

School of Engineering

Introduction to vehicle suspension Suspension Layouts

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Last Week

Suspension What does it do?

- ☐ Supports the weight of the vehicle
 - ☐ Isolates the vehicle body, passengers and contents from road surface irregularities
 - ☐ Maintains the wheel and tyre in contact with the road surface
 - ☐ Maintains (nearly) orientation of tyre to road
 - ☐ Transmits forces from the tyre contact patch into the vehicle structure
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- ☐ Comfort
 - ☐ Handling and traction
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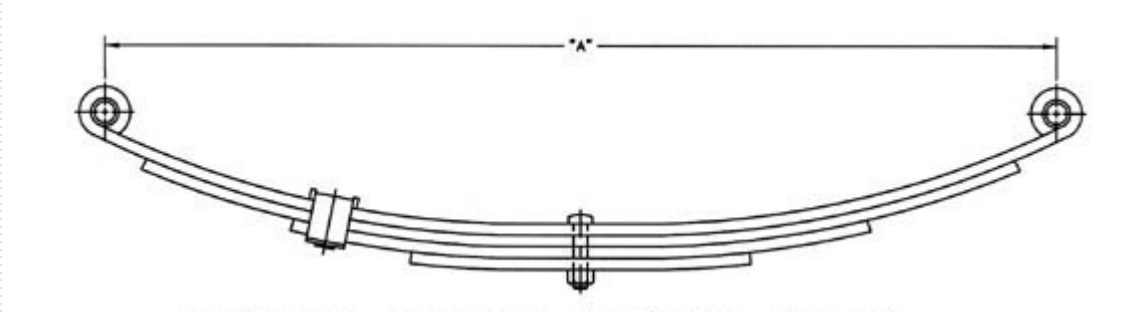
Suspension

- The complexity of this problem has lead to many different designs of suspension in an attempt to produce the best compromise between maintaining contact with the ground and giving a comfortable ride to the passengers. We will look at:
 - Swing axle
 - MacPherson strut
 - double wishbone
 - multi-link suspension
 - semi-trailing and trailing arm suspension
 - leaf springs
 - Panhard rod
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Suspension

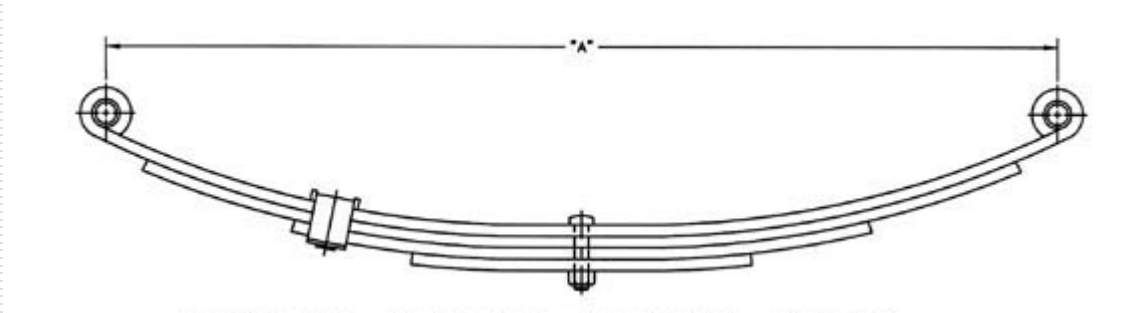
- Suspension systems can be broadly classified into two subgroups - dependent and independent. These terms refer to the ability of opposite wheels to move independently of each other.
 - A *dependent suspension* normally has a live axle (a simple beam or 'cart' axle) that holds wheels parallel to each other and perpendicular to the axle. When the camber of one wheel changes, the camber of the opposite wheel changes in the same way.
 - An *independent suspension* allows wheels to rise and fall on their own without affecting the opposite wheel. Suspensions with other devices, such as anti-roll bars that link the wheels in some way are still classed as independent.
 - A third type is a *semi-dependent* suspension. In this case, jointed axles are used, on drive wheels, but the wheels are connected with a solid member, most often a deDion axle. This differs from "dependent" mainly in unsprung weight.
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Leaf Springs



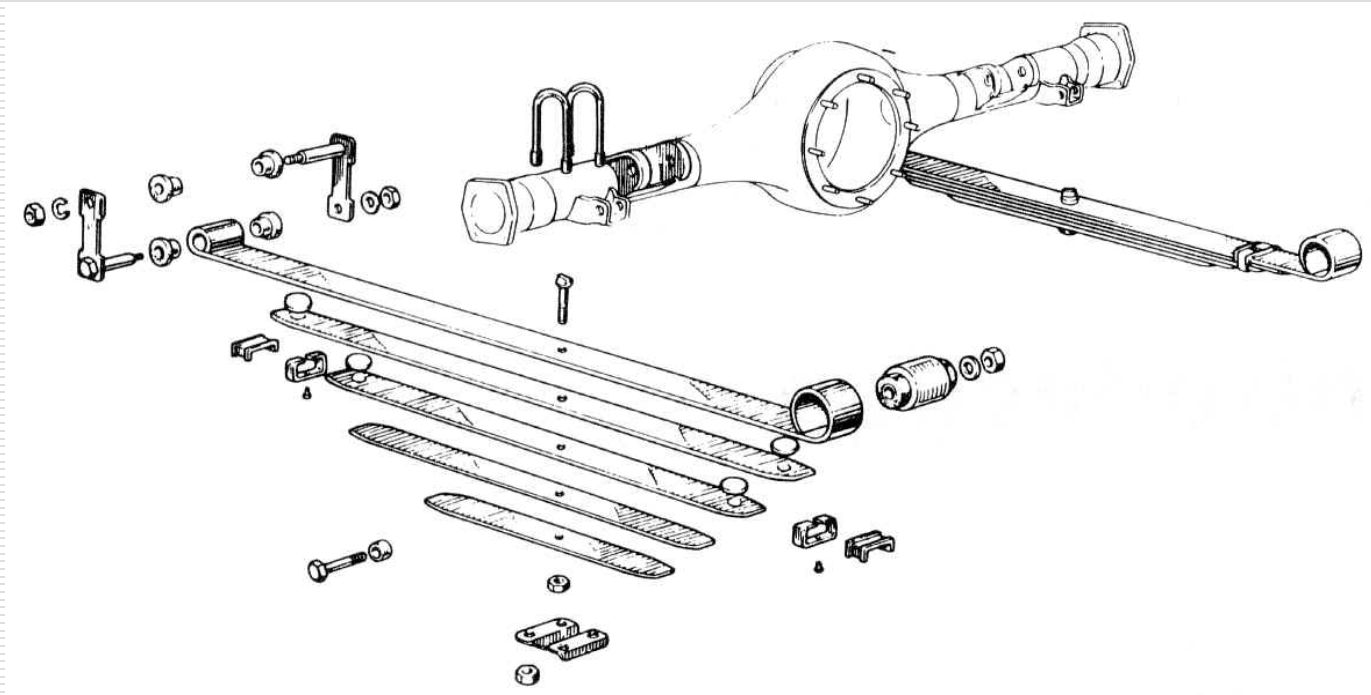
- Sometimes referred to as a **semi-elliptical spring** or **cart spring**, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body.
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Leaf Springs



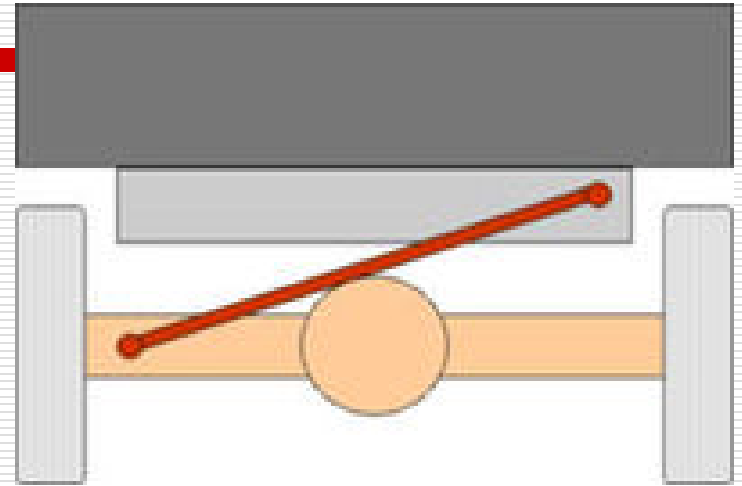
- ❑ For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with systematically shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions.
 - ❑ Leaf springs are still used on some vehicles as they can provide a less progressive rate of deflection to increased loading. This is useful in a commercial vehicle that can go from empty to heavily loaded without having the whole rear squat down.
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Leaf Springs



Panhard Rods

- A **Panhard rod** or **track bar** provides lateral location of the axle. Originally invented by the Panhard automobile company of France in the early twentieth century, this device has been widely used ever since.



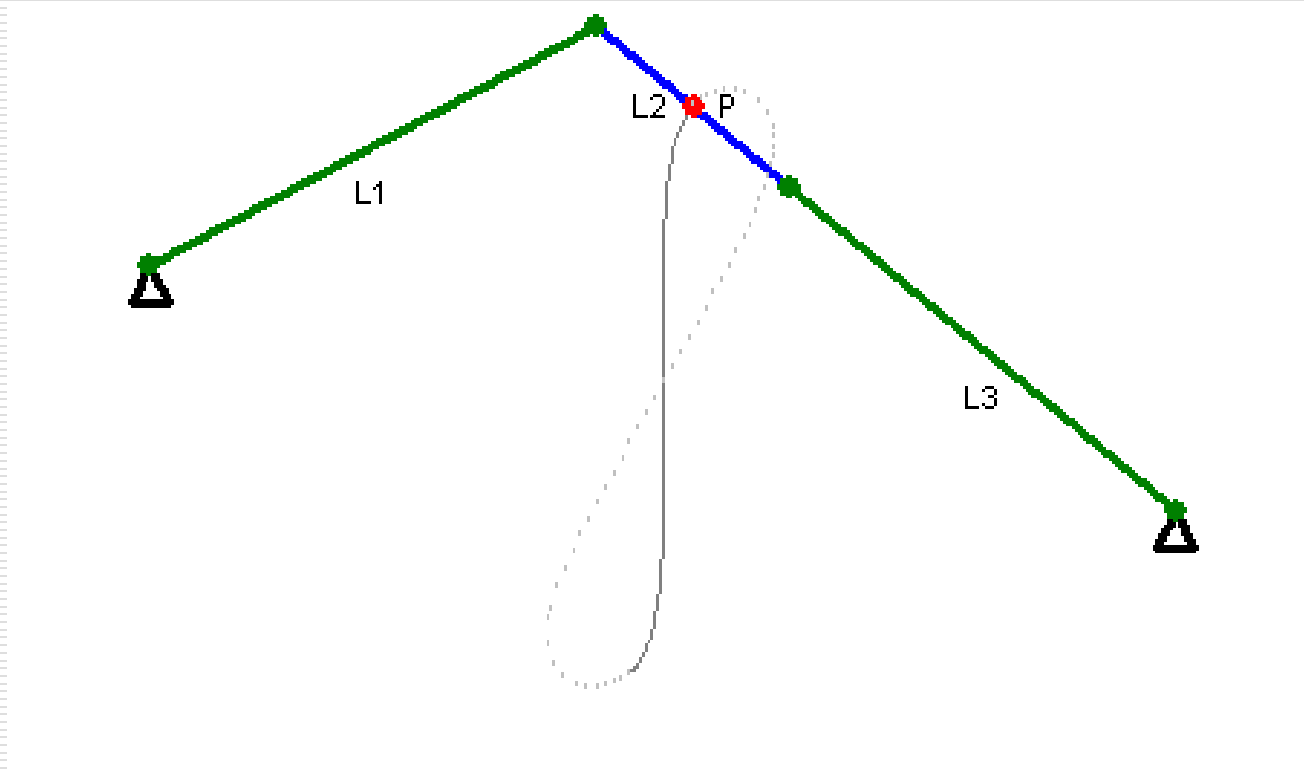
Panhard Rods

- While the purpose of the rear suspension of an automobile is to allow the wheels to move vertically with respect to the body, it is undesirable to allow them to move forward and backwards, or from side to side. It is this latter movement that the Panhard rod is designed to prevent. It is a simple device, consisting of a rigid bar running sideways parallel to the rear axle, connecting one end of the axle to the car body or chassis on the opposite side of the vehicle. The bar is attached on either end with pivots that permit it to swivel upwards and downwards only, so that the axle is in turn allowed to move in the vertical plane only.
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Panhard Rods

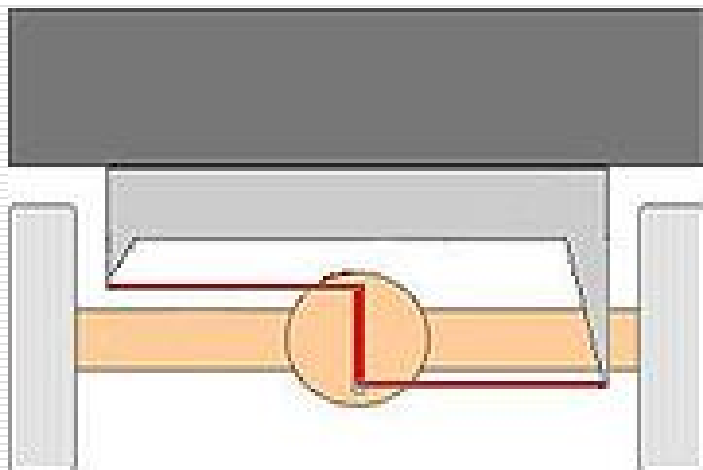
- The advantage of the Panhard rod is its simplicity. Its major disadvantage is that the axle must necessarily move in an arc, relative to the body, with the radius equal to the length of the Panhard rod. If the rod is too short, there will be excessive sideways movement between the axle and the body at the ends of the spring travel; therefore the Panhard rod is less desirable on smaller cars than larger.
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Watts Linkage

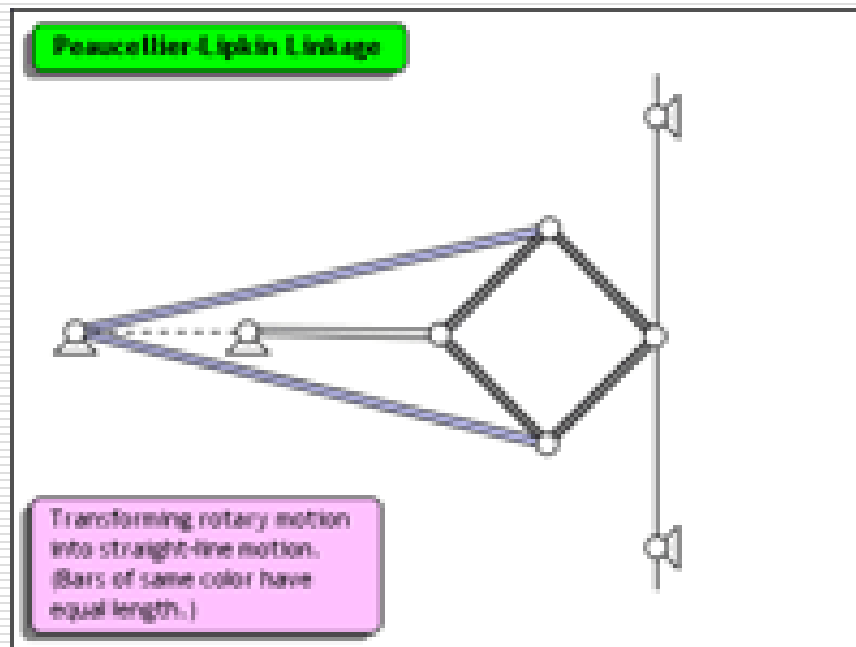




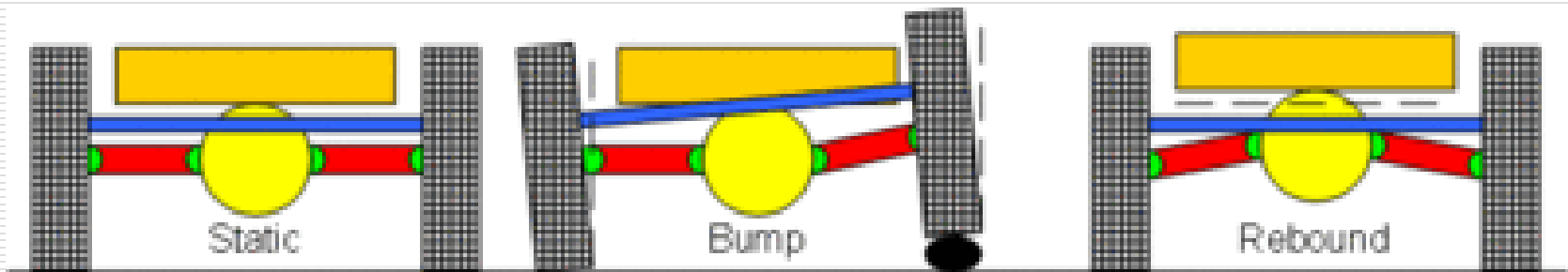
Watts Linkage



The peaucellier-lipkin linkage

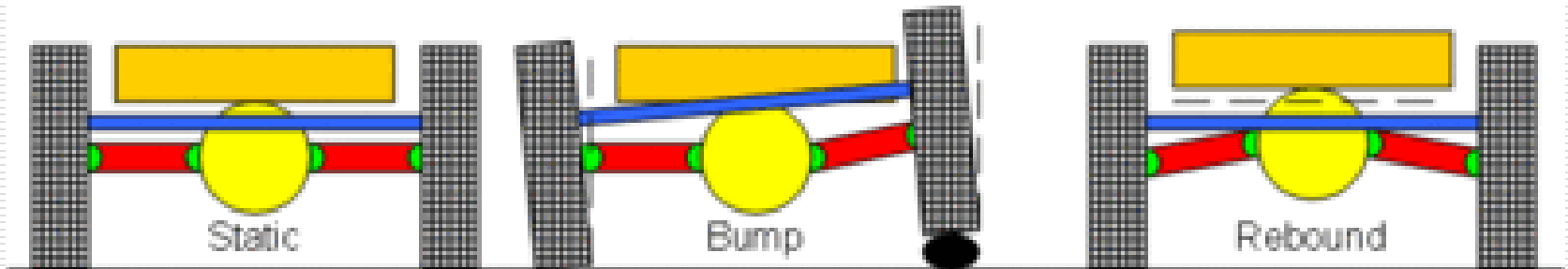


De Dion Suspension



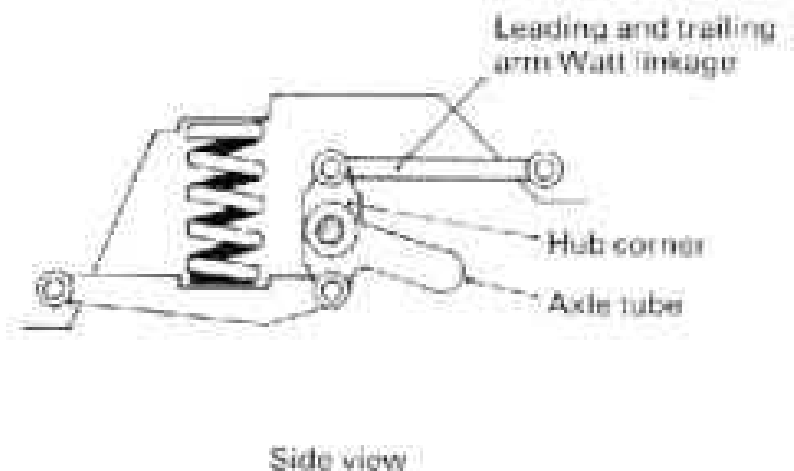
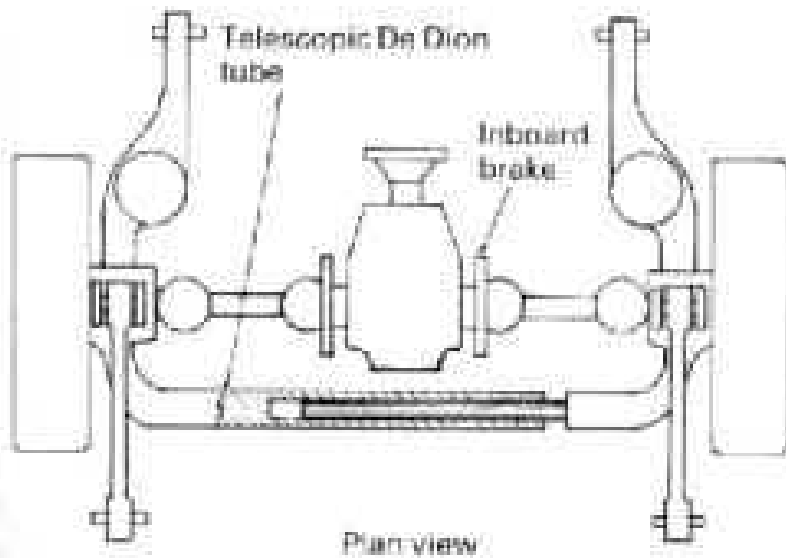
- A de Dion suspension is a semi-dependent suspension that uses universal joints at both the wheel hubs and differential, and uses a solid tubular beam to hold the opposite wheels in parallel.
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De Dion Suspension



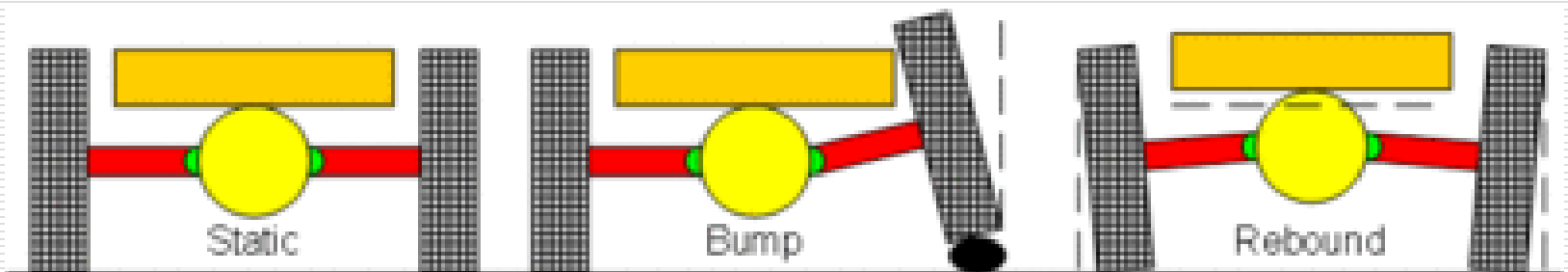
- Unlike an anti-roll bar, a de Dion tube is not directly connected to the chassis nor is it intended to flex. In suspension geometry it is close to the trailing beam suspension
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De Dion

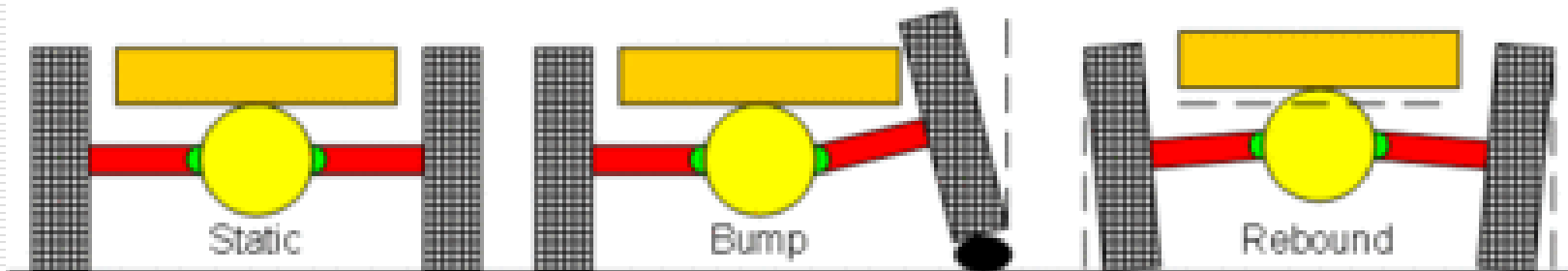


Swing Axles

- A **swing axle** suspension is a simple type of independent suspension used in automobiles. Swing axles have universal joints connecting the driveshafts to the differential, which is attached to the chassis. They do not have universal joints at the wheels - the wheels are always perpendicular to the driveshafts. Swing axle suspensions traditionally used leaf springs and shock absorbers.



Swing Axles

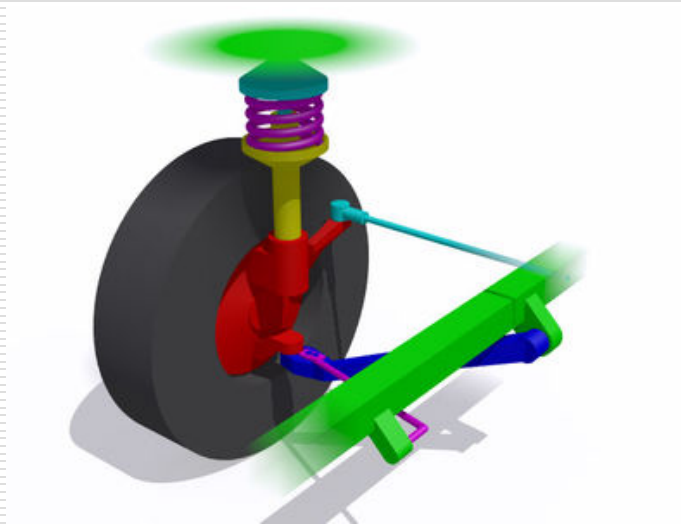


- This type of suspension was considered better than the more typical solid axle for two reasons:
 - It reduced unsprung weight since the differential is mounted to the chassis
 - It eliminates sympathetic camber changes on opposite wheels

Swing Axles

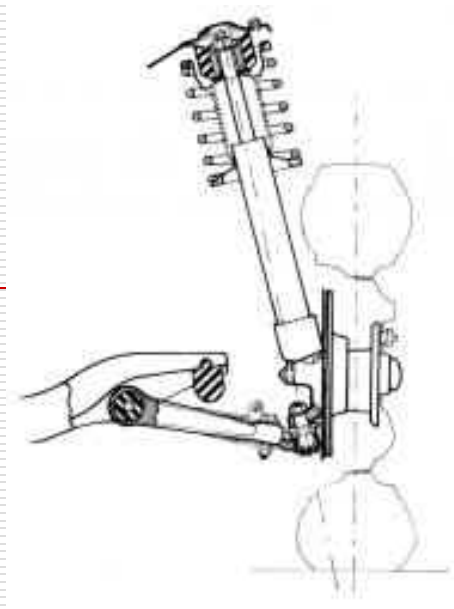
- However, there are a number of shortcomings to this arrangement:
 - A great amount of single-wheel camber change is experienced since the wheel is always perpendicular to the driveshaft
 - "Jacking" on suspension unloading (or rebound) causes negative camber changes on both sides
 - Reduction in cornering forces due to change in camber can lead to oversteer instability.
 - Swing Axles have been replaced by De Dion suspension systems and more independent designs and generally died out in the late 1960's.
 - Triumph Herald/Vitesse and Spitfire/GT6
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MacPherson Strut



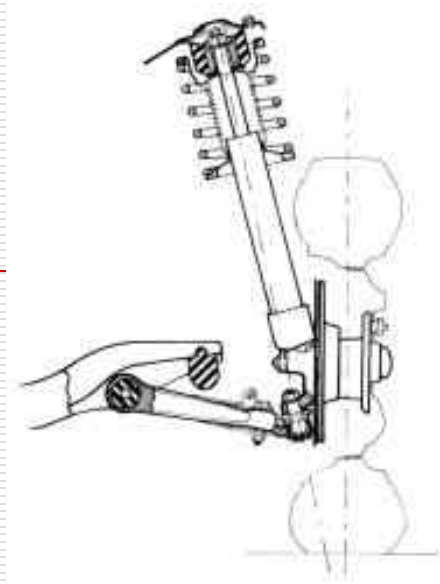
- It can be used for both front and rear suspensions, but is usually found at the front, where it provides a steering pivot (kingpin) as well as a suspension mounting for the wheel. Rear struts of a similar design are properly called Chapman struts.
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MacPherson Strut



- ❑ It consists of a small wishbone that provides a bottom mounting point for the wheel hub. This subframe provides both lateral and longitudinal location of the wheel.
 - ❑ The upper part of the hub is rigidly fixed to the inner part of the strut proper, the outer part of which extends upwards directly to a mounting in the body shell of the vehicle.
 - ❑ The strut will usually carry both the coil spring on which the body is suspended and the shock absorber, which is usually in the form of a coil-over damper, mounted within the strut.
 - ❑ The strut also usually has a steering arm built into the lower inner portion.
 - ❑
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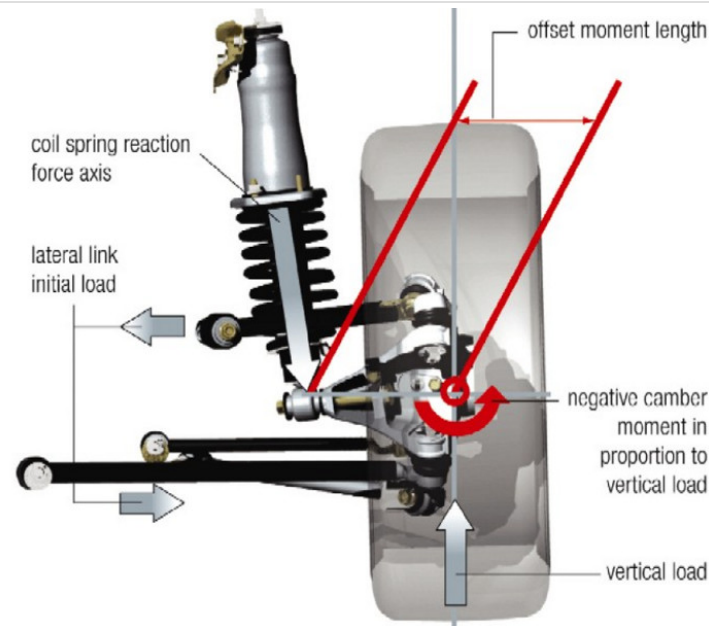
MacPherson Strut



- ❑ However this system cannot allow vertical movement of the wheel without some camber angle change, sideways movement, or both. It is not generally considered to give as good handling as wishbones, and allows less freedom to choose camber change and roll centre.
 - ❑ The wheel tends to lean with the body, leading to understeer.
 - ❑ Another drawback is that it tends to transmit noise and vibration from the road directly into the body shell, giving higher noise levels and a "harsh" feeling to the ride compared with systems such as double wishbones, requiring extra noise reduction or cancellation and isolation mechanisms.
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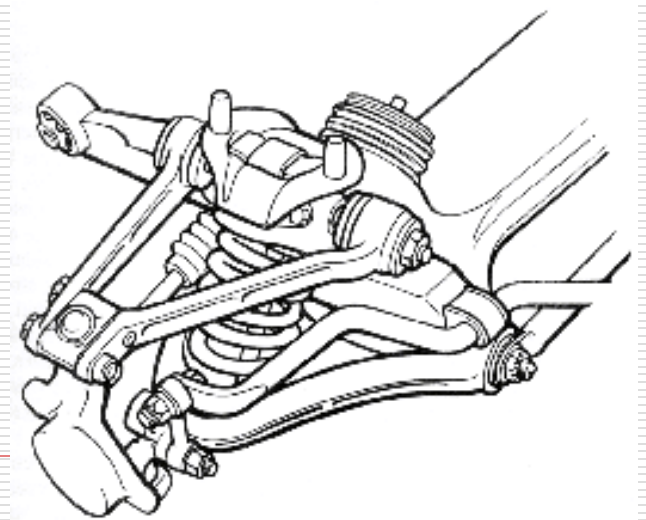
Double Wishbones

- ❑ Double-wishbones are usually considered to have superior dynamic characteristics, load handling capability and are still found on higher performance vehicles



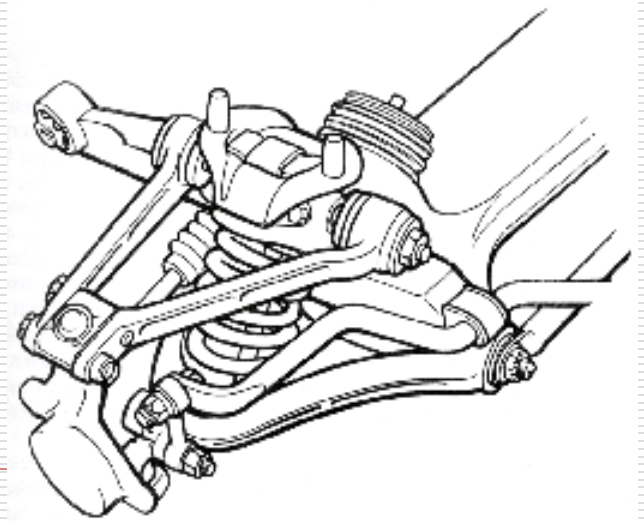
Double Wishbones

- ❑ **A double wishbone suspension** is an independent suspension design using two parallel wishbone-shaped arms to locate the wheel.
- ❑ Each wishbone (or arm) has two mounting positions to the chassis and one joint at the knuckle.

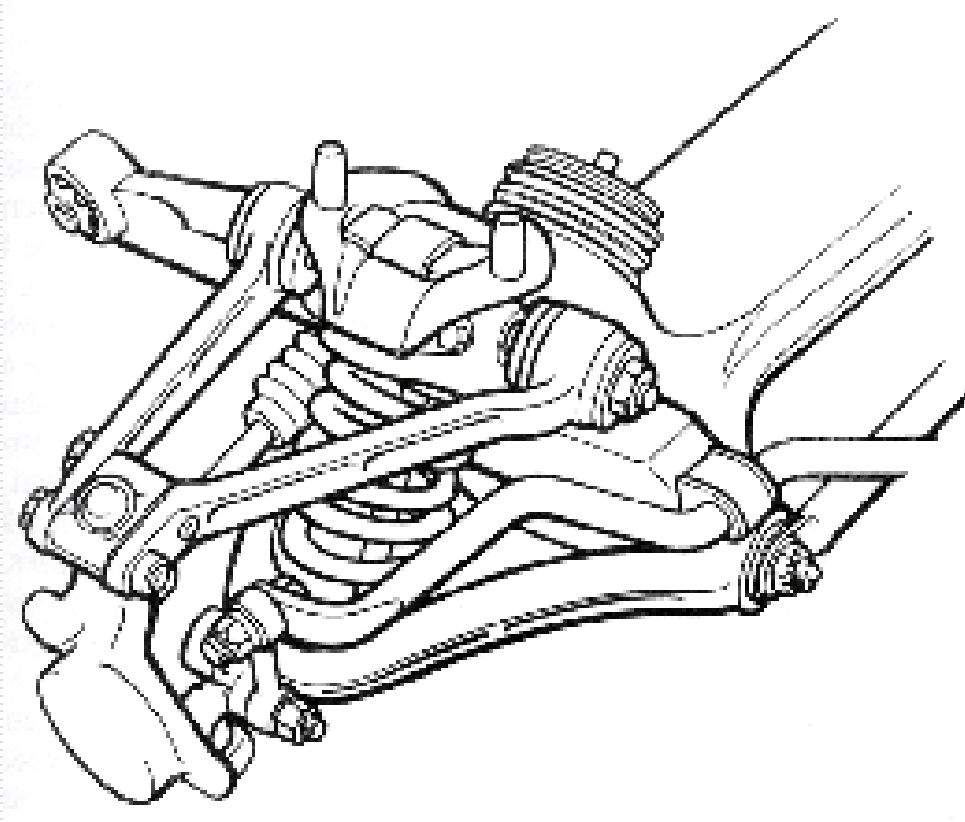


Double Wishbones

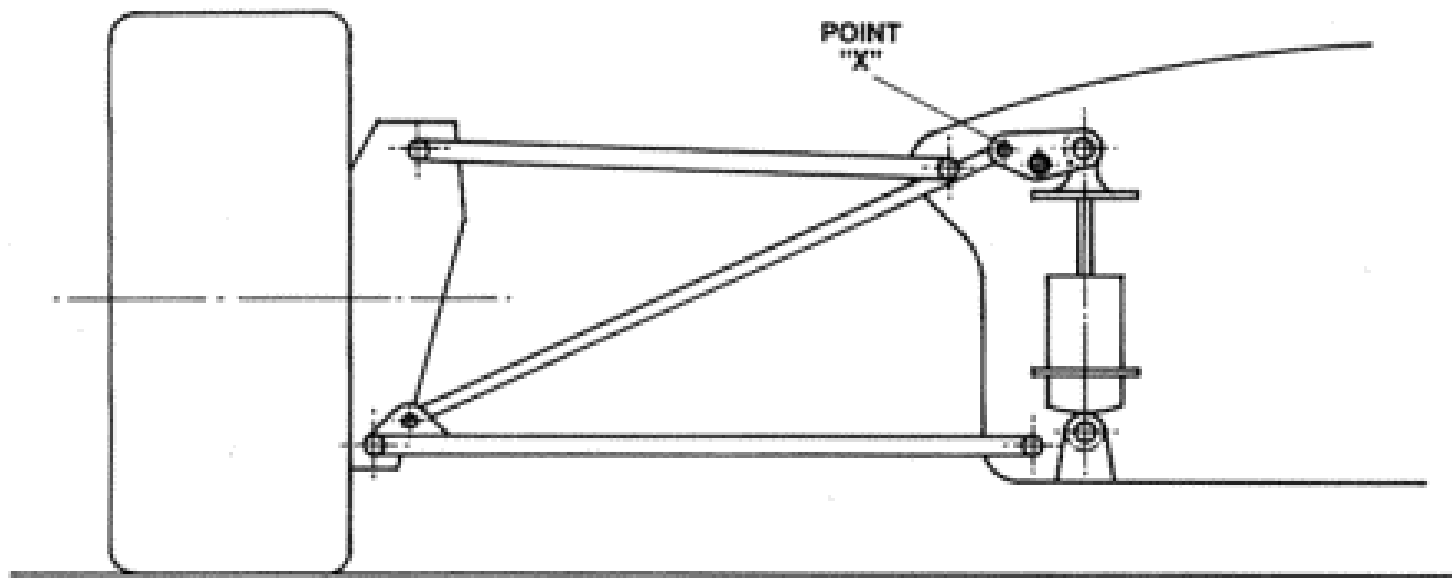
- ❑ The shock absorber and coil spring mount to the wishbones to control vertical movement.
- ❑ Double-wishbone designs allows control of the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle, toe, roll centre height, etc. etc.



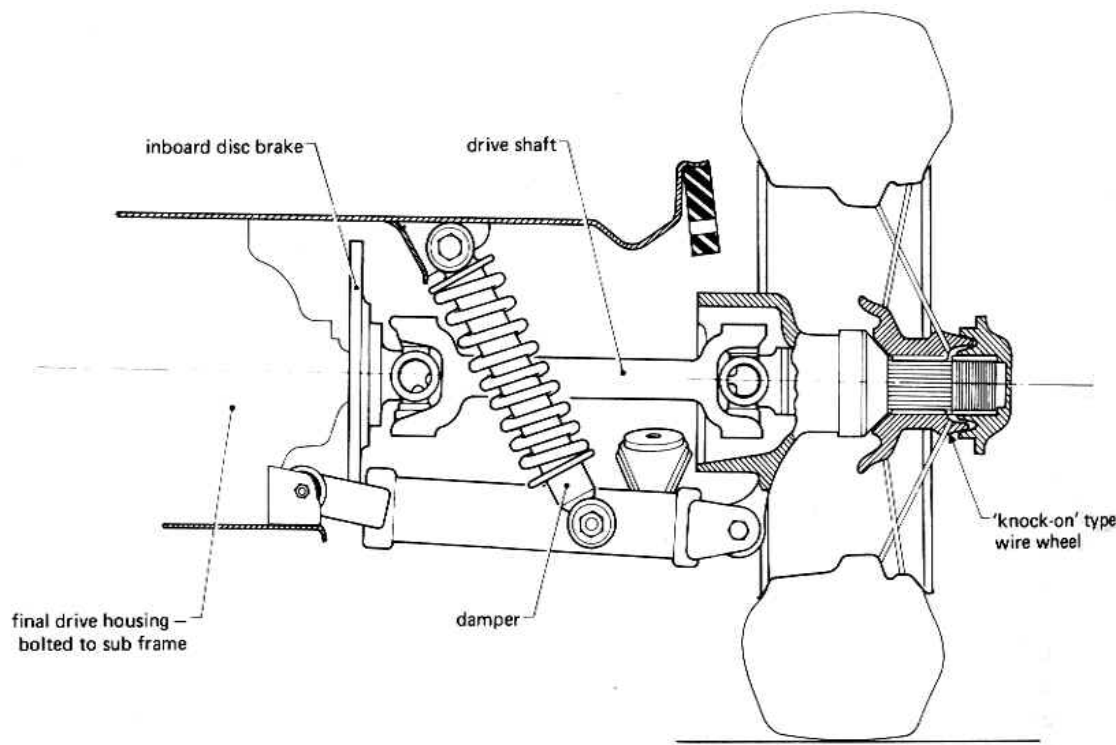
Double wishbones



Double wishbone with Push – pull spring/damper

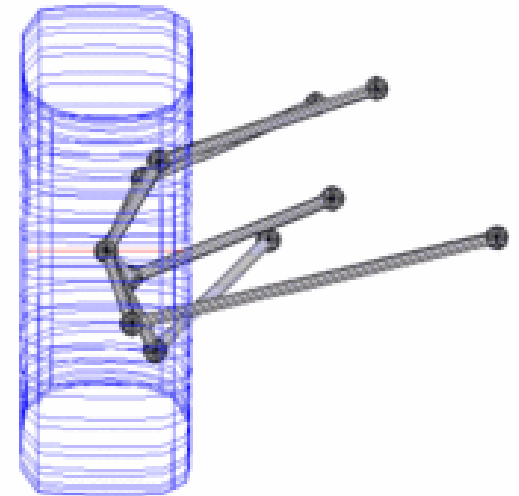


Transverse Link - Jaguar



Multi-Link Suspension

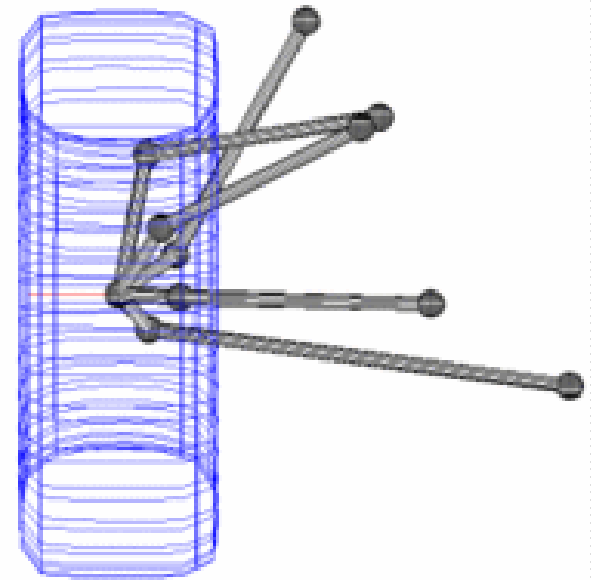
- Side view
 - The arms have to control camber, particularly the way that the camber changes as the wheel moves up (into jounce, or bump) and down into rebound or droop.



Multi-Link Suspension

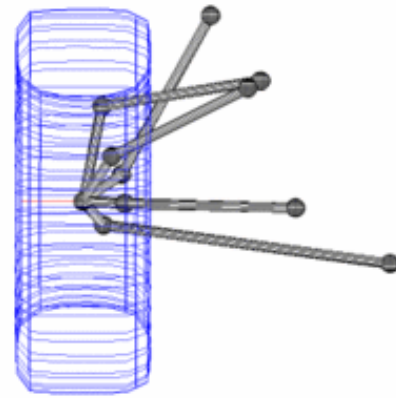
□ Top view

- The arms have to control toe/steer and lateral compliance. This needs a pair of arms longitudinally separated.



Multi-link Suspension

- A **multi-link suspension** is a type of vehicle suspension design typically used in independent suspensions, using three or more lateral arms, and one or more longitudinal arms. These arms do not have to be of equal length, and may be angled away from their 'obvious' direction.



Multi-link Suspension

- Typically each arm has a spherical joint (ball joint) or rubber bushing at each end. Consequently they react loads along their own length, in tension and compression, but not in bending. Some multi-links do use a trailing arm or wishbone, which has two bushings at one end.
 - On a front suspension one of the lateral arms is replaced by the tie-rod, which connects the rack or steering box to the wheel hub.
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Multi-Link Suspension

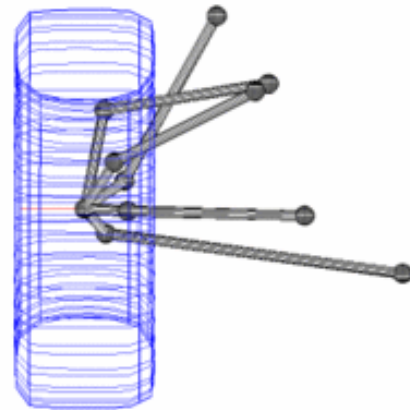
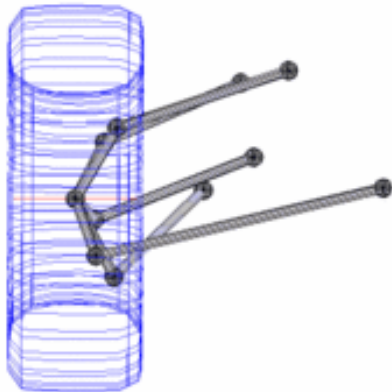
□ Advantages

- Multi-link suspension allows the auto designer the ability to incorporate both good ride quality and good car handling in the same vehicle.
 - In its simplest form the multi-link suspension is orthogonal - that is, it is possible to alter one parameter in the suspension at a time, without affecting anything else.
 - This is in direct contrast to say a double wishbone suspension where moving a hardpoint or changing a bushing compliance will affect two or more parameters.
 - Advantages also extend to off road driving. A multi-link suspension will allow the vehicle to flex more, this means simply that the suspension will be able to move more easily to conform to the varying angles of off roading. This being said, multi-link equipped vehicles are ideally suited for sports such as rock crawling, and desert racing.
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Multi-Link Suspension

❑ Disadvantages

- Multilink suspension is costly and complex. It is also difficult to tune the geometry without a full 3D computer aided design analysis. Compliance under load can have an important effect and must be checked using a multibody simulation software.



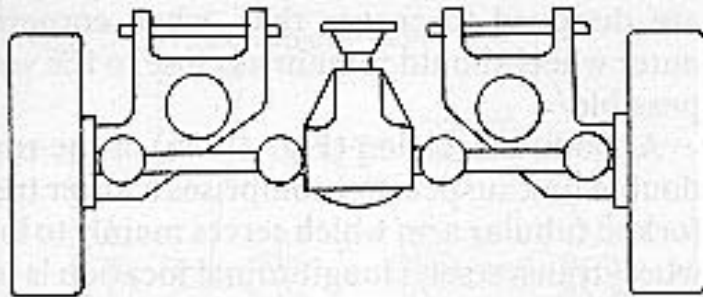
(Semi-)Trailing Arm Suspension

- A **semi-trailing arm suspension** is an independent rear suspension system in which each wheel hub is located only by a large, roughly triangular arm that pivots at two points. Viewed from the top, the line formed by the two pivots is somewhere between parallel and perpendicular to the car's longitudinal axis; it is generally parallel to the ground.
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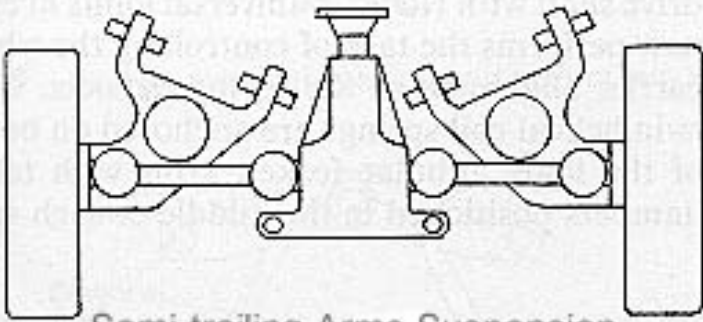
(Semi-)Trailing Arm Suspension

- ❑ Trailing-arm and multilink suspension designs are much more commonly used for the rear wheels of a vehicle where they can allow for a flatter floor and more cargo room.
 - ❑ Many small vehicles feature a MacPherson strut front suspension and trailing-arm rear axle.
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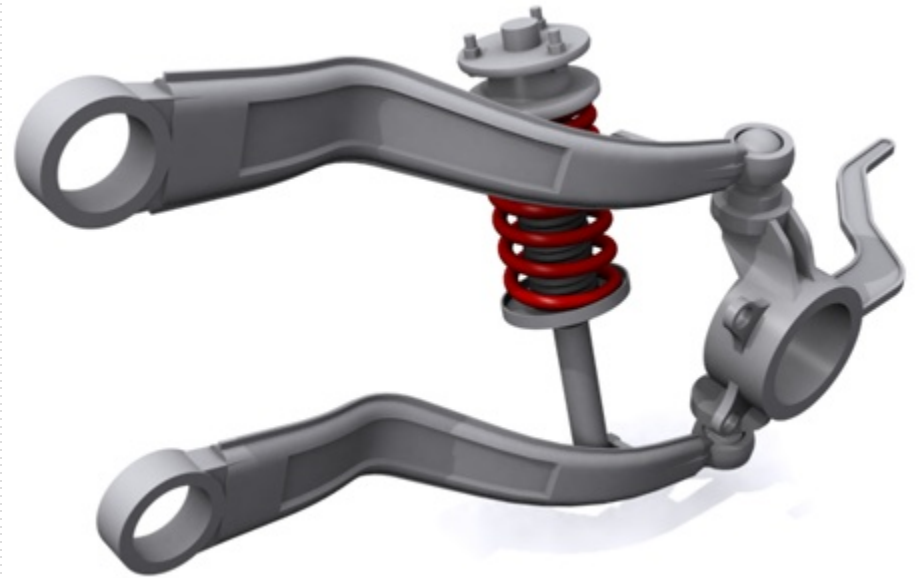
(Semi-)Trailing Arm Suspension



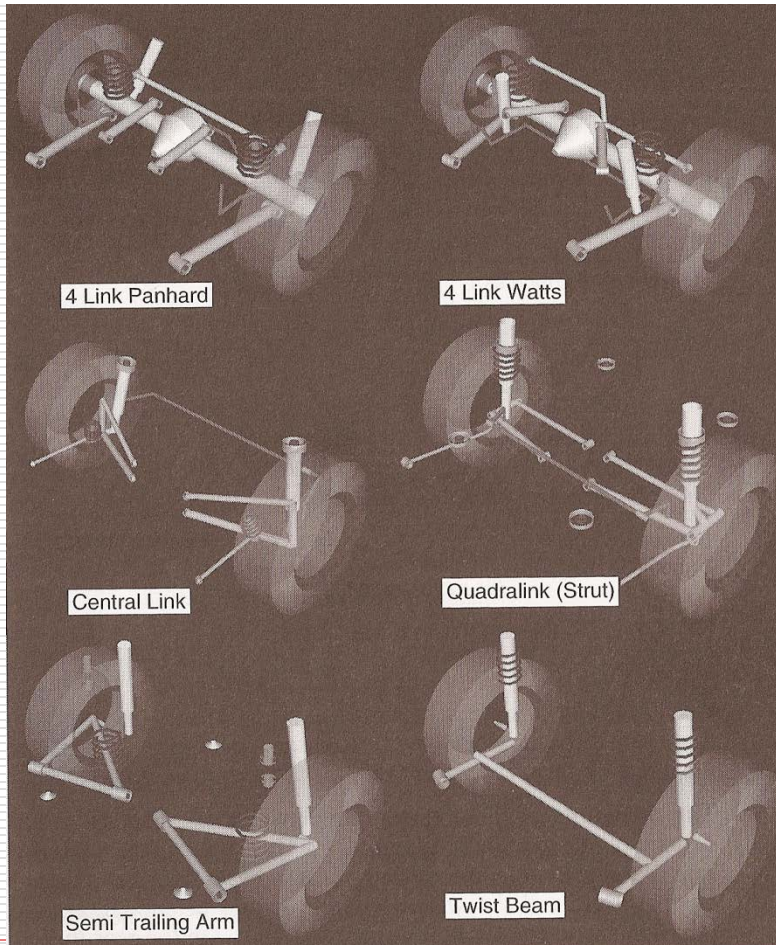
Trailing Arms Suspension



Semi-trailing Arms Suspension



Suspension Layouts



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