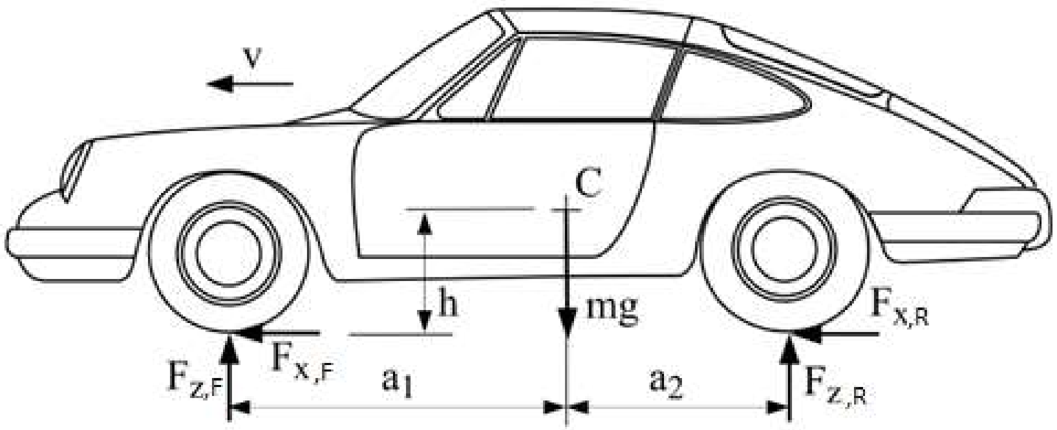
Longitudinal weight transfer

dynamic loads (and forces)



Longitudinal weight transfer

help me!

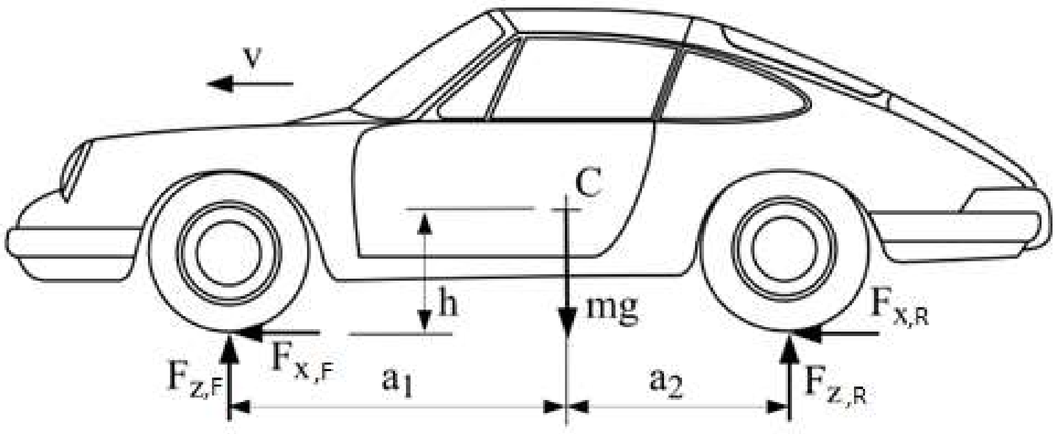


I’m going on a motorway with my own car, Waze warns of a pothole but it’s too late, inevitable to go through, what should I choose?

A. $\dot{v}$ should be 0, go through with constant speed
B. $\dot{v}$ should be negative, braking
C. $\dot{v}$ should be positive, accelerating
D. none of the soultions above helps, damage will be the same

Longitudinal weight transfer

help me!



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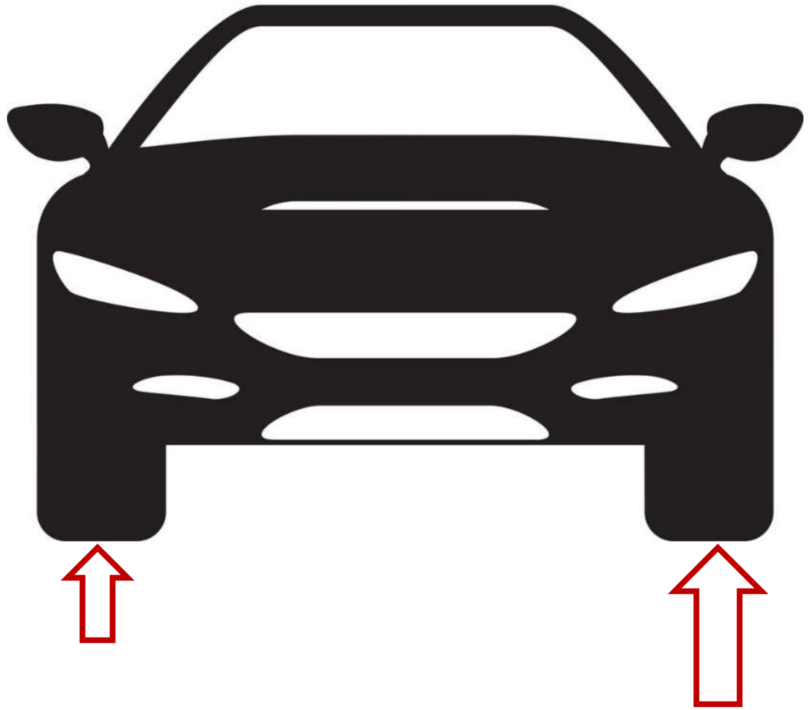
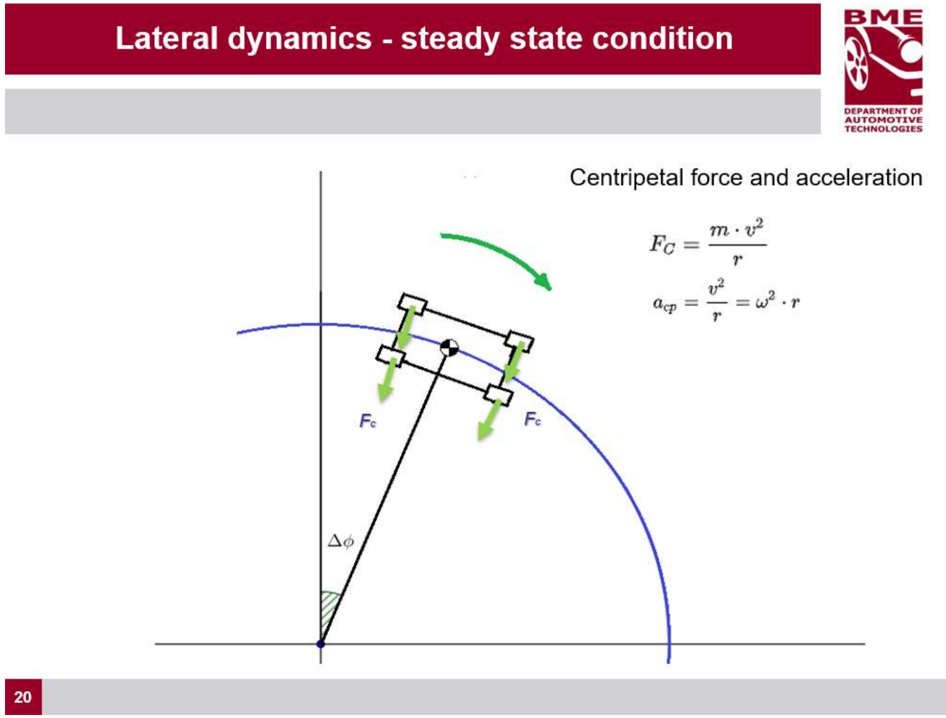
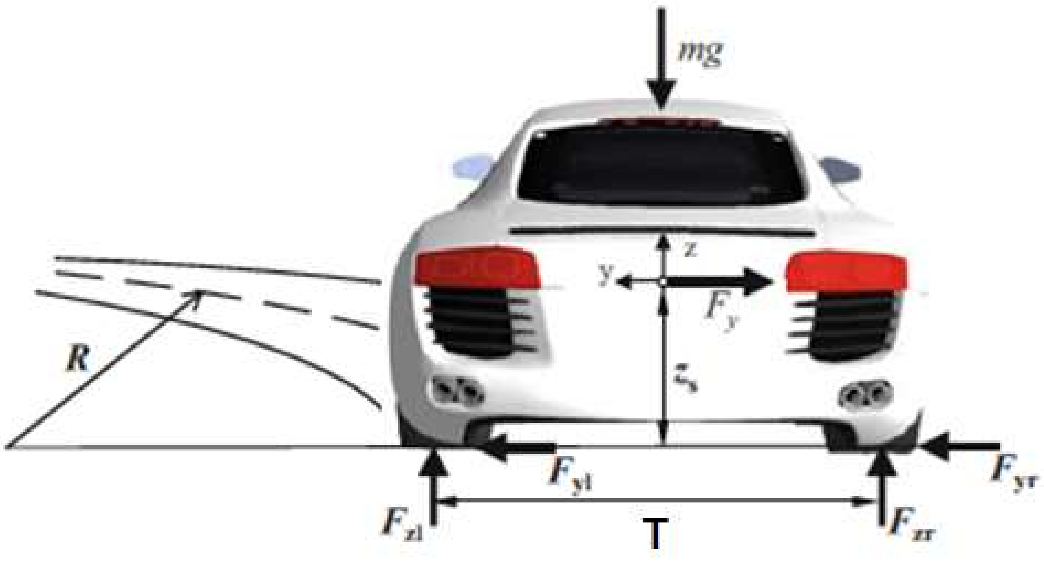
Lateral weight transfer

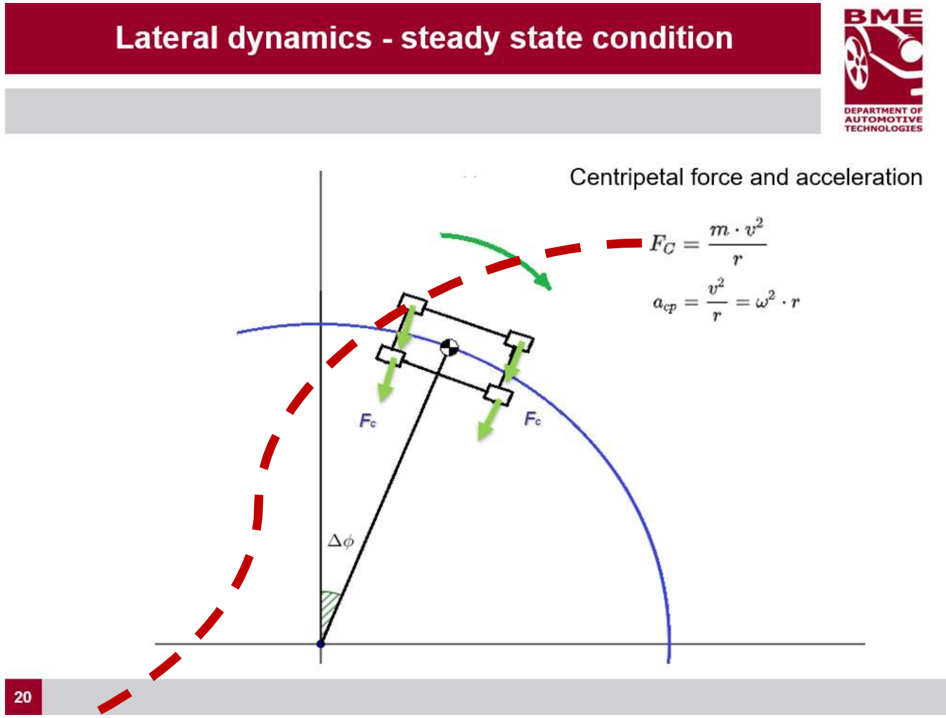




Lateral weight transfer

Steady state case





$$F_{cp} = \mathrm{m} \cdot a_y = m \cdot \frac{v^2}{R}$$

Lateral weight transfer

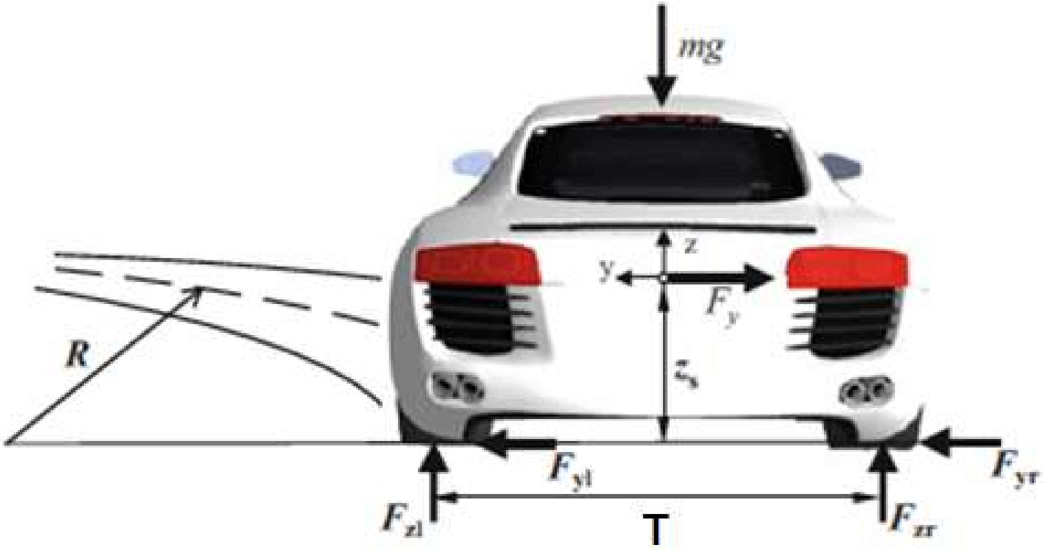
Steady state case

$$F_{z,1} = \frac{1}{2} \cdot m \cdot g \cdot \frac{a_2}{w} - F_{cp} \cdot \frac{h}{T} \cdot \frac{a_2}{w}$$

$$F_{z,2} = \frac{1}{2} \cdot m \cdot g \cdot \frac{a_2}{w} + F_{cp} \cdot \frac{h}{T} \cdot \frac{a_2}{w}$$

$$F_{z,3} = \frac{1}{2} \cdot m \cdot g \cdot \frac{a_1}{w} - F_{cp} \cdot \frac{h}{T} \cdot \frac{a_1}{w}$$

$$F_{z,4} = \frac{1}{2} \cdot m \cdot g \cdot \frac{a_1}{w} + F_{cp} \cdot \frac{h}{T} \cdot \frac{a_1}{w}$$



Lateral weight transfer

What does weight transfer depend on?

- CoG height
- CoG distance from front/rear axle
- weight of car
- amount and direction of acceleration
- wheelbase
- track

$$F_{z,4} = \frac{1}{2} \cdot m \cdot g \cdot \frac{a_1}{w} + F_{cp} \cdot \frac{h}{T} \cdot \frac{a_1}{w}$$

$$F_{cp} = \mathrm{m} \cdot a_y$$

nothing else!

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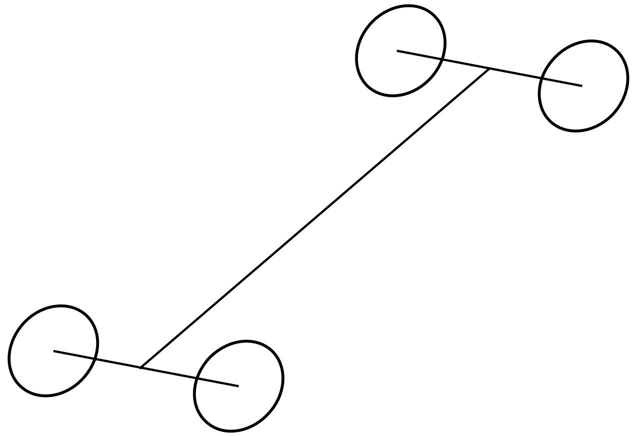

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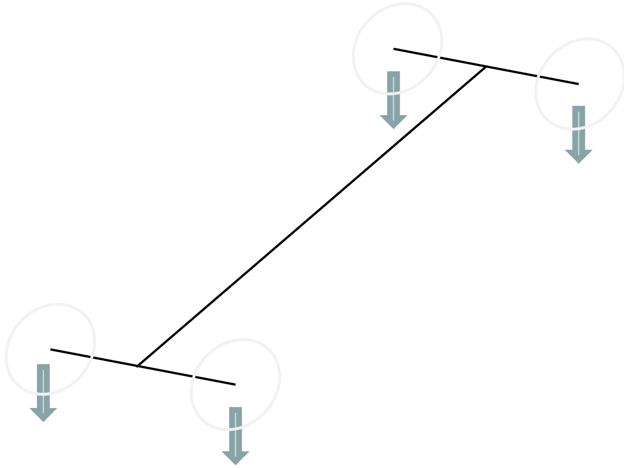

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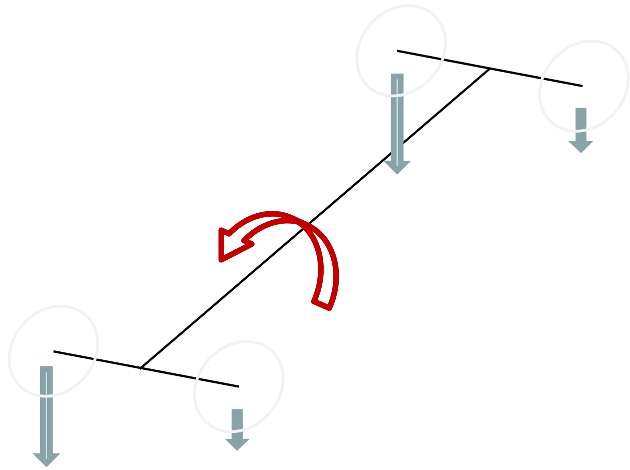

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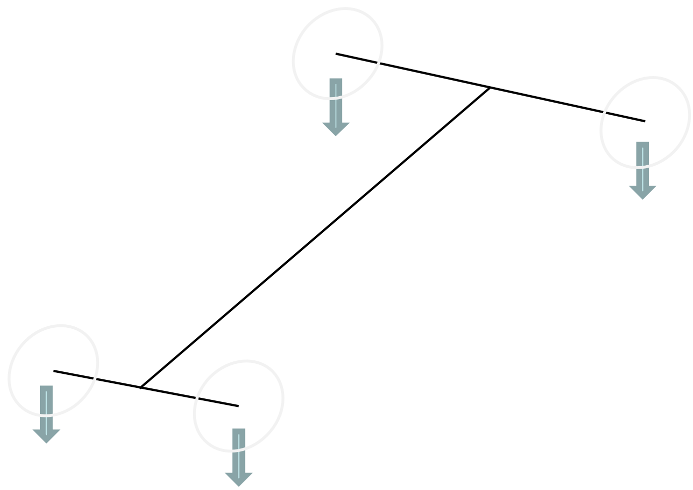

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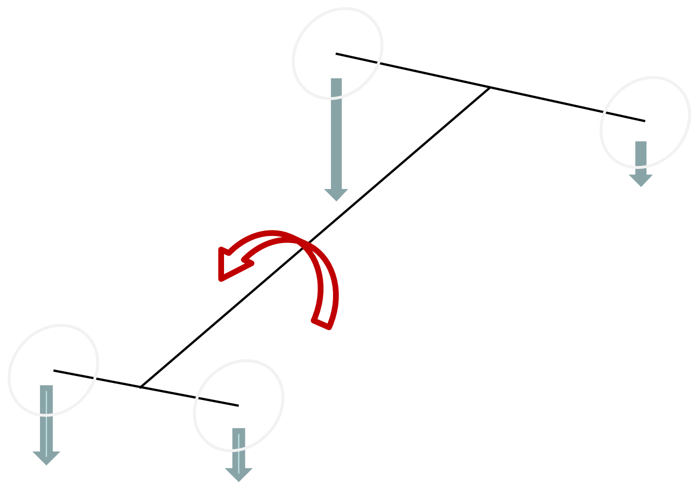
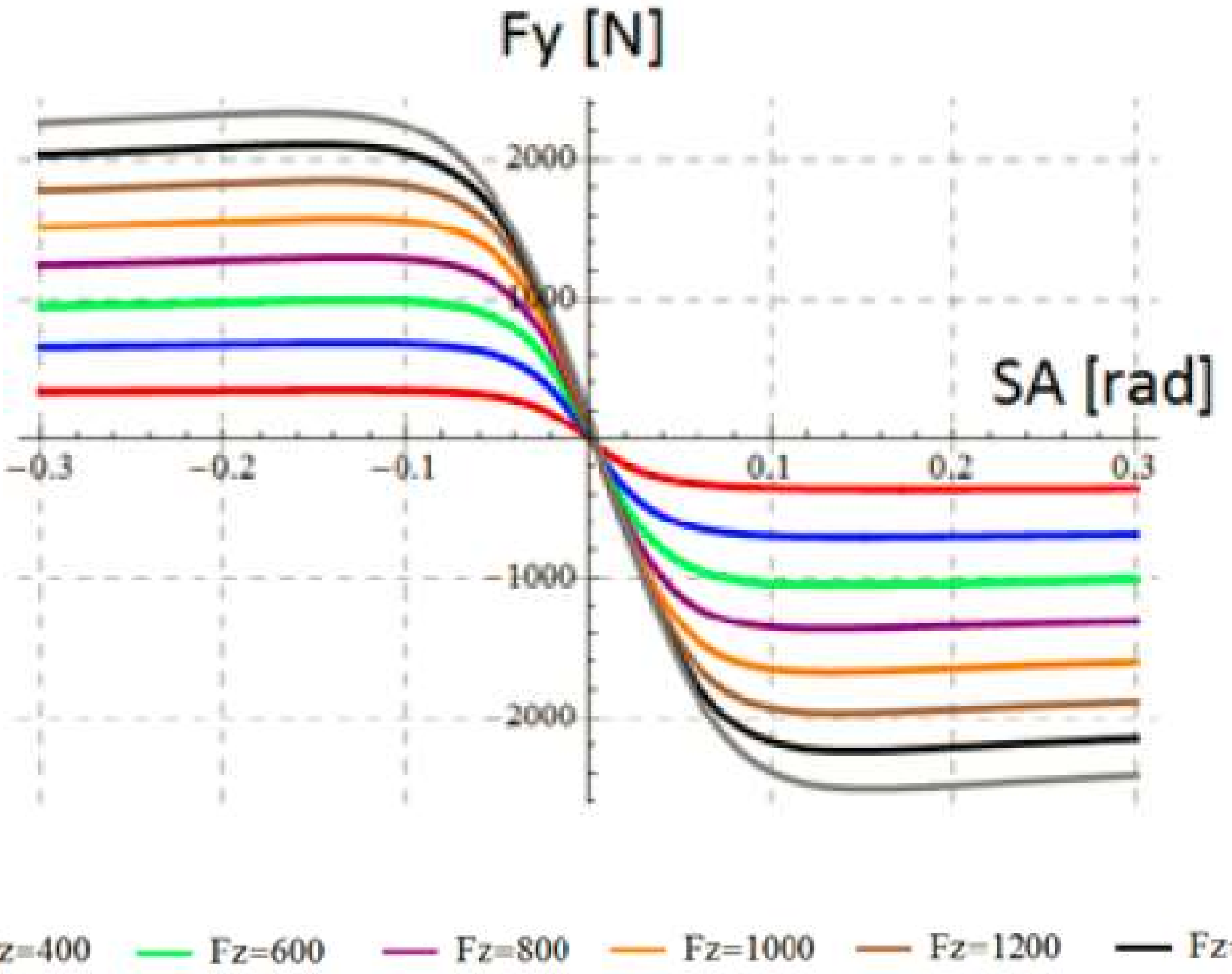


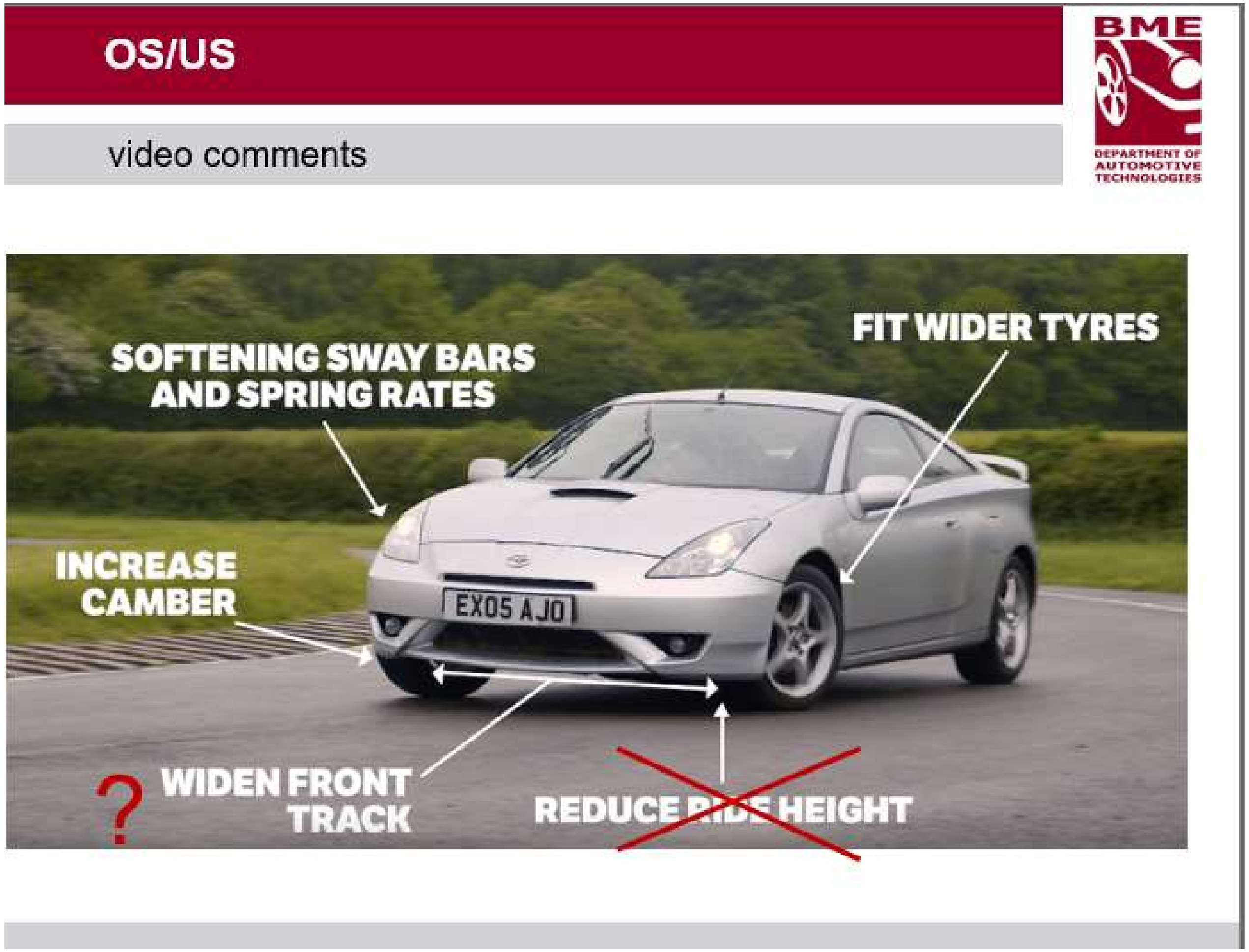
Effect of weight transfer…

…with tyre degressivity



from previous lecture…

video comments



Lateral weight transfer

https://www.facebook.com/photo?fbid=956716504863645&set=gm.1347862322229703

Midterm tests and exams

1

- know concepts and definitions – you are able to give definitions of :
  - different type of tyre radius
  - contact patch
  - tyre structures
  - slip ratio
  - slip angle
  - aware of the different characteristics of tyre behaviour and able to distinguish one from other
  - friction coefficient
  - brush tyre model and explanation of tyre force
  - able to orientate in the coordinate system of a vehicle
  - cornering stiffnes of a tyre
  - self aligning torque
  - pneumatic trail
  - friction ‚cirle'
  - steady state basics equations
  - transient basics equation
  - characteristics of transient basics diagrams

Midterm tests and exams

2

- assymetric tyre behaviour to acceleration and braking
- static vertical tyre loads
- longitudinal weight transfer with the help of longitudinal model
- lateral weight transfer in steady state cornering
- understanding the effect of tyre degressivity and weight transfer

Bibliography

- https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.nhra.com%2Fnews%2F2019%2Fnhra-announces-2020-lucas-oil-drag-racing-series-schedule&psig=AOvVaw1gEiiWHmijOxHpbS0OT3sU&ust=1615131277553000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCMDC4IT_m-8CFQAAAAAdAAAAABAD
- Optimum G Seminar by Claude Rouelle 2016 – Graz
- https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.vectorstock.com%2Froyalty-free-vector%2Fcar-frontview-icon-image-vector-12155010&psig=AOvVaw1hu57p4wtvijLerVJucABs&ust=1615139654671000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCIiAqp-enO8CFQAAAAAdAAAAABAj
- https://tudasbazis.sulinet.hu/hu/szakkepzes/kozlekedes/kozlekedesi-alapismeretek/az-iv-sugara/a-kicsuszasi-es-a-kiborulasi-hatarsebesseg-ivmenetben-ii

Thank you for your attention!

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