Department of Automotive Technologies –

Vehicle Mechanics Fundamentals

Gábor Sipos

DEPARTMENT OF AUTOMOTIVE TECHNOLOGIES

Lecture 3

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		

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Note

- Please do not consider operative information from online lecture, it’s an older record.
- Bring laptop to lab course!

Quiz

What kind of car part can you see on the picture?

A. 1-upright 2-rim, 3-wheel bearing, 4-tyre, 5- wheel nuts, 6-wheel stud
B. 1-upright 2-rim, 3-wheel, 4-tyre, 5- wheel studs, 6-brake caliper
C. 1-wheel hub 2-rim, 3-wheel bearing, 4-tyre, 5- wheel studs, 6-brake caliper
D. 1-wheel hub 2-rim, 3-wheel bearing, 4-tyre, 5- wheel nuts, 6-upright

Quiz

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D. 1-wheel hub 2-rim, 3-wheel bearing, 4-tyre, 5- wheel nuts, 6-upright

Quiz

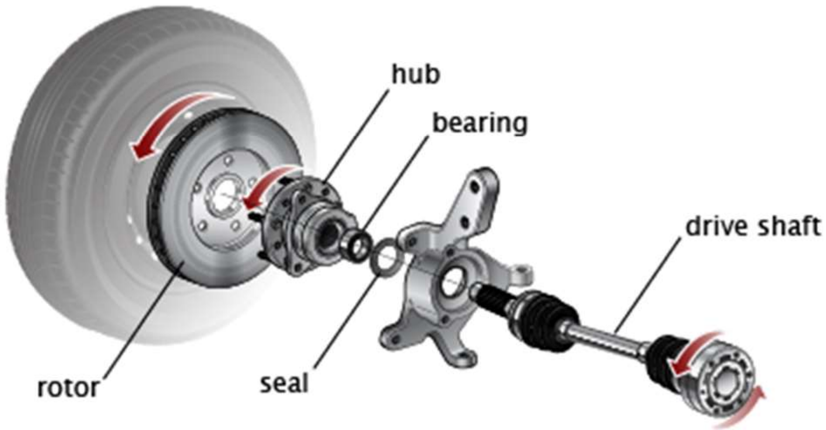
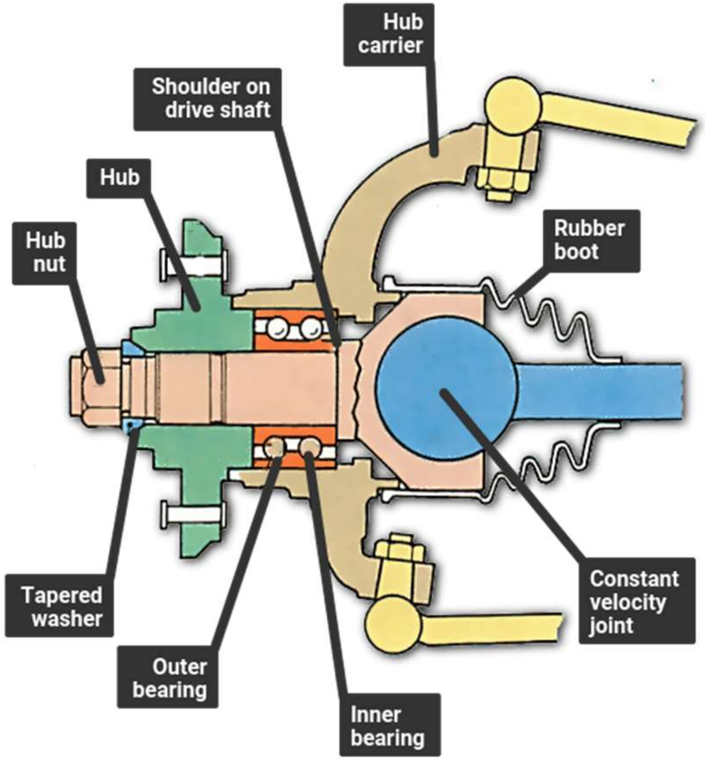
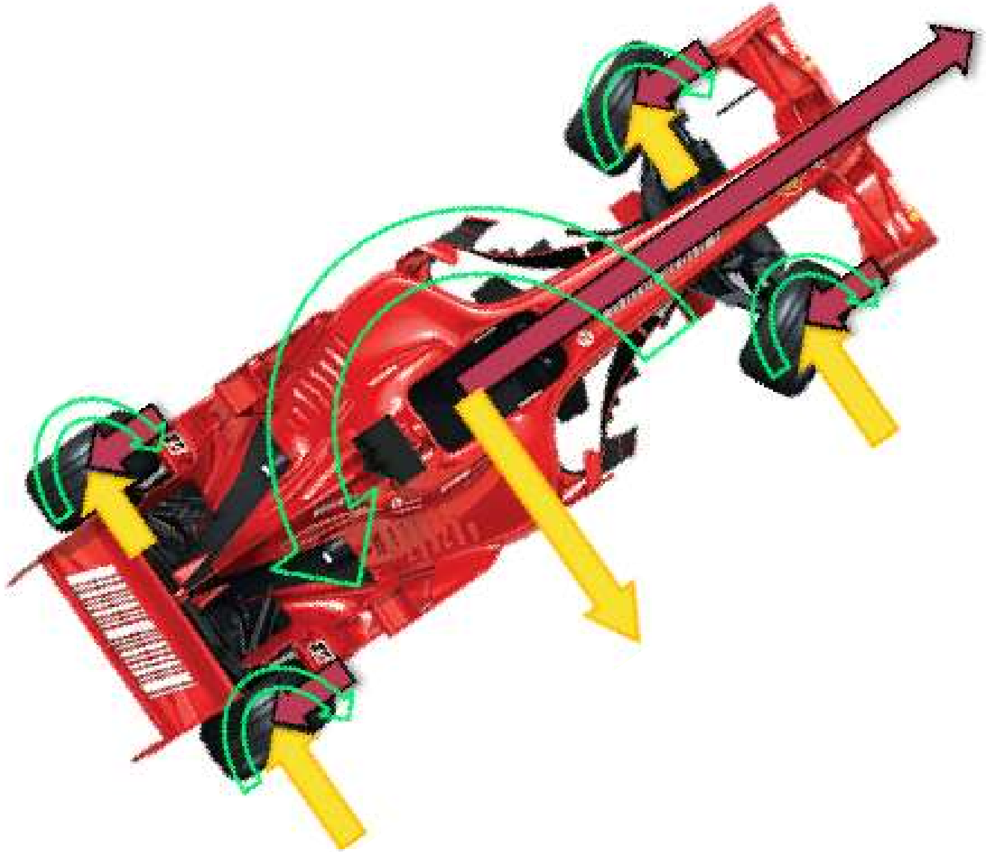


Image courtesy of ClearMechanic.com



Vehicle dynamics fundamentals



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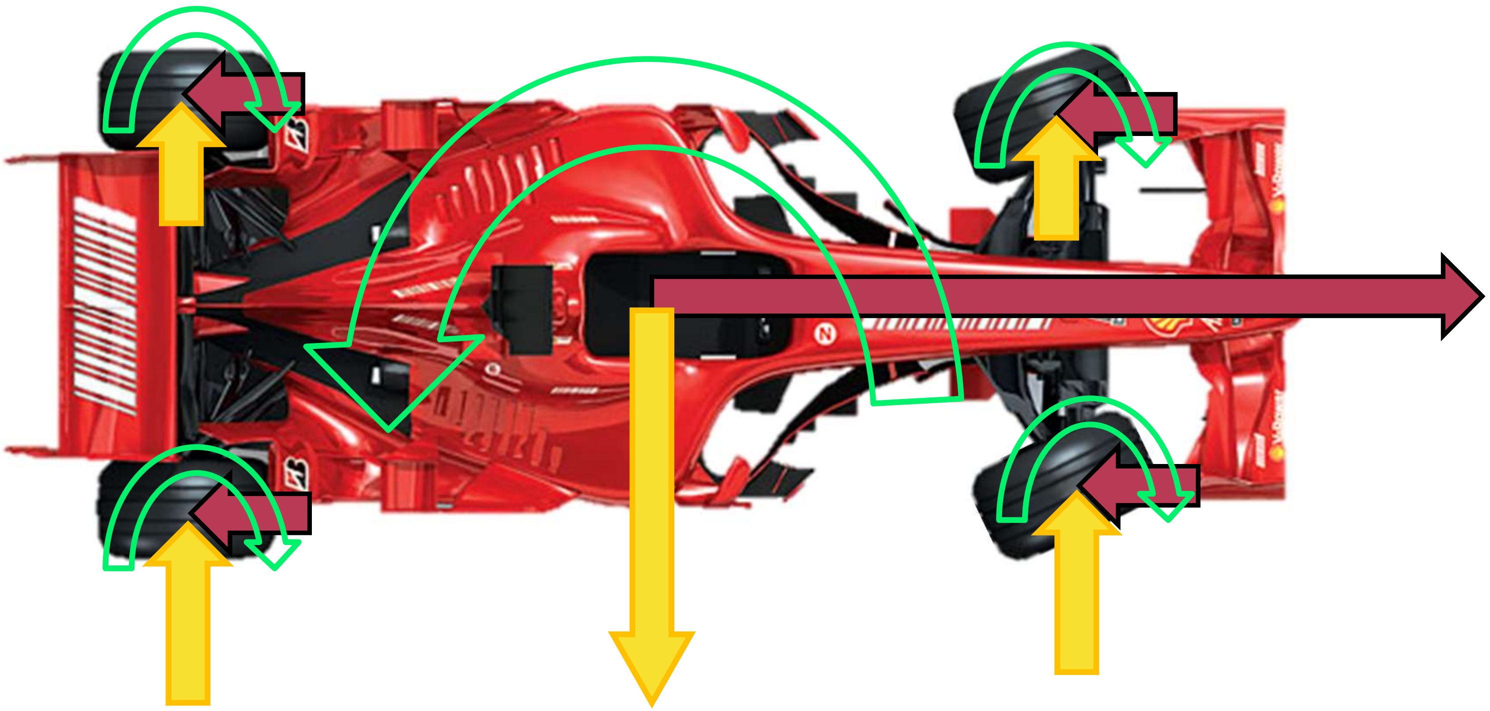
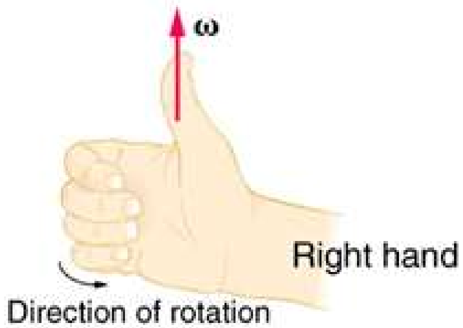
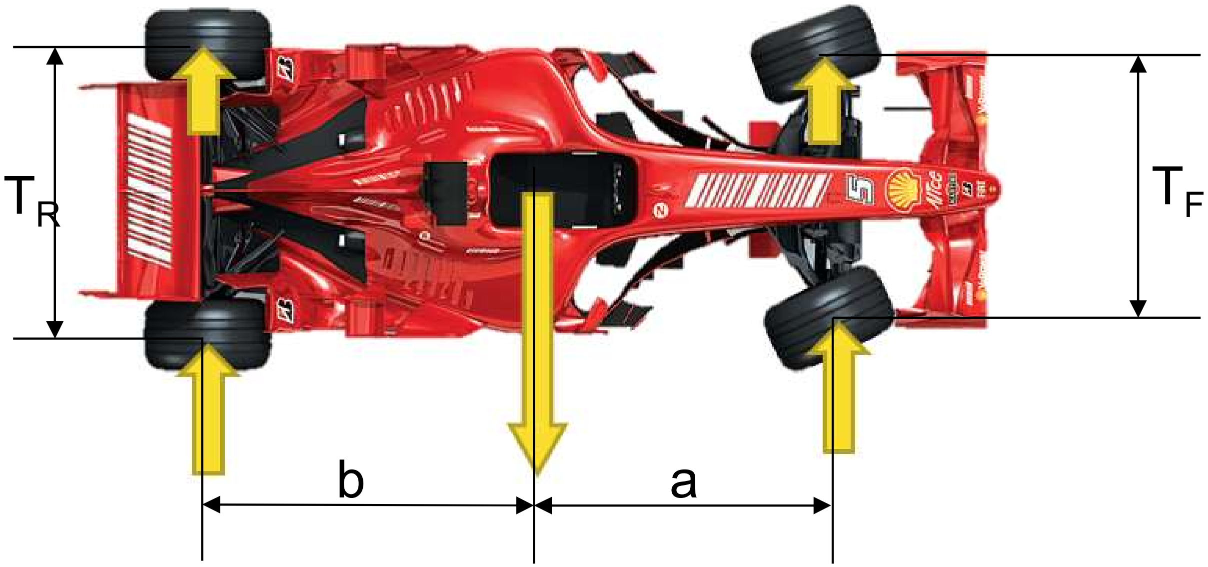




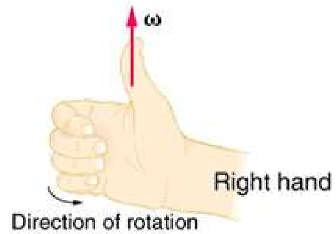
Steady State Basics



$$\sum F_y \rightarrow \quad F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}} = Mass \cdot Lateral\ Acc$$

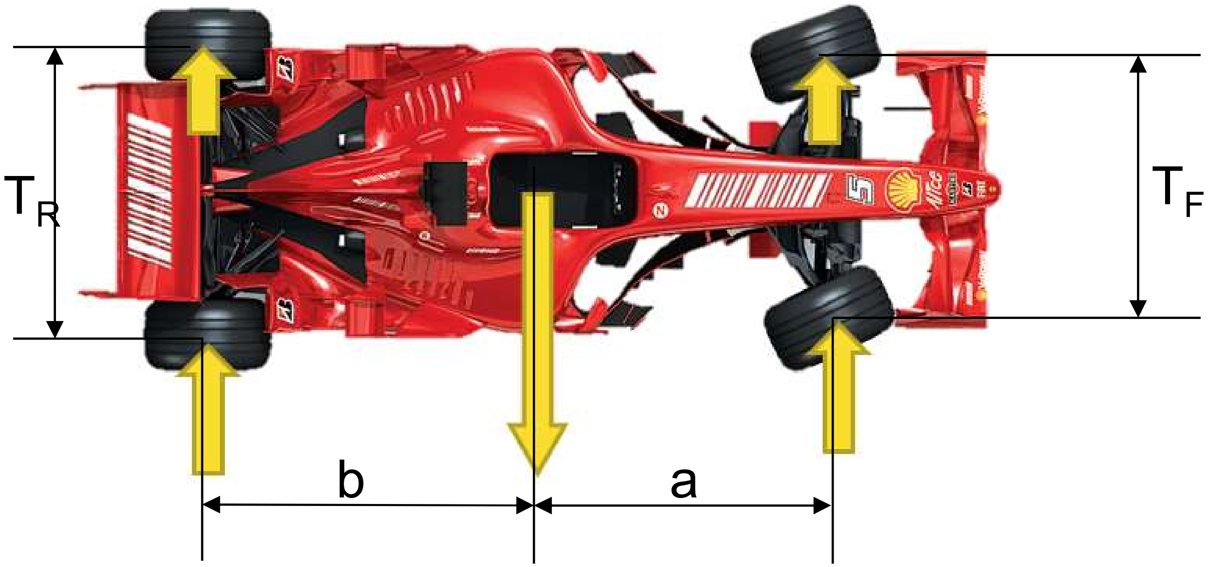
$$(F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}})/Mass = Lateral\ Acc$$

$$\sum M = 0 \rightarrow \quad \left(F_{y_{FL}} + F_{y_{FR}}\right) \cdot a - (F_{y_{RL}} + F_{y_{RR}}) \cdot b = 0$$



Vehicle dynamics fundamentals

Steady State Basics



$$A_f = A_r$$

$$(F_{y_{FL}} + F_{y_{FR}})/m_F = (F_{y_{RL}} + F_{y_{RR}})/m_R$$

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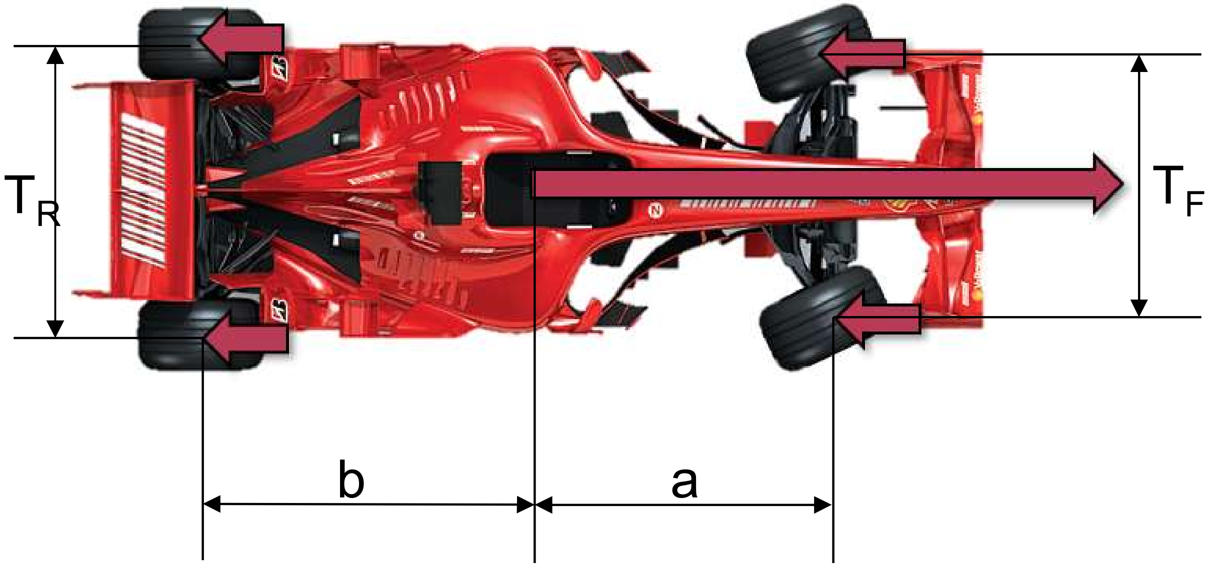
Steady State Basics



$$\sum F_x \rightarrow \quad F_{xFL} + F_{xFR} + F_{xRL} + F_{xRR} = Mass \cdot Longitudinal\ Acc$$

$$\sum M = 0 \rightarrow \quad \left(F_{xFR} \cdot \frac{T_F}{2} + F_{xRR} \cdot \frac{T_R}{2}\right) - \left(F_{xFL} \cdot \frac{T_F}{2} + F_{xRL} \cdot \frac{T_R}{2}\right) = 0$$

Steady State Basics

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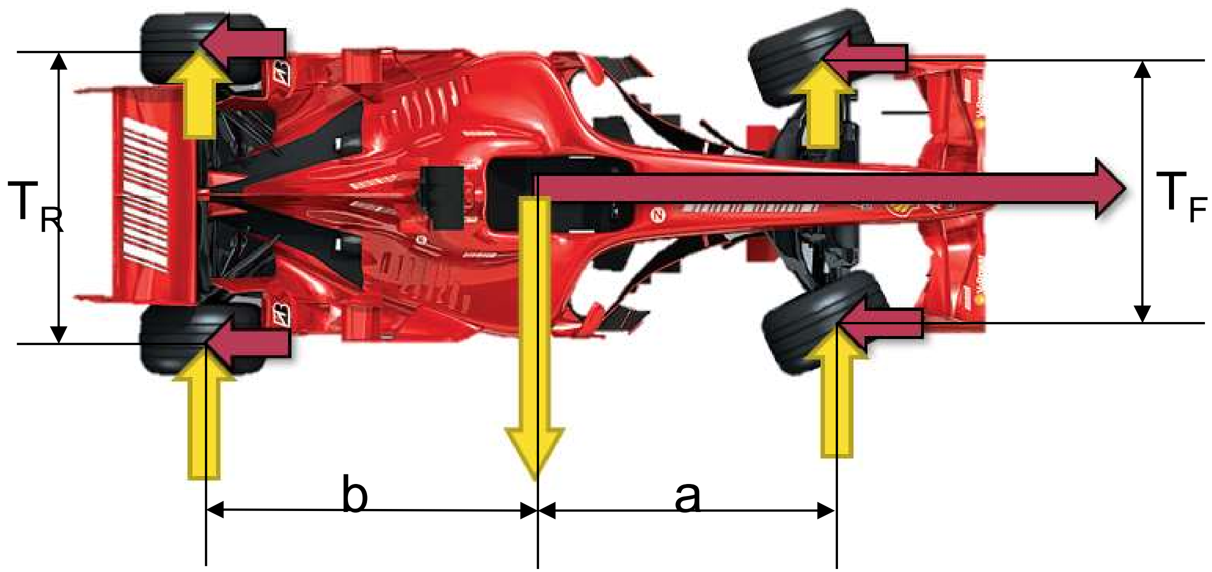

$$\sum F_y \rightarrow \quad F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}} = Mass \cdot Lateral\ Acc$$

$$\sum F_x \rightarrow \quad F_{x_{FL}} + F_{x_{FR}} + F_{x_{RL}} + F_{x_{RR}} = Mass \cdot Longitudinal\ Acc$$

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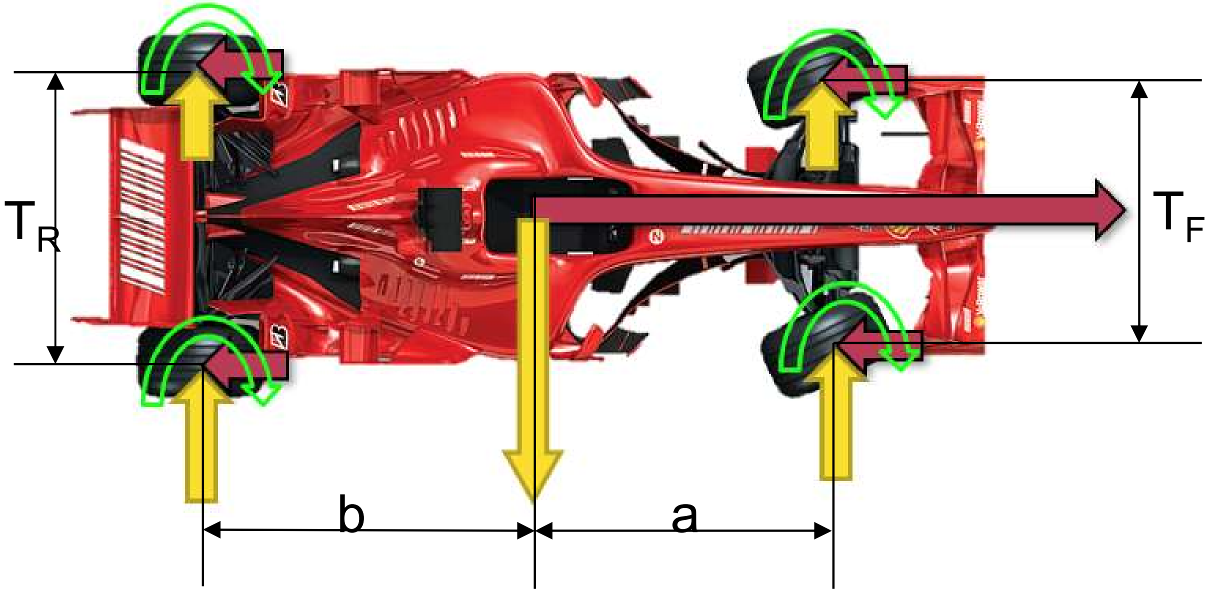
Vehicle dynamics fundamentals

Steady State Basics



$$\sum F_y \rightarrow \quad F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}} = Mass \cdot Lateral\ Acc$$

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$$- M_{z_{FL}} - M_{z_{FR}} - M_{z_{RL}} - M_{z_{RR}} = 0$$

Vehicle dynamics fundamentals

Steady State Basics - SkidPad

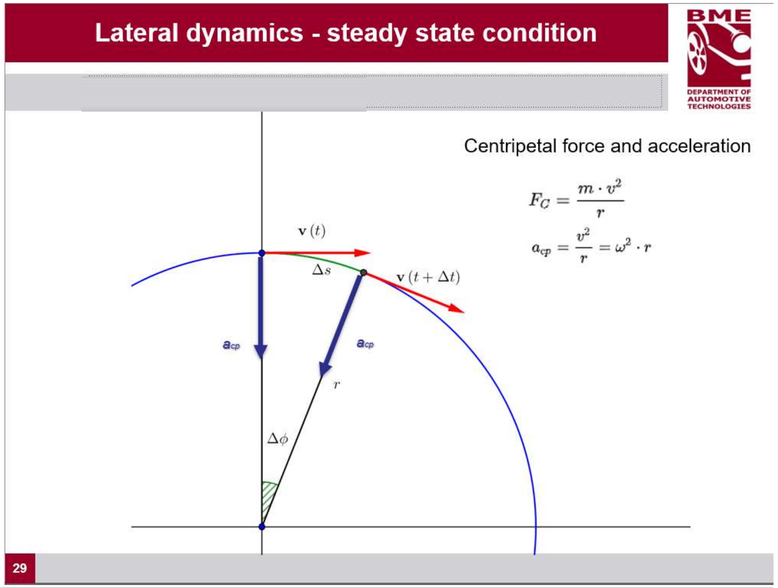
Vehicle dynamics fundamentals

Steady State Basics

$$V_x = \dot{\theta} R \qquad LatG = \frac{v^2}{R}$$

$$LatG = \frac{\dot{\theta} v^2}{v}$$

$$\dot{\theta} = \frac{LatG}{v_x}$$



Vehicle dynamics fundamentals

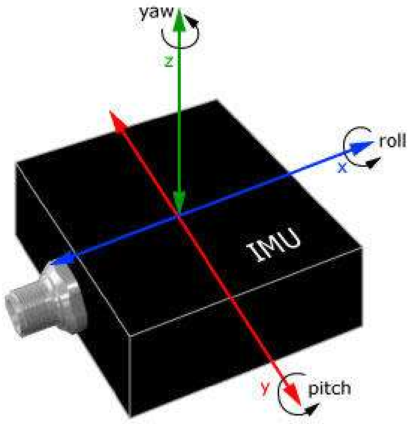
Steady State Basics

$$V_x = \dot{\theta} R \qquad LatG = \frac{v^2}{R}$$

$$LatG = \frac{\dot{\theta} v^2}{v}$$

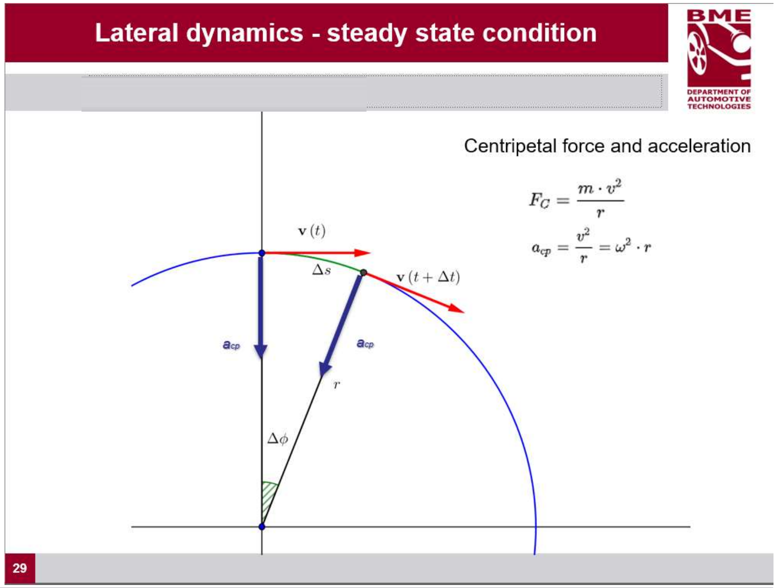
$$\dot{\theta} = \frac{LatG}{v_x}$$

latG sensor

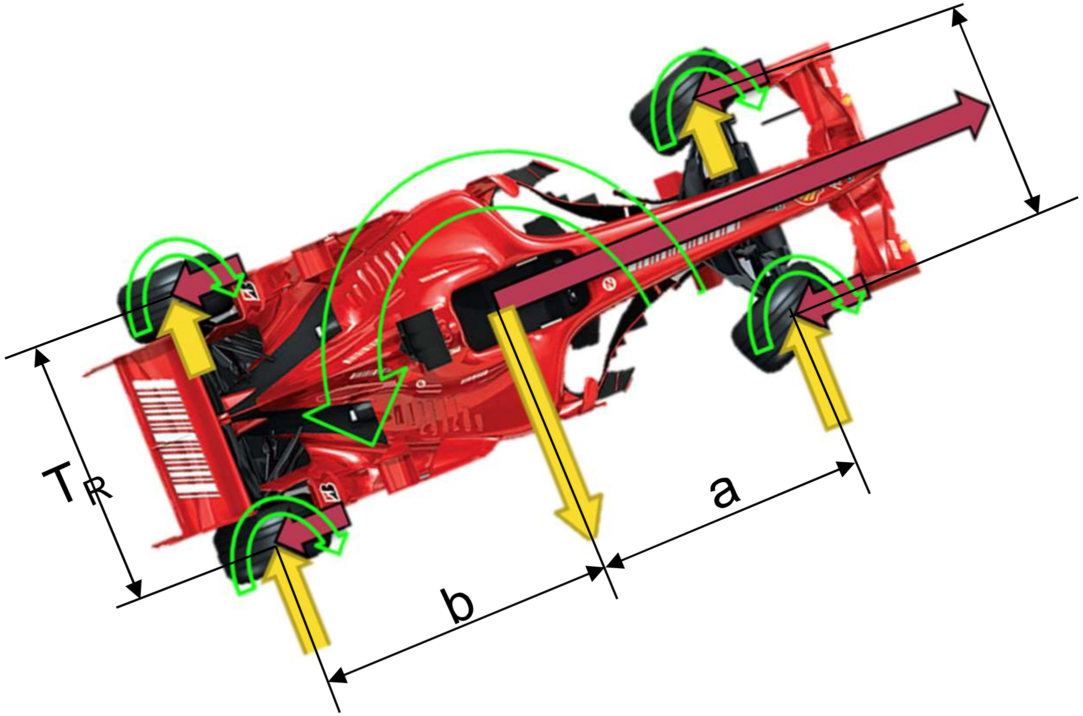


speed sensor
(~r_{dyn} ?)

yaw rate sensor



Transient Basics: Yaw Moment Equation



$\mathbf{I_{ZZ}}$: moment of inertia $[\boldsymbol{kgm^2}]$

$\mathbf{d^2\theta/dt^2}$: Yaw acceleration
: d(yaw rate)/dt
:d(gyro)/dt

$$\sum M \rightarrow \left[\left(F_{y_{FL}}+F_{y_{FR}}\right)\cdot a-\left(F_{y_{RL}}+F_{y_{RR}}\right)\cdot b\right]+\left[\left(F_{x_{FR}}\cdot\frac{T_F}{2}+F_{x_{RR}}\cdot\frac{T_R}{2}\right)-\left(F_{x_{FL}}\cdot\frac{T_F}{2}+F_{x_{RL}}\cdot\frac{T_R}{2}\right)\right]$$
$$-M_{z_{FL}}-M_{z_{FR}}-M_{z_{RL}}-M_{z_{RR}}=\mathrm{I_{ZZ}}\cdot d^2\,\theta/dt^2$$

E-Car design

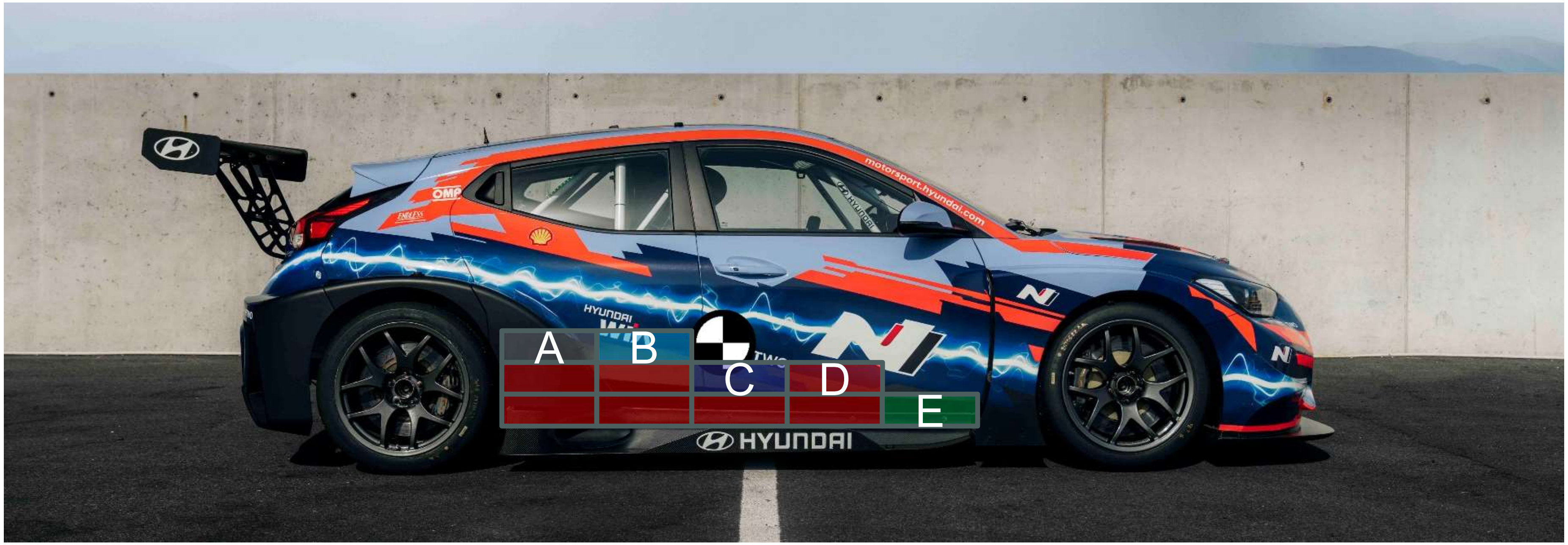
Where to place the last module of the newly designed battery for RWD car?

E-Car design

Where to place the last module of the newly designed battery for RWD car?

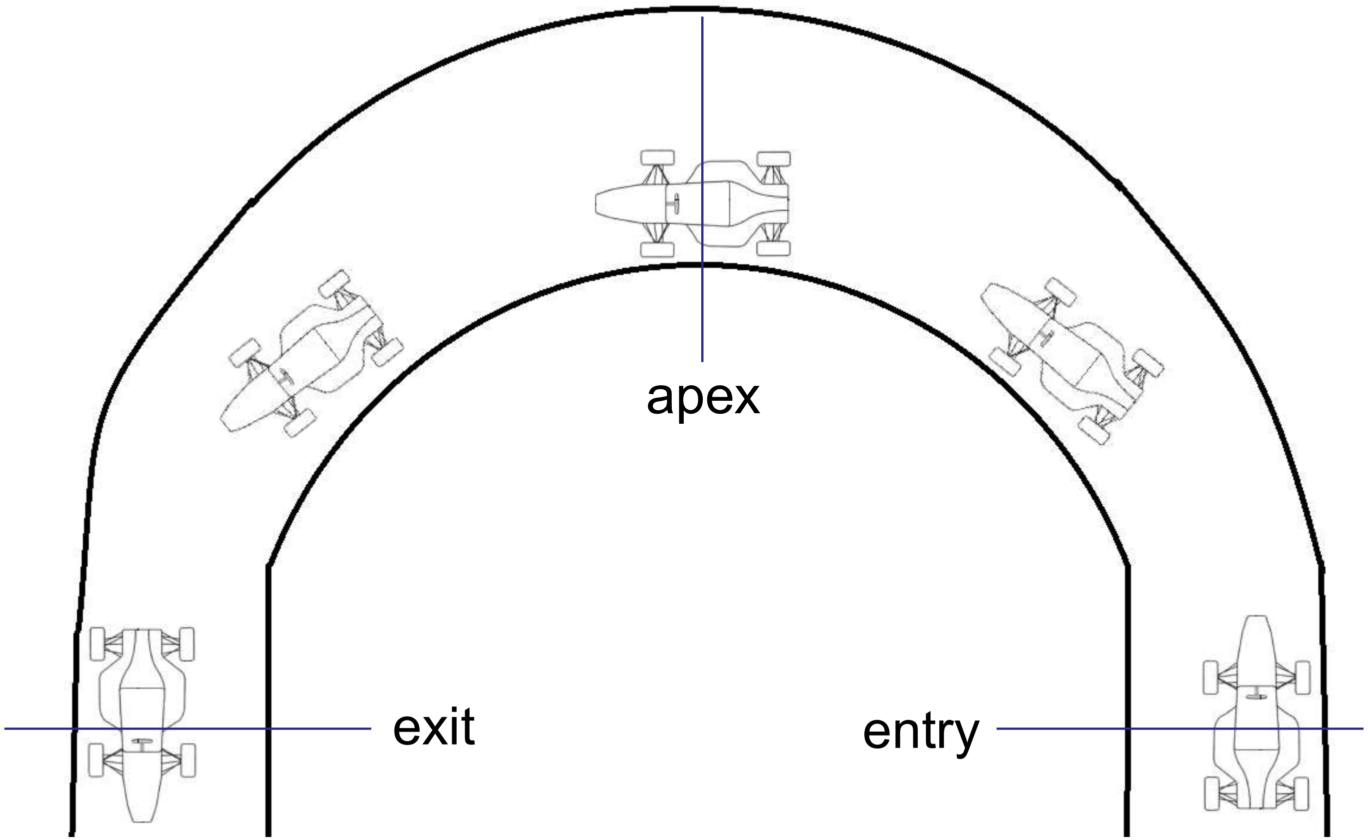
A – suggest to improve standing starts
B – suggest to improve standing starts & keep inertia low

C – suggest to keep inertia low, good compromise for CoG
D – suggest for lowest inertia and best option for CoG
E – suggest lowest CoG and good improvement of inertia



Analysis: 180° turn

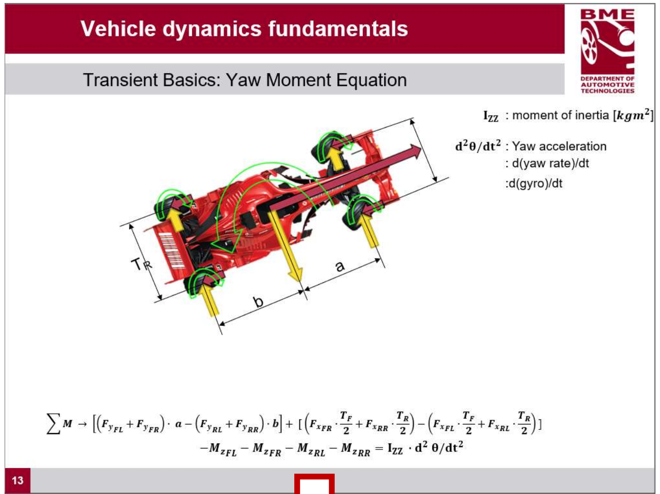
‚to use yaw moment’



Analysis: 180° turn

Conclusions

- To be ‚red car' we need more yaw velocity in less time -> greater yaw acceleration -> which means more yaw moment. Positive at corner entry and negative at corner exit. As a conclusion, more relative front grip at corner entry and more relative rear grip at corner exit required for the red car.
-



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$$- M_{z_{FL}} - M_{z_{FR}} - M_{z_{RL}} - M_{z_{RR}} = I_{ZZ} \cdot d^2\theta/dt^2$$

13

Analysis: 180° turn

Conclusions - example

entry

$$\left[\left(F_{y_{FL}} + F_{y_{FR}}\right) \cdot a - \left(F_{y_{RL}} + F_{y_{RR}}\right) \cdot b\right]$$

+3% +2%

apex

$$\left[\left(F_{y_{FL}} + F_{y_{FR}}\right) \cdot a - \left(F_{y_{RL}} + F_{y_{RR}}\right) \cdot b\right]$$

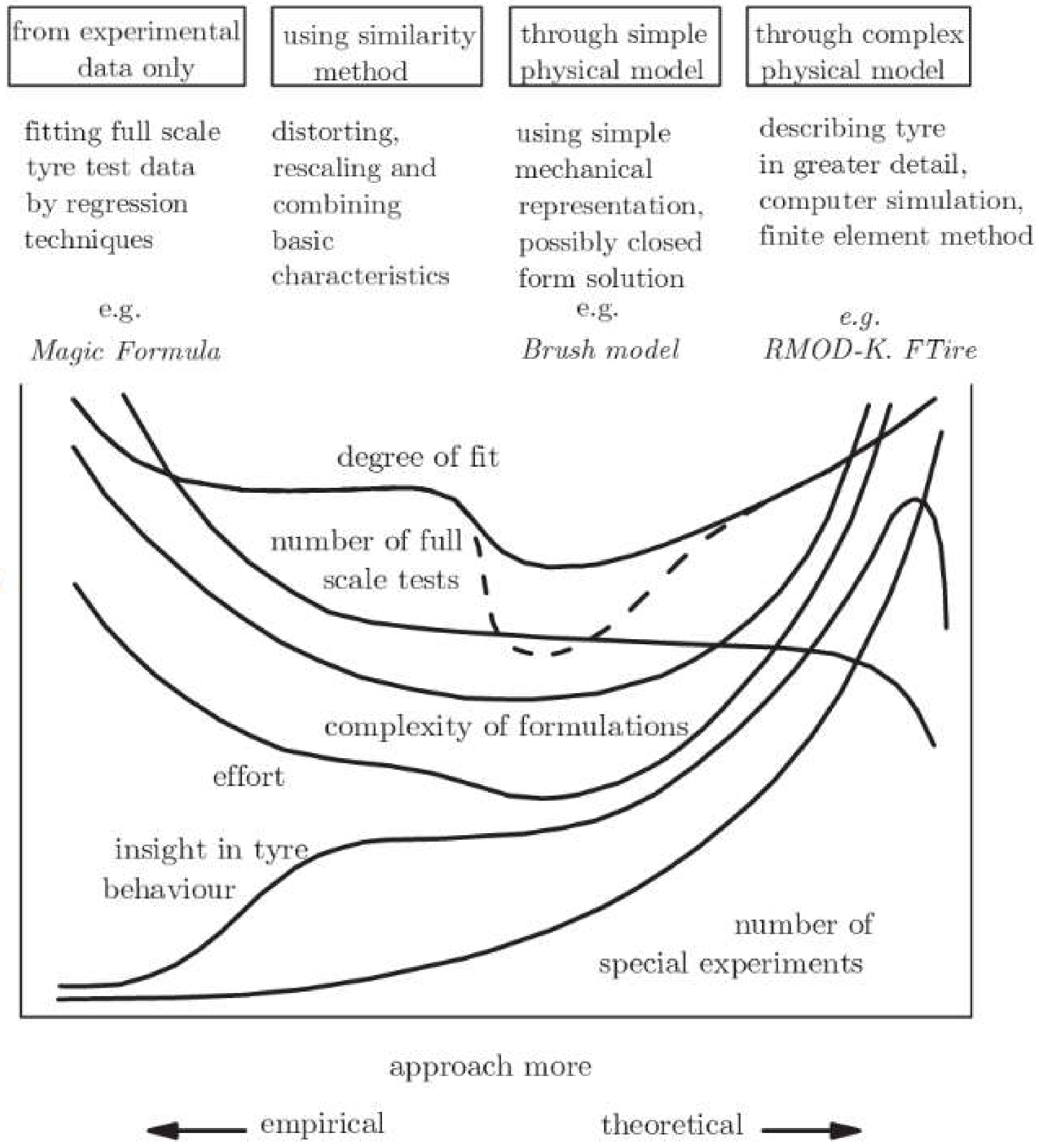
+4% +4%

exit

$$\left[\left(F_{y_{FL}} + F_{y_{FR}}\right) \cdot a - \left(F_{y_{RL}} + F_{y_{RR}}\right) \cdot b\right]$$

+2% +3%

Tyre model



2: Classification of tire models according to H.B.Pacejka

Tyre model

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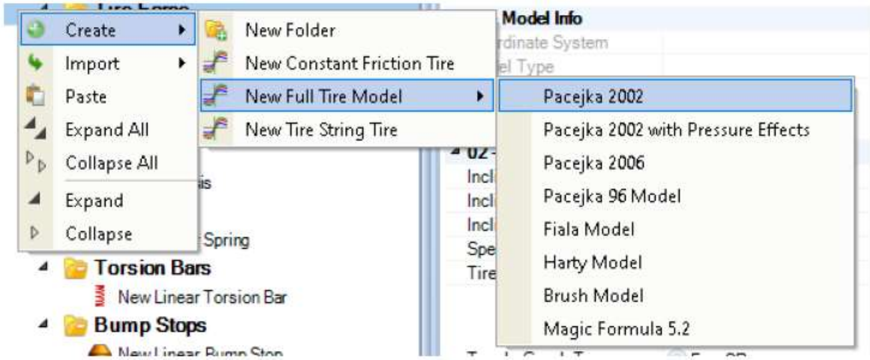
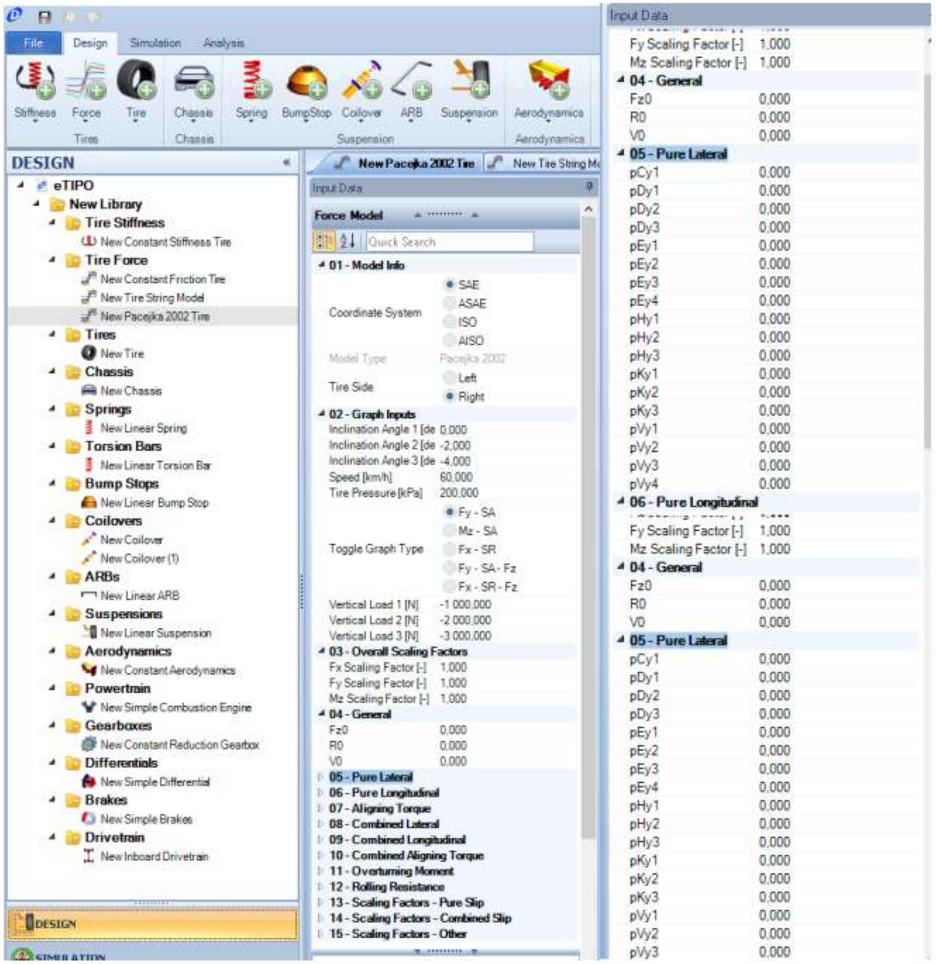
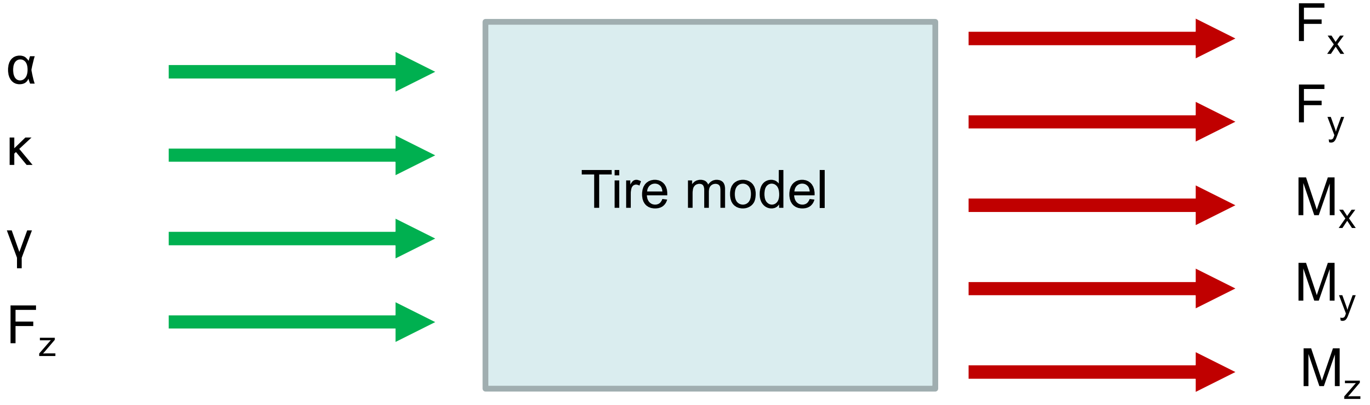
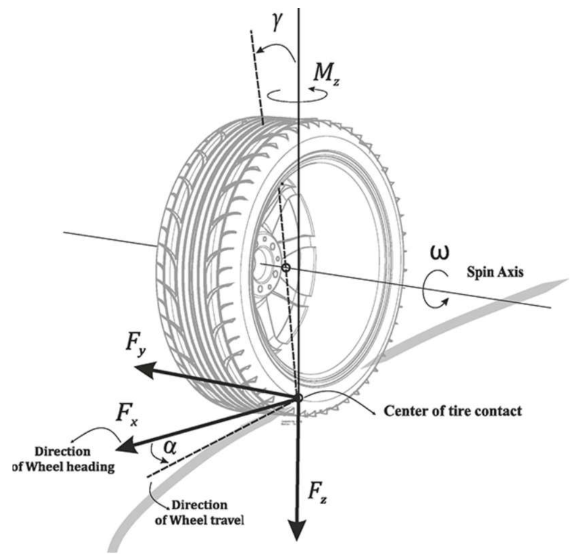


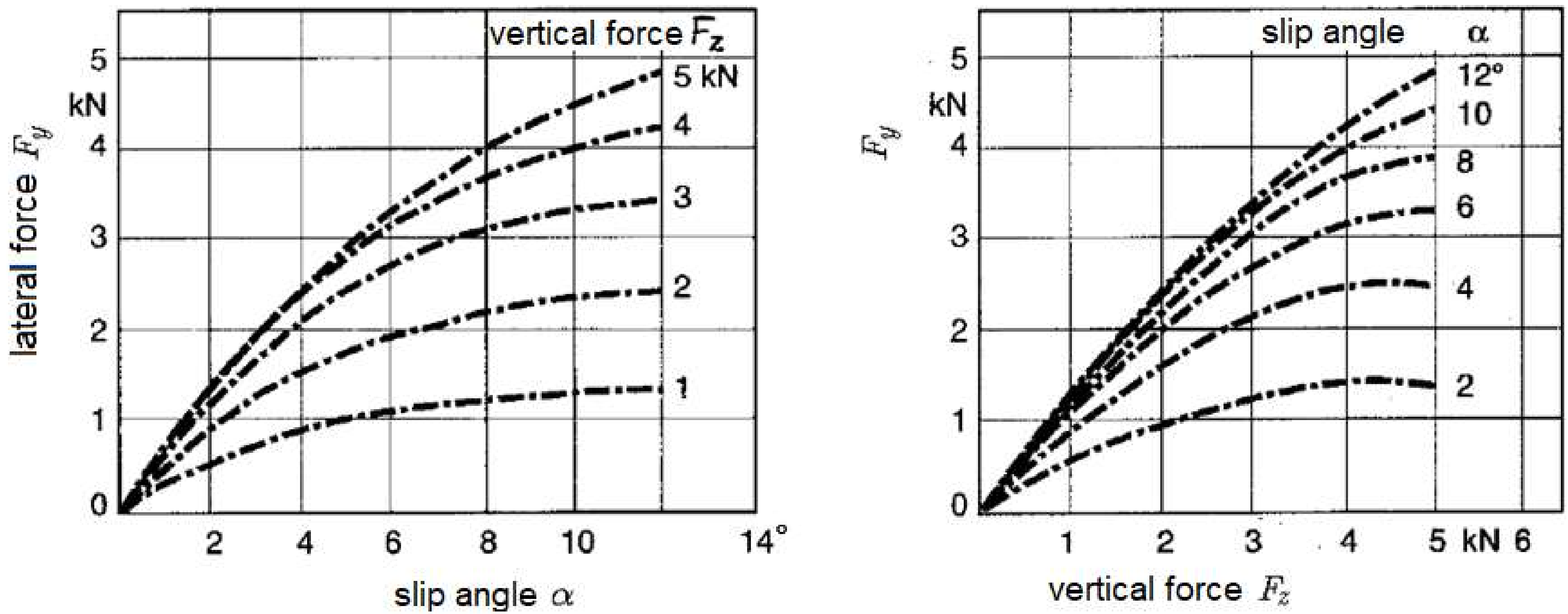


Tyre model


α
κ
γ
F_z
Tire model
F_x
F_y
M_x
M_y
M_z


γ
M_z
ω
Spin Axis
F_y
F_x
α
Center of tire contact
Direction of Wheel heading
Direction of Wheel travel
F_z

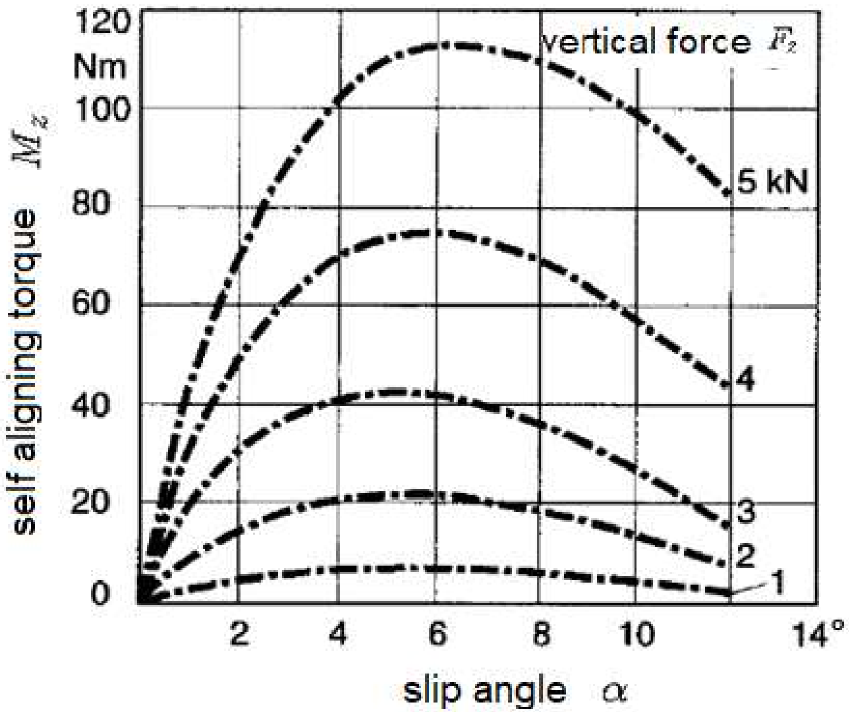
Vertical load, lateral force and slip angle diagrams

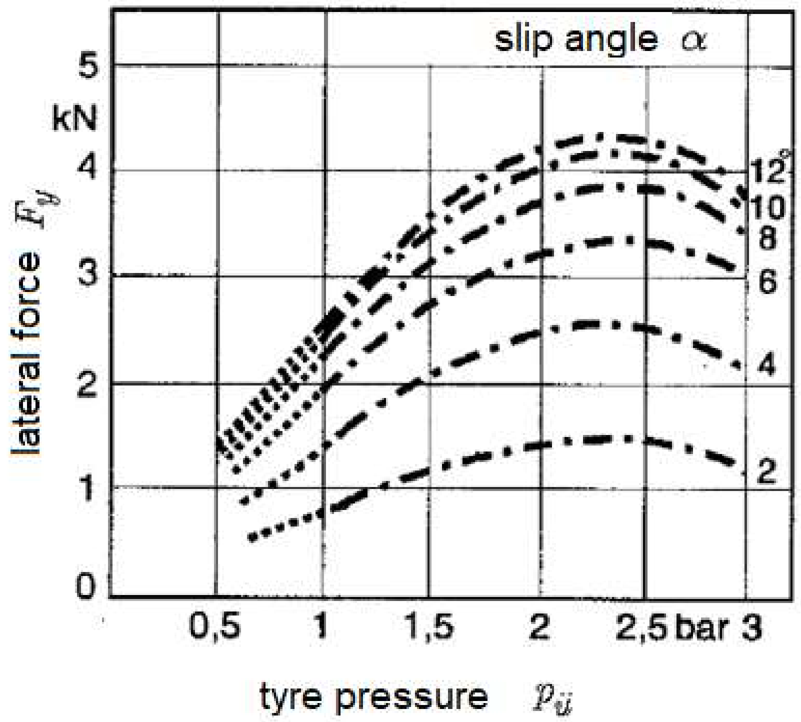


tyre	175 HR 14
	5 J x14
tread depth	9 mm
vehicle speed	14 m/s
tyre pressure	1,8 bar

Quelle: Wallentowitz 1997

Vertical load, lateral force and slip angle diagrams





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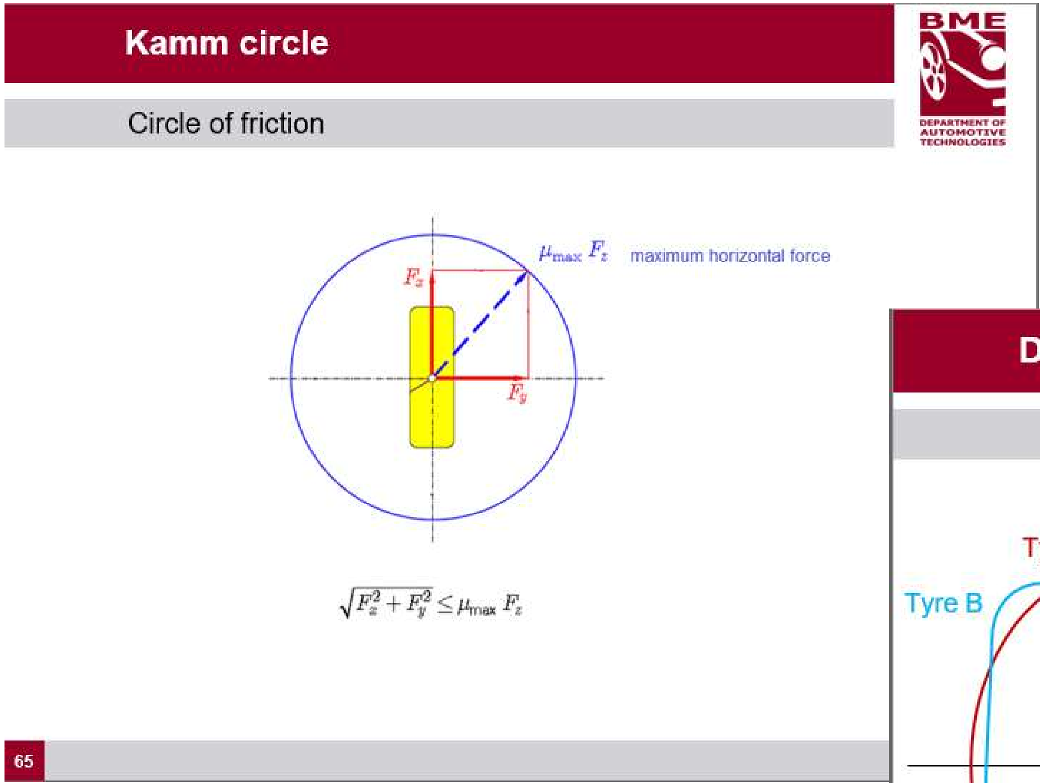
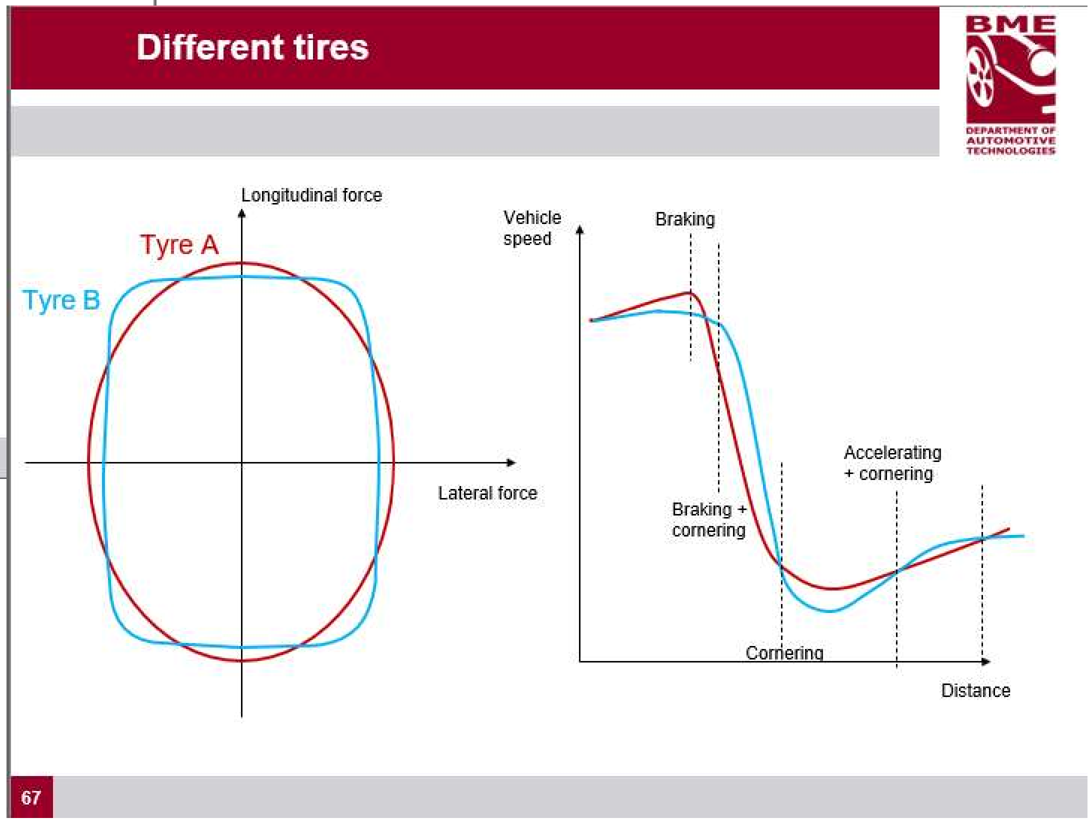
Vertical load, lateral force and slip angle diagrams

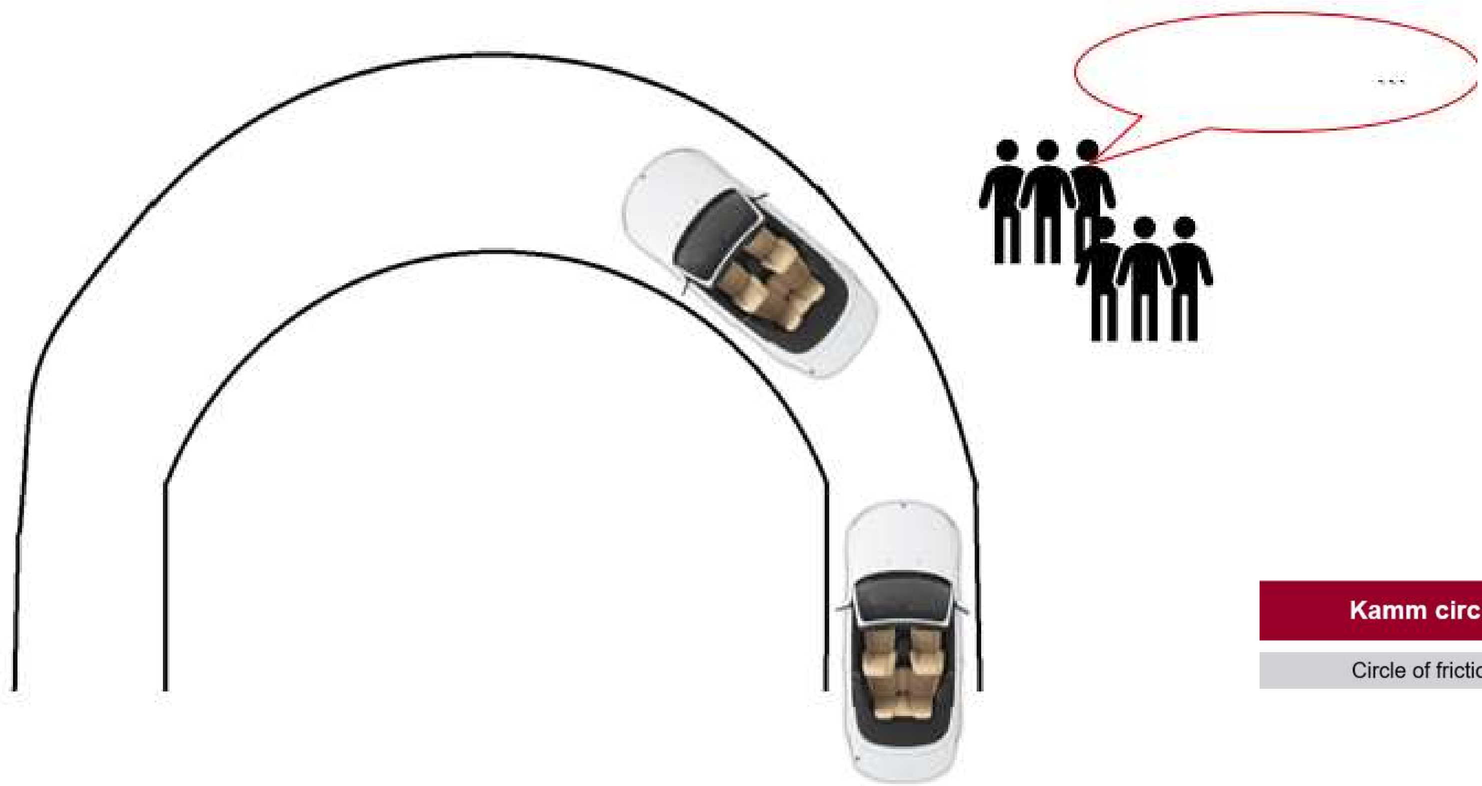
Conclusions - example

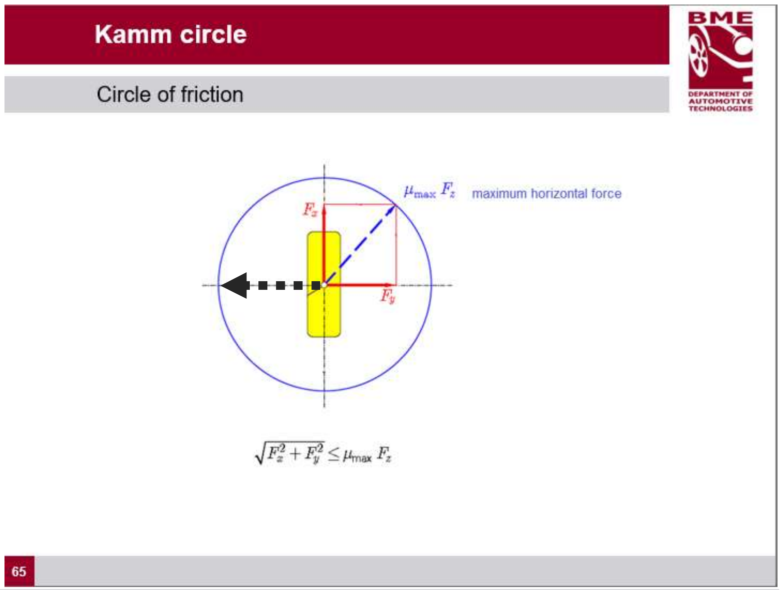




Case study

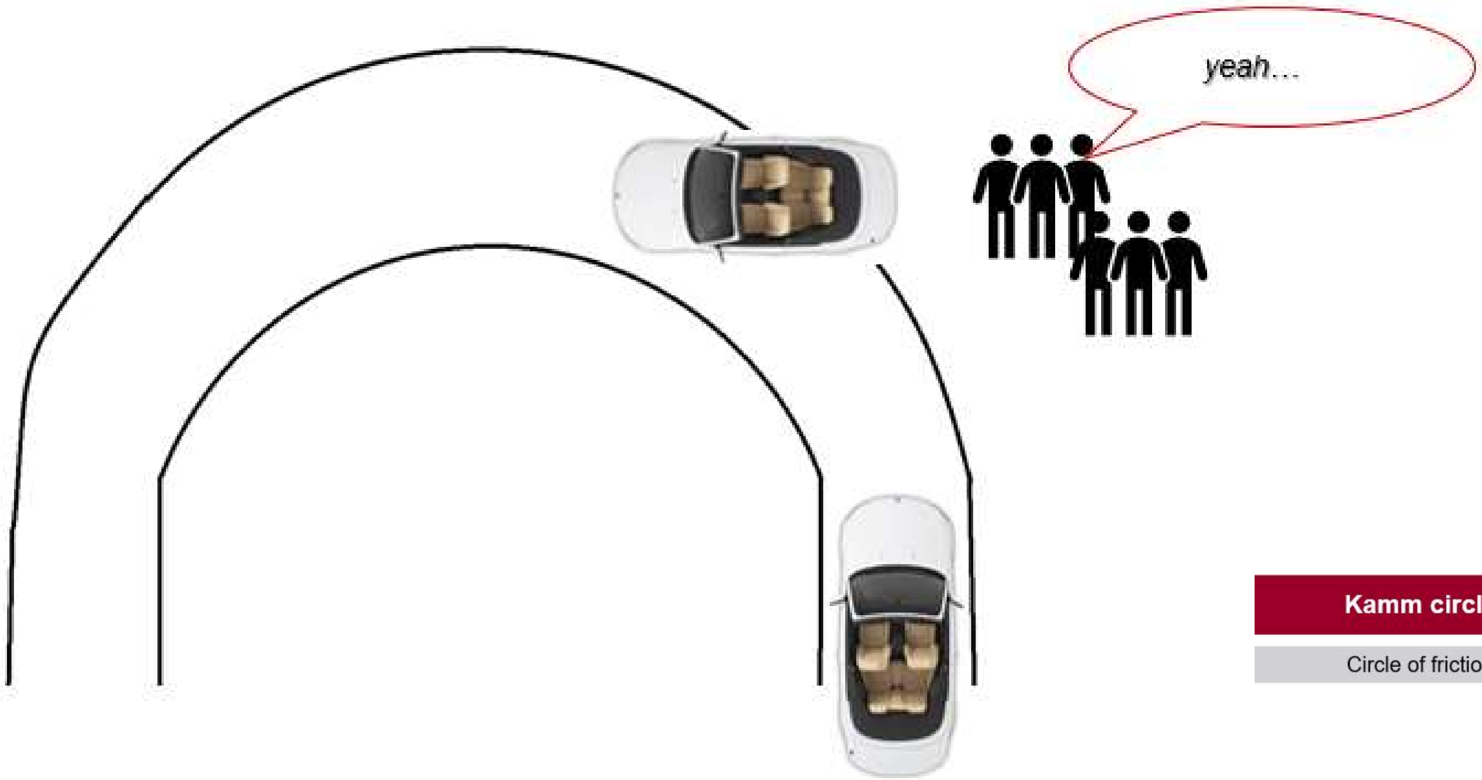
BMW

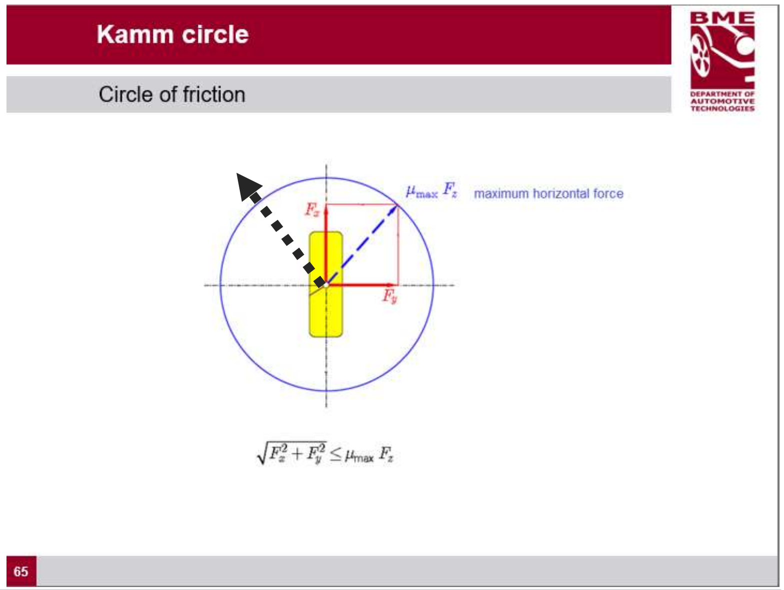




Case study

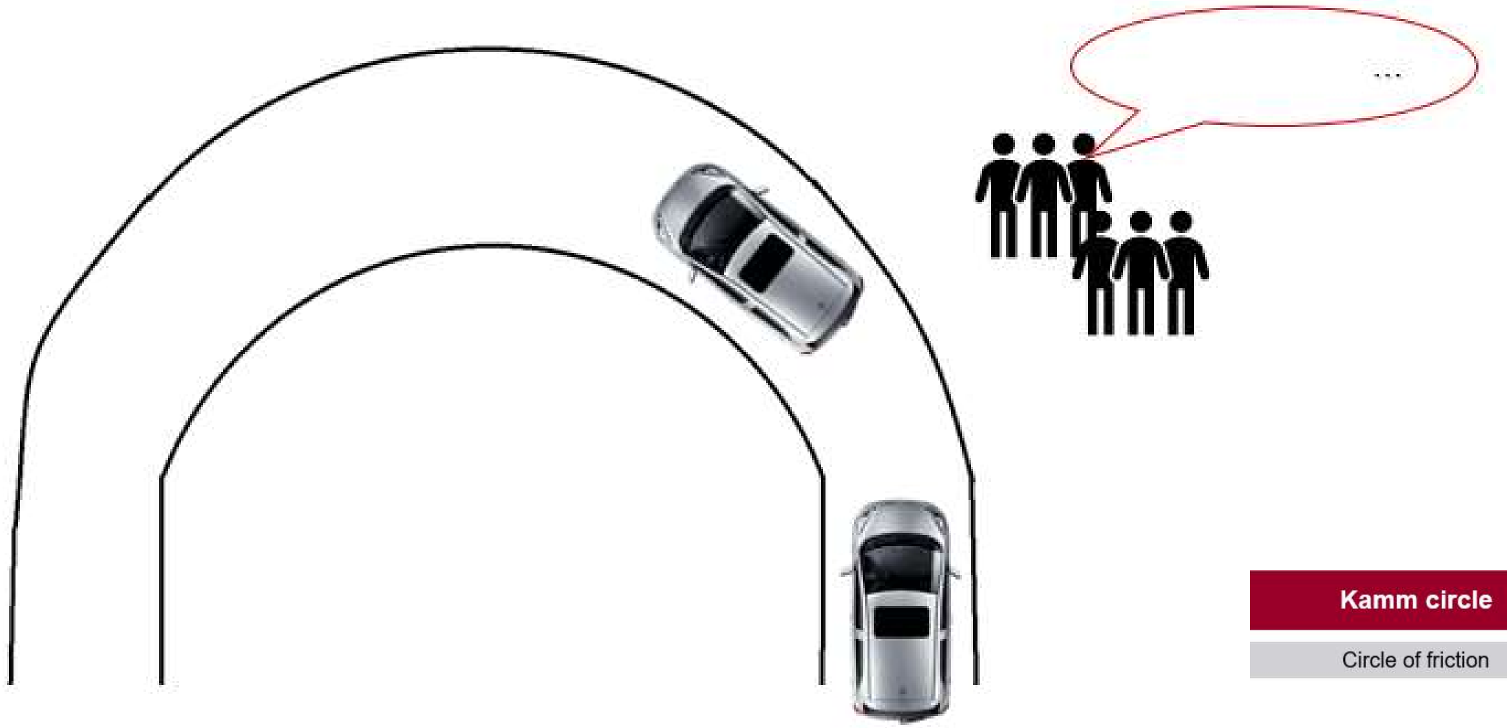
BMW

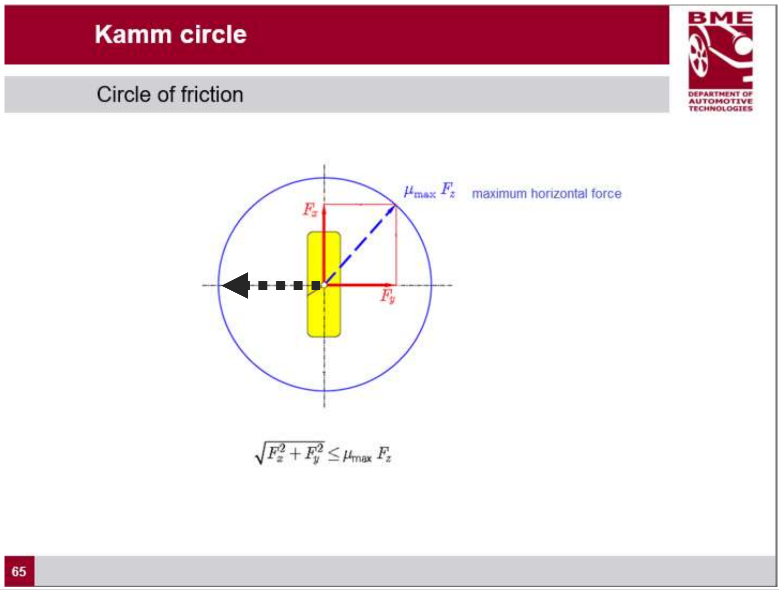




Case study

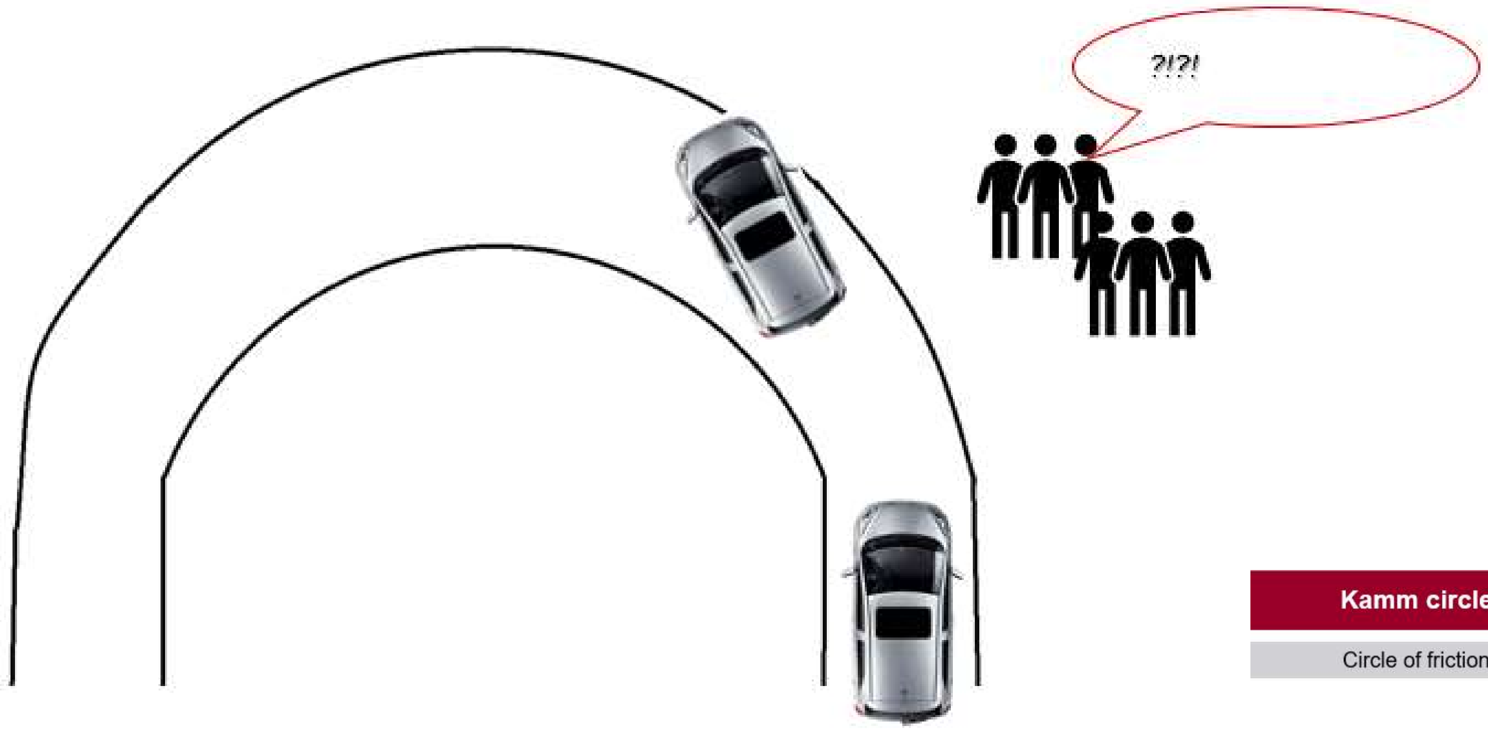
KIA

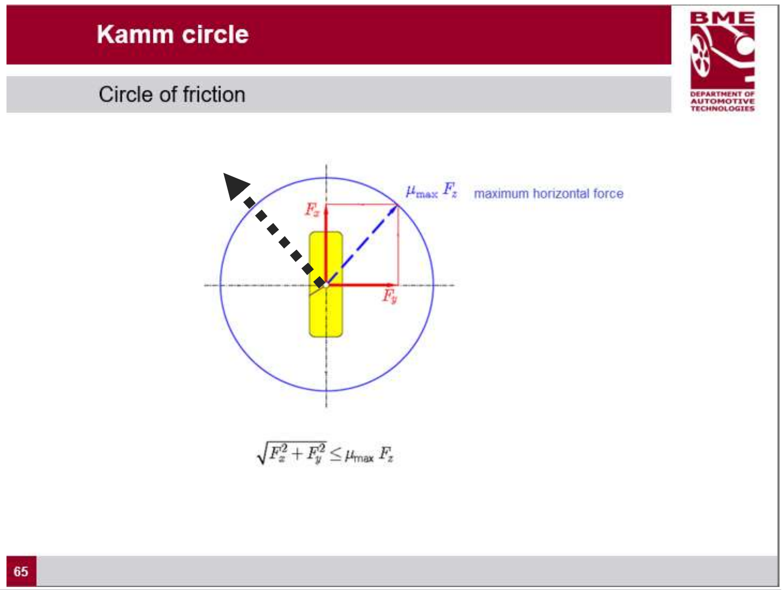




Case study

KIA





OS/US video

OS/US

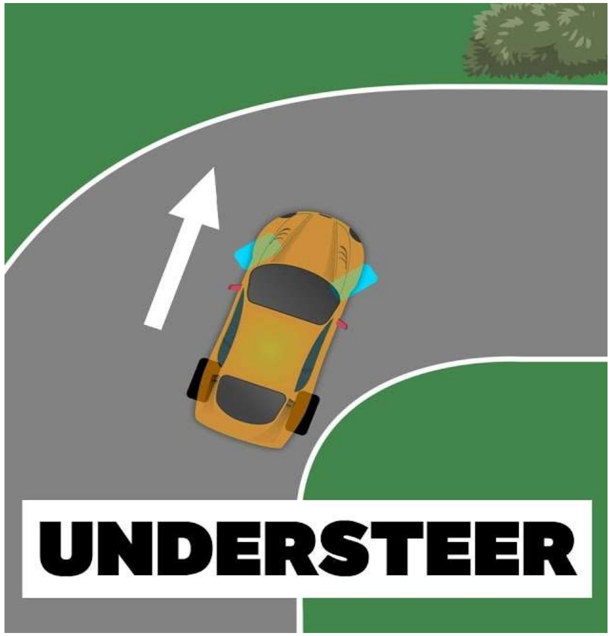
video comments

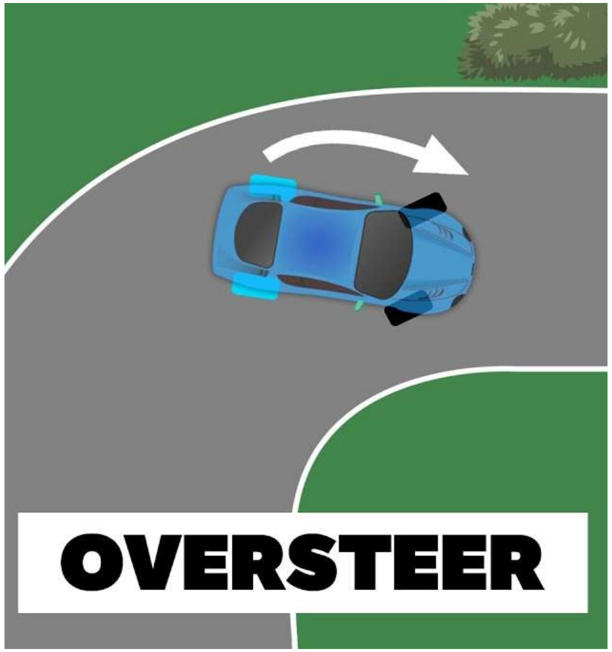
Understeer

- predictable
- easier to correct:reduce steering angle, lift off throttle
  - RWD: more throttle
- „Lift off oversteer”
- road cars

Oversteer

- better becasue you not see tree kills you
- reasons: throttle is too big at corner entry/ shift down / handbrake
- more difficult to handle





OS/US

video comments

OS/US

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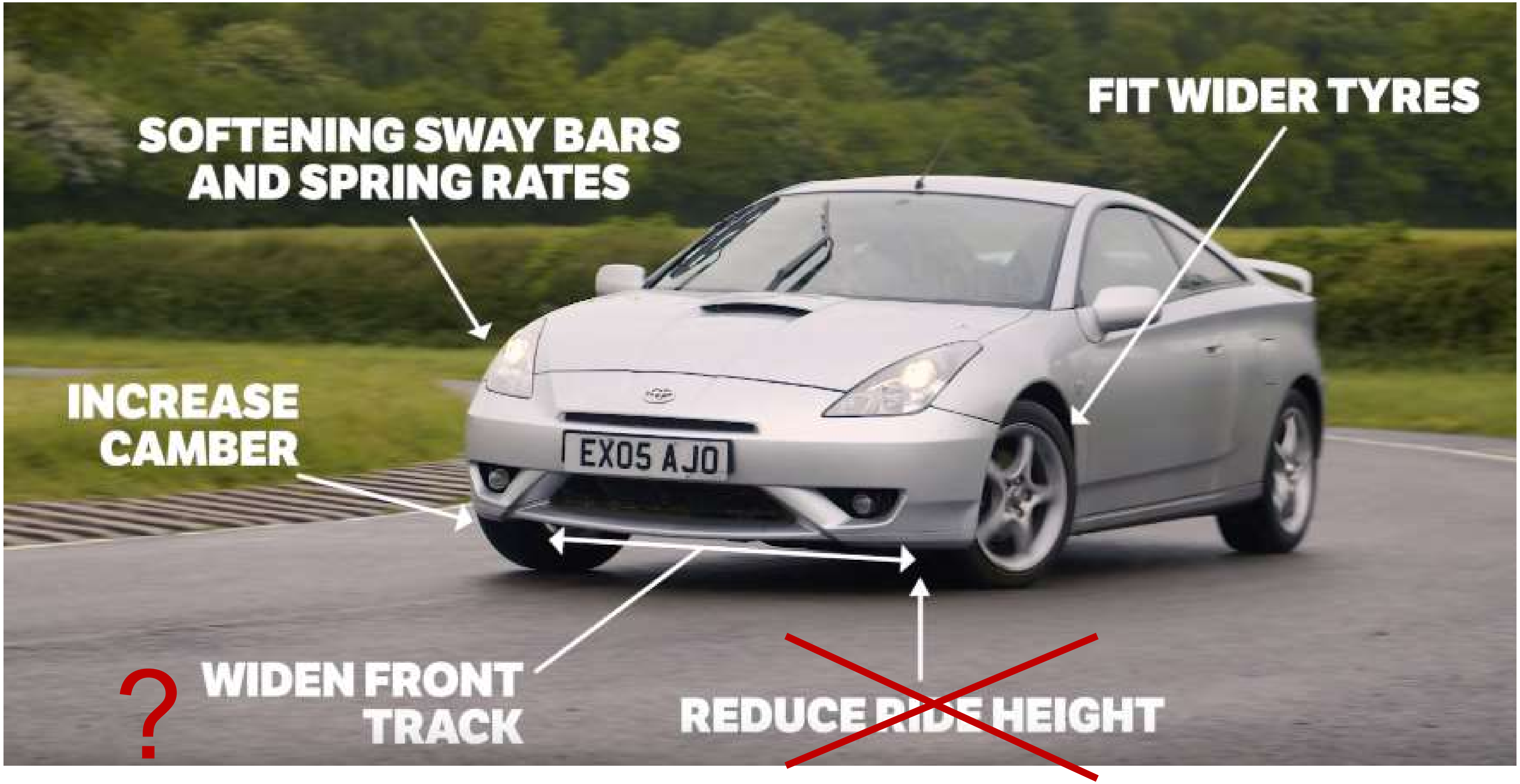

Midterm tests and exams

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- 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 ‚circle'
  - steady state basics equations
  - transient basics equation
  - characteristics of transient basics diagrams

Bibliography

- https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ebay.com%2Fitm%2FTOYOTA-HILUX-Genuine-2012-RHD-ESP-YAW-RATE-SENSOR-89183-60030-1901191-%2F192782917144&psig=AOvVaw3fQLFfTvbjW6tIvt9WA9H2&ust=1614098511238000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCPjyv9T3_e4CFQAAAAAdAAAAABAN
- Optimum G Seminar by Claude Rouelle 2016 – Graz
- https://www.youtube.com/watch?v=S0TIRkNWheQ
- https://www.sciencedirect.com/science/article/pii/S156849461500650X

Thank you for your attention!

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