Suspension systems

Non-independent suspension system
It has both left and right wheels attached to the same solid axle. When one wheel hits a bump in the road, its upward movement causes a slight tilt of the other wheel.

Independent suspension system
Both wheels move up and down independently.

Types of Suspensions:

Multi-link Suspension:

1. Multiple links are attached to the car frame and the wheel assembly.
2. Used in off-road vehicles as it can handle any force.
3. Mostly used in rear wheels.
4. Advantages:
    a. It is orthogonal, we can change one parameter without affecting the others.
    b. More comfort due to its high flexibility

c. The benefit of the triangulated and double-triangulated arrangement is that they do not need a Panhard bar. The benefits of this are increased articulation and potential ease of installation.

5. Disadvantages:
    a. Expensive
    b. Complex

Rigid Axle Suspension:

1. Features an axle that is perpendicular to the vehicle and connected to the wheels via a wheel spindle and can be combined with leaf springs or coiled springs.
2. Used in heavy-duty vehicles.
3. Advantages :
    a. Simple and inexpensive
    b. Space efficient
    c. High durability in a high workload environment
    d. Rigid camber angle(angle of tilt of wheels)
4. Disadvantages:
    a. Each wheel does not move independently.
    b. The bulky differential housing of a Hotchkiss live axle reduces ground clearance, hindering the vehicle's ability to ford deep mud, clear obstacles and negotiate deeply rutted roads.

Macpherson strut:

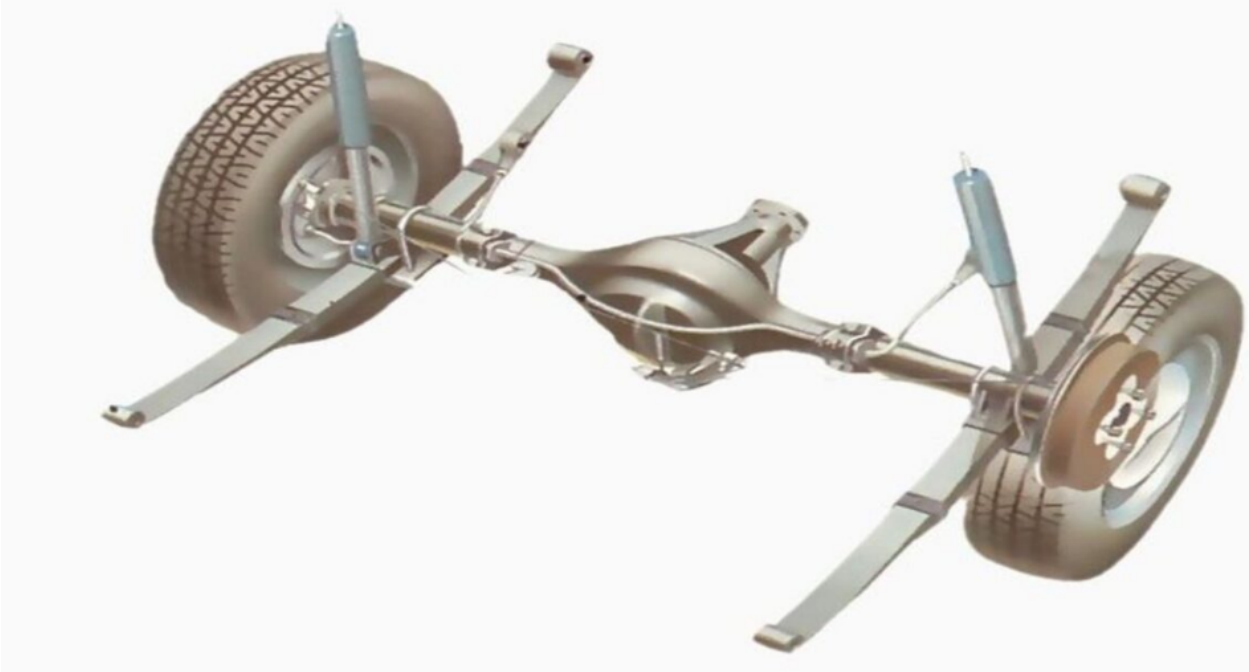
1. A steering pivot is present in the suspension itself so it is used as front suspension.
2. The suspension consists of a damper, a steering knuckle having two mounts and a track control arm.
3. The suspension can be modified to accommodate a variety of vehicles and driving conditions.
4. Advantages:
    a. Used on some high-performance cars because they tend to have relatively small suspension travel and so do not have the same kinematic problems.
    b. Simple design
    c. comfort, control and at the same time consume little space.
5. Disadvantages:

a. Geometric analysis shows the assembly cannot allow vertical movement of the wheel without some degree of either camber angle change, sideways movement, or both.

b.It is not generally considered to give as good handling as a double wishbone or multi-link suspension, because it allows the engineers less freedom to choose camber change and roll center.

6. Hi-per strut or revoknuckle - need to read upon this

Rigid leaf suspension



1. Similar construction to rigid axle.
2. Leaf springs(long bundles of spring material, mainly steel, that flex under pressure by the vehicle's axle) as dampers.
3. The steel is generally cut into rectangular sections and then once held together by metal clips at either end and a large bolt through the centre of the leafs.
4. The elasticity of the spring steel allows for a pliancy within the suspension for comfort and control of a car while moving.
5. Advantages:
    a. Due to the sheer amount of metal layered together, leaf springs offer a large amount of support between the wheels, axles and the car's chassis.
    b. They can take huge vertical loads being applied to them due to their tight-knit structure, hence why heavy duty industries still use them.
    c. Leaf springs coped much better with vehicle damping due to the friction between each plate of steel which made the response time after a vertical

flex in the suspension much quicker, thus making for a much more controllable car.

d. Simple and less expensive

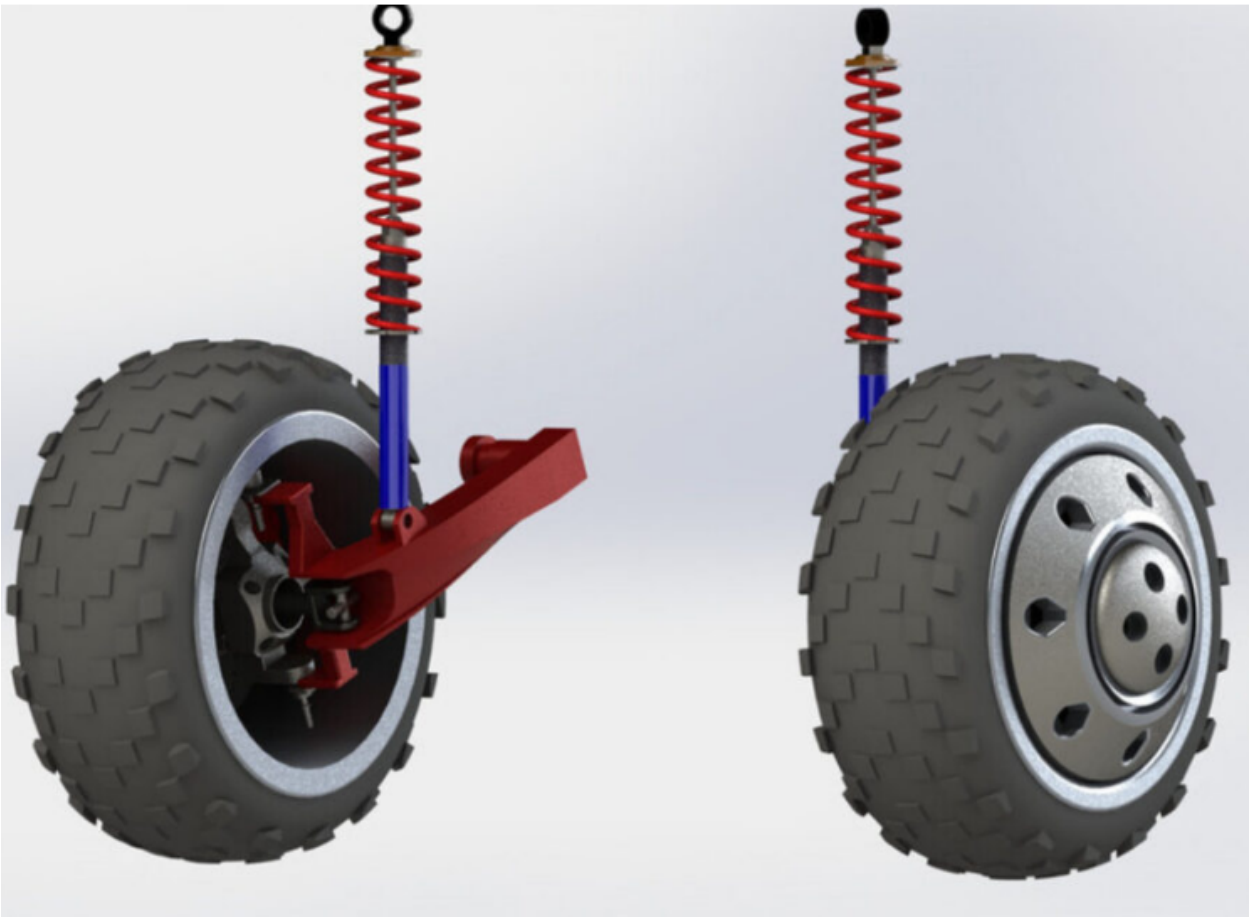
6. Disadvantages

a. Lack of adjustability

b. Leafs also allow very few directions of motion and are only really designed to move vertically, while a spring and damper combination can be manipulated into a much larger range of motion.

c. not meant for comfort and high speed or sharp cornering and will render the suspension to alter vehicle handling if put in those conditions.

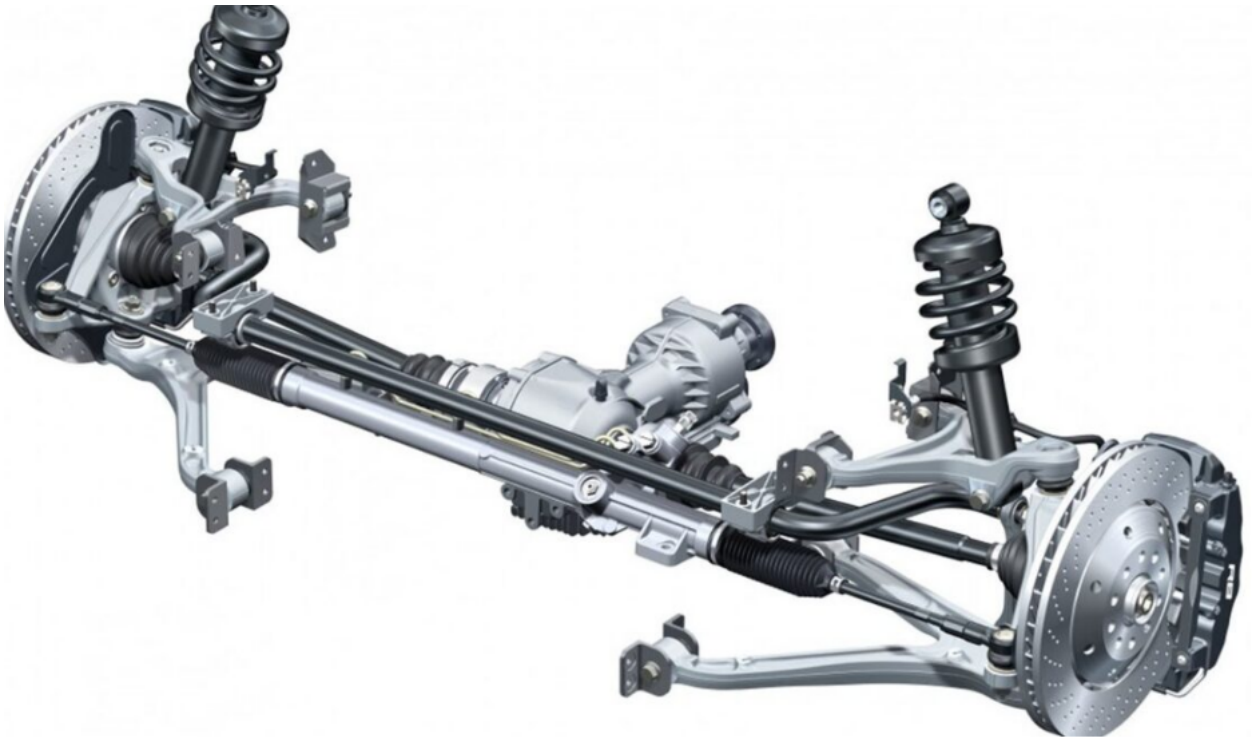
Trailing arm suspension:



1. The trailing arm suspension consists of a steel arm whose one end is pivoted to the vehicle's chassis and the other end to the rear axle and a damper.
2. Used mostly on the rear of a vehicle

3. Trailing suspension cannot be used for heavy duty vehicles as there are chances of the arm getting bent which would hamper handling
4. Advantages:
5. Disadvantages:
    a. Less refined
    b. It only allows the wheel to move up and down to deal with bump. Any lateral movement and camber change (with respect to the car body) is not allowed.
    c. Since they are rigidly attached to the wheels, inevitably more shock and noise could be transferred to the car body, especially under hard cornering or running on bumpy roads.
    d. A lot of unsprung weight of the trailing arm leads to poorer ride quality.

Double Wishbone suspension:



1. The double wishbone suspension consists of two A-shaped arms which look like wishbones.
2. The shock absorber and coil spring mount to the wishbones to control vertical movement.

3. Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle, toe pattern, roll center height, scrub radius, scuff.
4. Advantages:
    a. This arrangement is found only on independent suspensions and allows for greater control and comfort even at high speeds and fast cornering.
    b. Due to their agility, stability and comfort the double wishbone suspension and its modified versions are featured on luxury cars, sports cars and race cars.
    c. It is fairly easy to work out the effect of moving each joint, so the kinematics of the suspension can be tuned easily and wheel motion can be optimized.
    d. It is also easy to work out the loads that different parts will be subjected to which allows more optimised lightweight parts to be designed.
    e. They also provide increasing negative camber gain all the way to full jounce(The upward suspension travel that compresses the spring and shock absorber is called the jounce, or compression.) travel, unlike the MacPherson strut, which provides negative camber gain only at the beginning of jounce travel and then reverses into positive camber gain at high jounce amounts.
5. Disadvantages:

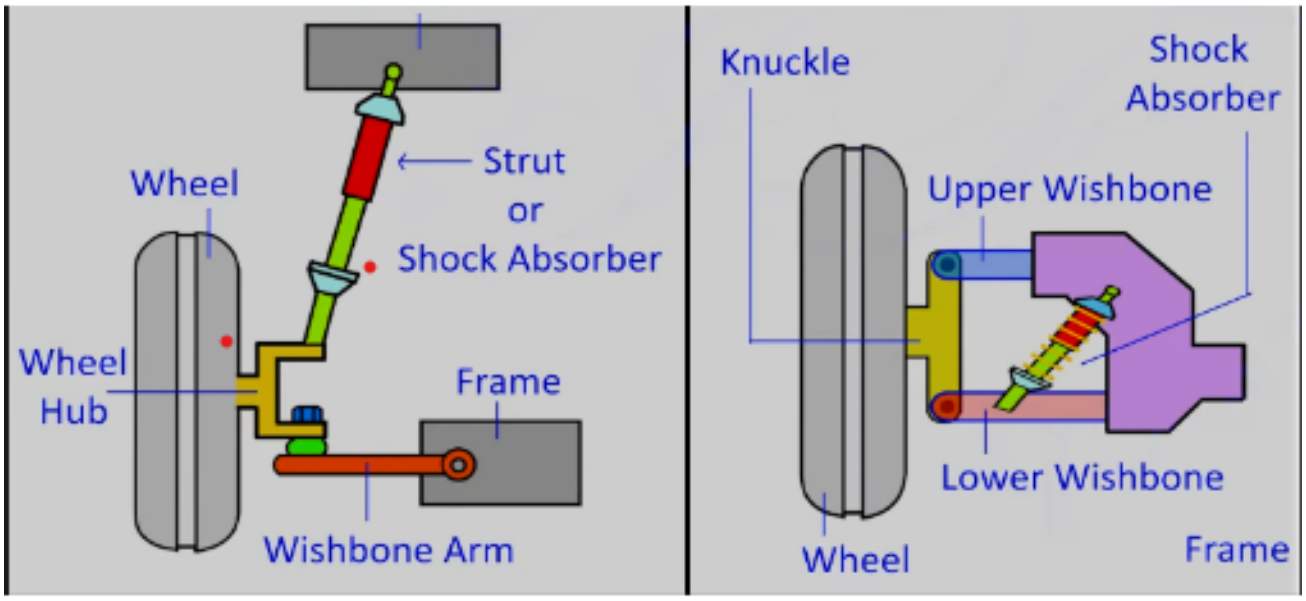
a. Double wishbone suspensions are more complex, impose more difficult packaging constraints and are thus often more expensive than other systems like a MacPherson strut.

b. Due to the increased number of components within the suspension setup, it takes much longer to service and is heavier than an equivalent MacPherson design.

Air Suspension:

1. uses air bellows in place of conventional coils and dampers.
2. These air bellows can be filled with air using an air compressor and deflated as well to adjust the ride height of the vehicle.
3. Advantages:
    a. Comfort
    b. Reduced noise and vibration
    c. Versatility on road
4. Disadvantages:
    a. Cost
    b. Maintenance
    c. Mechanical Issues- suspension may suffer malfunctions from rust or moisture damage from the inside, or an air fitting failure of the air tubing connecting to the air system. Leaks in air springs are also common and could lead to compressor burn out.

Preferred types:



Macpherson Strut

Double wishbone

Double wishbone:

1. Independent
2. Efficient Camber control(wheel stays attached to the ground)
3. Keeps the wheel perpendicular to the ground regardless of wheel movement

IF control arms are of equal length, different camber angles for both wheels.
To fix this we use suspensions with smaller upper control arm. Due to this the camber angle will be very small and thus the wheels stay flat on the ground.

DISADV:

1. More components, so expensive.
2. Difficult to maintain.

Macpherson strut:

1. Steering rod, suspension dampner
2. Coil spring- shock absorber integrated unit
3. Simple and low cost
4. Smaller than other suspension systems
5. Front wheel suspension, space in center for drive shaft.

DISADV:

1. Long assembly, not suitable for low cars.
2. Body roll in cornering due to camber.

Conclusion:

Front suspension - Macpherson strut
Rear suspension - Double wishbone

ALTO 800

Suspension, Steering & Brakes

Front Suspension	Mac Pherson Strut
Rear Suspension	3-Link Rigid Axle
Steering Column	Collapsible
Turning Radius (Metres)	4.6
Front Brake Type	Disc
Rear Brake Type	Drum

- High-profile tyres mounted on 12'' rims.
- Gas charged front and rear dampers.
- Tweaked suspension and tall tyre side walls cushion bad stretches.
- Wheelbase does not stay flat at speed; there is considerable vertical movement.

TATA Tigor EV

Suspension, Steering & Brakes

Front Suspension	Independent MacPherson strut with coil spring
Rear Suspension	Twist beam with dual path strut
Steering Type	Electric
Steering Column	Tilt
Turning Radius (Metres)	5.1m
Front Brake Type	Disc
Rear Brake Type	Drum

- 14'' rims; 175/65 section tyres.
- Recommended tyre pressure: Front - 33 psi Rear - 38 psi (battery pack directly above the rear suspension.
- Stiff suspensions - increase driver sensitivity, improve handling response, and improve tire contact on smooth roads, conversely, it can decrease ride quality, handling performance, and grip on bumpy roads.
- Big bumps have an effect, otherwise it is comfortable.

Hyundai Kona EV

Suspension, Steering & Brakes

Front Suspension	McPherson strut type
Rear Suspension	Multi - link
Steering Type	Electric
Steering Column	Tilt & telescopic
Front Brake Type	Disc
Rear Brake Type	Disc

- Stiff suspension system unlike other hyundai cars.
- *Electronic stability control :
  Improves stability by detecting and reducing traction.
  When ESC detects loss of steering control, it automatically applies the brakes to help steer the vehicle where the driver intends to go.
  Braking is automatically applied to wheels individually, such as the outer front wheel to counter oversteer, or the inner rear wheel to counter understeer.
- *Electronic controlled suspension :
  Active & Adaptive Electronic suspension.

TATA Nexon EV Max

Suspension, Steering & Brakes

Front Suspension	Independent MacPherson strut with coil spring
Rear Suspension	Twist beam with dual path Strut
Steering Type	Electric
Turning Radius (Metres)	5.1
Front Brake Type	Disc
Rear Brake Type	Disc

- Stiffened suspension

Bajaj Qute

Front Brakes	Drum
Rear Brakes	Drum
Front Suspension	Hydraulic Telescopic Shock Absorber
Rear Suspension	Hydraulic Telescopic Shock Absorber
Handbrake	Manual
Front Tyre & Rim (width, mm / height, % / Radius, inch)	R12
Rear Tyre & Rim (width, mm / height, % / Radius, inch)	R12
Wheels Size (width, mm / height, % / Radius, inch)	R12

Strom Motors R3

Front Suspension	MacPherson Struct
Rear Suspension	Dual Shock Absorbers
Shock Absorbers Type	Dual Shock Absorbers
Front Brake Type	Hydraulic Disc
Rear Brake Type	Drum

Mahindra E-verito

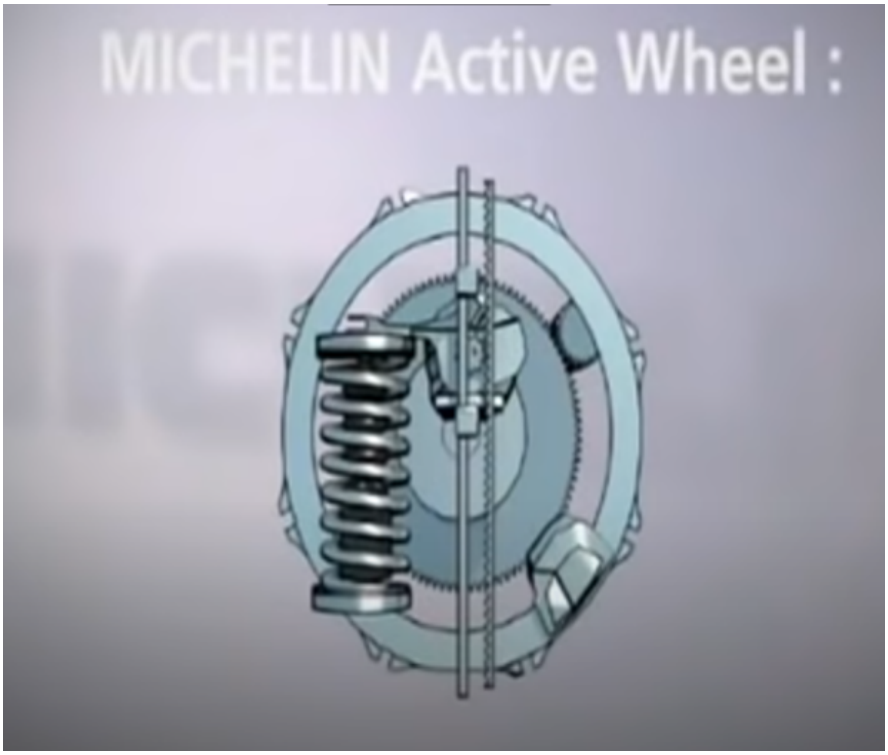
Suspension Front	MacPherson Type with Wishbone Link	Suspension Rear	H-Section Torsion Beam with Coil Spring
Brakes Front	Disc	Brakes Rear	Drum
Steering Type	Hydraulic	Minimum Turning Radius	5.25mm
Tyre Size	185/70 R14	Alloy Wheel Size	14
Tyre Type	Tubeless,Radial		

MG ZS EV

Suspension Front	MacPherson Strut	Suspension Rear	Torsion Beam
Brakes Front	Disc	Brakes Rear	Disc
Steering Type	Electric	Tyre Size	215/55 R17
Alloy Wheel Size	17	Tyre Type	Tubeless, Radial

Hub motor system :

- [Michelin Active Wheel: Tire which Electric Motor and Suspension - YouTube]



- FullVehicleSuspensionSystemwithIn-WheelElectricMotors.pdf
- applsci-10-03929 (1).pdf
- Active suspension control of electric vehicle with in-wheel motor.pdf

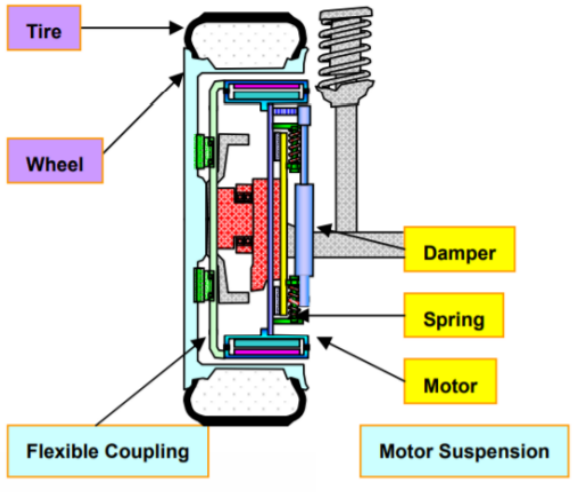
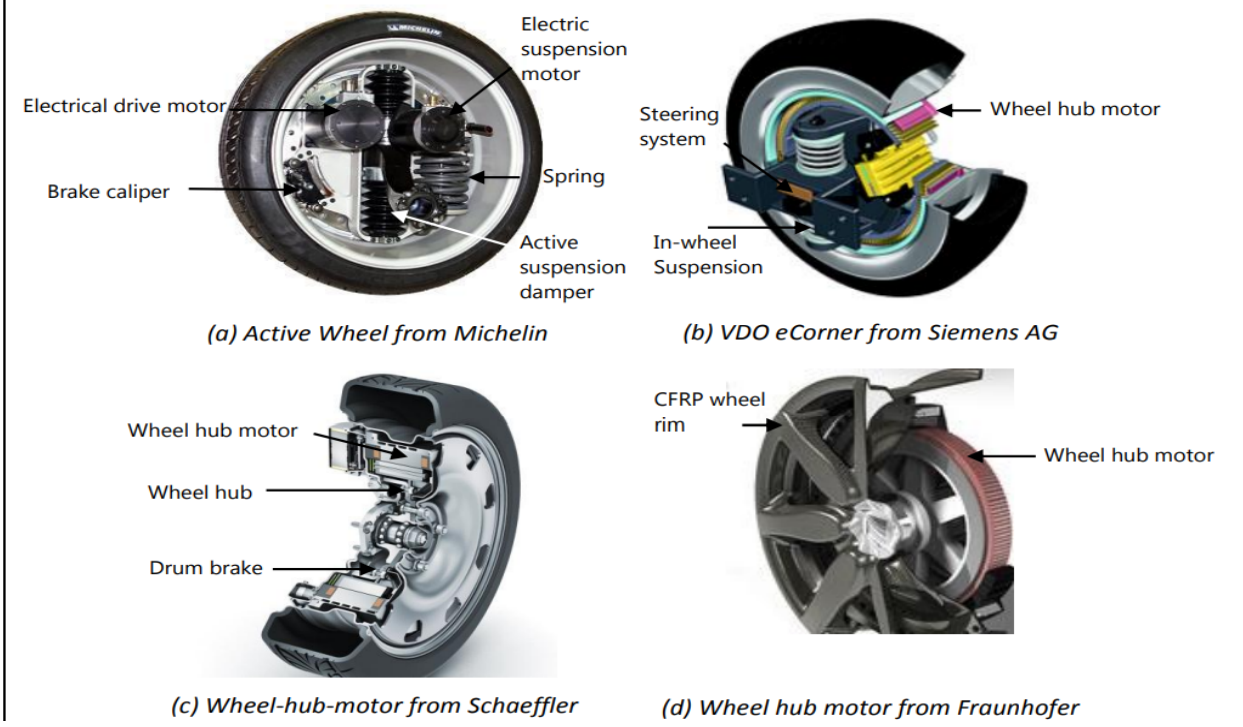


Figure 1-2 Bridgestone's Dynamic-Damping In-wheel Motor Drive System [9].

- Approach for the Development of Suspensions with Integrated Electric Mot…

Figure 1.1: *Wheel hub motors* (Fischer, 2014) (Vijayenthiran, 2008) (Sterbak, 2007) (Wöstmann, 2011).



(a) Active Wheel from Michelin

(b) VDO eCorner from Siemens AG

(c) Wheel-hub-motor from Schaeffler

(d) Wheel hub motor from Fraunhofer

Figure 1.2: *Schaeffler Wheel Module* (Harkort, et al., 2018)

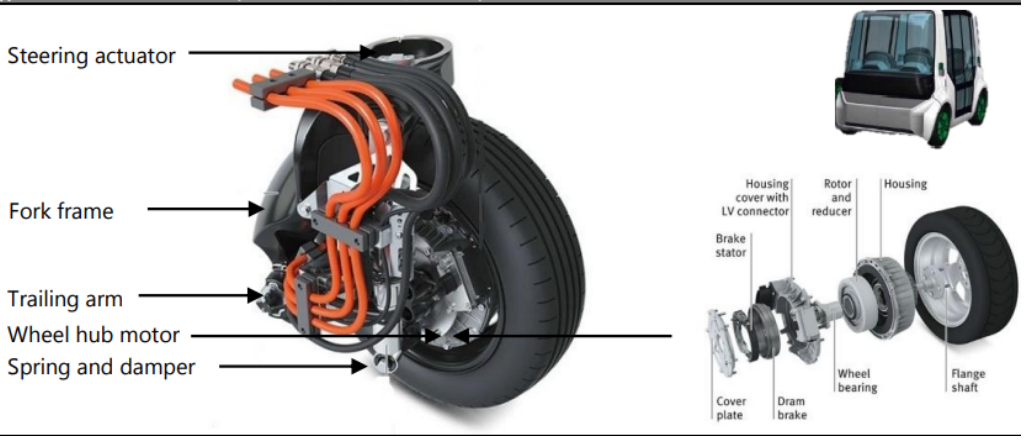
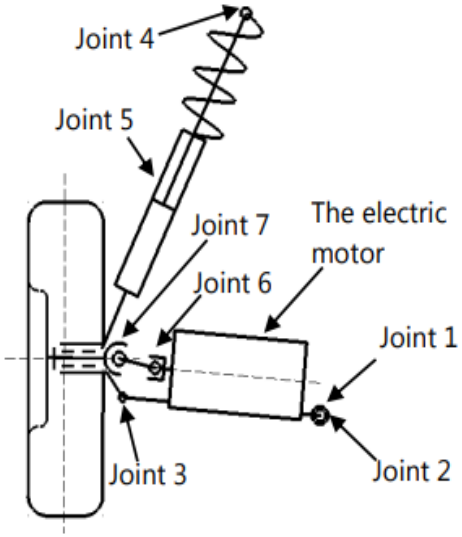
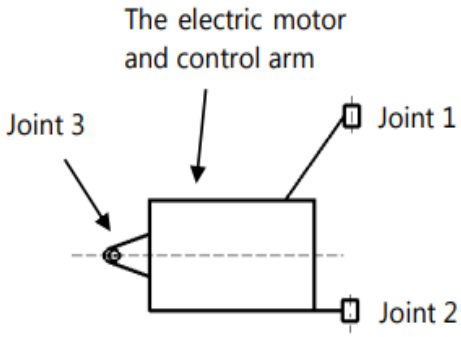


Figure 1.3: *Electric Twist Beam (eTB) from ZF AG* (Buchmeier, 2014)

Figure 4.5: *Concept 1 by combining the McPherson suspension with an electric motor*



(a) *McPherson suspension combined with an electric motor*



(b) *Combined structure of the lower arm and the electric motor*

- [Effect of in-wheel motor suspension system on electric vehicle ride comfort | Extrica - Publisher of International Research Journals]