# Department of Automotive Technologies – Vehicle Mechanics Fundamentals



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Lecture 3

03. 13. 2023.

# **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		





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





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





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
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Image courtesy of ClearMechanic.com

rotor

seal

<u>\_\_\_</u>











#### **Steady State Basics**



$$\sum F_{y} \rightarrow F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}} = Mass \cdot Lateral Acc$$
$$(F_{y_{FL}} + F_{y_{FR}} + F_{y_{RL}} + F_{y_{RR}})/Mass = Lateral Acc$$
$$\sum M = 0 \rightarrow (F_{y_{FL}} + F_{y_{FR}}) \cdot a - (F_{y_{RL}} + F_{y_{RR}}) \cdot b = 0$$





### **Steady State Basics**



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



### **Steady State Basics**



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

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



### **Steady State Basics**



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

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

$$\sum M = \mathbf{0} \rightarrow \left[ \left( F_{y_{FL}} + F_{y_{FR}} \right) \cdot \mathbf{a} - \left( F_{y_{RL}} + F_{y_{RR}} \right) \cdot \mathbf{b} \right] + \left[ \left( F_{x_{FR}} \cdot \frac{T_{F}}{2} + F_{x_{RR}} \cdot \frac{T_{R}}{2} \right) - \left( F_{x_{FL}} \cdot \frac{T_{F}}{2} + F_{x_{RL}} \cdot \frac{T_{R}}{2} \right) \right] = \mathbf{0}$$



### **Steady State Basics**



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

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

$$\sum M = \mathbf{0} \rightarrow \left[ \left( F_{y_{FL}} + F_{y_{FR}} \right) \cdot \mathbf{a} - \left( F_{y_{RL}} + F_{y_{RR}} \right) \cdot \mathbf{b} \right] + \left[ \left( F_{x_{FR}} \cdot \frac{T_{F}}{2} + F_{x_{RR}} \cdot \frac{T_{R}}{2} \right) - \left( F_{x_{FL}} \cdot \frac{T_{F}}{2} + F_{x_{RL}} \cdot \frac{T_{R}}{2} \right) \right]$$

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



### Steady State Basics - SkidPad



### **Steady State Basics**



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

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

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



### **Steady State Basics**



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### **Transient Basics: Yaw Moment Equation**





$$\sum M \rightarrow \left[ \left( F_{y_{FL}} + F_{y_{FR}} \right) \cdot a - \left( F_{y_{RL}} + F_{y_{RR}} \right) \cdot b \right] + \left[ \left( F_{x_{FR}} \cdot \frac{T_F}{2} + F_{x_{RR}} \cdot \frac{T_R}{2} \right) - \left( F_{x_{FL}} \cdot \frac{T_F}{2} + F_{x_{RL}} \cdot \frac{T_R}{2} \right) \right] - \left( M_{z_{FL}} - M_{z_{FR}} - M_{z_{RR}} - M_{z_{RR}} - M_{z_{RR}} - M_{z_{RR}} \right) - \left( F_{z_{FL}} \cdot \frac{T_F}{2} + F_{z_{RL}} \cdot \frac{T_R}{2} \right) \right]$$

### 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





### ,to use yaw moment'





### Conclusions

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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.





### Conclusions - example

entry  

$$\left[\left(F_{y_{FL}} + F_{y_{FR}}\right) \cdot a - \left(F_{y_{RL}} + F_{y_{RR}}\right) \cdot b + 3\% + 2\%\right]$$

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

$$+ 4\% + 4\%$$

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%





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





		Input Data	
File Design Simulation Analysis		Eu Scaling Factor [-]	1.000
Constant Constant Constant		Ma Scaling Factor [1]	1,000
		A M - General	1,000
∽o ≓o €o =o €o <		Ev0	0.000
Stiffness Force Tire Chassis Spring Bun	npStop Collover ARB Suspension Aerodynamics	PO	0,000
	• • • • • • • • • • • • • • • • • • • •	NO	0.000
Tires Chassis	Suspension Aerodynamics	A OF Durent strend	0,000
DESIGN *	🖉 New Pacejka 2002 Tire 🦨 New Tire String Me	* UD-Trure Lateral	0.000
eTIPO	Innat Data 0	eDu1	0.000
4 🔁 New Library	Internet and a second s	pDy2	0.000
4 ib Tire Stiffness	Force Model + ······· +	pDy2	0,000
(1) New Constant Stiffness Tire	1 Quick Search	pDy5	0.000
🔺 อ Tire Force		pEy?	0,000
P New Constant Friction Tire	- UT-MODE IND	pEyz pEy2	0.000
P New Tire String Model	• SAE	pEy3	0.000
J <sup>R</sup> New Pacelika 2002 Tim	Coordinate System	pEy4	0.000
A In Tiros	EIS0	pHy1	0,000
Alexa Tice	AISO	pHy2	0.000
d Changin	Model Type Pacepka 2002	pHy3	0,000
	Tire Side	pKy1	0,000
Mew Chassis	Right	pKy2	0,000
A 🔂 Springs	4 02 - Graph Inputs	рКуЗ	0.000
New Linear Spring	Inclination Angle 1 [de 0.000	pVy1	0,000
Torsion Bars	Inclination Angle 2 (de -2,000	pVy2	0,000
New Linear Torsion Bar	Second Republ 60,000	pVy3	0.000
Bump Stops	Tire Pressure (kPa) 200.000	pVy4	0.000
len New Linear Bump Stop	. Eu., SA	4 06 - Pure Longitudina	al de la constante de la consta
4 😑 Coilovers	Ma. SA	Eu Capline Eactor [.]	1,000
New Cailover	Toople Graph Tupe Ex. 50	Ma Scaling Easter [1]	1,000
New Coilover (1)	Figure Greph Type Fix Sh	A M. Consol	1,000
🔺 📴 ARBs	Fy - 58-F2	F=0	0.000
Im New Linear ARB	FX-SR-FZ	P20	0.000
4 🎃 Suspensions	Vertical Load 7 (N) -1 000,000	NO	0.000
New Linear Suspension	Vertical Load 3 INI -3 000 000	A DE Destate	0,000
Aerodynamics	4 03 - Overall Scaling Factors	4 UD - Pure Lateral	0.000
Vew Constant Aerodynamics	Fx Scaling Factor [-] 1,000	pLy1	0,000
4 😳 Powertrain	Fy Scaling Factor [-] 1,000	pDy1	0,000
V New Simple Combustion Engine	Mz Scaling Factor [-] 1,000	pUy2	0.000
4 Cearboxes	4 04 - General	pDy3	0,000
New Constant Reduction Gearbox	P0 0,000	pEy1	0.000
A Differentials	V0 0.000	pEy2	0,000
A New Simple Differential	P 05 - Pure Lateral	pEy3	0,000
A Broken	D 06 - Pure Longitudinal	pEy4	0.000
A New Simple Drakes	07 - Aligning Torque	pHy1	0,000
New Simple brakes	08 - Combined Lateral	pHy2	0,000
	10 09 - Combined Longitudinal	pHy3	0.000
L New Inboard Universan	11 - Overhuming Moment	pKy1	0.000
	12-Rolling Resistance	pKy2	0.000
	13 - Scaling Factors - Pure Slip	pKy3	0.000
DESIGN	14 - Scaling Factors - Combined Slip	pVy1	0,000
	0 15 - Scaling Factors - Other	pVy2	0.000
Bernan extent		pVy3	0.000









#### Vertical load, lateral force and slip angle diagrams









### Vertical load, lateral force and slip angle diagrams

BME

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### Conclusions - example



BMW

![](_page_28_Picture_2.jpeg)

![](_page_28_Picture_3.jpeg)

BMW

![](_page_29_Picture_2.jpeg)

![](_page_29_Figure_3.jpeg)

KIA

![](_page_30_Picture_2.jpeg)

![](_page_30_Figure_3.jpeg)

KIA

![](_page_31_Picture_2.jpeg)

![](_page_31_Figure_3.jpeg)

![](_page_32_Picture_0.jpeg)

![](_page_32_Picture_1.jpeg)

![](_page_32_Picture_2.jpeg)

### OS/US

### video comments

#### Understeer

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

![](_page_33_Picture_8.jpeg)

#### Oversteer

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

![](_page_33_Picture_13.jpeg)

![](_page_34_Picture_0.jpeg)

![](_page_34_Picture_1.jpeg)

#### video comments

![](_page_34_Picture_3.jpeg)

![](_page_35_Picture_0.jpeg)

#### video comments

![](_page_35_Picture_2.jpeg)

![](_page_35_Picture_3.jpeg)

### **Midterm tests and exams**

![](_page_36_Picture_1.jpeg)

- 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

![](_page_37_Picture_1.jpeg)

- 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=AOvVaw3fQLFfTvbjW6tlvt9WA9H2&ust=1614098511238000&source=images&cd=vfe&ved=0CAIQjRxq FwoTCPjyv9T3\_e4CFQAAAAAdAAAAABAN
- Optimum G Seminar by Claude Rouelle 2016 Graz
- <u>https://www.youtube.com/watch?v=S0TIRkNWheQ</u>
- https://www.sciencedirect.com/science/article/pii/S156849461500650X

## Thank you for your attention!

![](_page_38_Picture_1.jpeg)