Department of Automotive Technologies –
Vehicle Mechanics Fundamentals

Gábor Sipos

Lecture 9

Schedule of the semester

DEPARTMENT OF AUTOMOTIVE TECHNOLOGIES

Week nr.	Official nr.	Date	Lecture (Monday)		Lab (date+1;Tuesday)	
1	1	12th Feb	1	General information, Tyre, Driving force	1	Lab
2	2	19th Feb	2	Longitudinal and lateral behaviour		
3	3	26th Feb	3	Concepts and over/understeer	2	Lab
4	4	4th Mar	4	Weight transfer		
5	5	11th Mar	5	Bicycle model	3	Lab
6	6	18th Mar	T1	Midterm exam I. ONLINE		
7	7	25th Mar	6	Braking and brakes ONLINE	4	Lab ONLINE
8		1st Apr	-	Break		
9	8	8th Apr	7	Systems of the vehicle		
10	9	15th Apr	8	Quarter vehicle model ONLINE	T1 R	Exam 1 - subsequent ONLINE
11	10	22th Apr		Break		
12	11	29th Apr	T2	Midterm exam II. ONLINE		Break
13	12	6th May	9	Tyre management		
14	13	13th May	10	Racecar engineering	T2 R	Exam 2 - subsequent
	14	20th May	11	Semester championship presentation		

Note

Reminder

4. Timeline

Deadline for the submission is 6th of May, 18:00. Result will be published soon. After submission deadline there is no possibility to participate in the championship. Furthermore, once after the team submitted its car, there is no possibility to change on it, even if the deadline is still not over.

Idea

14	**13**	13th May	10	Racecar engineering	T2 R	Exam 2 - subsequent

Reminder

	14	20th May	11	Semester championship presentation		

Tyre management

Tyre management

over inflated

properly inflated

under inflated

Tyre management

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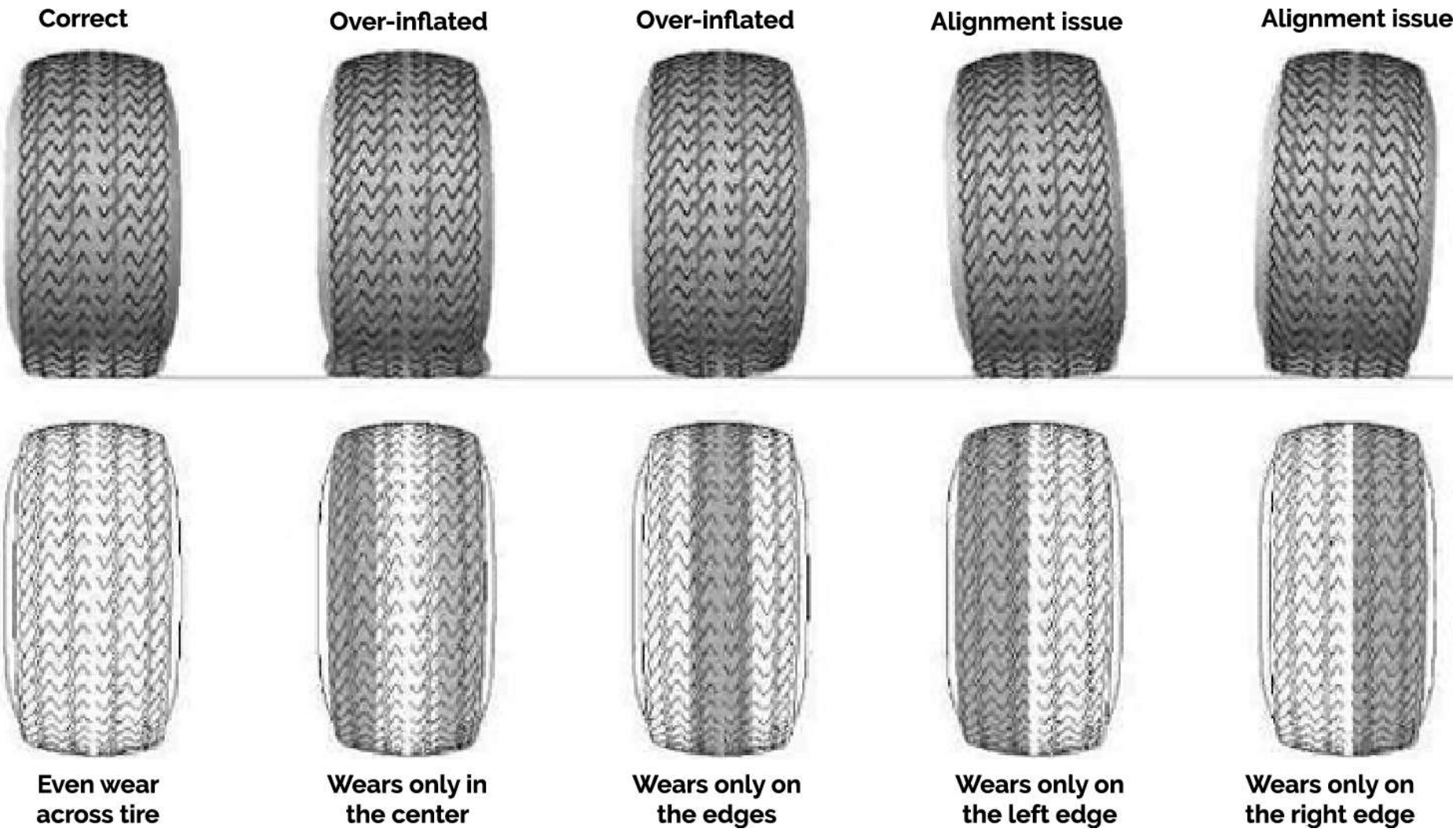
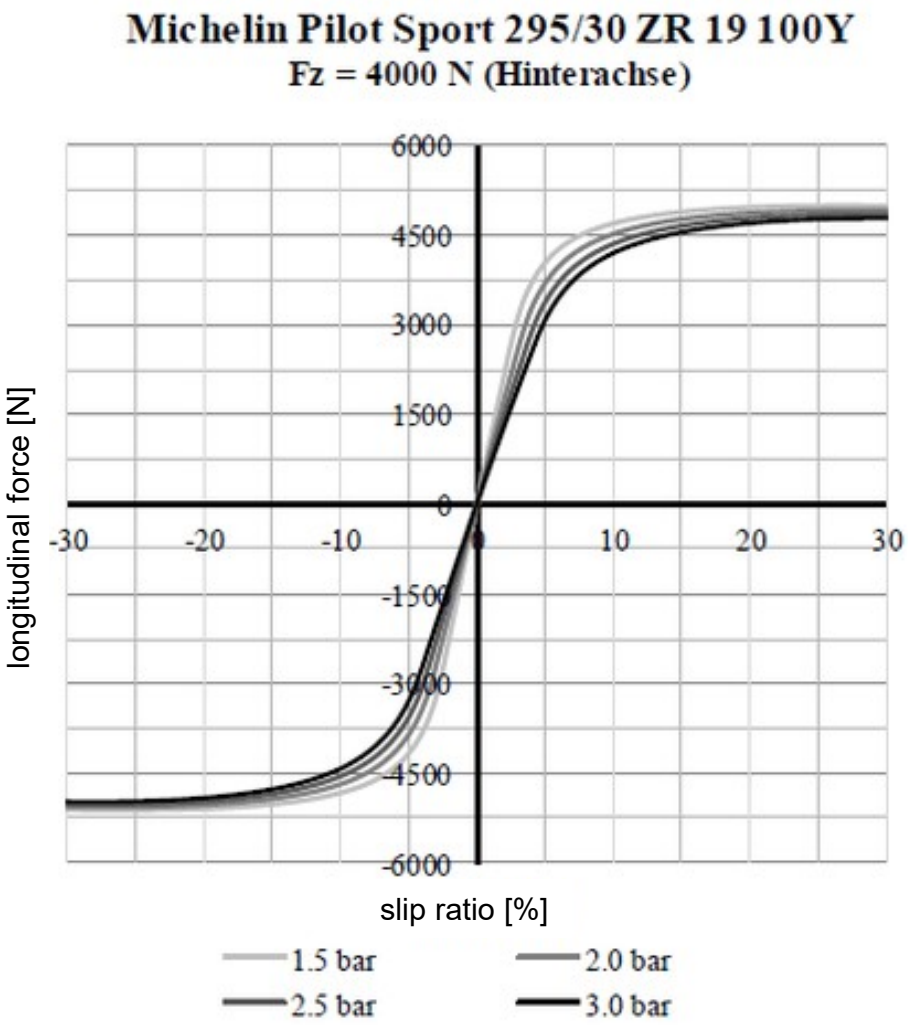
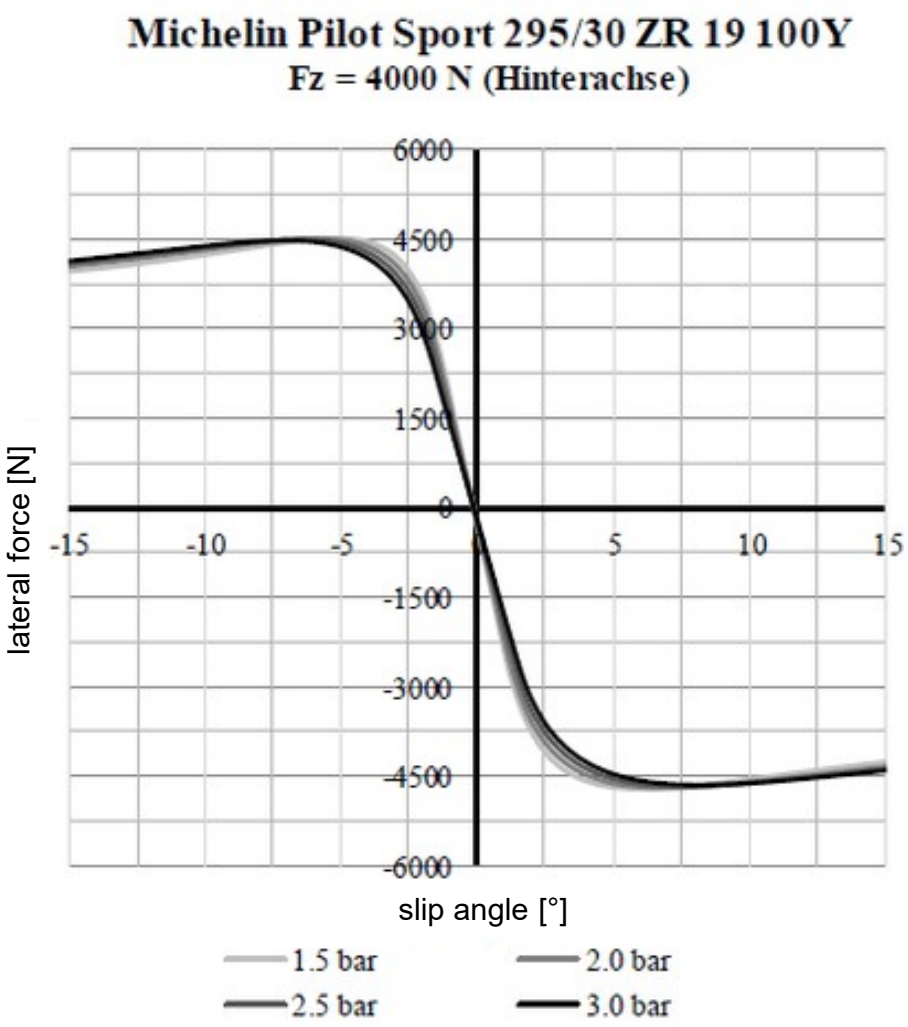
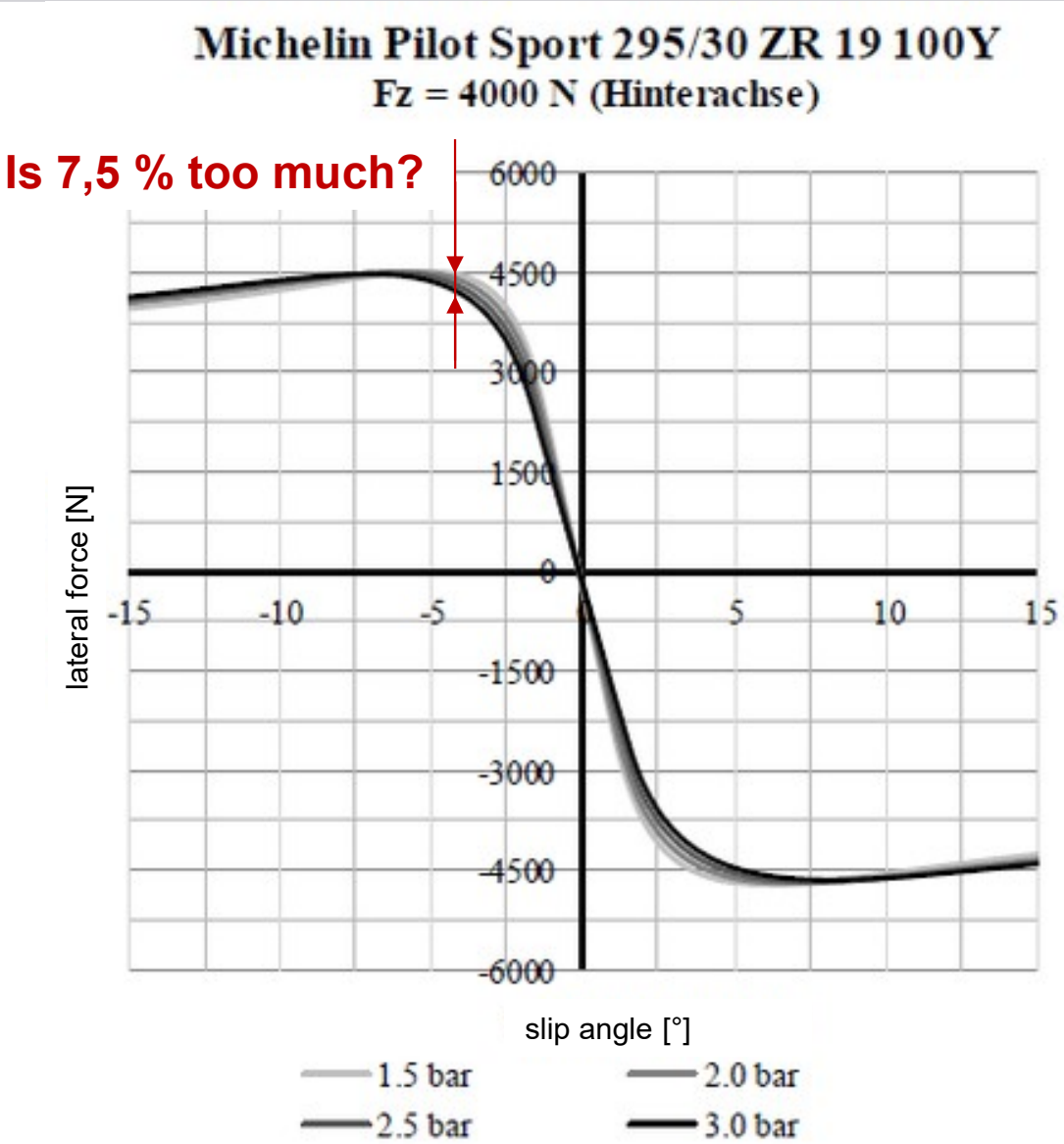


Tyre management





Tyre management

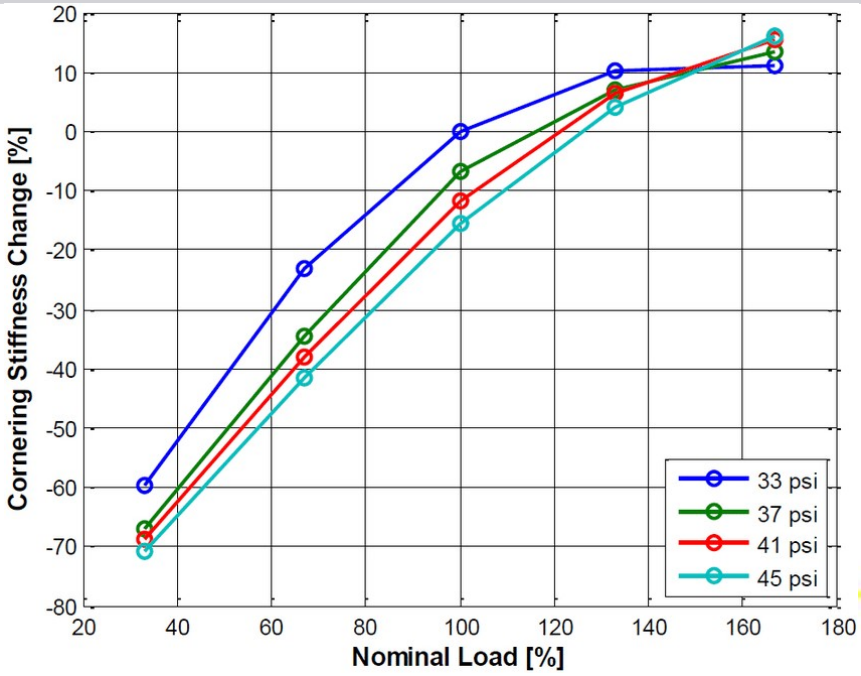


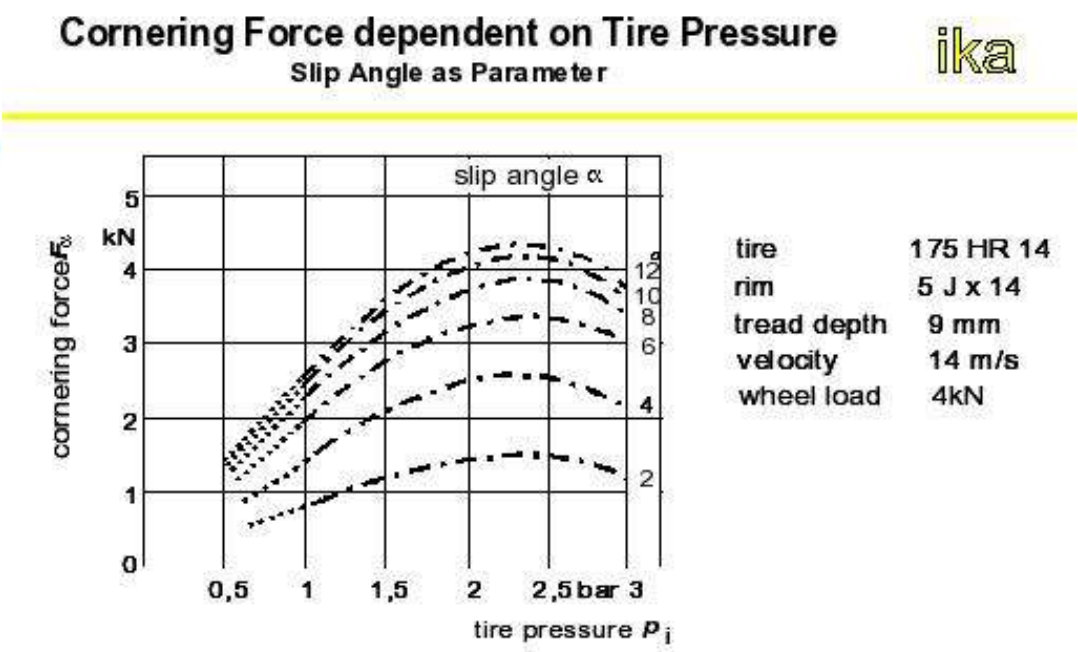
Tyre management

FORMULA 1 GULF AIR BAHRAIN GRAND PRIX 2022 - QUALIFYING

POS	NO	DRIVER	CAR	Q3	Diff	Diff %
1	16	**Charles Leclerc**	FERRARI	**1:30.558**		
2	1	**Max Verstappen**	RED BULL RACING RBPT	**1:30.681**	**0,123**	**0,403%**
3	55	**Carlos Sainz**	FERRARI	**1:30.687**	**0,129**	**0,422%**
4	11	**Sergio Perez**	RED BULL RACING RBPT	**1:30.921**	**0,363**	**1,188%**
5	44	**Lewis Hamilton**	MERCEDES	**1:31.238**	**0,68**	**2,225%**
6	77	**Valtteri Bottas**	ALFA ROMEO FERRARI	**1:31.560**	**1,002**	**3,279%**
7	20	**Kevin Magnussen**	HAAS FERRARI	**1:31.808**	**1,25**	**4,091%**
8	14	**Fernando Alonso**	ALPINE RENAULT	**1:32.195**	**1,637**	**5,357%**
9	63	**George Russell**	MERCEDES	**1:32.216**	**1,658**	**5,426%**
10	10	**Pierre Gasly**	ALPHATAURI RBPT	**1:32.338**	**1,78**	**5,825%**

Tyre management





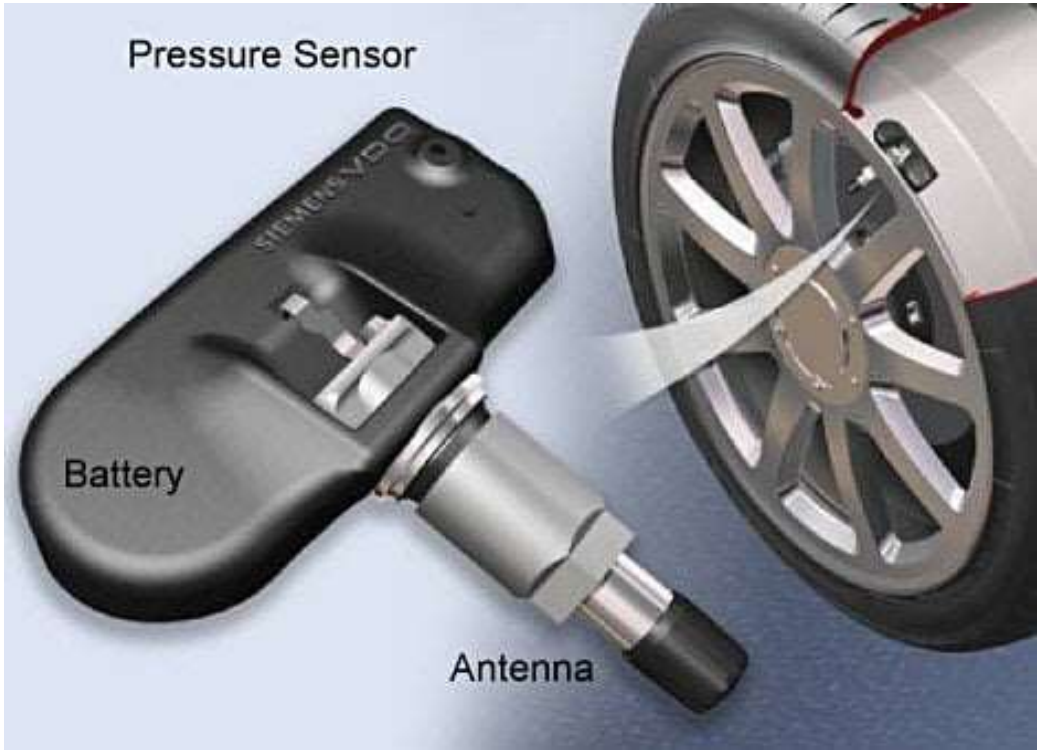
Tyre pressure change:

- cornering stiffness
- peak force

Tyre management

Tyre pressure change:
- cornering stiffness
- peak force

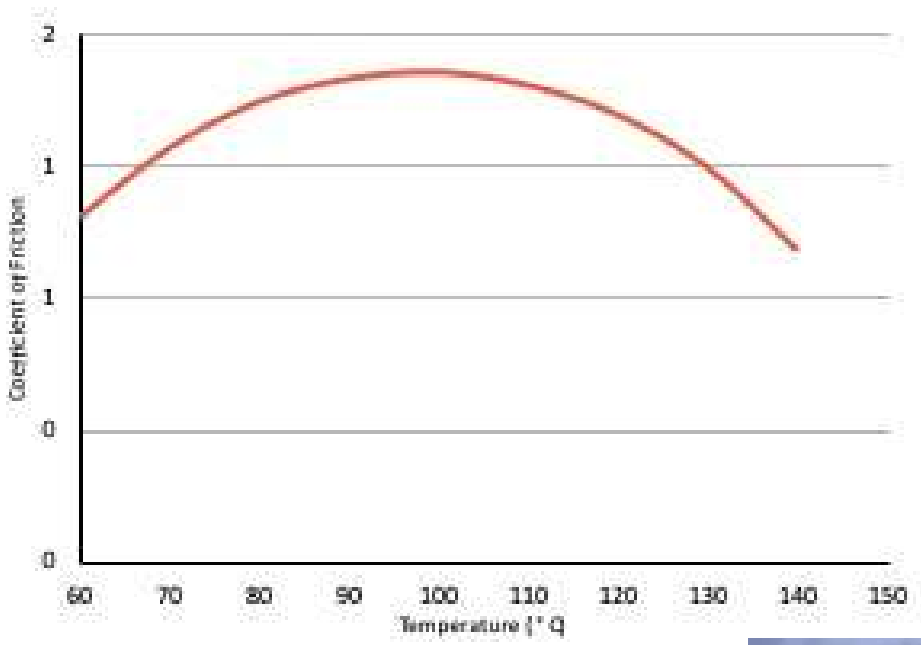
Consequences:
- different pressue
- different cornering stiffness
- different traction ellipse
- different vertical stiffness

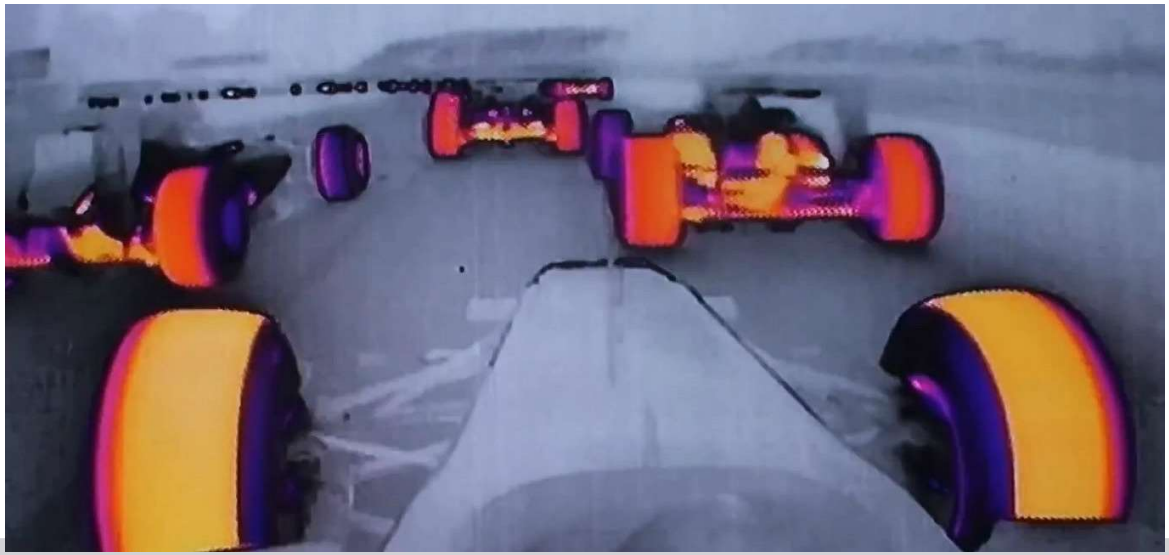


TPMS

Tyre management

Temperature dependence





Pressure management

Considering:

- ambient temperature
- humidity
- track temperature
- gas we use

Ideal Gas Equation $PV=nRT$

- P = pressure (absolute)
- V = volume (gas)
- n = number of moles in the gas
- R = universal gas constant (8.314 J/mol K)
- T = temperature (K)

Pressure management

Ideal Gas Equation PV=nRT

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

Assume that the volume change is reasonably small:

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

Press. bar	Temps K 291,15	293,15	295,15
0,8			
1			
1,2			
1,4			
1,6			

Pressure management

YourDataDriven (c) 2019 www.yourdatadriven.com

Race Car Tyre Pressure Setup Calculator

Step:		Left	Right			
1	Target Pressure	27	27	Front		
	(also Wet Setting)	26	26	Rear		
2	Initial Scaling factor	1.15	1.2			
	(use tables & track layout)	1.2	1.25			
				degC		
3	Initial Cold Setting	**23.5**	**22.5**	15	Ambient Air	
		21.7	**20.8**			
				degC		
4	Test Run - Hot Results	28.4	29.1	15	Ambient Air	
	(Used to adjust scaling)	27.1	25.9	24	Track Temp	
	Auto adjusted scaling factor	1.21	1.29			
		1.25	1.25			
				degC		(psi)
5	Adjusted Cold Setting	**22.3**	**20.9**	15	Ambient Air	0
	(should achieve target)	**20.8**	**20.9**	24	Track Temp	0

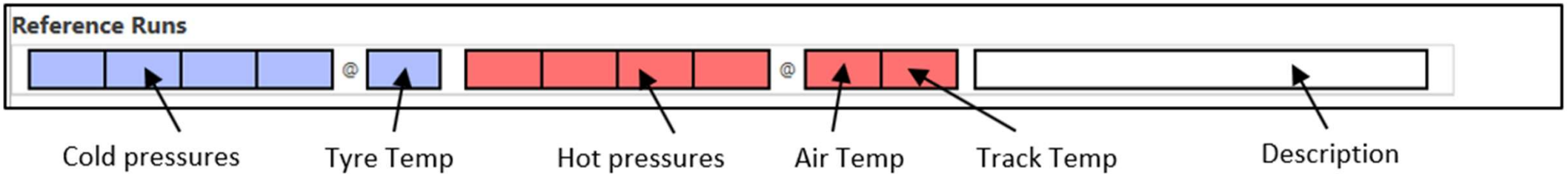
Compensation (psi) - Use if tyres & conditions drift after cold set

Reference Data:	Target Hot Pressure		Temp compensation (psi / deg C)	
Category	(psi)	(bar)	Air (psi)	Track (psi)
F1, F2, F3	18.0 - 23.0	1.25 – 1.50	0.1	0.1
LMP, GT, BTCC	26.0 – 29.0	1.80 – 2.00		

or

Vehicle Mass	Cold (psi)	Target Hot (psi)	Typical Scaling Factor Range	
Very Light < 800kg	17 – 22	22 – 29	1.29	1.32
Light 800kg – 1000kg	20 – 26	24 – 32	1.20	1.23
Heavy 1000kg – 1400kg	23 – 27	28 – 40	1.22	1.48
Very Heavy > 1400kg	27 – 35	37 – 40	1.37	1.14

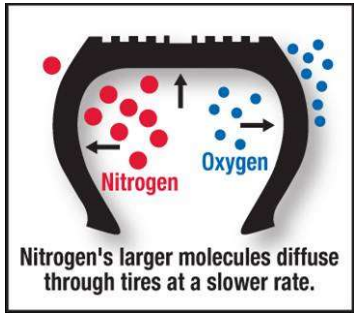
Pressure management

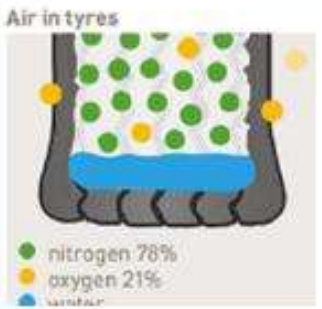


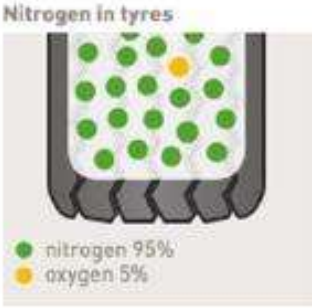
Pressure management

These vehicles subject tires to extreme temperature conditions, and the use of nitrogen allows better control over tire pressure as tire temperature increases. Compressed air holds moisture and the amount of moisture may vary from tire to tire. During extreme usage, the amount of moisture in the tire causes the tire temperature to increase more rapidly, and in a non-linear way that can be unpredictable.

With dry nitrogen, the effects of moisture are eliminated and the increase in tire pressure due to temperature is more linear and predictable than with air. The tires also run cooler, which is especially important in racing because the grip of race tires is highly dependent on tire temperature.







Braking system

Braking system

Function

- stop, decelerate the car
- help the balance of te car
- regain energy (heat/kinetic)

Braking system

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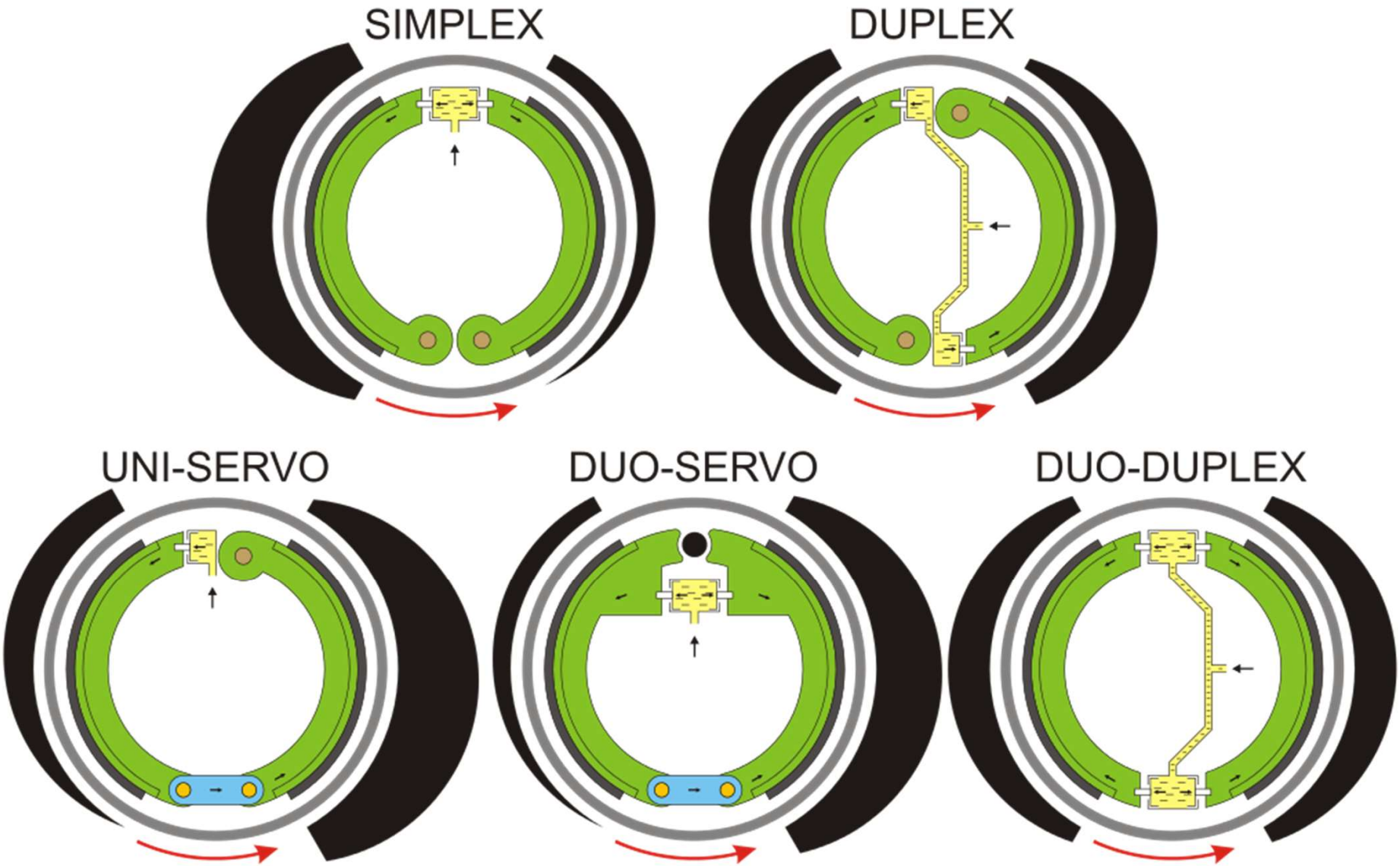
brakes: decreasing the velocity of vehicles, keep vehicles stopped, control speed of vehicles

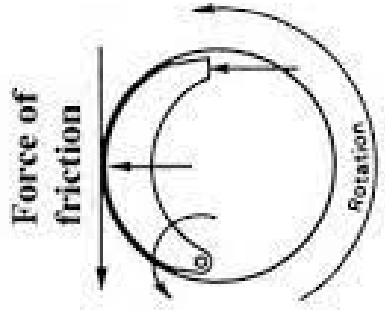
groups

- by friction surfaces:
  - disc
  - band
  - drum
  - conical
- by direction of braking force
  - radial (pl.: drum brake)
  - axial (pl.: disc brake)
- by position of friction surfaces
  - outside
  - inside

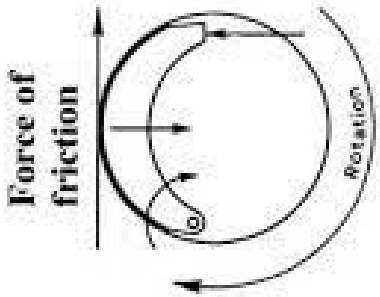
Braking system



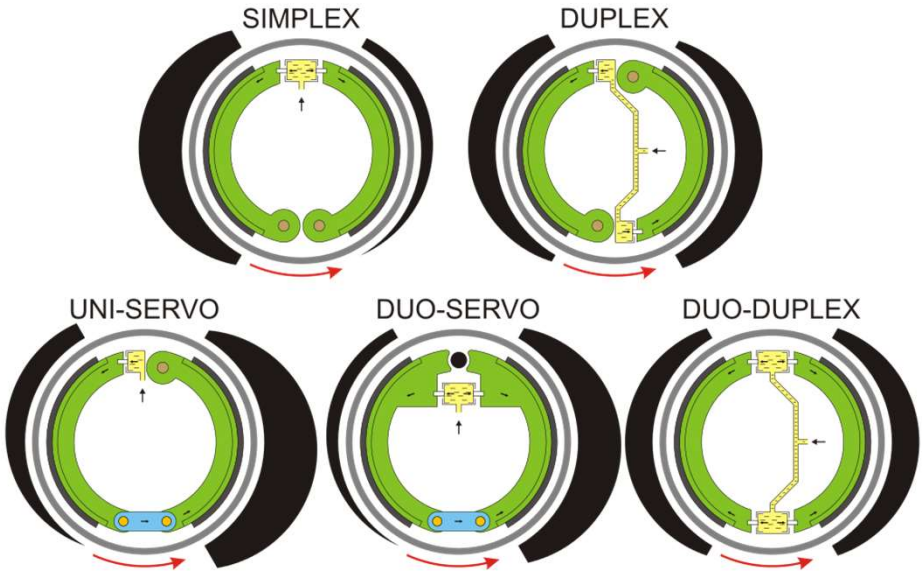
Braking system



Leading shoe
self-servo effect



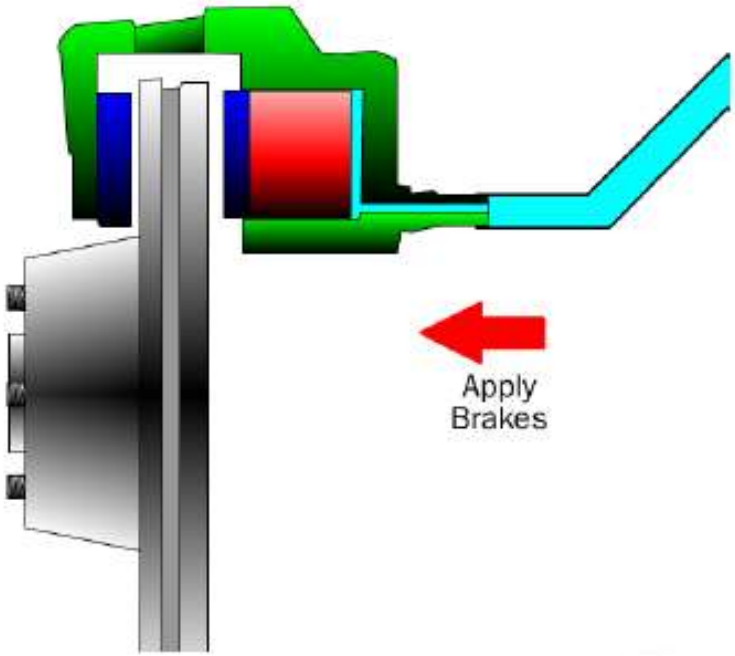
Trailing shoe
no self-servo effect

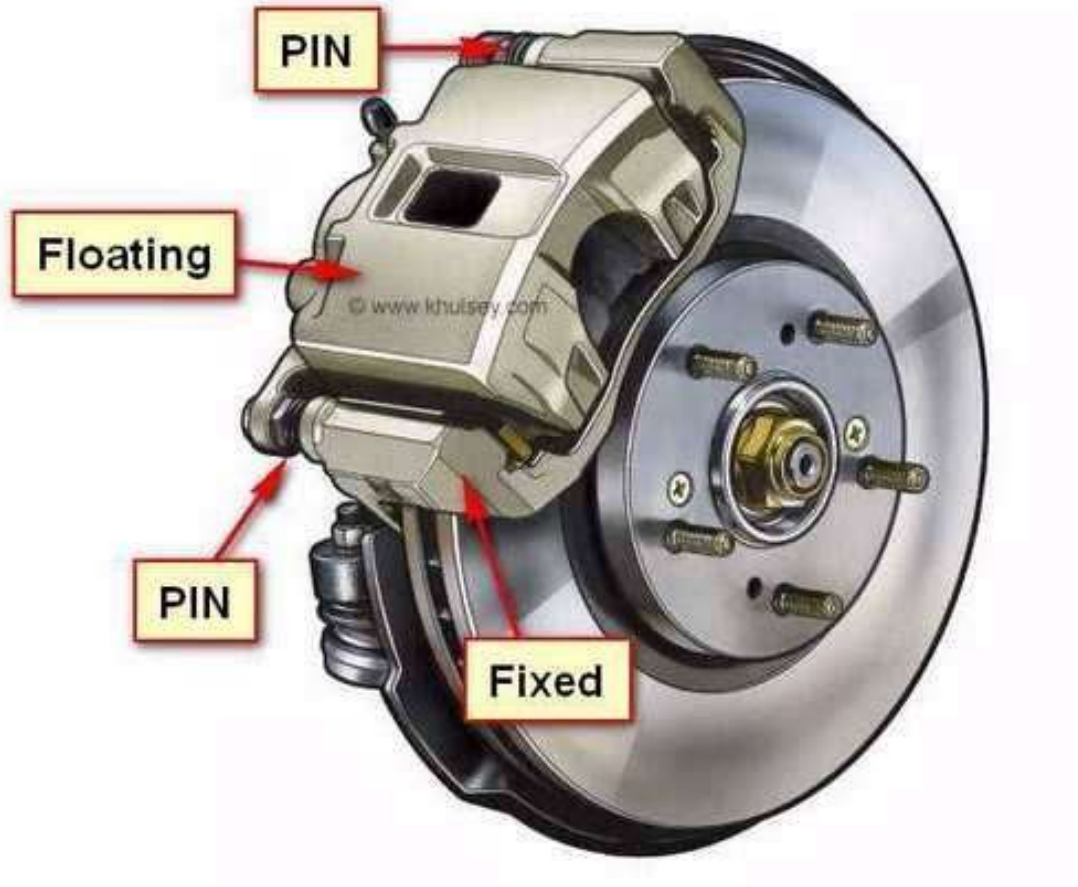


- Simplex
  - more efficient left side as leading shoe, right side: trailing
- Duplex
  - two leading shoe

Self-servo effect as main principle regarding effectivity.

Disc - floating caliper





Disc vs drum

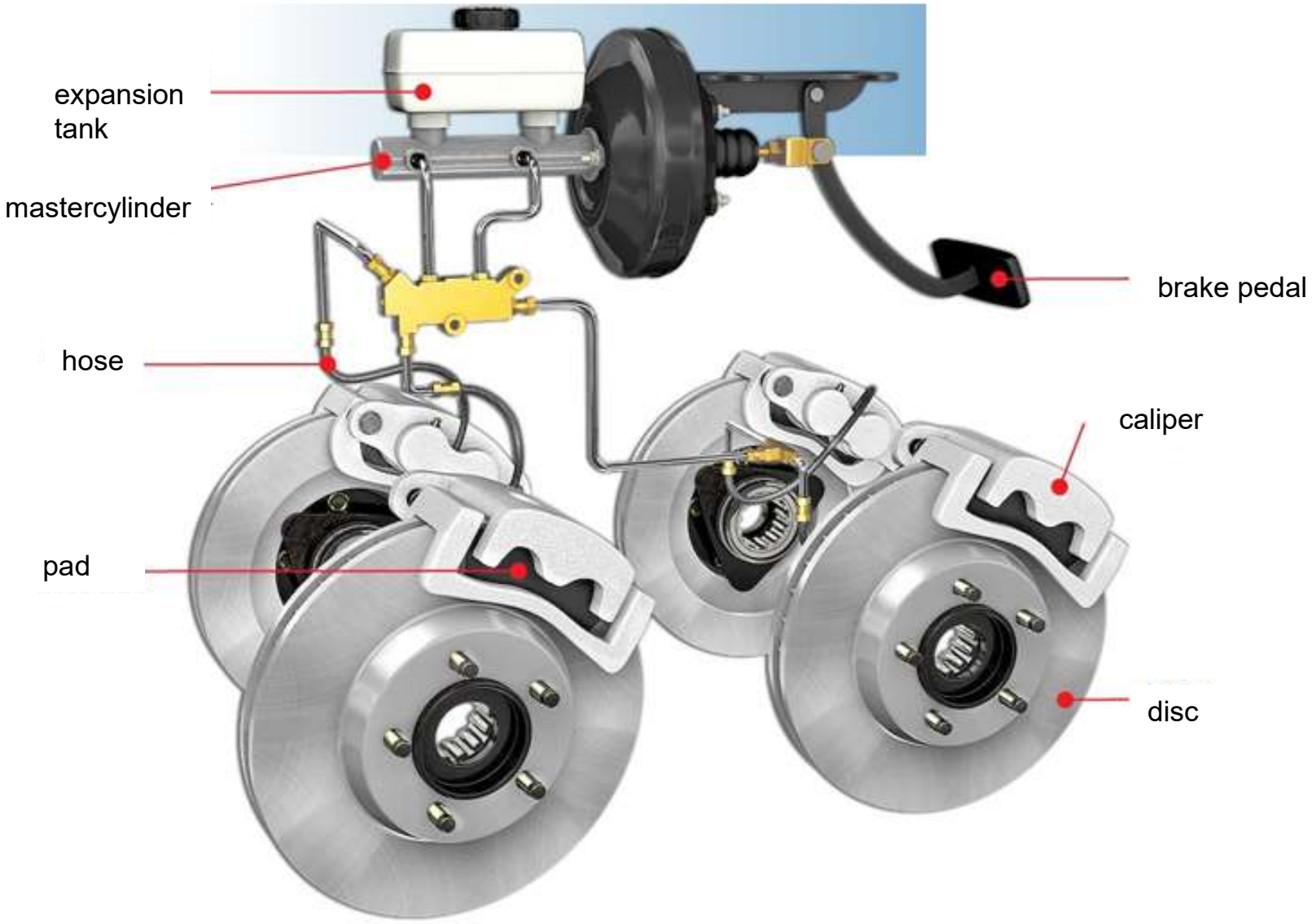
Disc

- pressure distribution better thorugh surface
- stability
- easier to cool, pads less sensitivity to heat
- thermal expansion towards the pads
- easier to maintain

Drum

- cheap
- wear is slow
- lower system pressure
- parts are covered by drum
- lower peak temperature
- self-energising
- easier to apply handbrake

Disc - floating caliper



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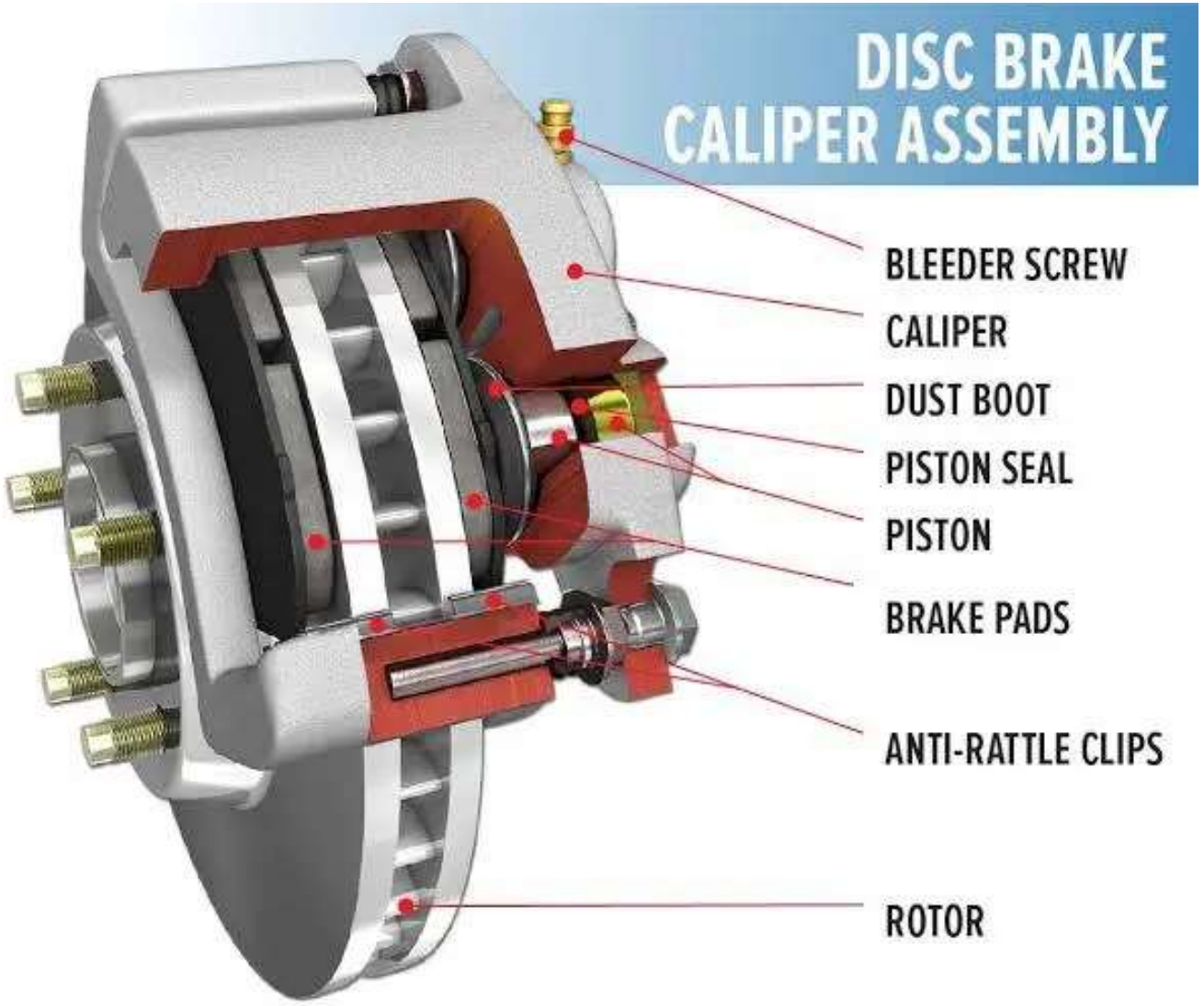
Disc - floating caliper



Braking system

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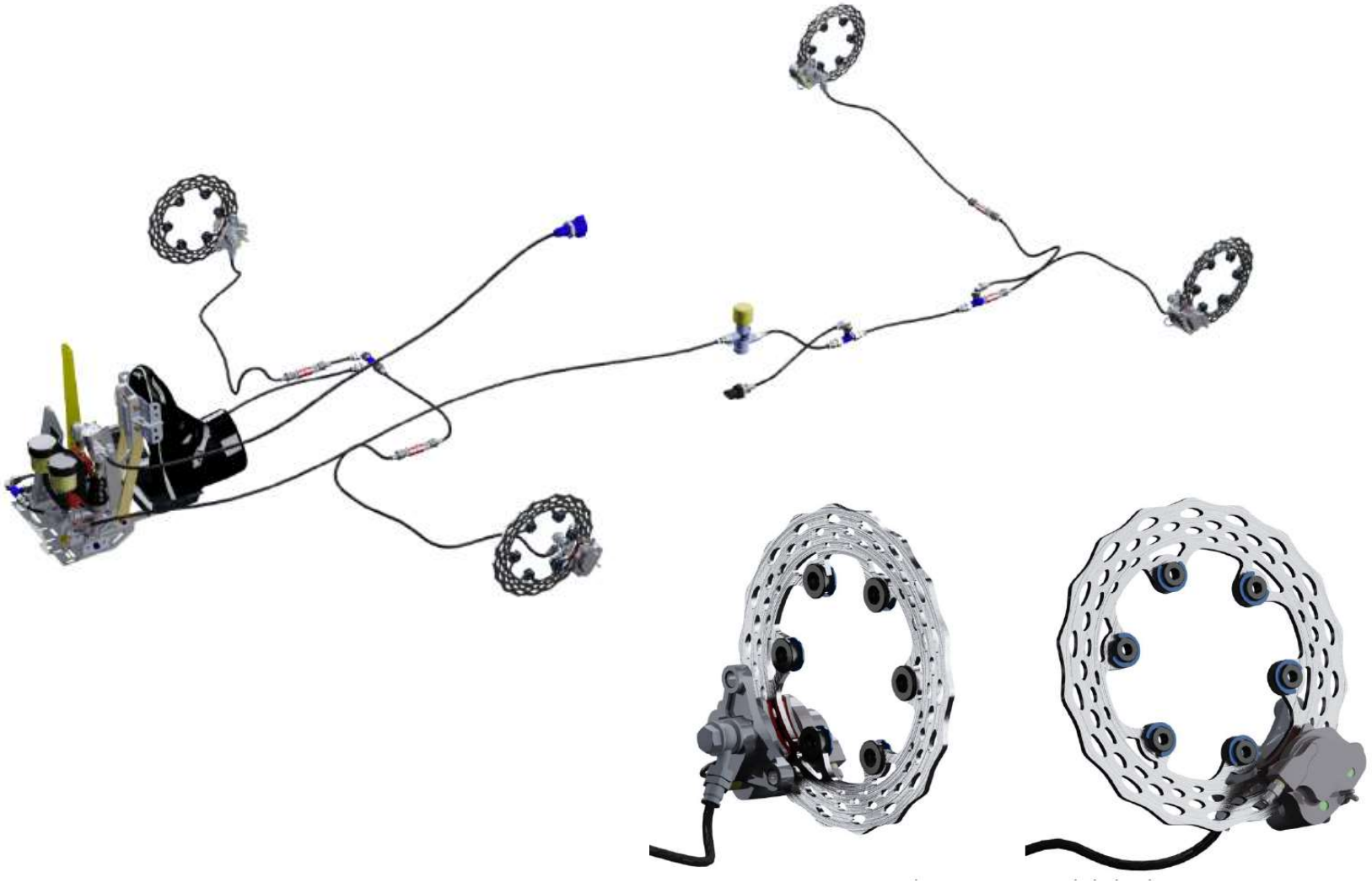

Power flow:

Brake pedal

↓

Balance bar

↓

Master cylinders

↓

Proportioning valve

↓

Brake calipers

↓

Brake pads

↓

Brake discs

↓

Tires

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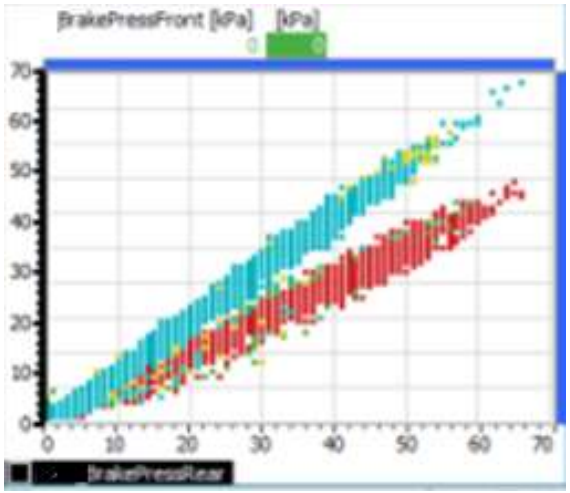
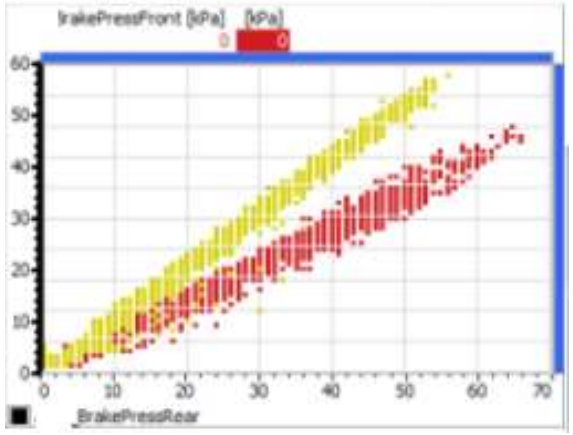
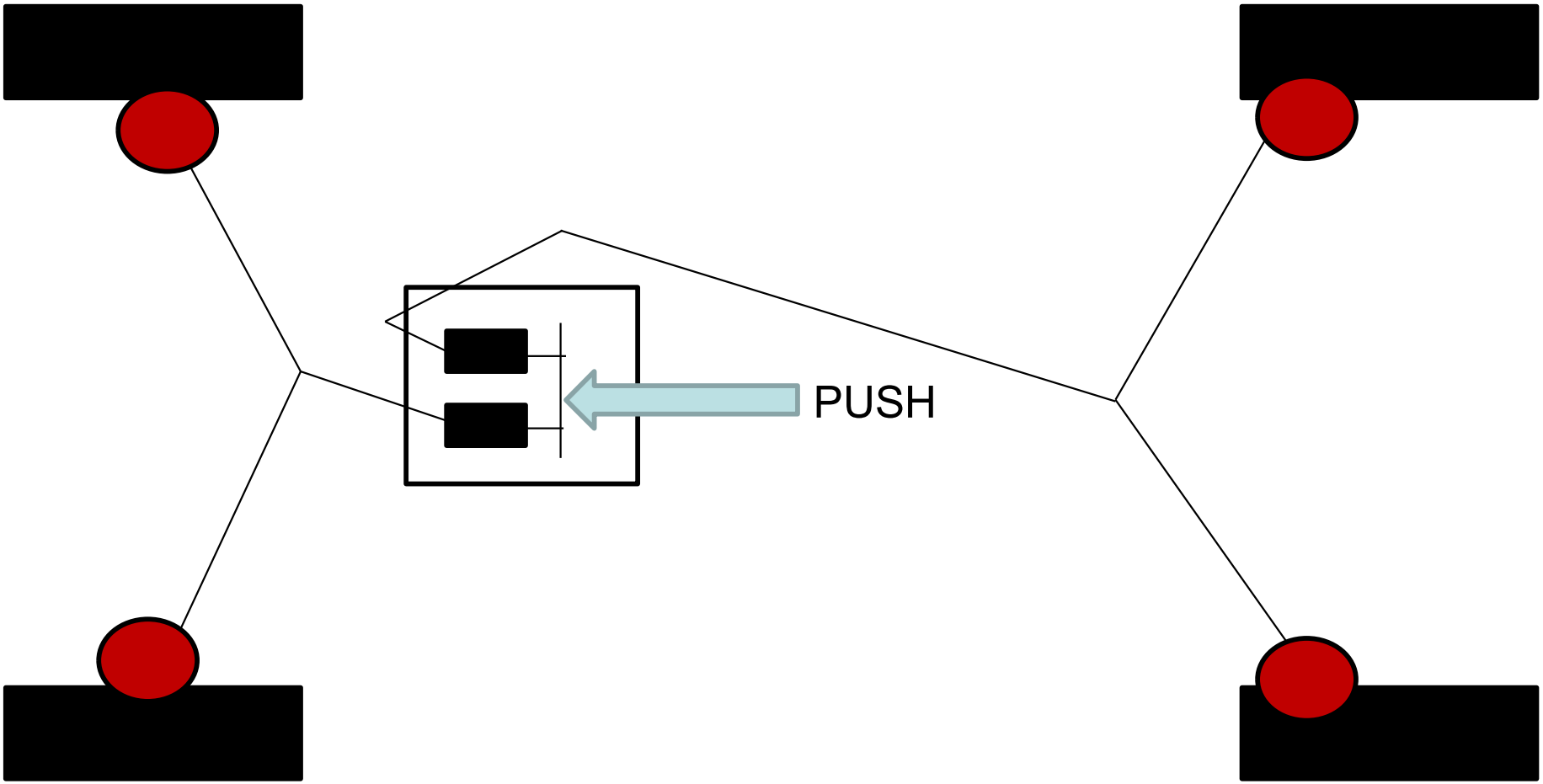
Question





?

Brake system



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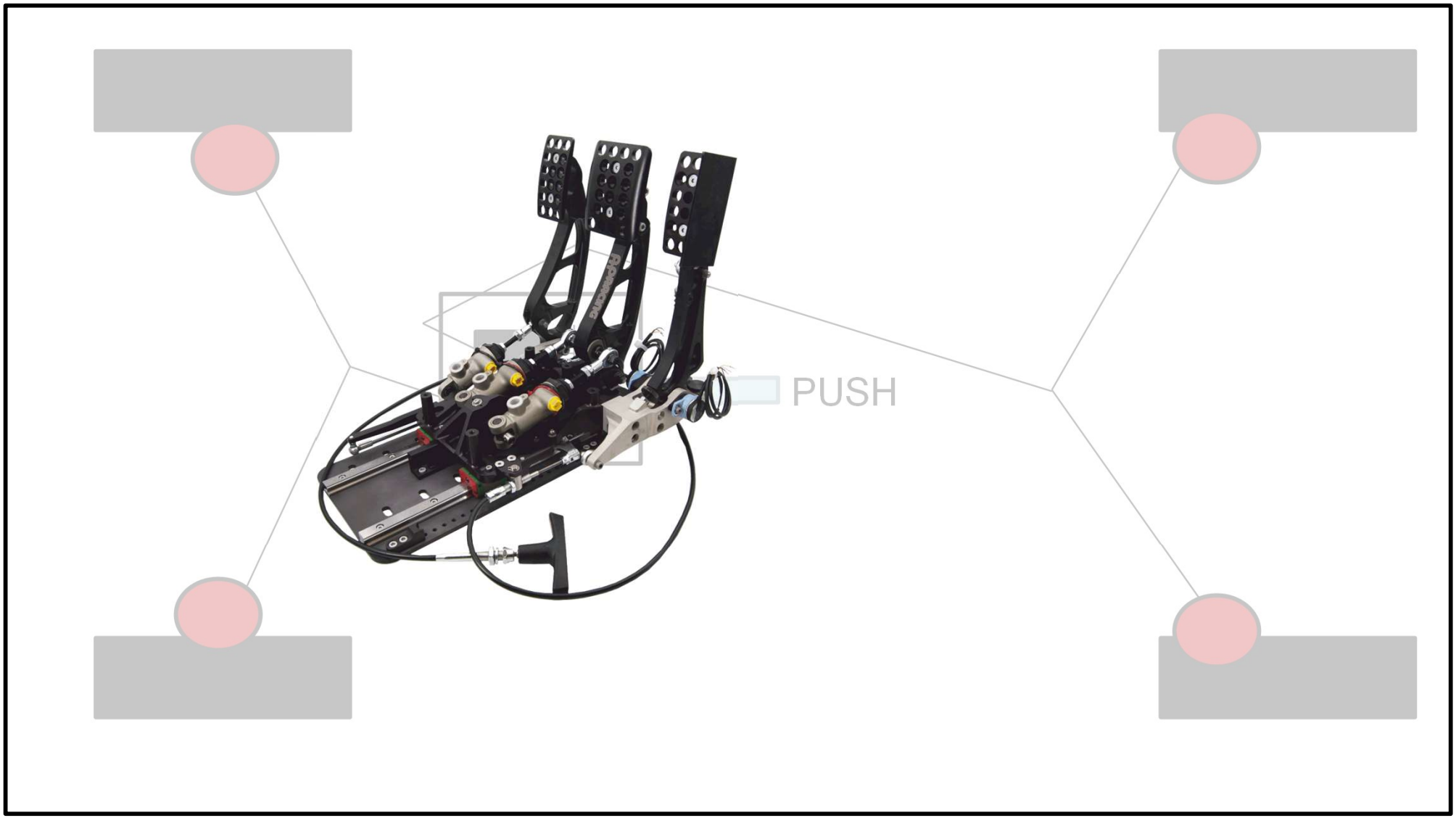
Brake system



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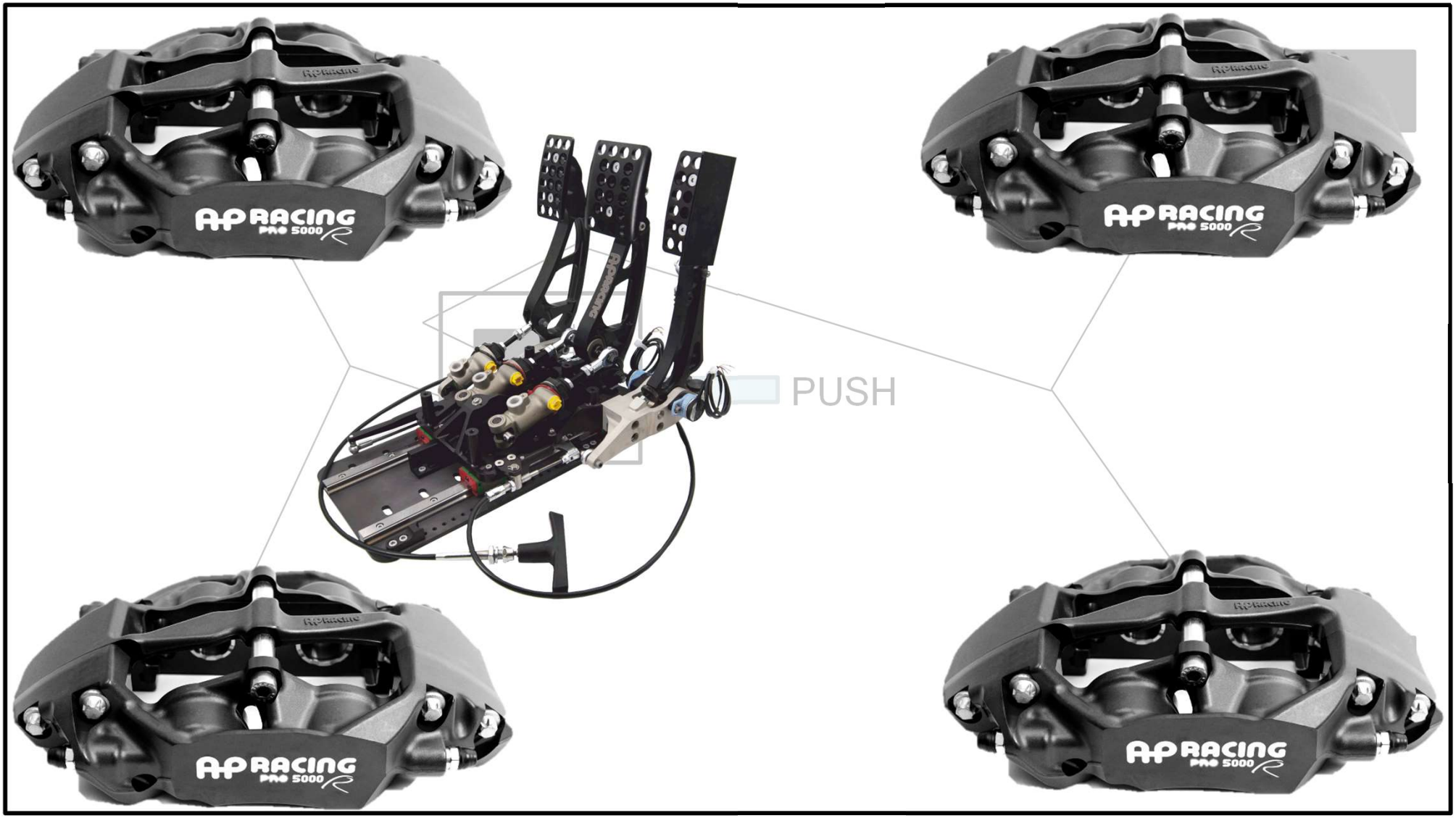
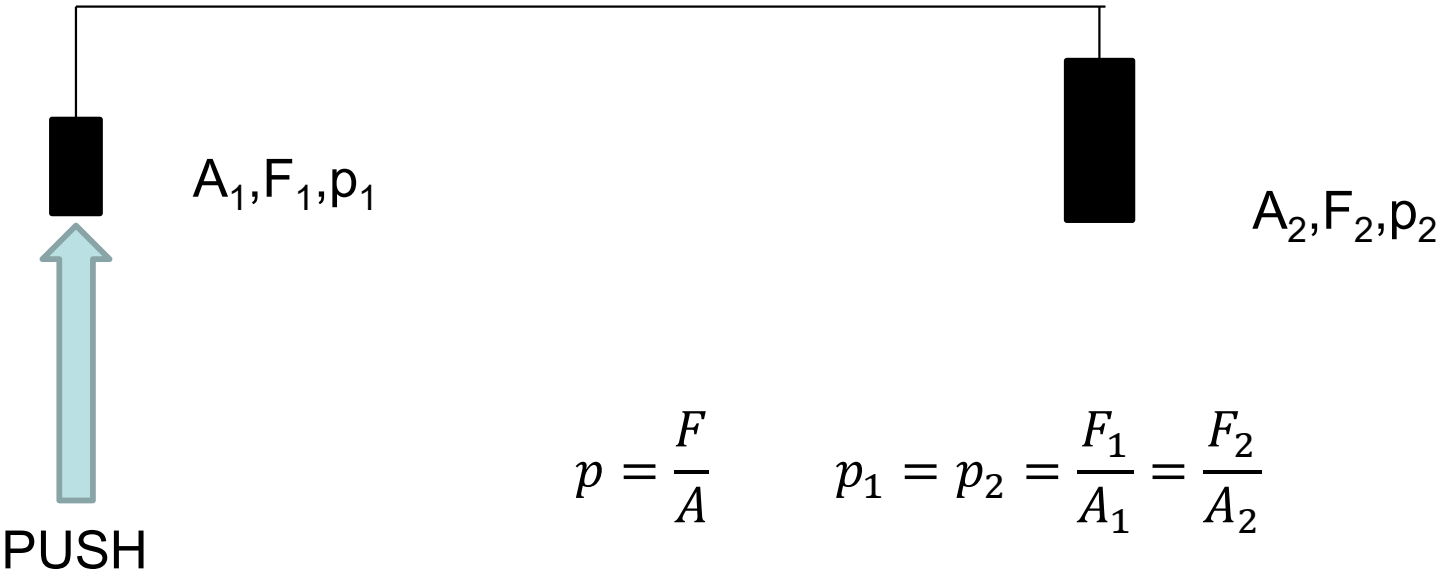
Brake system



Brake system



$$p = \frac{F}{A} \qquad p_1 = p_2 = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Brake system

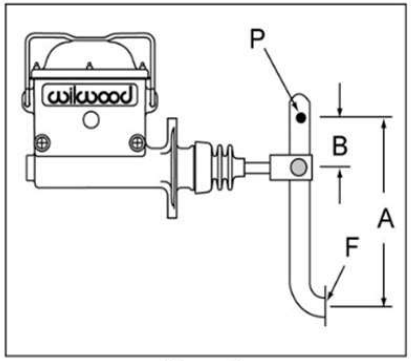


Figure 1

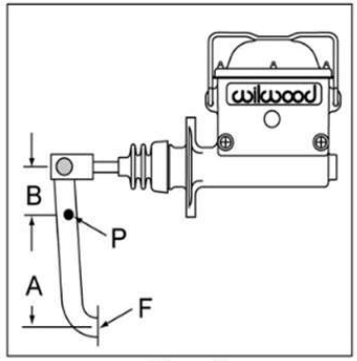


Figure 2

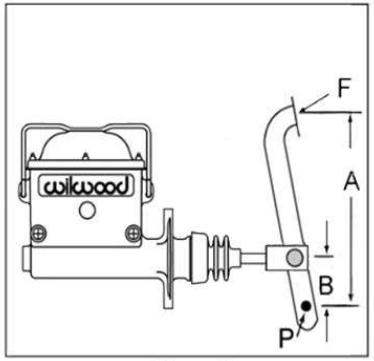


Figure 3

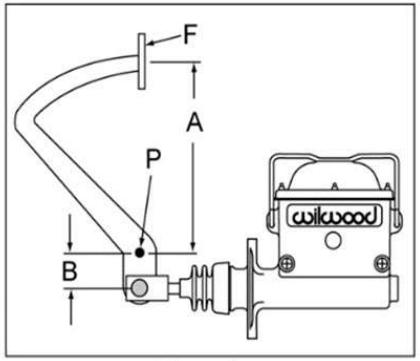
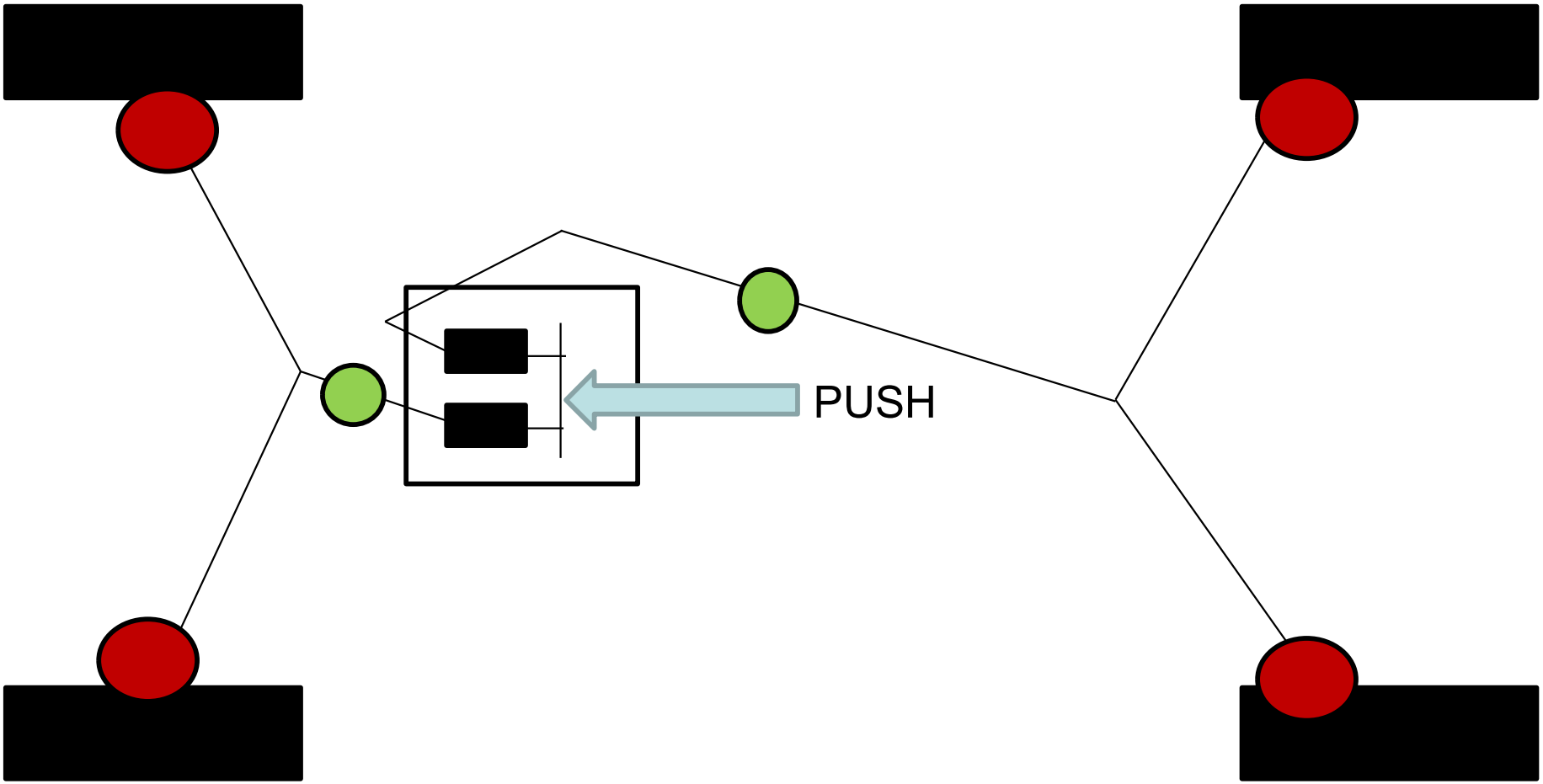


Figure 4

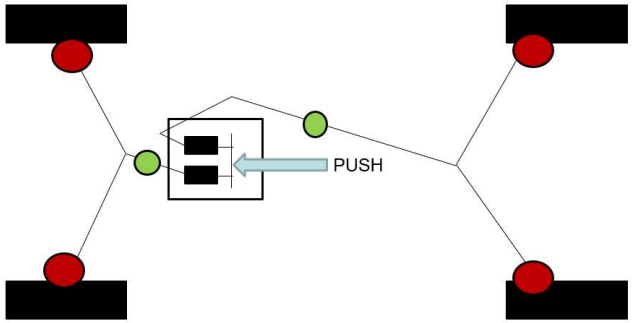
Brake system



Brake system

Based on a known balance bar chart by pressure measurement, what parameters of brake system should be considered to evaluate it properly?

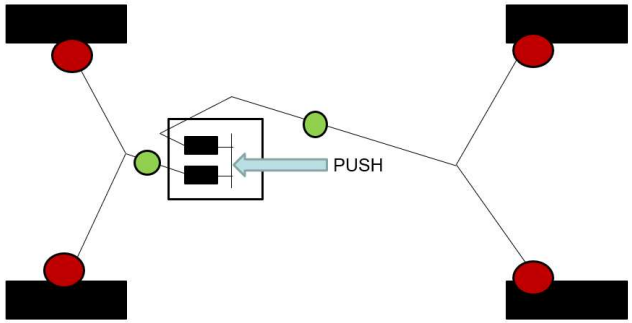
- Pedal box geometry (e.g. Brake pedal length)
- Balance bar
- Master cylinders diameter
- Position of pressure sensor
- Propotional valve
- Piston diameter
- Pad size
- Pad type
- Diameter of disc



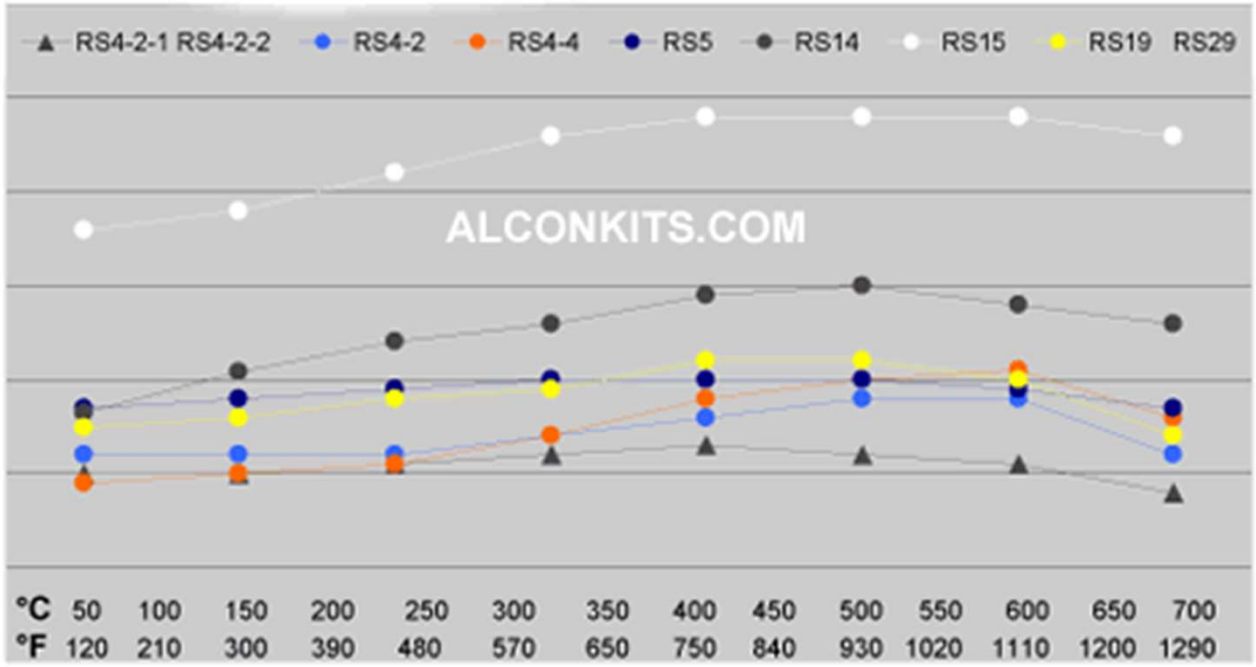
Brake system

Based on a known balance bar chart by pressure measurement, what parameters of brake system should be considered to evaluate it properly? (assuming sensor position showed by figure below)

- Pedal box geometry (e.g. Brake pedal length) ✗
- Balance bar ✗
- Master cylinders diameter ✗
- Position of pressure sensor ✓
- Propotional valve ✓
- Piston diameter ✓
- Pad size ✓
- Pad type ✓
- Diameter of disc ✓

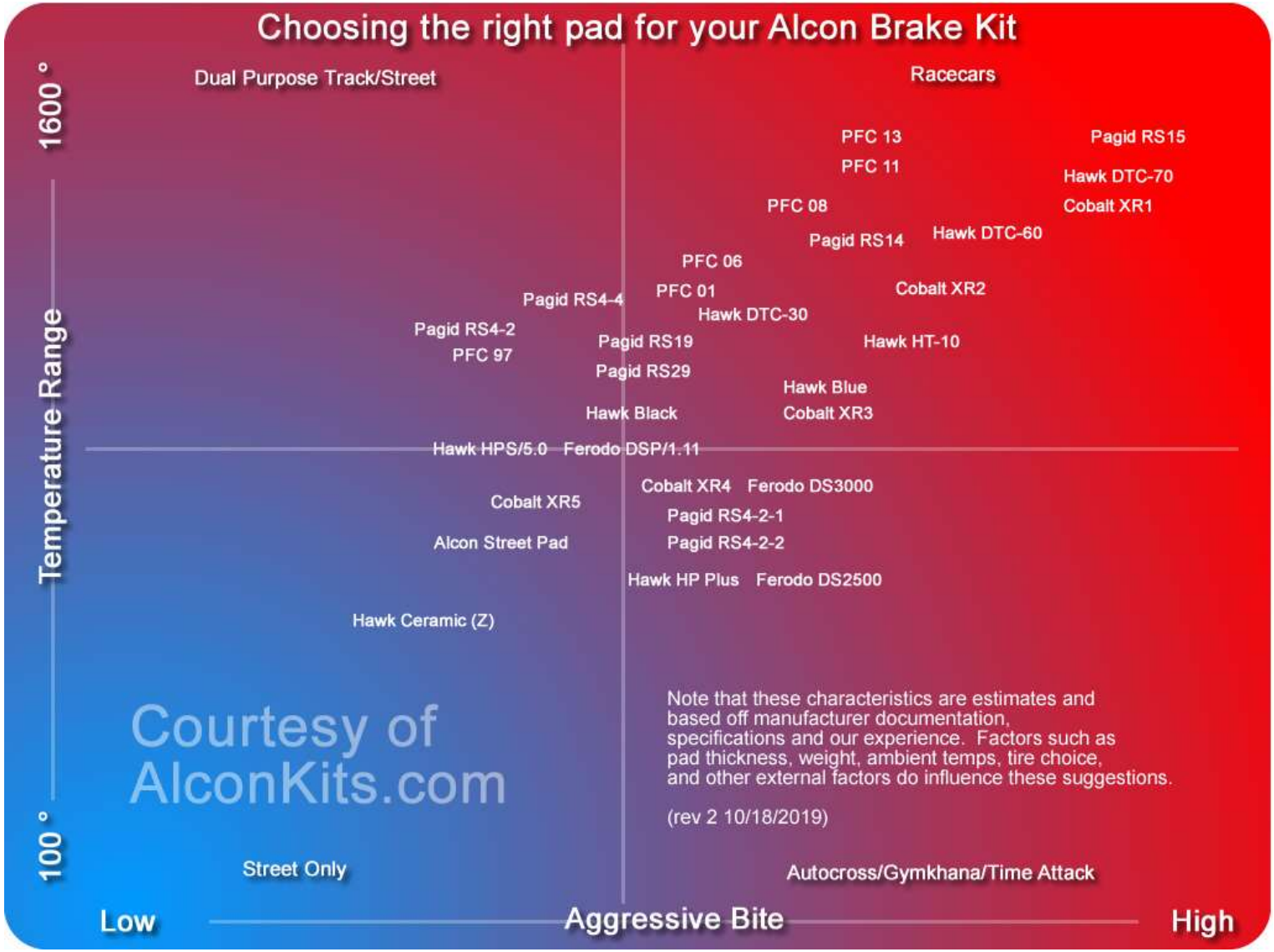


Brake system

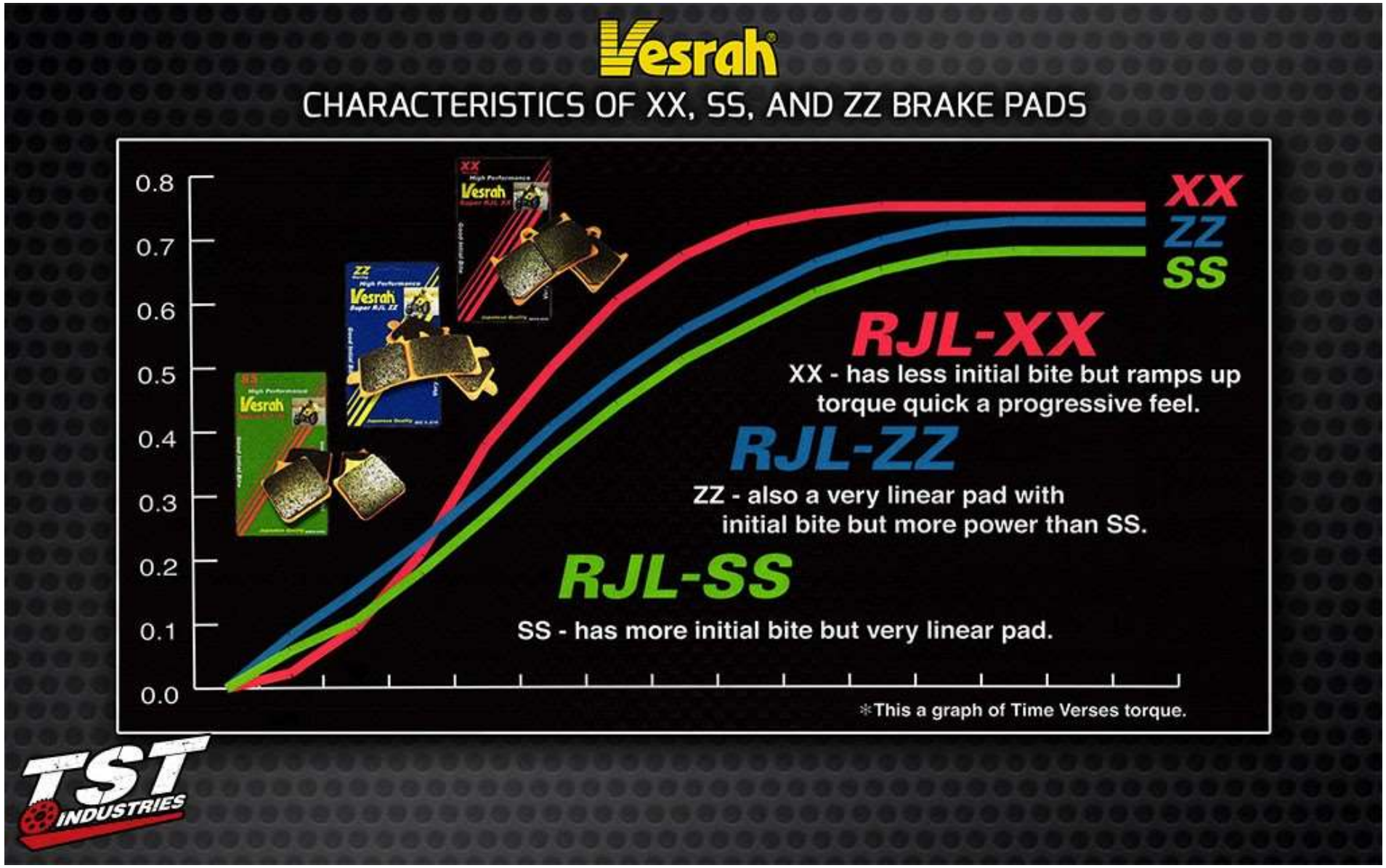


Friction vs Temperature Graph

Brake system

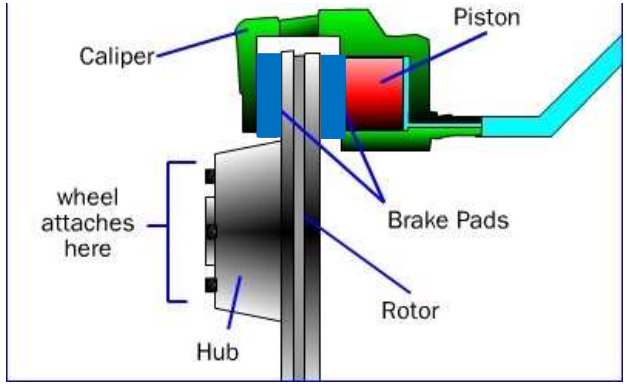


Brake system

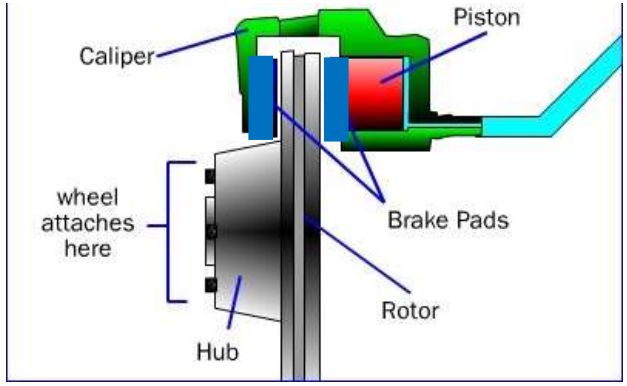


Anti knockback spring – what can be the purpose?

Anti knockback spring



Design space



Reality

Brake system

- Brake balance chart
- Front-axle blocks / rear-axle blocks
- Bite, confidence
- Braking performance

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
- braking system components
- optimal brake force distribution
- specific braking force
- EBD basic working principle
- Motorsport relevant braking aspects
- Functional structure
- Powertrain: Types of resistance
- CoP
- Gearbox/Propulsion unit: power and powered machine tuning
- Traction force diagram
- 3 main type of chassis structure
- CoG determination methods

Midterm tests and exams

3

- suspension basics
- brake system elements and working
- quarter vehicle model basics
- tyre management
- tyre pressure, temperature basics

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Thank you for your attention!

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