MAK 3101
Taşıt Titreşimleri

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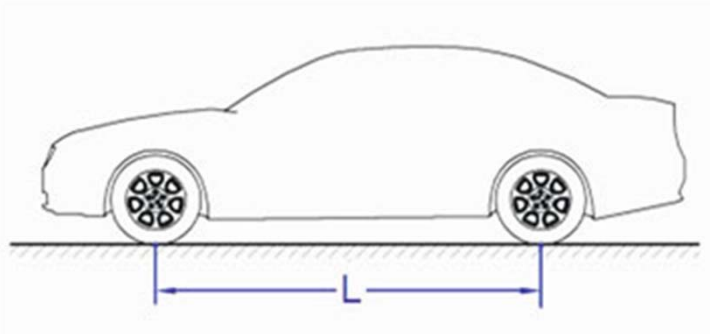
Hybrid Powertrains

Suspension Kinematics

- Suspension kinematics determine the spatial movement of the wheels during jounce/rebound (compression/ extension) and steering.
- In order to calculate suspension kinematics, such parameters are required:
  - position of the center of gravity,
  - axle weights,
  - axle loads,
  - brake force distribution, and propulsion power distribution for all-wheel-drive vehicles etc.

Wheelbase *L*

- The distance in the vehicle's xy plane between the center of tire contact at the front wheels and the center of tire contact at the rear wheels.



Wheelbase *L*

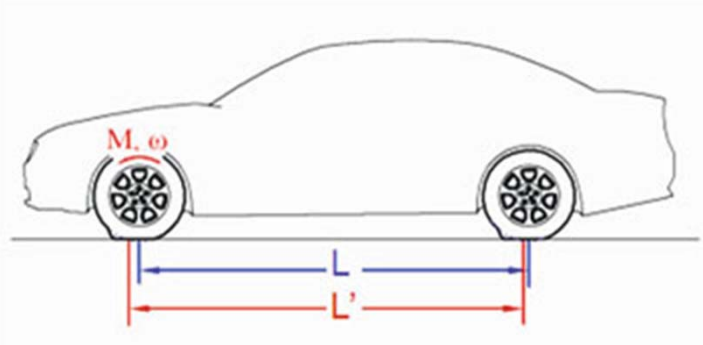
- A vehicle with a longer wheelbase features:
- ♦ more room for passengers
- ♦ improved ride comfort
- ♦ improved safety

Wheelbase *L*

- A vehicle with a shorter wheelbase features:
- ♦ better maneuverability (cornering, parking)
- ♦ lower costs and lower weight

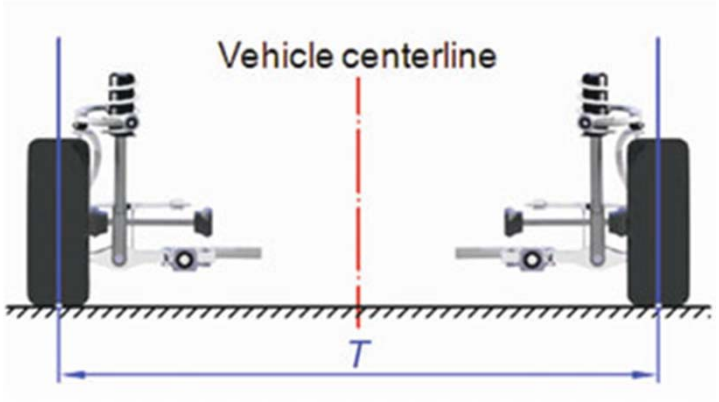
Wheelbase change

- The advantages of this are:
- Horizontal impacts are mitigated due to compliance.
- The springing motion of the suspension is increased.
- The disadvantages of this are:
- Fluctuations in wheel RPM
- Torsional vibrations in the drivetrain.
- Wheel-speed signals (ABS) can be incorrect.
- Wheel hop during braking can result.



Track width *T*

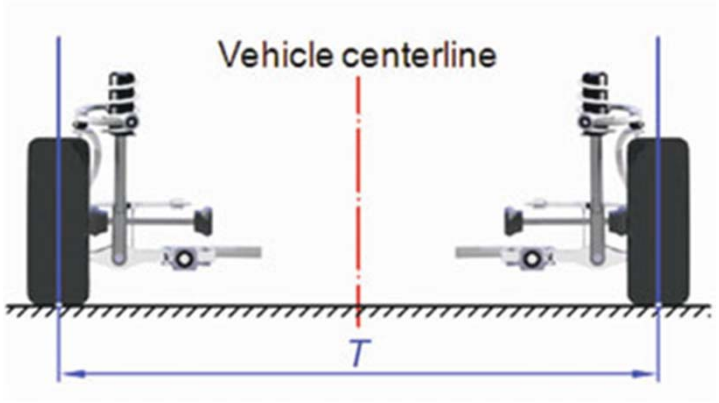
- The distance in the yz plane between the centers of tire contact on a single axle



- Wide track width results in:
- Better driving behavior
- Reduced vehicle roll
- Improved design aesthetics

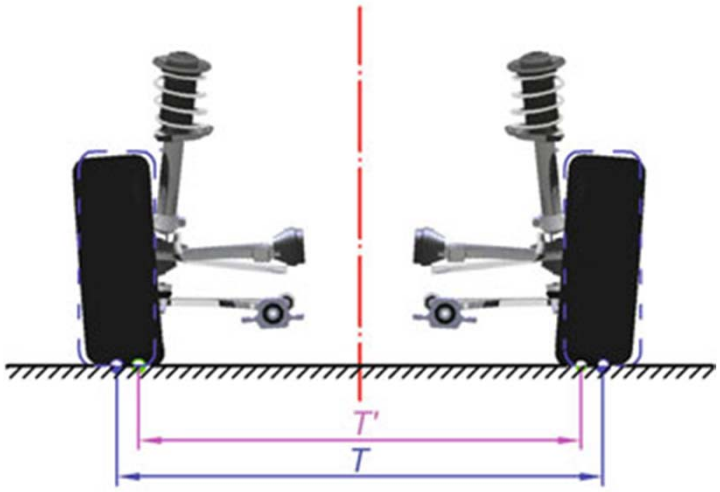
Track width *T*

- The distance in the yz plane between the centers of tire contact on a single axle
- Narrow track width has following disadvantages:
- Less stability
- Increased vehicle roll
- Less room for passengers and powertrain



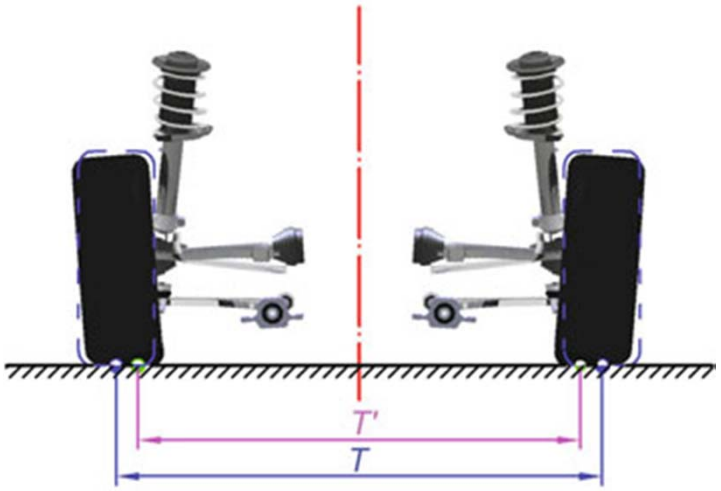
Track width change

- Camber changes and suspension kinematic effects during suspension compression and extension can change the position of the contact patch, thus changing the track width



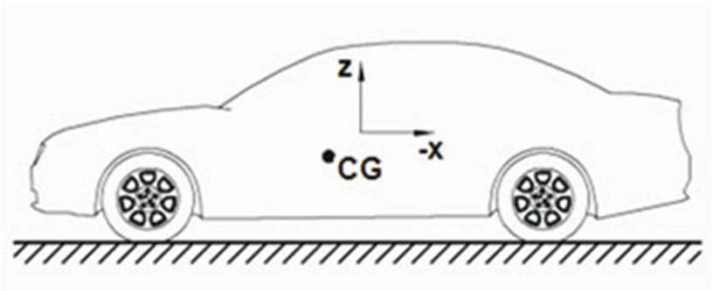
Track width change

- The disadvantages of this are:
- The tire slides along the road surface.
- Straight line tracking is impaired.
- Lateral forces are created.
- Rolling resistance is increased.
- Steering is affected.



Vehicle center of gravity

- The imaginary point at which the vehicle's entire mass can be concentrated.

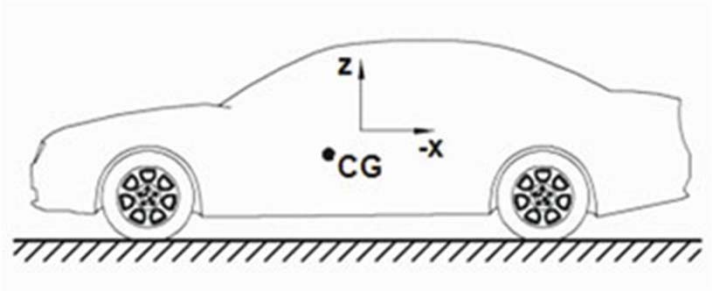


A low center of gravity results in:

- Good handling and driving safety
- Reduced vehicle pitch and roll
- Reduced wheel load fluctuations on inclined surfaces

Vehicle center of gravity

- The imaginary point at which the vehicle's entire mass can be concentrated.
- A high center of gravity results in:
- Increased rear axle load on inclined surfaces.

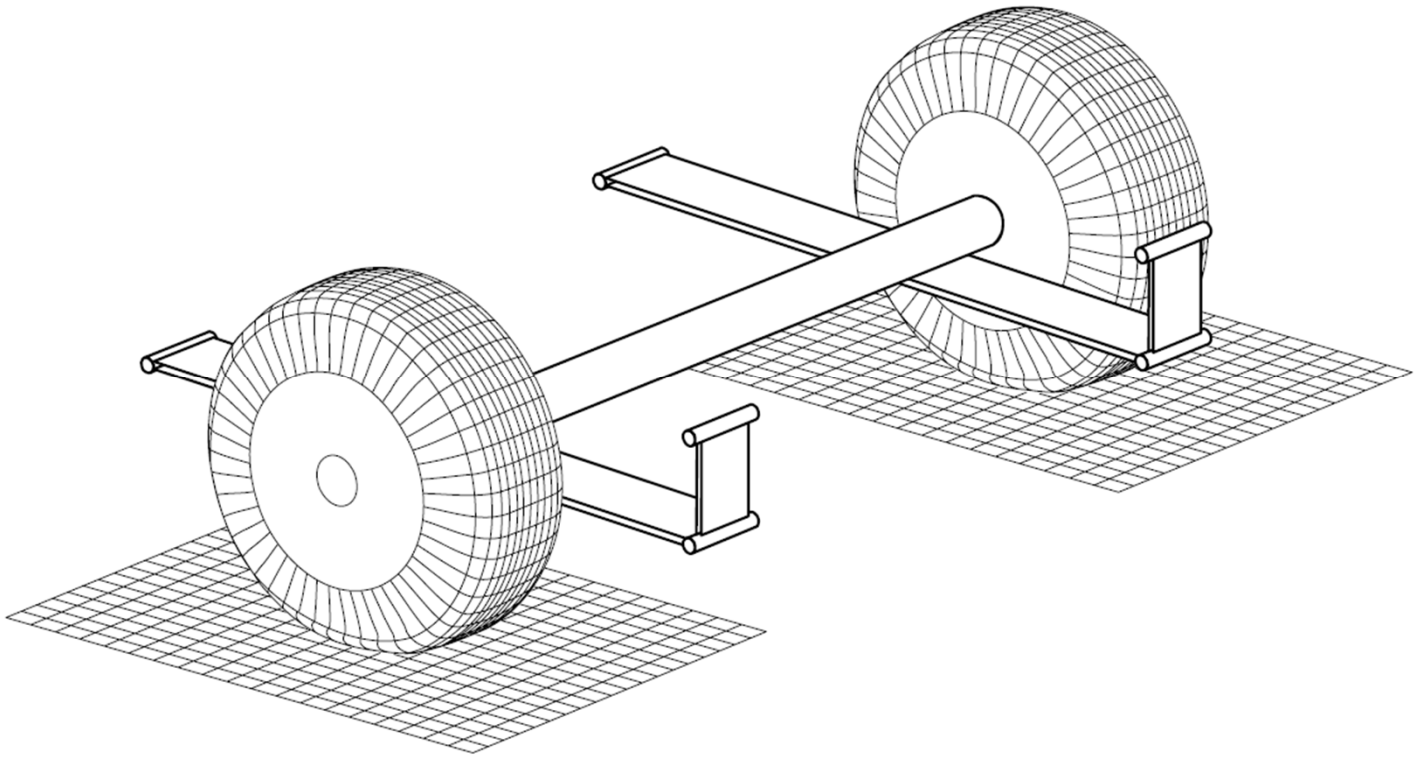


Axle-load distribution

- The ratio of the distance in the x-direction between the center of gravity and the front and rear axles.
- Typical values in vehicle neutral position:
- 44:56 to 56: 44.

Dependent suspension systems

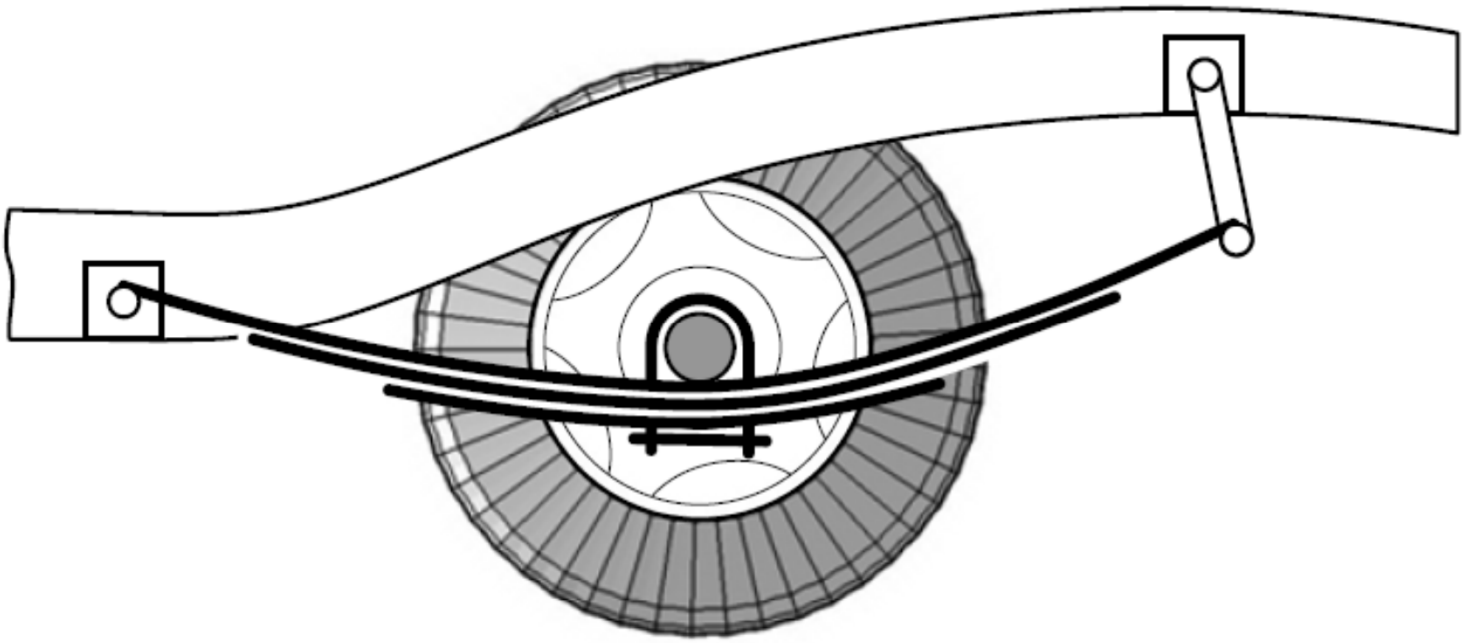
A suspension with a solid connection between the left and right wheels is called dependent suspension.



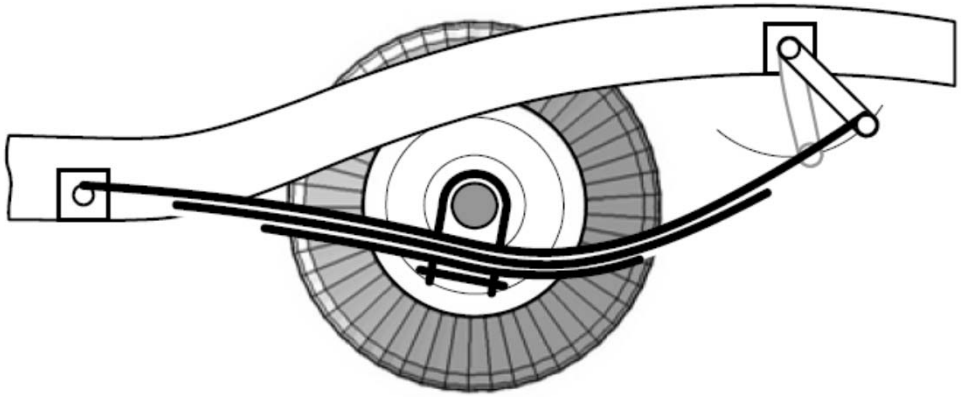
A solid axle with leaf spring suspension

Hotchkiss drive

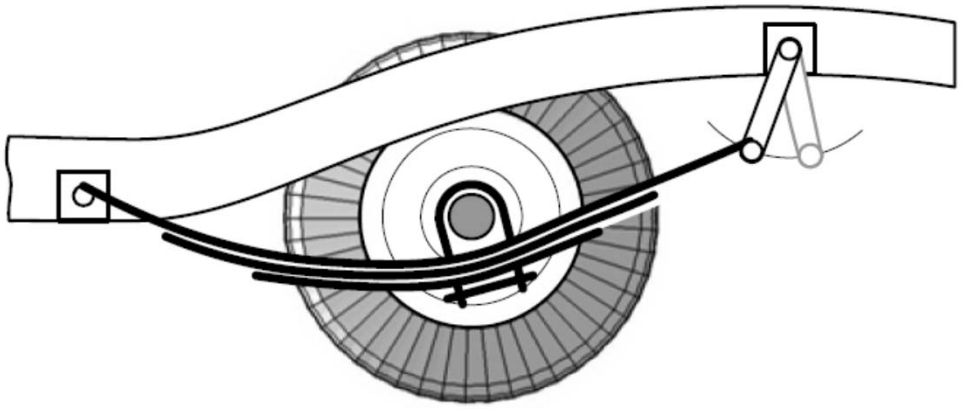
When a live solid axle is connected to the body with nothing but two leaf springs, it is called the Hotchkiss drive



Hotchkiss drive drawbacks

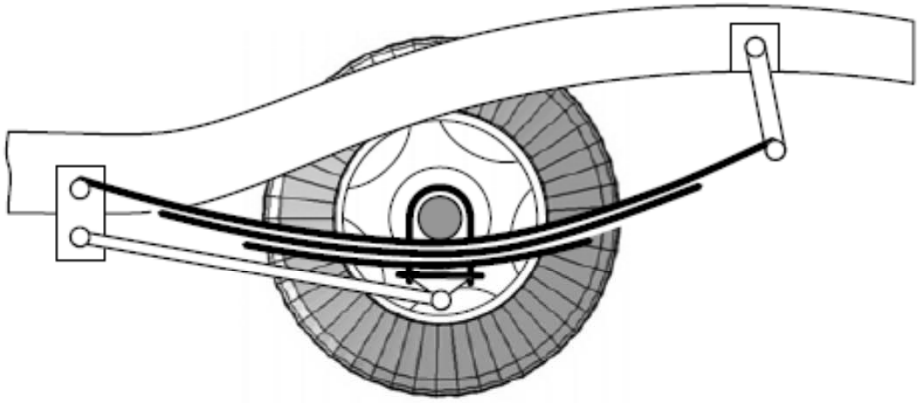


(*a*) Acceleration

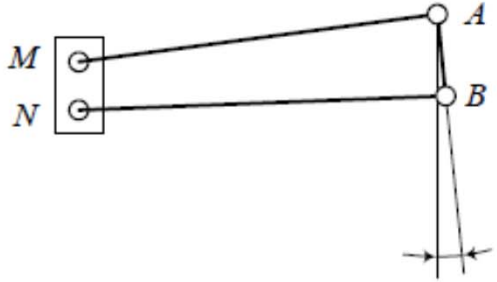


(*b*) Braking

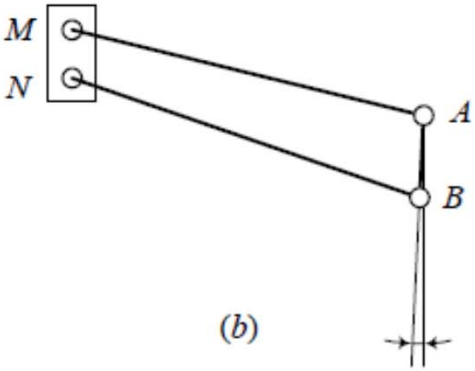
Anti-tramp bar



(a)



(a)



(b)

Hotchkiss drive drawbacks

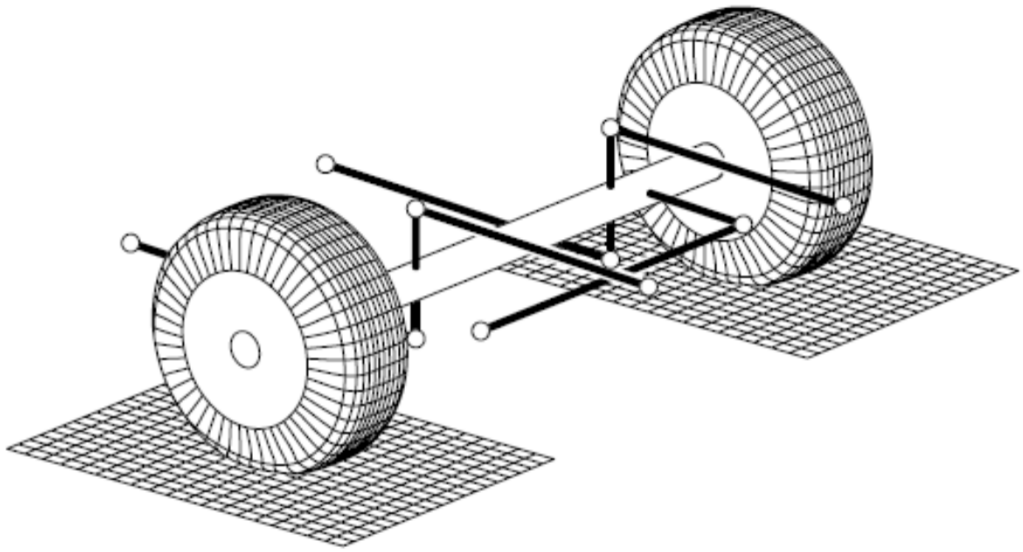
- The front wheels need room to steer left and right. Therefore, leaf springs cannot be attached close to the wheel hubs, and must be placed closer to the middle of the axle. That gives a narrow spring-base, which means that a small side force can sway or tilt the body relative to the axle through a considerable roll angle due to weight transfer. This is uncomfortable for the vehicle passengers, and may also produce unwanted steering. The solid axle positively prevents the camber change by body roll. The wheels remain upright and hence, do not roll on a side. However, a solid axle shifts laterally from its static plane and its center does not remain on the vehicle's longitudinal axis under a lateral force.

Hotchkiss drive drawbacks

- A solid axle produces bump-camber when single-wheel bump occurs. If the right wheel goes over a bump, the axle is raised at its right end, and that tilts the left wheel hub, putting the left wheel at a camber angle for the duration of deflection.

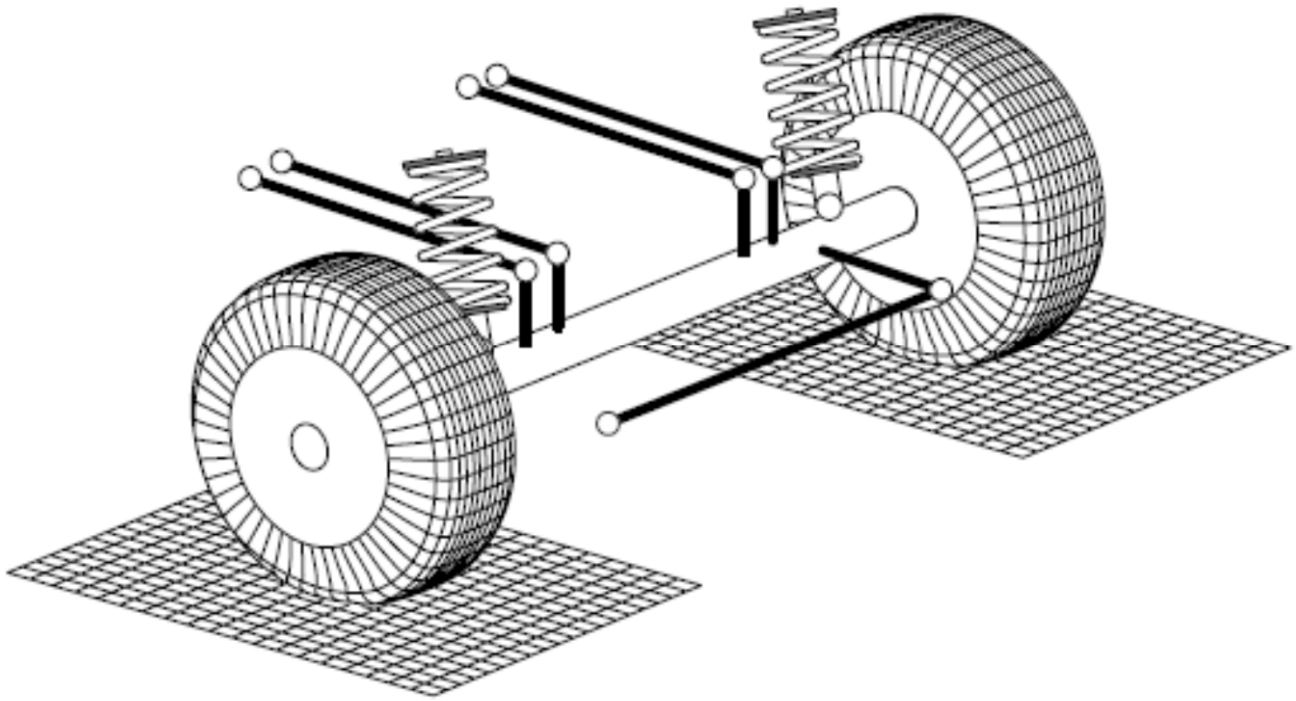
- A solid axle is counted as an unsprung member, and hence, the unsprung mass is increased where using solid axle suspension. A heavy unsprung mass ruins both, the ride and handling of a vehicle. Lightening the solid axle makes it weaker and increases the most dangerous problem in vehicles: axle breakage. The solid axle must be strong enough to make sure it will not break under any loading conditions at any age. As a rough estimate, 90% of the leaf spring mass may also be counted as unsprung mass, which makes the problem worse.
- The unsprung mass problem is worse in front, and it is the main reason that they are no longer used in street cars. However, front solid axles are still common on trucks and buses. These are heavy vehicles and solid axle suspension does not reduce the mass ratio ε = ms/mu very much. When a vehicle is rear-wheel-drive and a solid axle suspension is used in the back, the suspension is called live axle. A live axle is a casing that contains a differential, and two drive shafts. The drive shafts are connected to the wheel hubs. A live axle can be three to f our times heavier than a dead I-beam axle. It is called live axle because of rotating gears and shafts inside the axle.

Watt linkage and Panhard arm



- A panhard bar prevents the rear axle from moving side-to-side.

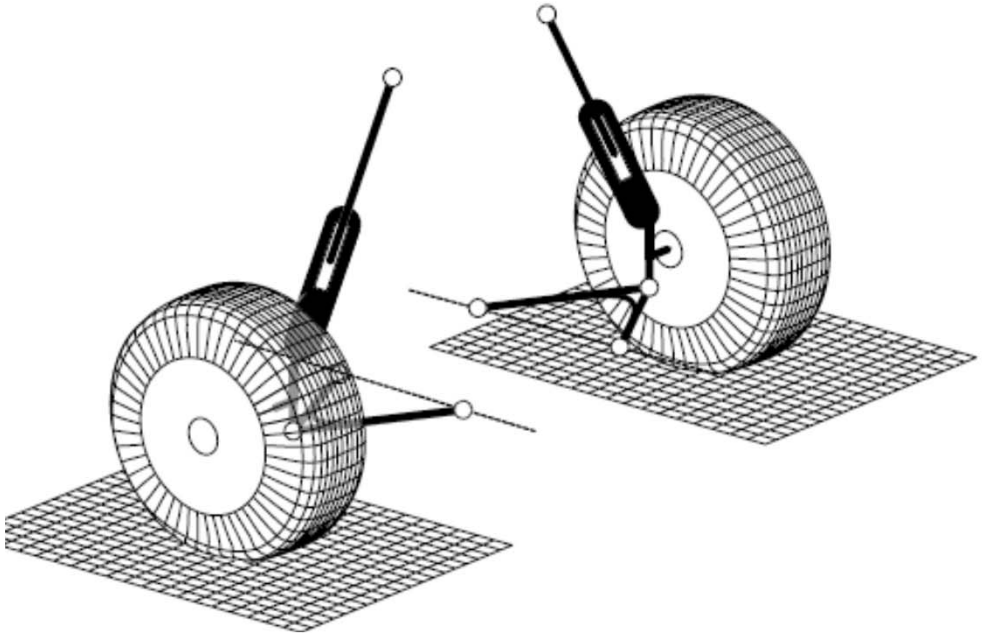
Coil spring solid axle

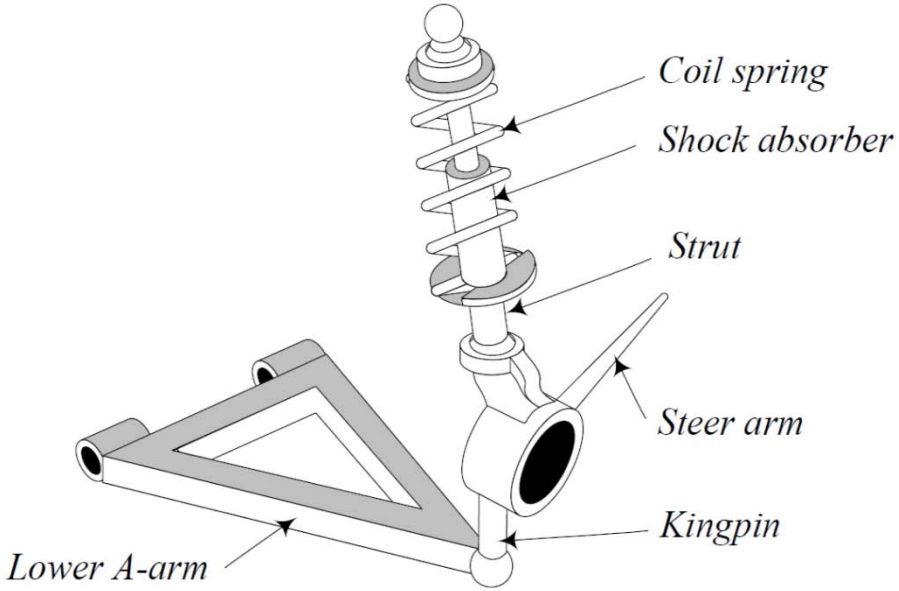


Coil spring solid axle

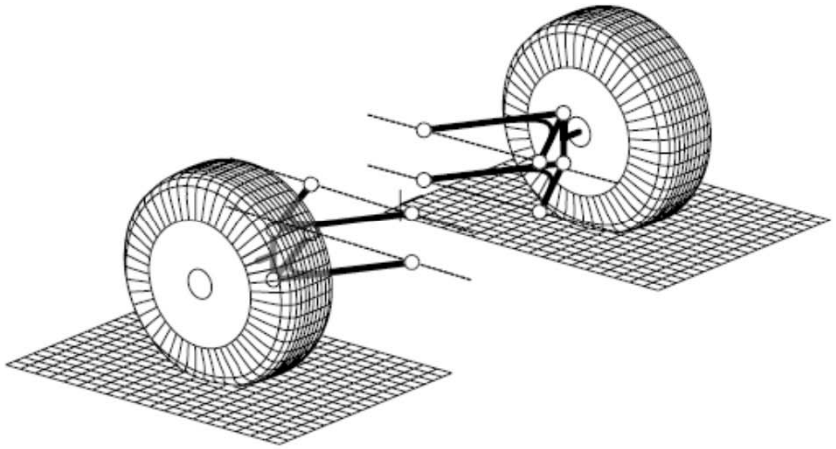
- To decrease the unsprung mass and increase vertical flexibility of solid axle suspensions, it is possible to equip them with coil springs. The suspension mechanism is made of four longitudinal bars between the axle and chassis. The springs may have some lateral or longitudinal angle to introduce some lateral or longitudinal compliance.

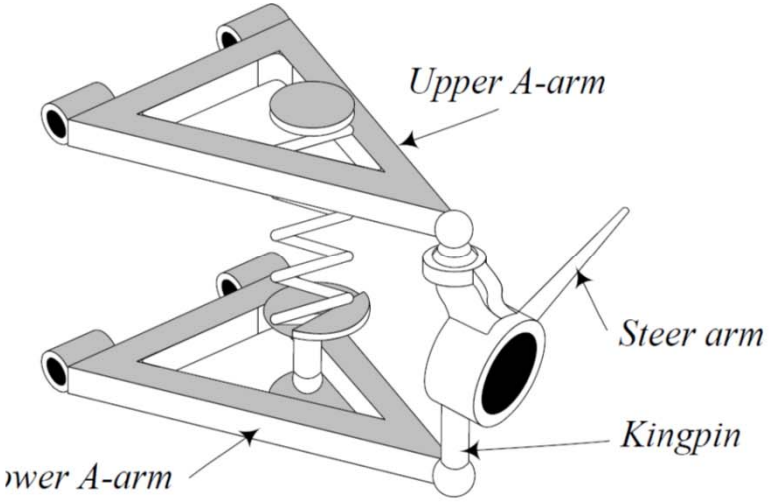
Independent suspension systems





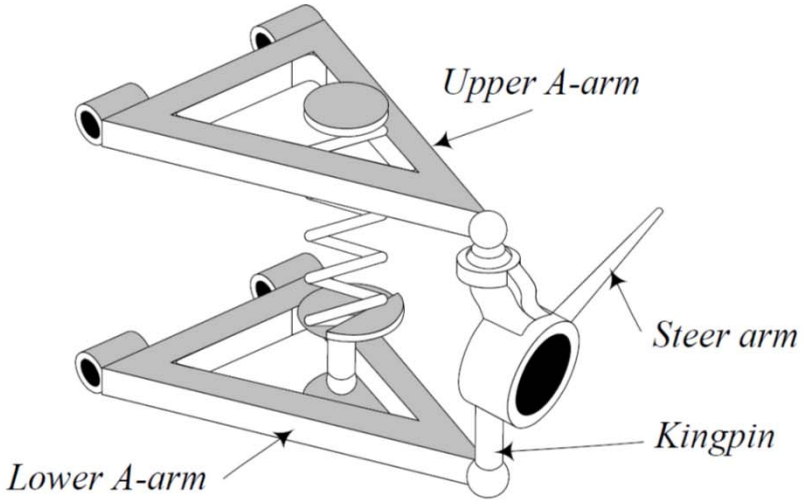
Doble A arm suspension

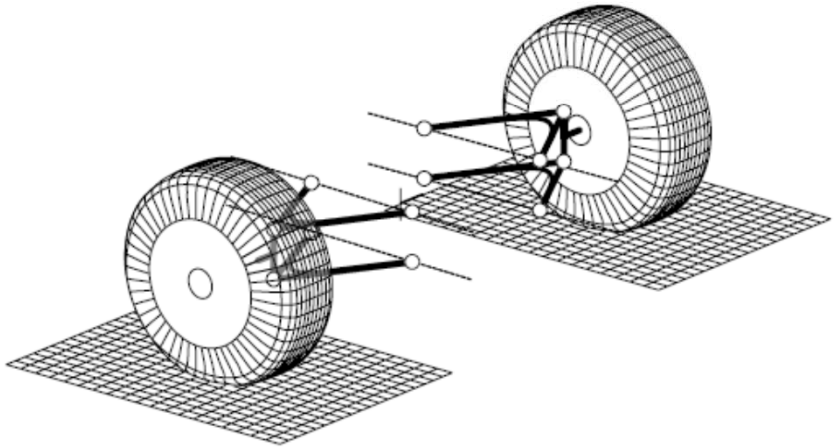




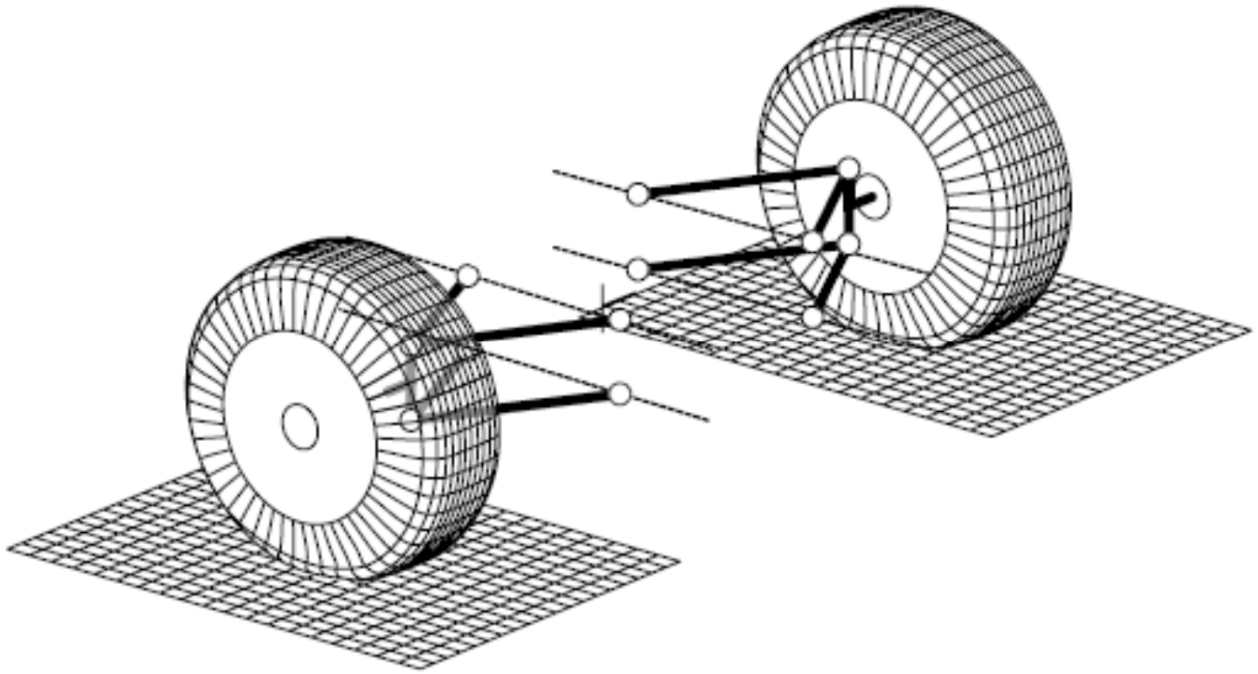
Doble A arm suspension

Consider a double A-arm suspension mechanism. The coil spring may be between the lower arm and the chassis. It is also possible to install the spring between the upper arm and the chassis. In either case, the lower or the upper arm, which supports the spring, is made stronger and the other arm acts as a connecting arm.



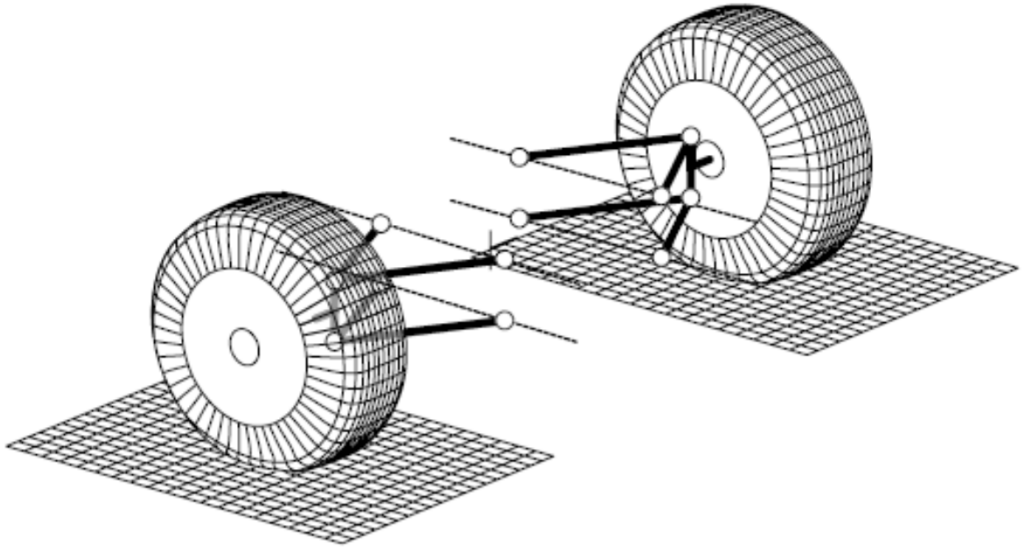


Multi-link suspension mechanism

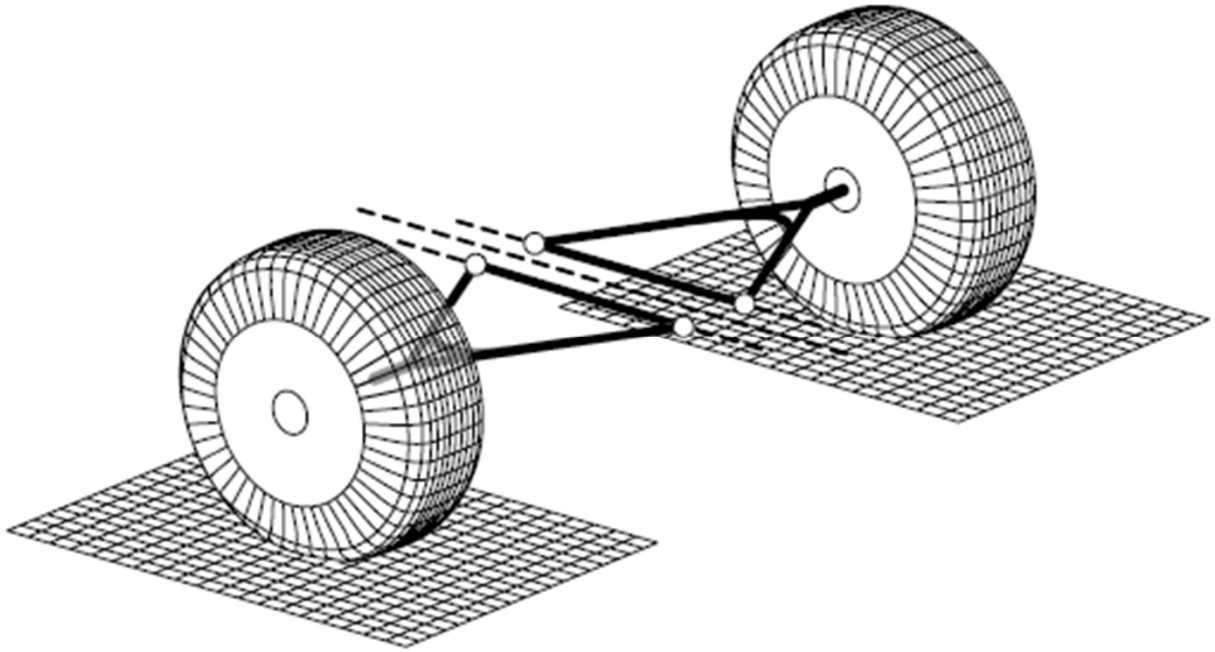


Multi-link suspension mechanism

When the two side bars of an A-arm are attached to each other with a Joint then the double A-arm is called a multi link mechanism. They are more expensive, less reliable, and more complicated compare to a double A-arm four-bar linkage.

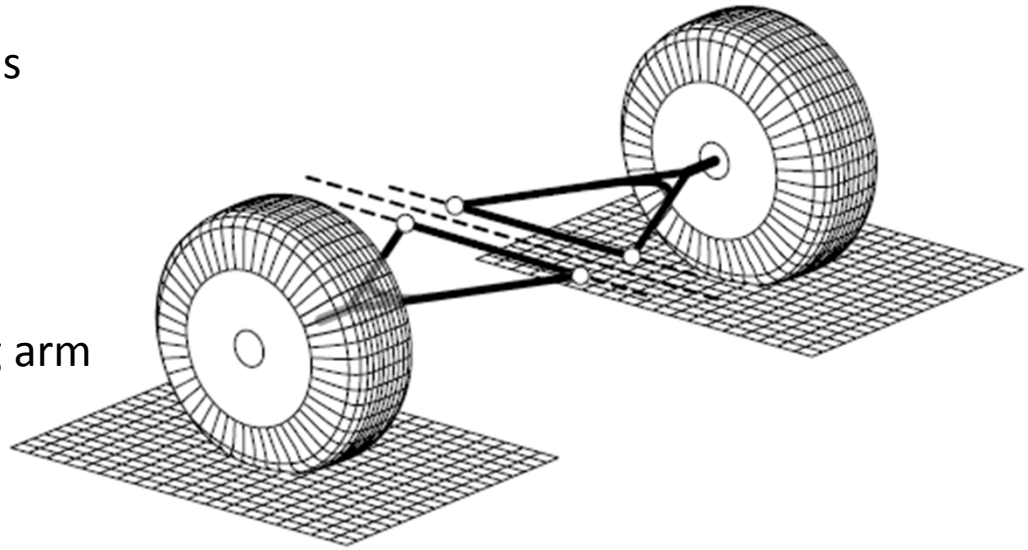


Swing arm suspension

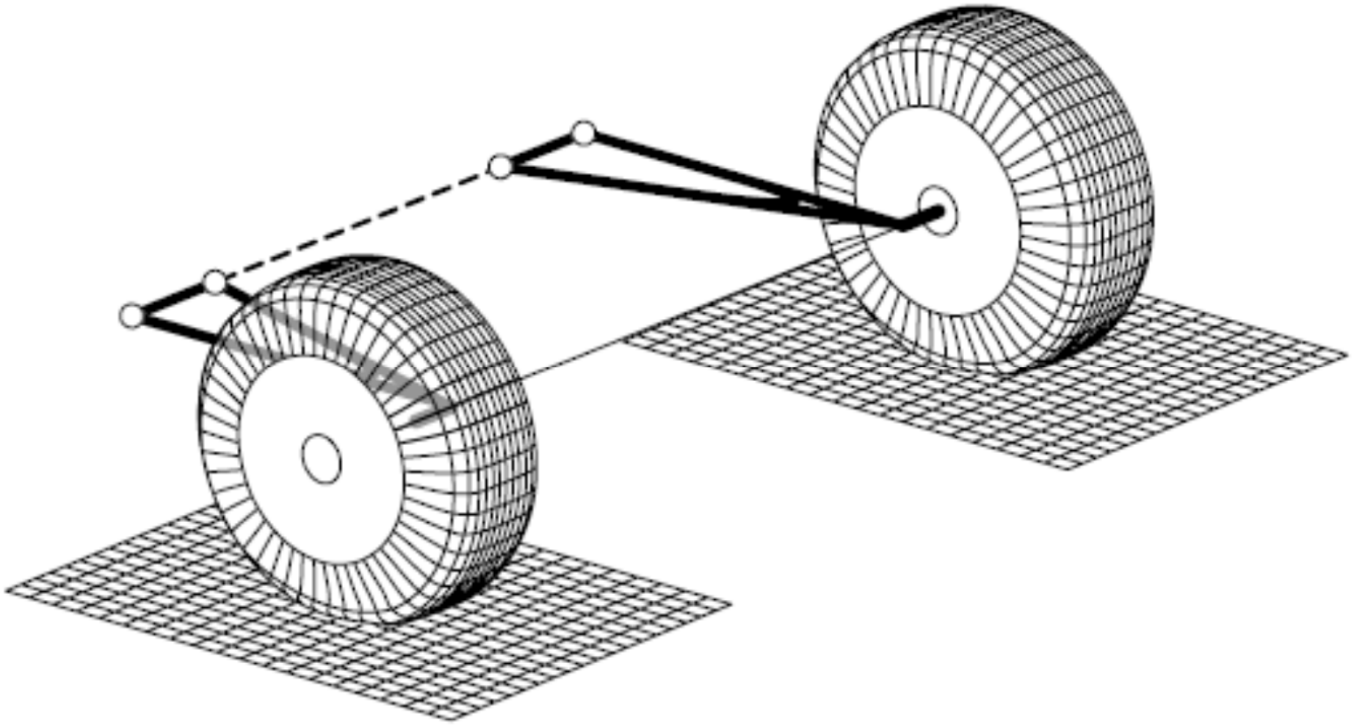


Swing arm suspension

An independent suspension may be as simple as a triangle. The base of the triangle is jointed to the chassis and the wheel to the tip point. The base of the triangle is aligned with the longitudinal axis of the vehicle. Such a suspension mechanism is called a swing axle or swing arm.
The variation in camber angle for a swing arm suspension is maximum, compared to the other suspension mechanisms.

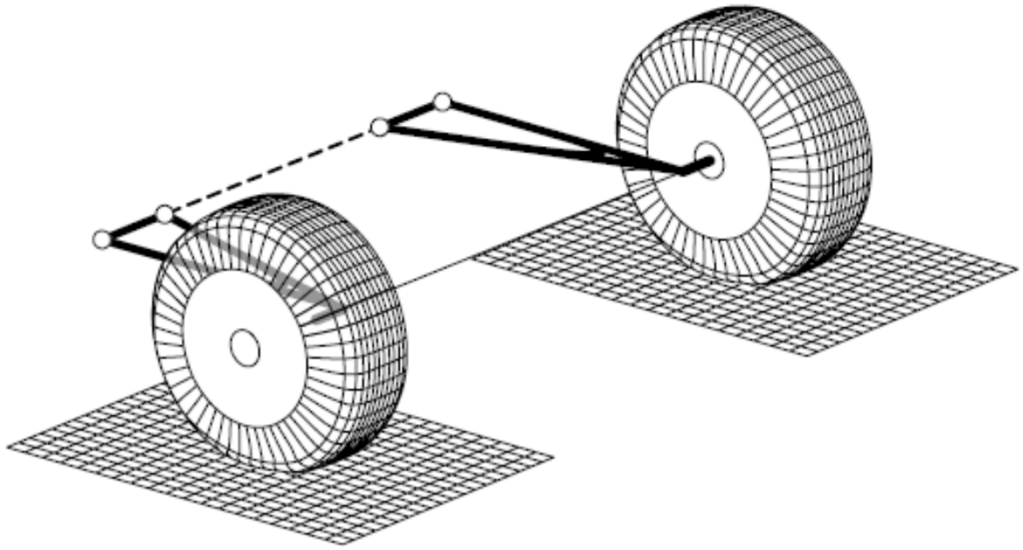


Trailing arm suspension

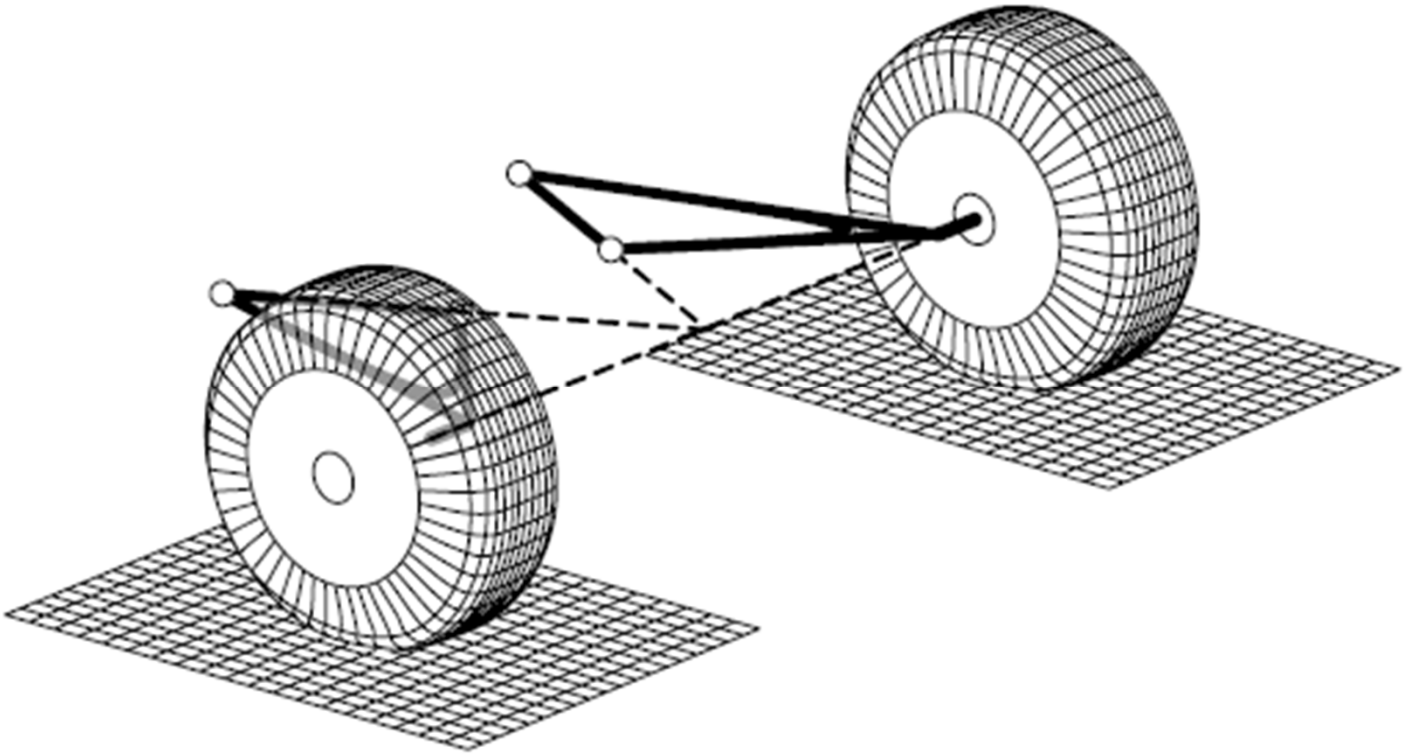


Trailing arm suspension

The camber angle of the wheel, supported by a trailing arm, will not change during the up and down motion

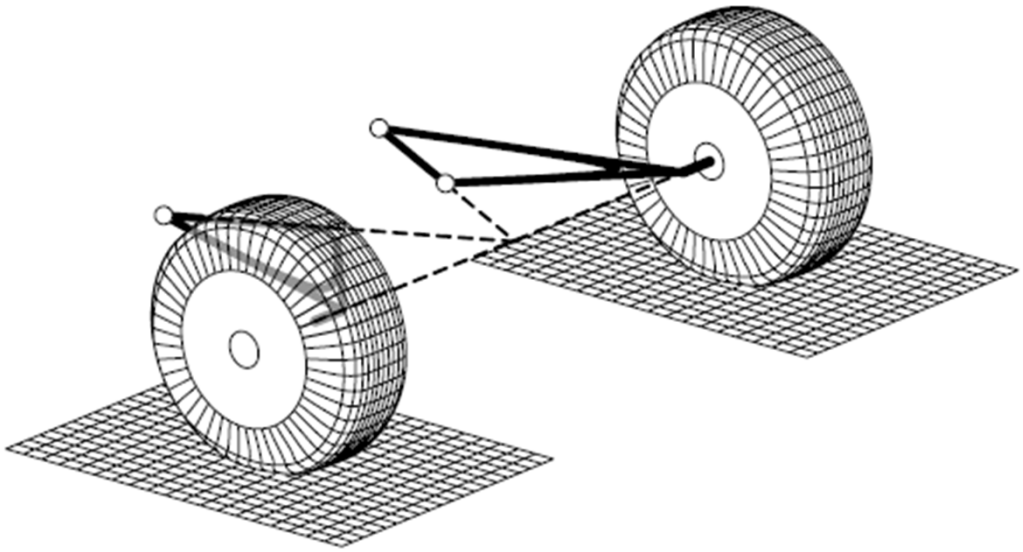


Semi-trailing arm suspension

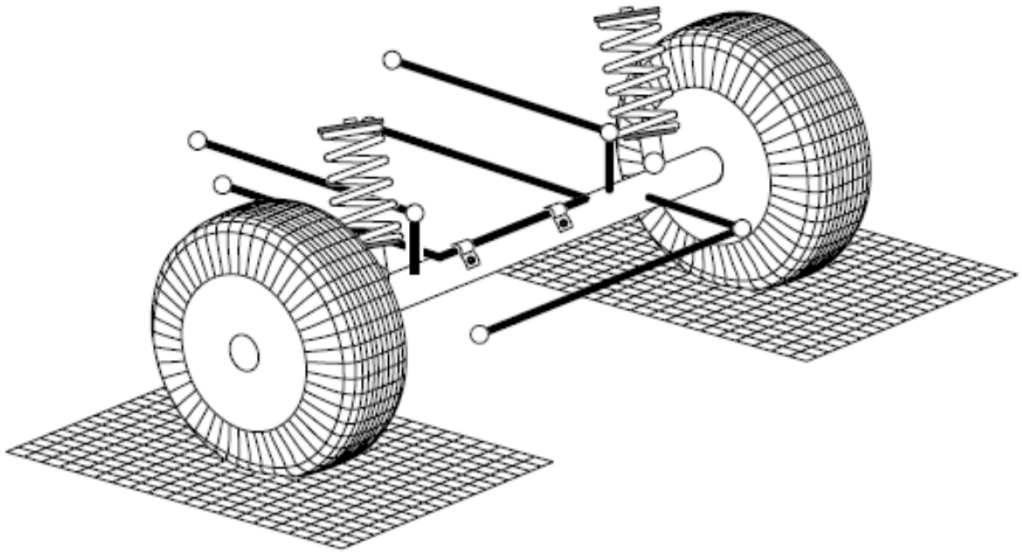


Semi-trailing arm suspension

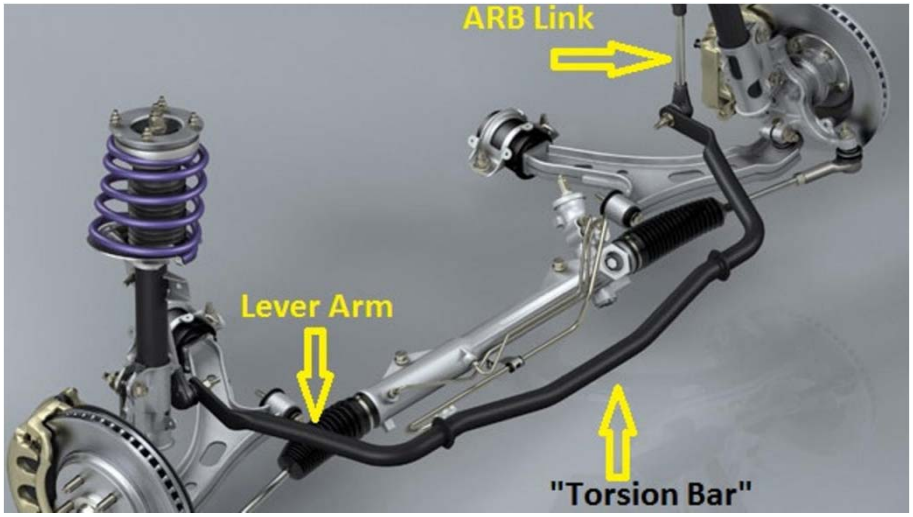
Semi-trailing arm suspension, is a compromise
between the swing arm and trailing arm suspensions. The joint axis
may have any angle, however an angle not too far from 45 deg is more
applied. Such suspensions have acceptable camber angle change, while they
can handle both, the lateral and longitudinal forces.

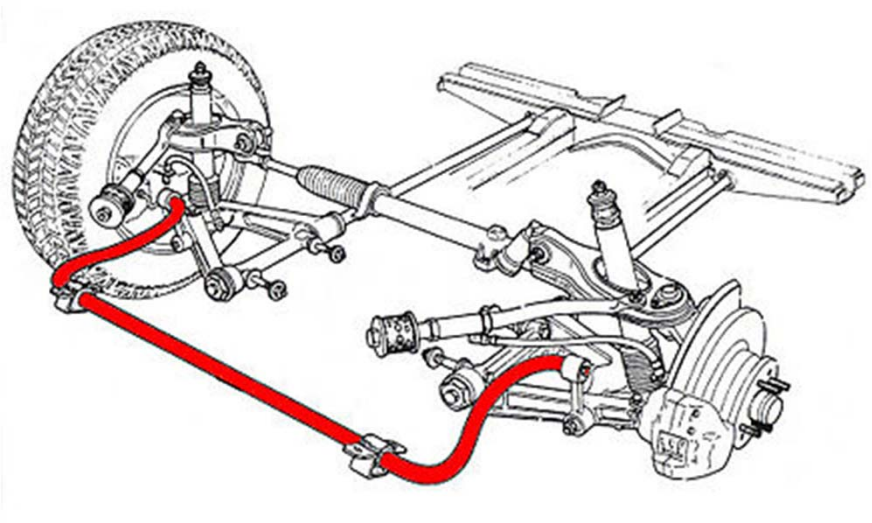


Anti-roll bar/Stabilizer

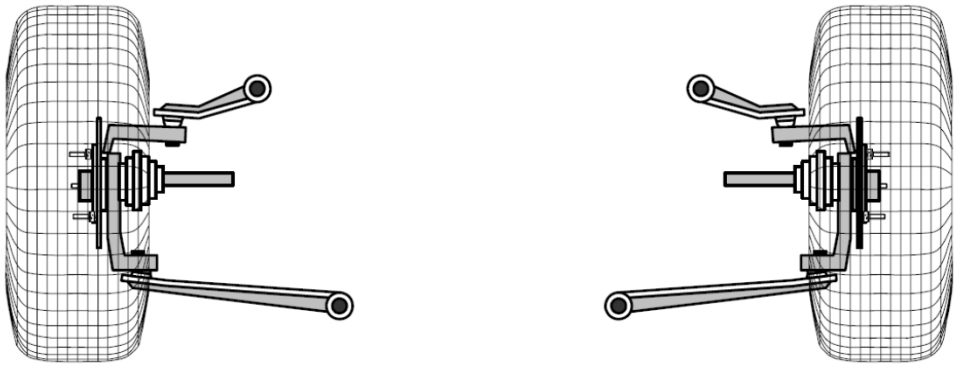


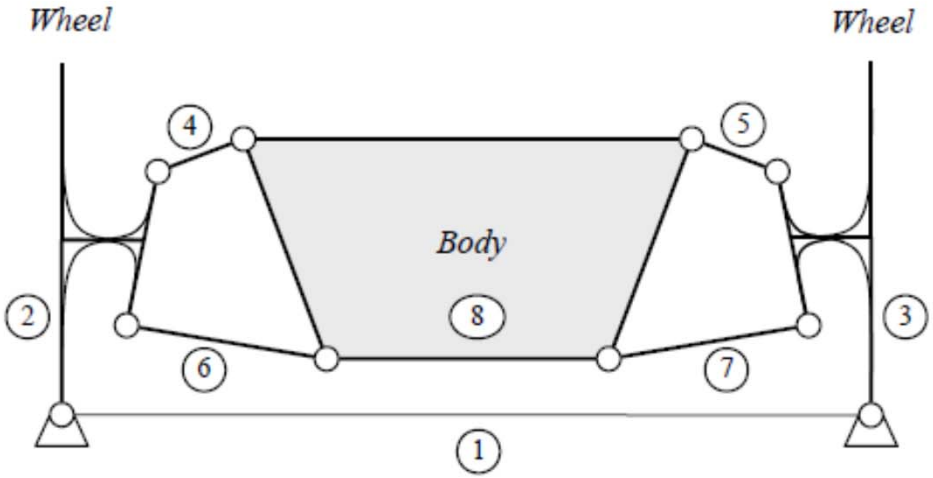
Coil springs are used in vehicles because they are less stiff with better ride comfort compared to leaf springs. herefore, the roll stiffness of the vehicle with coil springs is usually less than in vehicles with leaf springs. To increase the roll stiffness of such suspensions, an antiroll bar must be used. The antiroll bar is also called a stabilizer.


ARB Link
Lever Arm
"Torsion Bar"



Roll Center



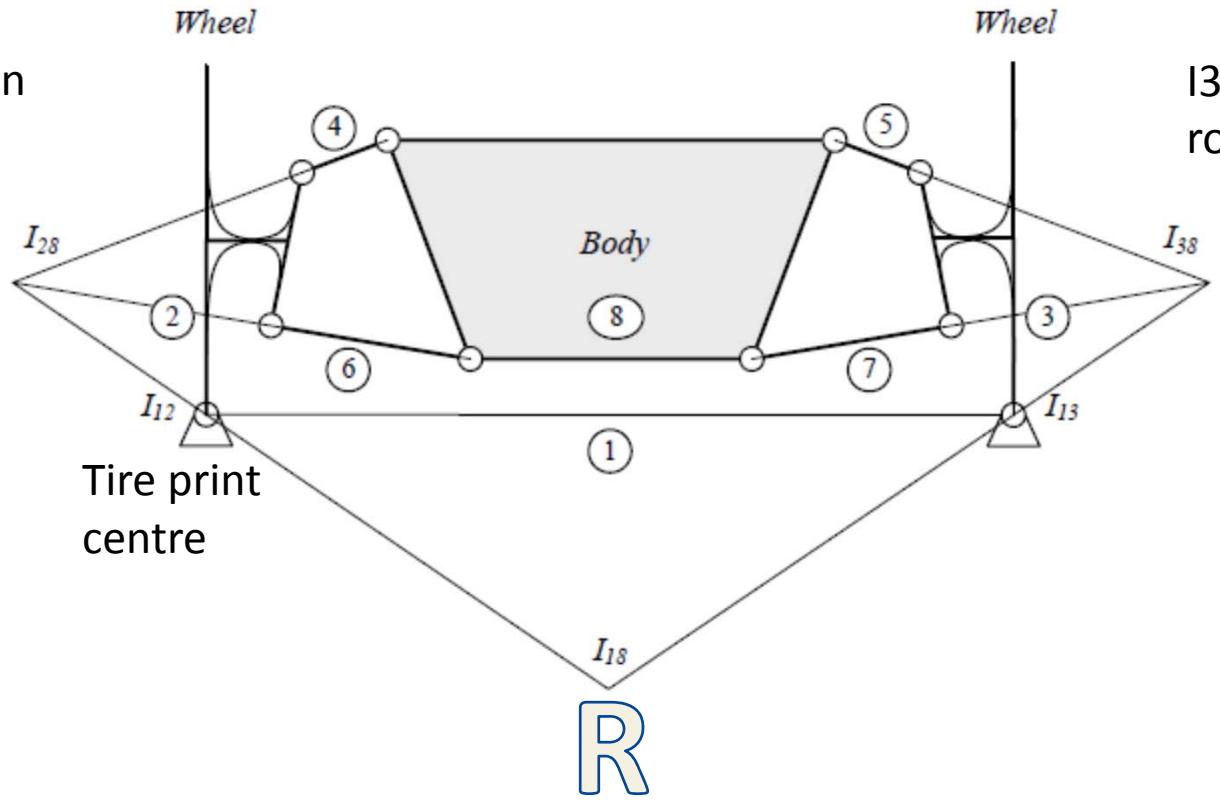


The roll axis is the instantaneous line about which the body of a vehicle rolls. Roll axis is found by connecting the roll center of the front and rear suspensions of the vehicle.

Roll center/Kennedy theorem Double-A arm

I28-Suspension roll centre

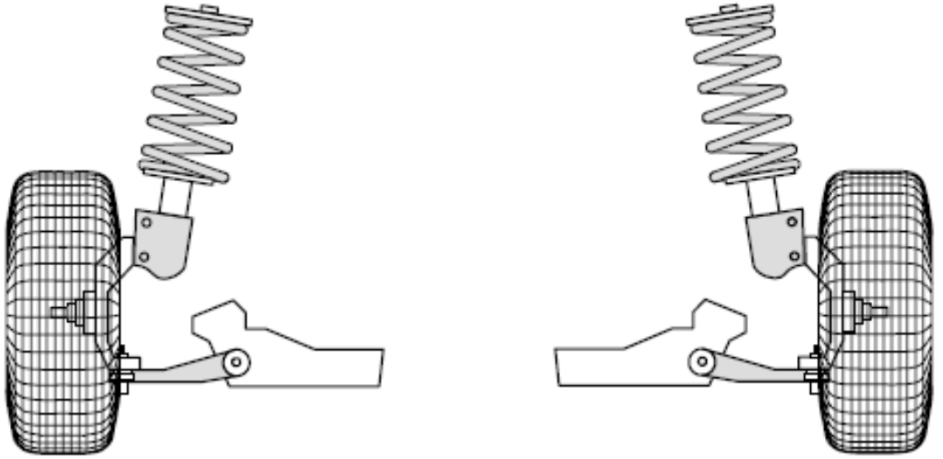
I38-Suspension roll centre

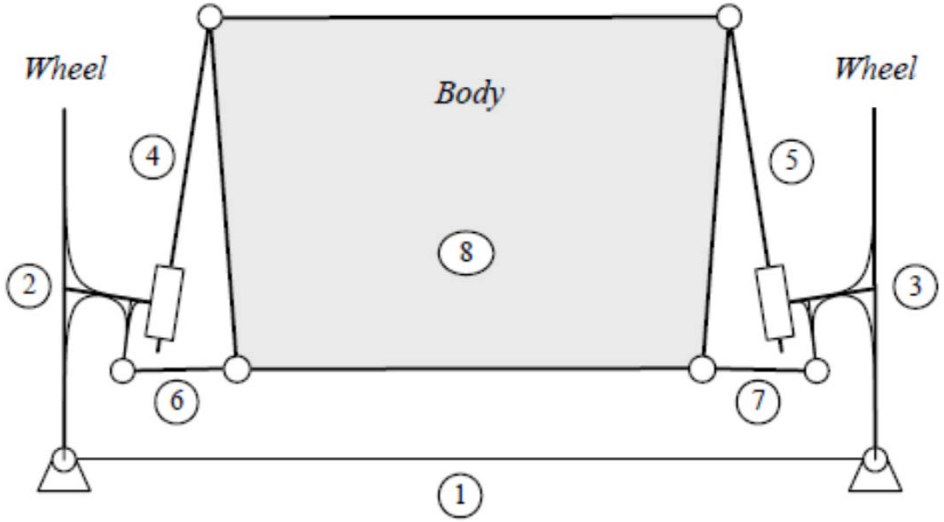


Tire print centre

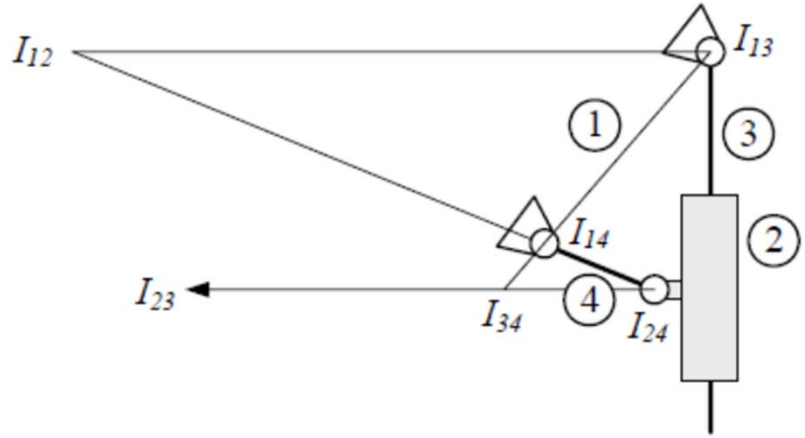
The instant center of rotation of a wheel with respect to the body is called suspension roll center.

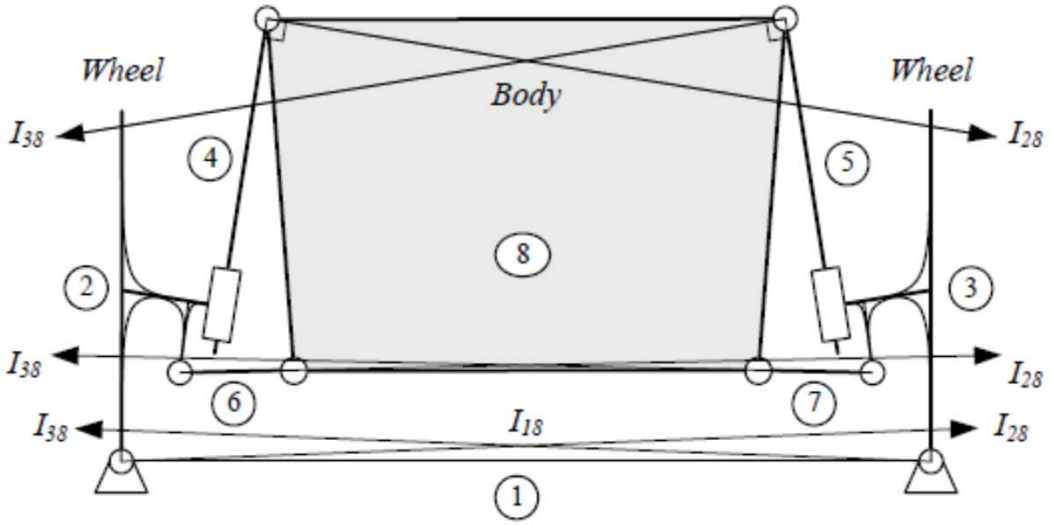
McPherson Roll centre



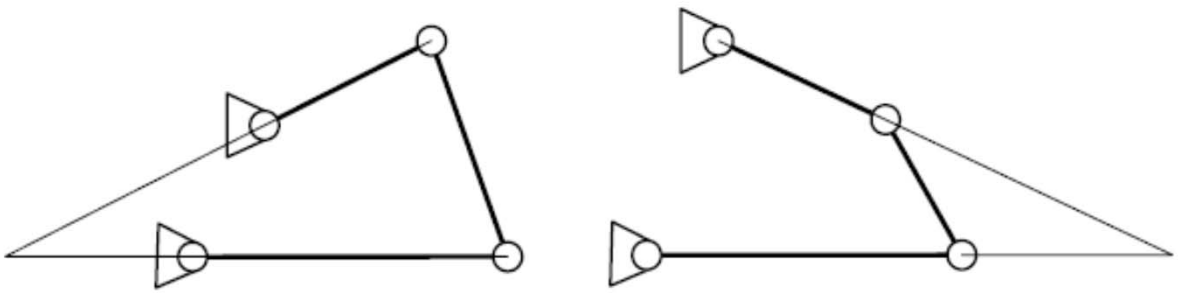


McPherson Roll centre

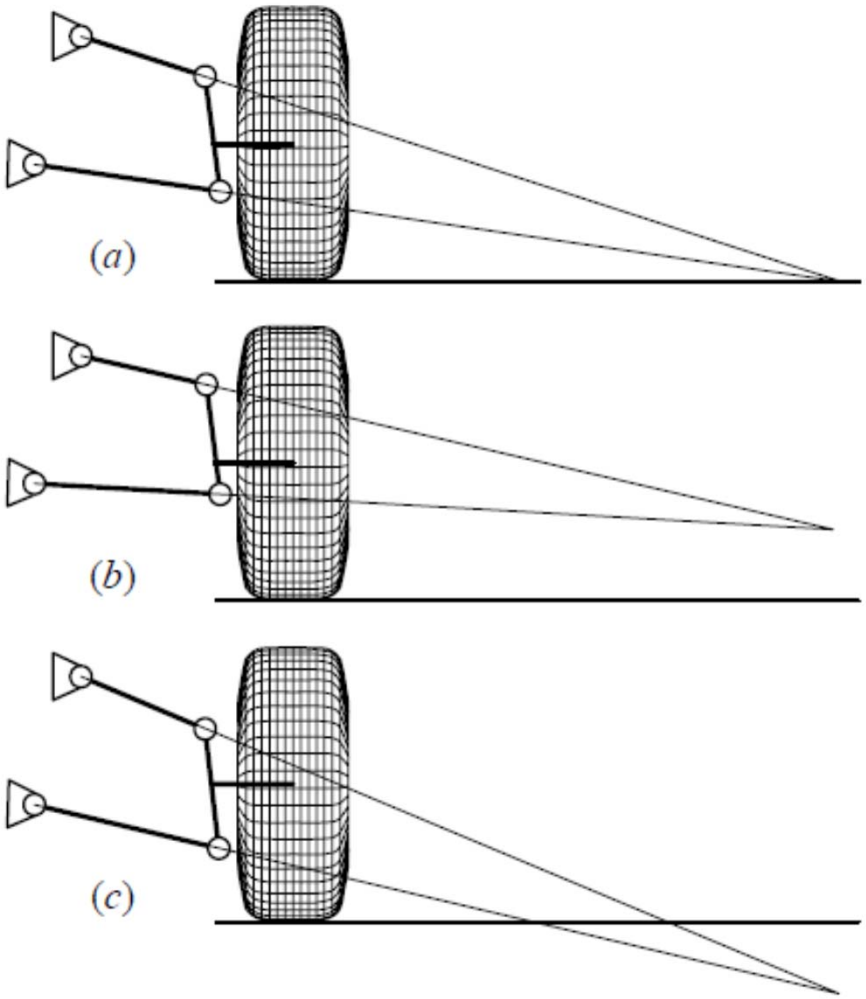




Internal/External suspension roll centre

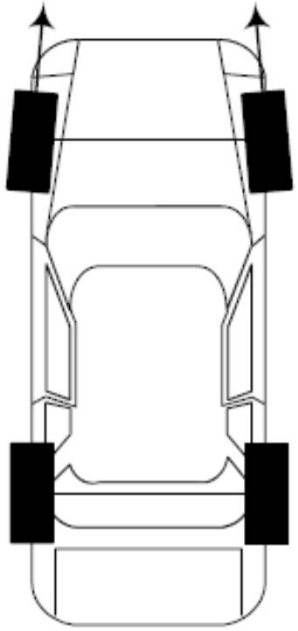


Suspension roll centre height

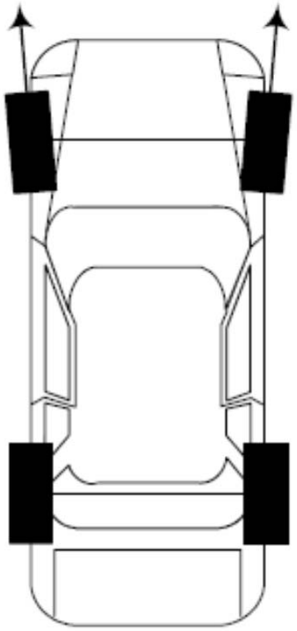


Car tire relative angles

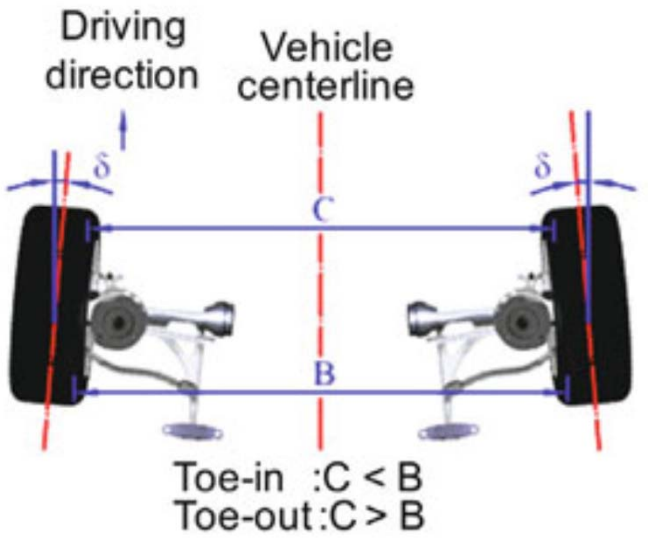
Toe-in and Toe-out



Toe-in



Toe-out



Toe settings affect three major performances: tire wear, straight-line stability, and corner entry handling.

Toe

- Excessive toe-in causes accelerated wear at the outboard edges of the tires,
- while too much toe-out causes wear at the inboard edges.
- Toe-in increases the directional stability of the vehicle, and toe-out increases
- the steering response. Hence, a toe-in setting makes the steering function lazy, while a toe-out makes the vehicle unstable.

Toe-in and directional stability

- Toe settings have an impact on directional stability. When the steering wheel is centered, toe-in causes the wheels to tent to move along paths that intersect each other in front of the vehicle. However, the wheels are in balance and no turn results. Toe-in setup can increase the directional stability caused by little steering fluctuations and keep the car moving straight.

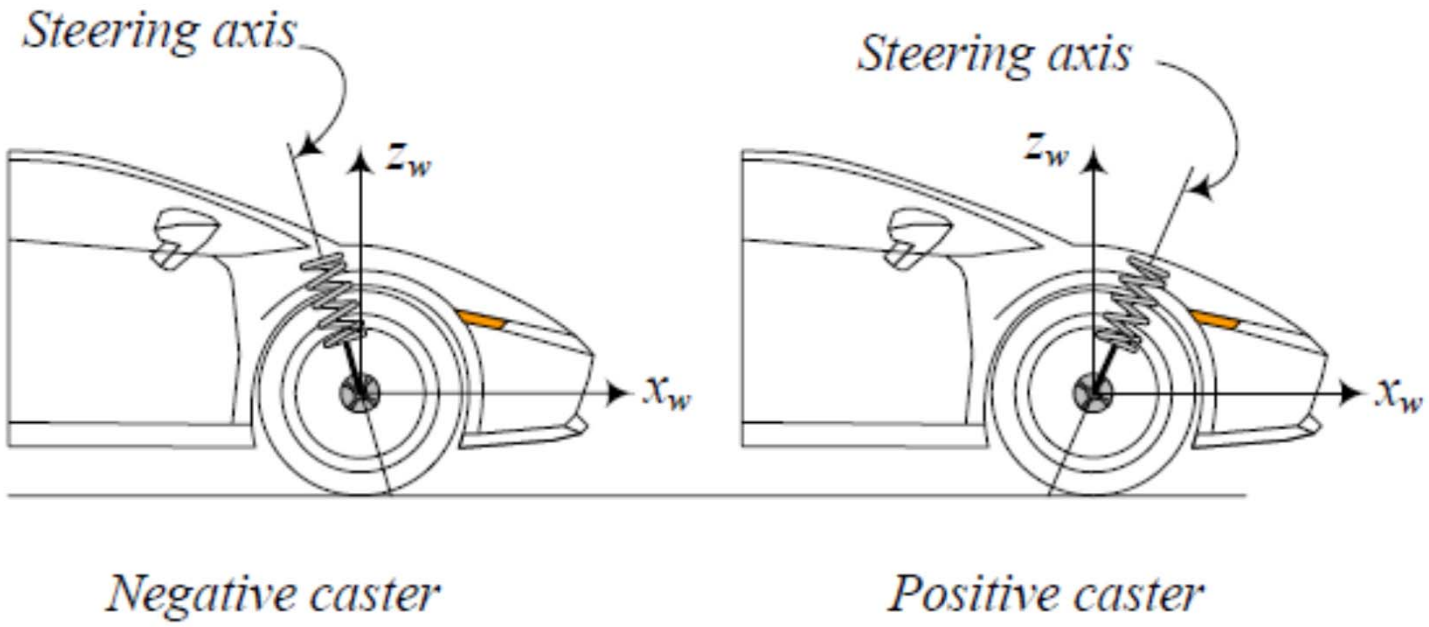
Toe-out sharper steering response

- If a car is set up with toe-out, the front wheels are aligned so that slight disturbances cause the wheel pair to assume rolling directions that approach a turn. Therefore, toe-out encourages the initiation of a turn, while toe-in discourages it. Toe-out makes the steering quicker. So, it may be used in vehicles for a faster response. The toe setting on a particular car becomes a trade-off between the straight-line stability afforded by toe-in and the quick steering response by toe-out. Toe-out is not desirable for street cars, however, race car drivers are willing to drive a car with a little directional instability, for sharper turn-in to the corners. So street cars are generally set up with toe-in, while race cars are often set up with toe-out.

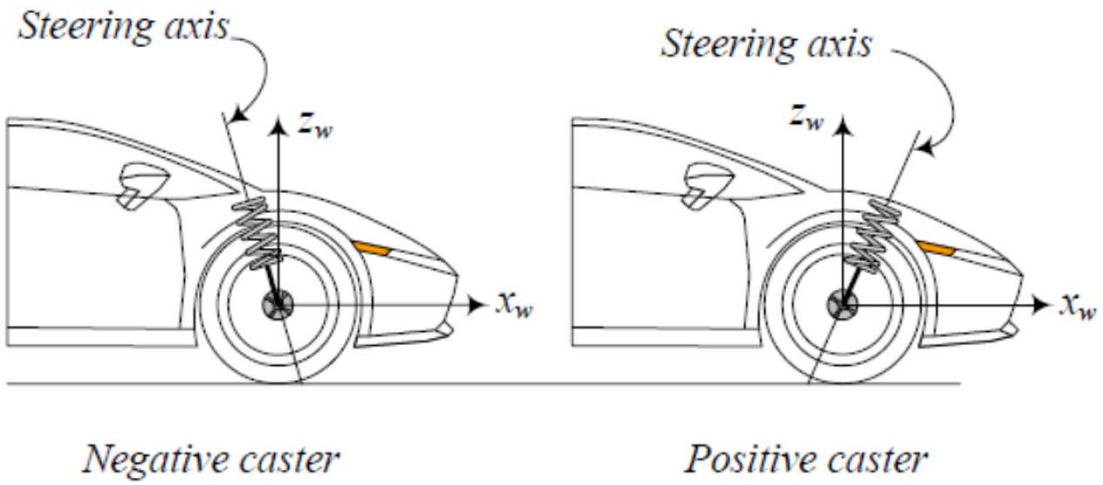
Toe effect

- Front toe-in: slower steering response, more straight-line stability, greater wear at the outboard edges of the tires.
- Front toe-in: slower steering response, more straight-line stability, greater wear at the outboard edges of the tires.
- Front toe-zero: medium steering response, minimum power loss, minimum tire wear.
- Front toe-out: quicker steering response, less straight-line stability, greater wear at the inboard edges of the tires.

Caster angle



Caster angle



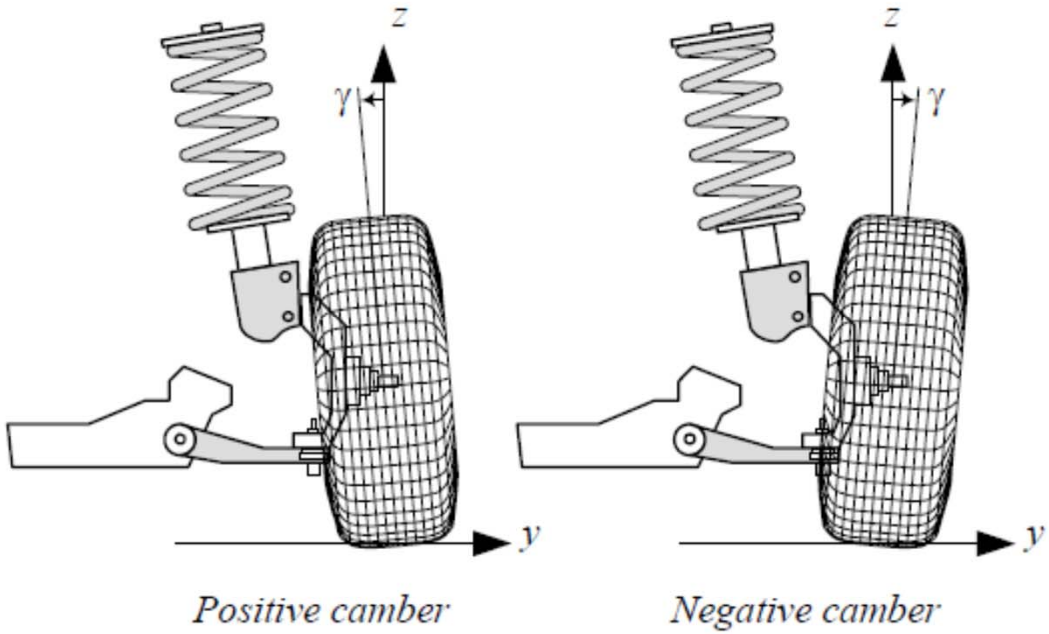
Caster is the angle to which the steering pivot axis is tilted forward or rearward from vertical, as viewed from the side. Negative caster aids in centering the steering wheel after a turn and
makes the front tires straighten quicker. Most street cars are made with 4−6deg negative caster. Negative caster tends to straighten the wheel when the vehicle is traveling forward, and thus is used to enhance straight-line stability. While greater caster angles improves straight-line stability, they also cause an increase in steering effort.

Characteristics of caster in front axle

- Zero castor provides: easy steering into the corner, low steering out of the corner, low straight-line stability.
- Negative caster provides: low steering into the corner, easy steering out of the corner, more straight-line stability, high tireprint area during turn, good turn-in response, good directional stability, good steering feel.

Camber

Camber is the angle of the wheel relative to vertical line to the road, as viewed from the front or the rear of the car.



Positive camber *Negative camber*

–2° to +2° @ Neutral posisiton

Trust