formula to find the critical speed!

Y_R can be neglected → because we have a relation that is the inverse of the speed! become very little!

FOR → UNDERSTEERING car → no critical speed

↘ OVERSTEERING CAR $(N_\beta < 0)$ → so we have a positive value for $-N_\beta m V$

↓

there is a CRITICAL SPEED

slide 29 → shows that a OS vehicle increasing the speed improves the ability to respond to the change of δ → faster in control!

↓

problem, reach critical speed in a very reactive zone of the steering ~~wh~~ wheel!

In US is the opposite, but for average velocity all the vehicles are similar!

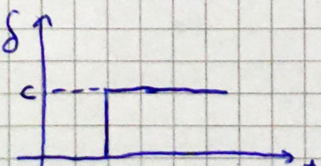
the car start to turn more of how you expect at a certain speed

<u>TRANSIENT RESPONSE</u>

before we assumed that the radius of the corner was constant

→ the only way to go out from an UNSTABLE REGIME is to correct the trajectory acting on the steering wheel.

Now! what happen with a step-wise change in the steering wheel?



SHARP CHANG

suddenly change from $\delta = 0$ to $\delta = c$ we obtain a slow/fast transient that lead to our vehicle.

What happen in the TRANSIENT REGION?

YAW velocity → we see "noise"
LATER ACCELERATION → notice that is not a step

⟹ NOT A STEP as the INPUT

→ at the exam can ask the plot of slide 34, response for a step wave change

TIME CONSTANT of rotational velocity (τ_2) tells that if we want a short τ_2 (fast response) we have high value of N_β and so we need an OS vehicle

- depend also on the mass of the vehicle!

- for larger velocity the τ_2 is higher, the response is slower!

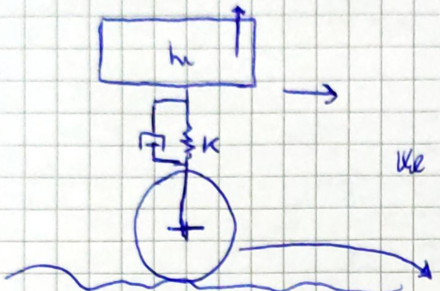
ξ → damping factor and how it change the plot increasing it!

increasing it we try to avoid the overshot!

VERTICAL DYNAMICS

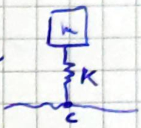
- Allow to ~~pr~~ predict the effect of the road impacting the comfort and the vertical tire contact

→ Road with holes, bump → vehicle must ABSORB all the energy thanks to the SUSPENSION



we are interested in the vertical effect

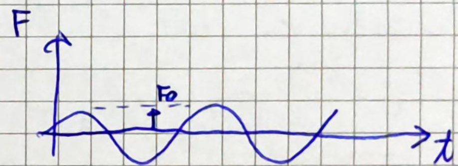
also the tire can be modelled as a



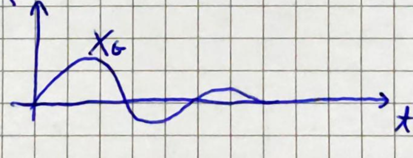
NB In the QUARTER CAR MODEL the mass M of the vehicle is $= \frac{M_{vehicle}}{4}$

OSCILLATOR THEORY | 1 DOF

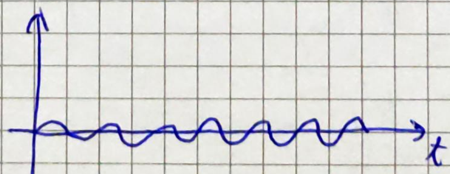
is applied an harmonic load



- GENERAL INTEGRAL
  input for initial transitory



- PARTICULAR INTEGRAL



for slide 8 remember the plot + the single equation!

slide 9 → remember the X formula!

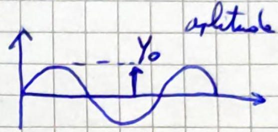
amplitude of the oscillation...

slide 12 → important the TRASMISSIBILITY

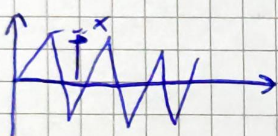
F_0 → static force

slide 13 →

impose a displacement on y



the displacement of x depend on the relation between k, c, m



slide 14 → REMEMBER the PLOT → for 0 and 2 we have 1, for 1 we have RESONANCE

$\frac{X}{Y_0}$ displacement between the car body and the ground

after 2 is a good behaviour

with $\omega_n \to 0$ → $\left(\frac{\omega}{\omega_n}\right)^2 \uparrow$ and we have a very comfortable car (work at the right part of the plot)

then with a very high m, but we can't for longitudinal and lateral dynamics.

So the idea is to get a SOFT suspension!

slide 15 → the K of the model is not the ~~same~~ K of the real car!

QUARTER ~~B~~CAR MODEL

Just represent the back or the front of a vehicle

→ NB formula to get the 2 masses! (different approach)

slide 19 → better to have low damping & but very dangerous ~~...~~ in the RESONANCE region

for different frequencies different situation for the passenger!

slide 22: a real DAMPER is NOT LINEAR

~~...~~ we want low force in bump and high force in REBOUND to avoid that the wheel ~~...~~ detach from the ground!

FORCE MOMENT AND G-G DIAGRAMS

tools to showing the effect of lateral dynamics of a vehicle!

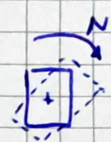
FORCE MOMENT PLOT

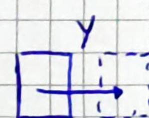
start from → C_n ⊕ | N ↓ max torque that ~~you~~ vehicle can ~~apply~~ give in the vertical direction

normalized to w (weight), l (wheel base)

Y ↓ max force that a vehicle give in y direction

N and y plotted in the one PLOT





β is the drifting of the body...

slide 6 → in point P we have a lot of lateral acceleration

but also a small angular acceleration

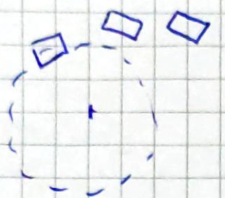
point T is the max point to continue to rotate

the position of the point P tell us if the vehicle is stable or not stable!

point P below → STABLE

point P above → unstable

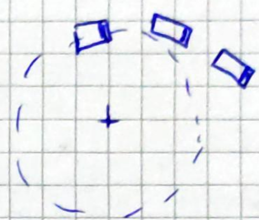
TERMINAL DRIFT



SPIN

DANGEROUS

PLOW



G-G diagrams

~~help~~ helpful to understand the max lateral and longitudinals ~~dynamics~~ capabilities!
(must be plotted for different speed)

→ can be parametrize with δ (steering angle) and β_p (pressure of braking pedal) and T_p (throttle pedals)

slide 11 → plot for a specific velocity!

SUSPENSION

KINEMATICS

REPRESENT → ROTATION of ~~body~~ wheel respect to the ~~wheel~~ body

INSTANTANEOUS CENTER (IC) = body respect to the wheel, ~~the~~ movement for ~~to~~

→ is on the intersection of the two rods in this four bar linkage

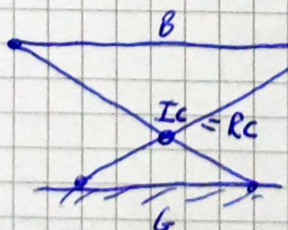
Knowing the IC we can delete the linkage and connect the wheel to a single point (IC)

ASSUMPTION → IC stay in the same position for the entire suspension movement

It is common to define two IC → FRONT VIEW, SIDE VIEW ⇒ OBTAINED the INSTANT AXIS

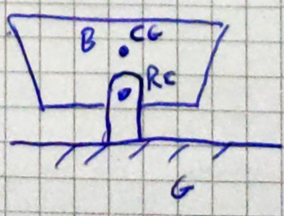
ROLL CENTER HEIGHT (RCH) =

RC → instantaneous center of B (body) respect to G (ground)



→ Knowing RC and the CG of the vehicle we can understand the tilt during curve

slide ↑ →



bigger is the distance between RG and CG the higher is the rolling behaviour slide 6 → if the IC is near the wheel the camber will change a lot during the suspension movement

SCRUB → is the LATERAL movement of the tire during the suspension movement

21

if IC stay at the ground level → SCRUB = 0

ANTI DIVE - ANTI SQUAT (ANTI LIFT)

considering the IC in the SIDE VIEW, depending the position of the IC respect to the center of tire we have anti dive, anti SQUAT effect

ANTI-LIFT → IC higher than the center of the tire!

NB during the brake → NO dive is good

FRONT SUSPENSION

interesting parameters due to the steering system!

CASTER ANGLE related to the mechanical trail

the axis we have the rotation due to the steer

our choice!

higher is the mechanical TRAIL and easier the tire will allign automatically to the direction of the car!

(8-12°)

<u>KINGPIN</u> related to the SCRUB

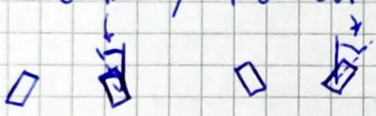
↓

control where the scrub radius is! → obtaining positive or negative value

CAMBER

angle of the tire respect to the vertical line

TOE IN / TOE OUT



VEDUTA DALL'ALTO

TOE OUT → help the handling

TOE IN → help for the stability

TYPE OF SUSPENSION

MCPHERSON (FRONT SUSPENSION) = allow to save space, the ~~draw~~ drawback is the camber change during the brake and the weight

DOUBLE WISHBONE (A-ARM) (BOTH FRONT/REAR) = best possibility! quite expensive!

TRAILING ARM (REAR SUSPENSION) = we can't control the camber!

SEMI-TRAILING ARM = possibility to manage a little bit the camber but NOT used anymore

SWING AXLE = NOT USED ANYMORE, camber change a lot during the operation

H-ARM, tri-link strut = used in Jeep car or trucks

FIVE LINKS (MULTILINK) = similar to the double wishbone but with a different structure

↓

but we can move the ~~the~~ HARD POINTS where we want!

Control the CAMBER, toe in, toe out during the movement of the suspension

NEED of computer simulation to optimize it!

PANHARD = still used in TRUCKS,

TORQUE TUBE = very simple, used in US cars, also in racing cars!

the ~~shaft~~ differential goes up and down!

NASCAR TYPE = issue that are NOT INDIPENDENT SUSPENSION!

DE DION = it is heavy! the differential stay fixed!

TWIST AXLE = super simplified! NOT USED ANYMORE