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## Introduction to vehicle suspension

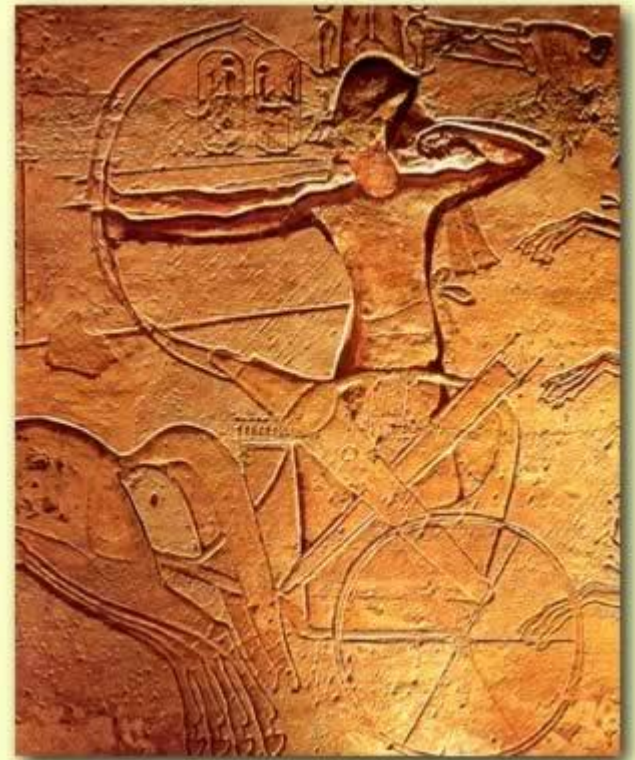
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# Chariot





# Why have suspension?

- There are two basic problems:
  - ride
  - Handling

- First recognised by?

- Myceneans 1600 - 1200 BC - Compliant Chariot Wheels

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“...used wheels of thin willow or elm, usually with only four spokes. Such a construction was highly springy and resilient and it seems to have enabled these vehicles to have been galloped across the rough ground of the Greek hillsides, where a heavier and more rigid vehicle would have been useless.”



# Why have suspension? Ride

- The term suspension comes from the days of horse drawn carriages.
- The roads were particularly poor – there was no national highways agency.
- The ride was particularly harsh and passengers frequently complained of a sore 'derrier'
- A solution was to attach the wheels to a frame and suspend the whole occupant structure by compliant leather straps

# Suspension





Suspension

## Vehicle isolation - “ride”

- Isolation from road imperfections
- Predominantly vertical inputs with some longitudinal
- Vehicle features to improve ride:
  - motion between wheels and body
  - elastic element to carry weight
  - damping element to dissipate energy
  - linkage to maintain wheel alignment
  - elastomers for medium-frequency isolation
  - soundproofing

# Handling

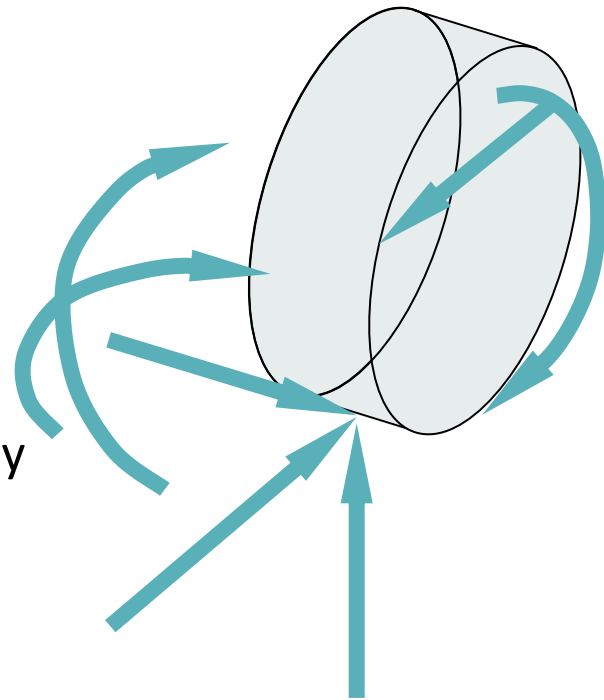
- “Handling” is
  - different to maximum steady state lateral acceleration (“grip”)
  - Slightly awkward to define
- Prodrive’s working definition
  - “a quality of a vehicle that allows or even encourages the operator to make use of all the available grip”

# Handling

- Use emotional definitions like:
- “*Confidence*” (consistency / linearity to inputs)
- “*Fun*” (high yaw gain, high yaw bandwidth)
- “*Fluidity*” (yaw damping between manoeuvres)
- “*Precision*” (disturbance rejection)

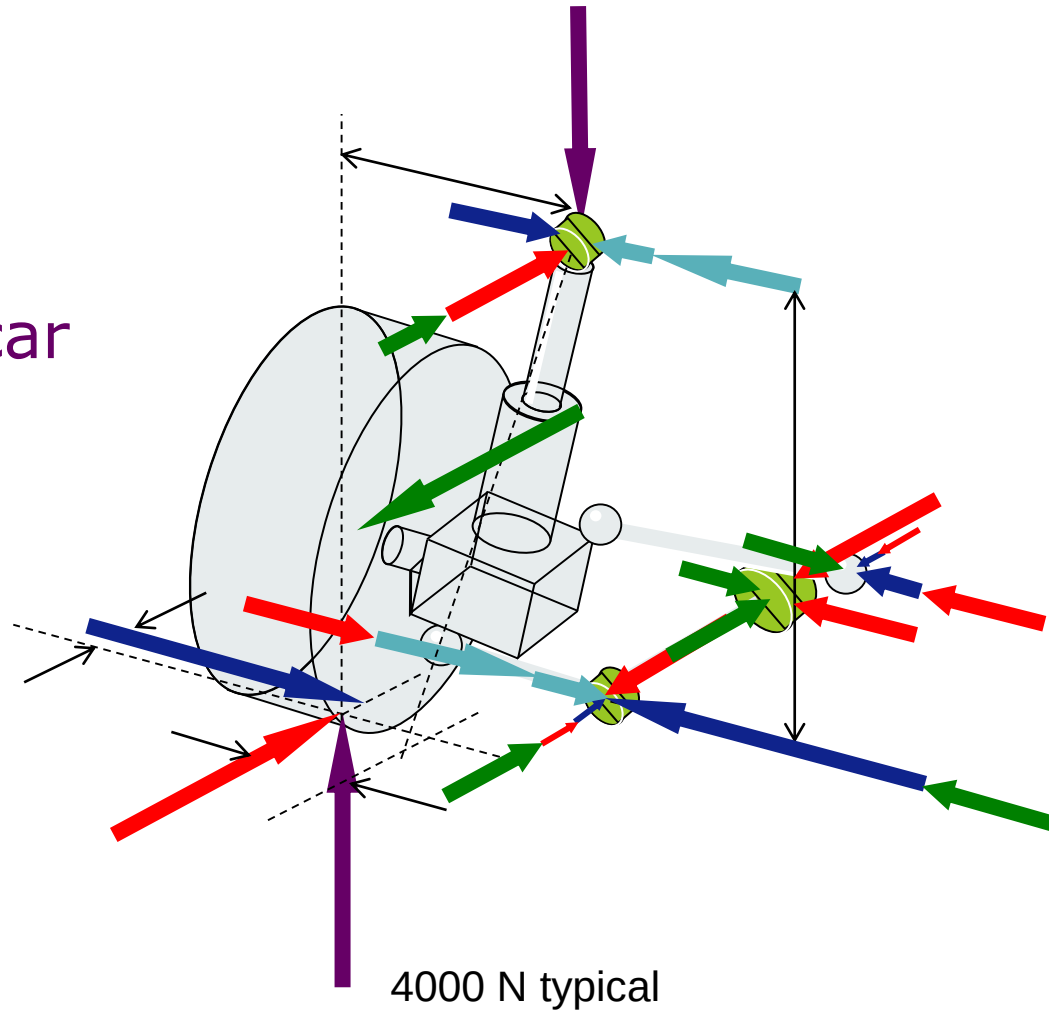
# What must a vehicle suspension linkage system do ?

- Suspension hardware must
  - support vehicle weight
  - transmit braking loads from tyre to body
  - transmit lateral loads to body
  - maintain geometry despite applied loads
  - transmit propulsive loads from tyre to body



# Structural considerations

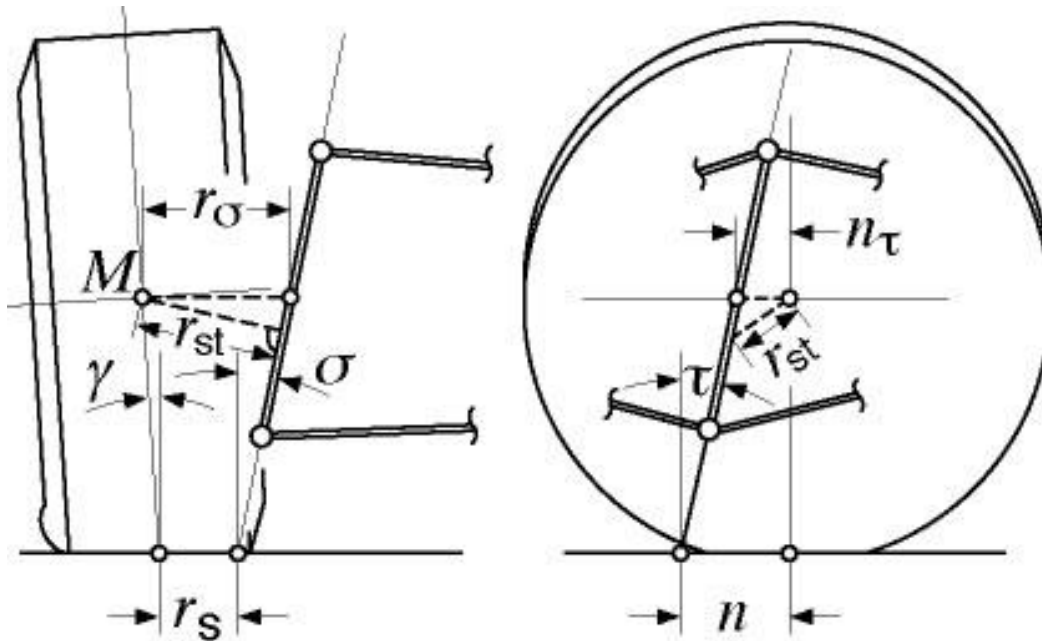
weight of car  
cornering  
braking  
driving



# What must a vehicle suspension do ?

- Suspension hardware must
  - Allow vertical movement of the wheel and tyre
  - Minimise changes to wheel alignment during the vertical wheel travel
  - Allow sufficient angular articulation of the steering wheels
  - Minimise changes to wheel alignment during the angular wheel travel
- “Let nothing steer the wheels but the steering” - Colin Chapman

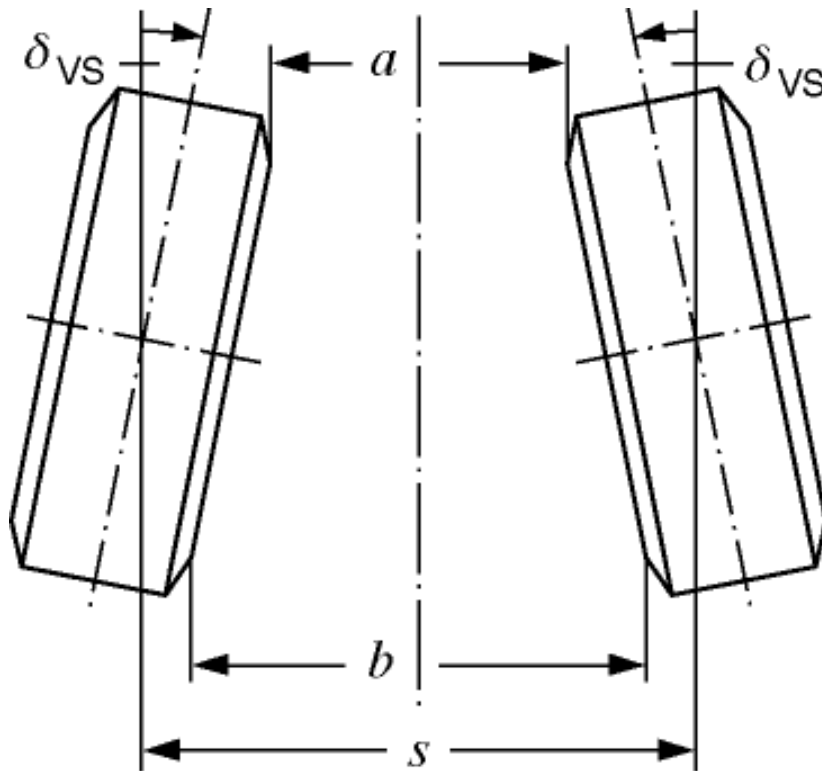
# Camber and caster



## Wheel position.

$M$  Center of wheel,  
 $r_{st}$  Radius of deflection leverage,  
 $nt$  Caster offset,  
 $n$  Positive caster,  
 $\tau$  Caster angle,  
 $r_\sigma$  Kingpin inclination offset,  
 $r_s$  Kingpin offset,  
 $\gamma$  Camber angle,  
 $\sigma$  Kingpin angle.

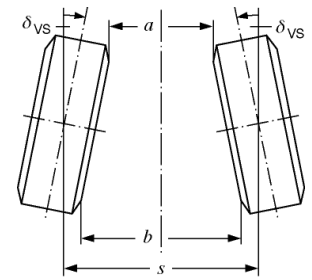
# Suspension toe



## Toe-in

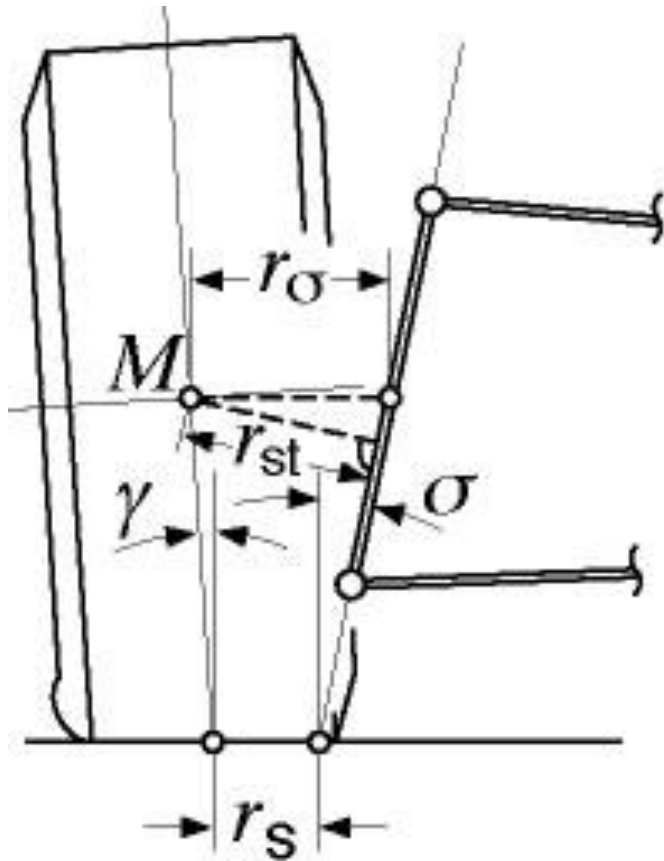
$\delta_{vs}$  Toe-in angle,  
Distance between wheels:  
 $a$  Front  
 $b$  Rear  
 $b-a$  Toe-in (in mm),  
 $s$  Track.

# Toe-in



- Is the angle between the vehicles longitudinal axis and a plane through the tyre centre
- It can also be defined as the distance between the front and rear of the wheel rim.
- On the front steering wheels typical values are:
  - Rear wheel drive, front toe-in 5-20 minutes
    - To provide straight line stability
  - Front wheel drive, front toe-out 0-20 minutes
    - To compensate for motive forces

# Wheel position – camber

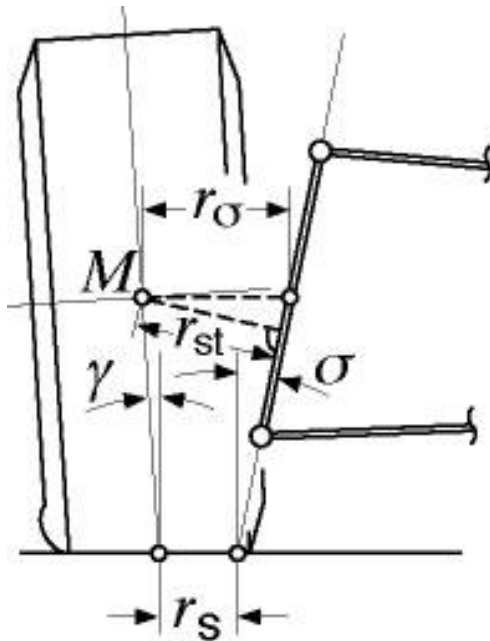


## **Wheel position.**

$M$  Center of wheel,  
 $r_{st}$  Radius of deflection leverage,  
 $r_O$  Caster offset,  
 $n$  Positive caster,  
 $\tau$  Caster angle,  
 $r_s$  Kingpin inclination offset,  
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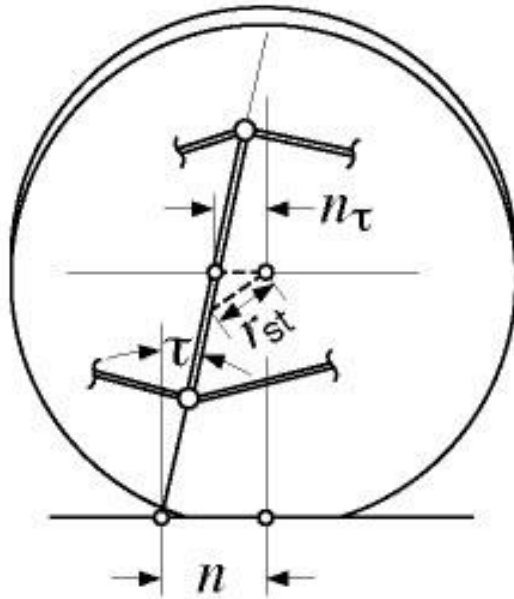
# Wheel position – camber



$\gamma$  Camber angle,  
Inclination of wheel axis in relation to  
the road surface in a vertical plane  
The angle is considered -ve when the  
top of the wheel is angled towards  
the centre of the vehicle.

Camber  
creates small auxillary side forces  
compensates for the effects of roll angle during cornering

# Wheel position – caster



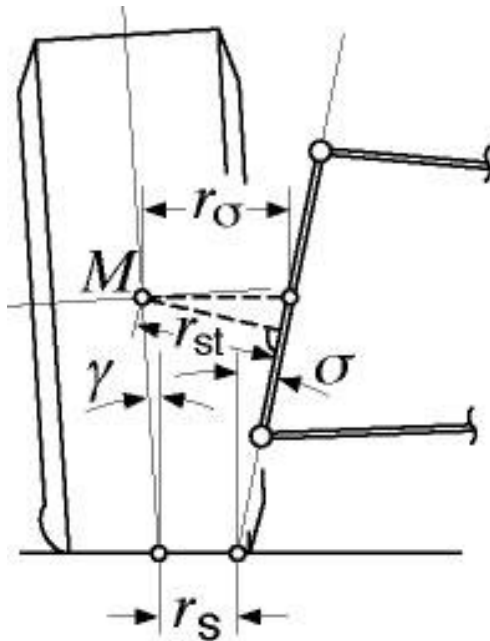
$n$  Positive caster,  
Distance from wheel contact point to  
where the point of the steering axis  
hits the road

$\tau$  Caster angle,  
The angle from the steering axis  
(viewed from the side) and the  
vertical

## Caster

Determines the degree of self centering action of the steering  
Influences straight running  
Influences steering forces when cornering

# Wheel position – King pin



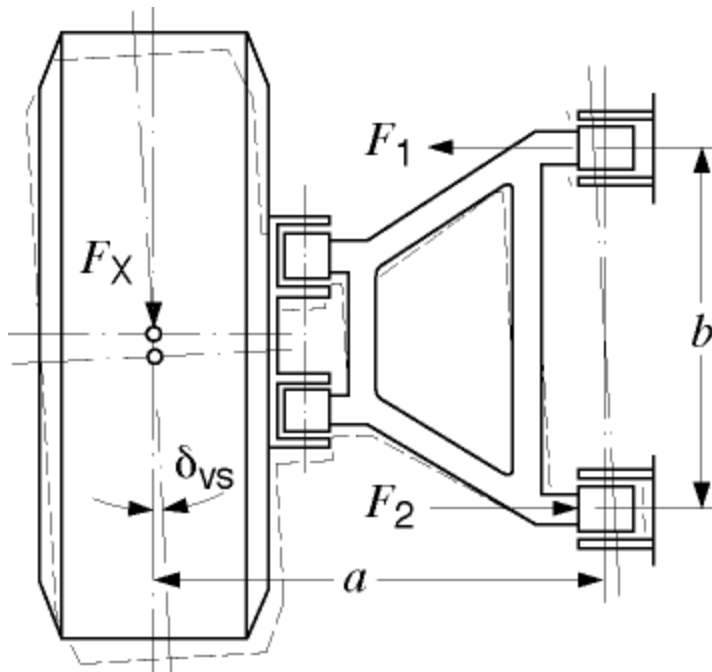
$r_s$  Kingpin offset or steering offset  
Distance between the wheel contact point and where the steering axis hit the ground

$\sigma$  Kingpin angle.

Difference between the steering axis and the vehicle longitudinal plane.

The kingpin offset combines with the effect of traction and braking forces to generate loads on the steering and effects steering forces and feel

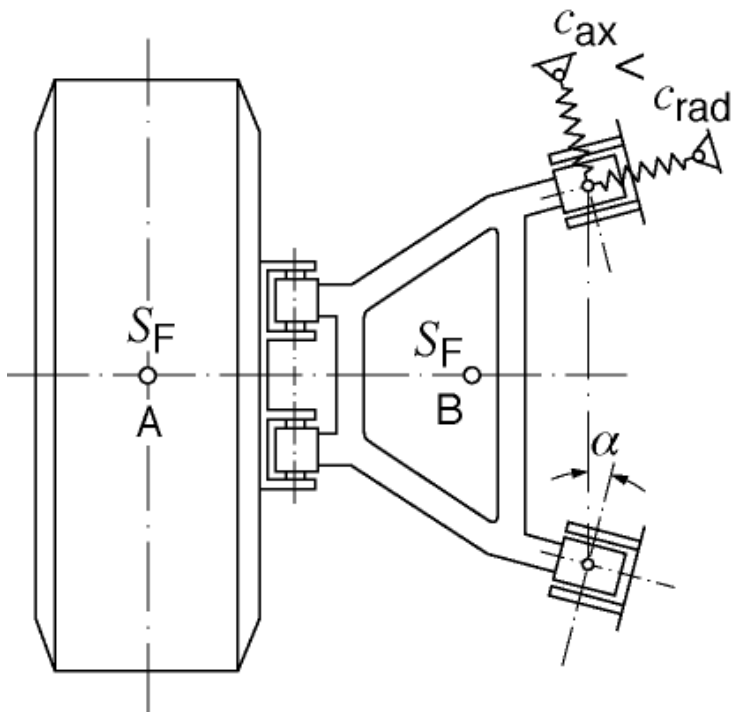
# Suspension



## Wheel displacement by longitudinal force $F_X$ .

$F_1, F_2$  Suspension-arm mounting forces,  
 $a$  Distance between wheel axes and suspension arm,  
 $b$  Suspension arm mounting separation,  
 $\delta_{vs}$  Toe-in angle.

# Suspension



## **Positioning of suspension-arm mountings to counteract steering deflection due to flexibility**

SF Center of gravity (A Reduction, B Complete equalization),  
 $c_{ax}$   $c_{rad}$  Axial/radial spring constants  
 $\alpha$  Alignment angle.