

AUTOMOBILE ENGINEERING

Module 3

CO3	Explain the working of suspension, steering and braking system of Automobile		
M3.01	Illustrate the working of different suspension systems with figure.	2	Understanding
M3.02	Interpret Steering wheel - steering column steering gears - worm and worm sector - rack and pinion –re circulating ball - power steering etc. Analyze	6	Understanding
	camber -caster -king pin inclination - toe in and toe out of wheels. Ackerman steering mechanism.		
M3.03	Understand wheels &tyres. Types of wheels - Disc wheels - cast wheels - size of wheel and Tyre-tubeless tyres and tubed tyres -tyre material.	3	Understanding
M3.04	Illustrate the working of Braking system with neat figure.	4	Understanding

Suspension systems -Types and components- leaf spring – coil spring- spring shackle - air suspension
Steering wheel - steering column steering gears - worm and worm sector - rack and pinion –re circulating ball - power steering - camber -caster -king pin inclination - toe in and toe out. Ackerman steering mechanism.
wheels & tyres: Types of wheels - Disc wheels - cast wheels - size of wheel and Tyre -tubeless tyres and tubed tyres -tyre material.
Brakes, Types - mechanical - hydraulic -air brake - master cylinder- disc brake –working of ABS and EBD.

SUSPENSION SYSTEM

- A suspension system is a set of mechanical connections, springs, and dampers that connect the wheels to the chassis. It has traditionally performed two functions: managing the vehicle's handling and braking for safety, and keeping passengers comfortable from bumps, vibrations, and other factors. It is a mechanical system of springs or shock absorbers connecting the wheels and axles to the chassis of a wheeled vehicle.
- It also aids in maintaining proper vehicle height and alignment. It also controls the vehicle's orientation and must keep the steering wheel perpendicular to the ground for maximum grip. The suspension also helps to safeguard the car and its contents from damage and wear. The front and rear suspensions of a car may be designed differently.
- TYPES
- Conventional type
- Independent type
- Air suspension

<https://www.youtube.com/watch?v=nJqt14tmrRw&t=40s>

- **Functions**
- Shock forces are reduced as much as possible
- Maintain the proper ride height of your car, proper alignment of the wheels, proper tire contact
- Serve as weight support for the vehicle
- To eliminate transmission to car component road shocks.
- To maintain a solid grip on the road while driving, cornering, or braking.
- To maintain the correct steering geometry.
- Torque and braking reflexes must be resisted.
- Maintaining vehicle stability while traveling over uneven terrain or turning in order to reduce the tendency for rolling, pitching, or vertical movement.
- To protect passengers from road shocks and give a comfortable ride.
- To reduce the strains caused by road shocks on the motor vehicle's mechanism and offer a cushioning effect.
- While traveling over tough, uneven terrain, keep the body absolutely level. The up and down movements of the wheels should be proportional to the movement of the body.
- To protect the vehicle's structure from stress loading and vibration caused by road surface irregularities while maintaining its stability.

CONVENTIONAL SUSPENSION

- Two wheels are mounted on either side of the rigid axle
- When one wheel encounters the bump, both the wheel do not execute parallel up and down motion
- So it gives rise to gyroscopic effect and wheel wobble
- Rear driving wheels mounted on live axle suspended by laminated leaf springs and shock absorbers

INDEPENDENT SUSPENSION SYSTEM

- Both the front and the rear wheel are utilized
- Design incorporated in the front wheels
- One wheel goes down ,the other wheel does not have much effect

ADVANTAGES OF INDEPENDENT SUSPENSIONS OVER CONVENTIONAL SUSPENSION.

- 1. Low unsprung weight.
- 2. Better Handling and Cornering
- 3. Softer suspension compared to rigid type.
- 4. Better ride quality.
- 5. Improved vehicle stability and Steering
- 6. Overcomes the ill-effect on steering geometry.
- 7. More space to accommodate the engine. .

- **Car suspension components**
- **1. Spring**
- Spring is one of those parts which you may have come across in your day-to-day life. It is generally coiled up and elastic. The spring compresses or extends depending on the external force applied. The spring in the car suspension also works on the same principle.
- The primary job of a car suspension spring is to store energy generated when the car drives over a bump, pothole, etc.
- The amount of energy stored by a spring depends on various factors such as material, length, coefficient of spring, etc.
- There are two types of springs used in suspensions: coil spring and leaf spring.
- Coil springs are one of the most common springs, and you can see them on most cars.
- Leaf springs were used in older cars, and you can also find them on heavy-duty vehicles such as trucks with solid axles.
- A leaf spring can store more energy than a coil spring. Hence, heavy-duty vehicles use leaf springs.

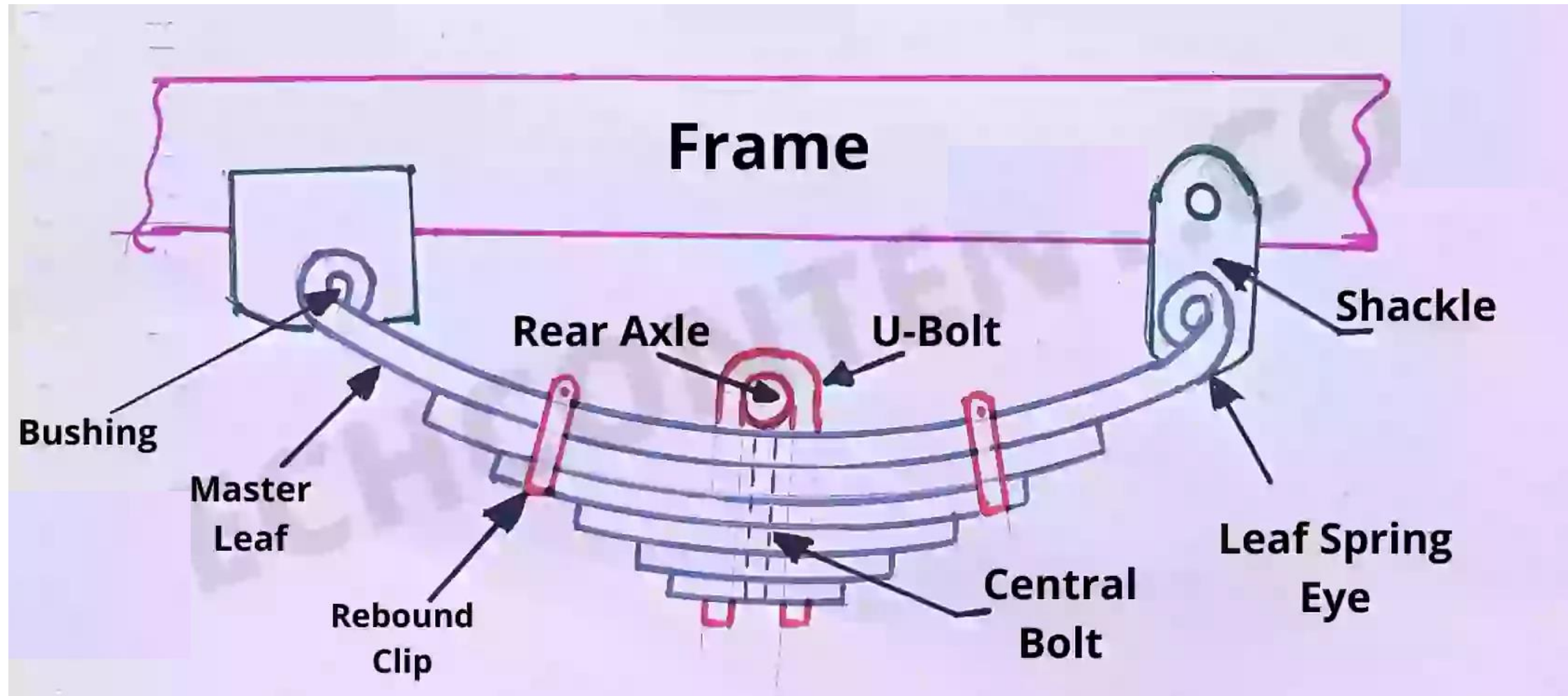
- **Dampers/Shock absorbers**
- A damper or shock absorber is a fluid/gas-filled reservoir encased within a tube. It is fitted between the car's frame and wheels. The upper mount of the shock absorber is connected to the frame. The lower mount is attached to the axle.
- The damper's upper mount is connected to a piston rod attached to the piston with tiny holes. The piston sits in a tube that is filled with hydraulic fluid.
- When the wheels go over a bump/dip on the road, the spring extends/compresses.
- The energy stored in the spring is transferred to the damper via the upper mount.
- The energy is dissipated to the piston rod and then into the piston.
- Due to the energy, the piston moves through the oil. The oil is then forced through the piston holes and is channelled into a separate chamber.
- **Struts**
- The struts are not an individual component of a suspension system. Instead, they are the structural components comprising spring and shock absorber. In simple words, a damper wrapped with a coil spring is called a strut. A strut integrates the different suspension components into one compact assembly.

- **Anti-roll bar**
- The anti-roll bar is responsible for preventing the car's body from rolling when driving on corners/road irregularities. It is a metal rod that connects the left and right sides of the suspension
- When the suspension moves up/down (left or right wheel) due to road irregularities, the anti-roll bar transfers the energy to the other wheel (left or right side).
- It results in a level ride and reduces the possibility of the car rolling while going through a corner.
- Almost all cars are fitted with an anti-roll bar as standard.
- It reduces understeer and oversteer

<https://www.youtube.com/watch?v=nk8WVpRN1kg>

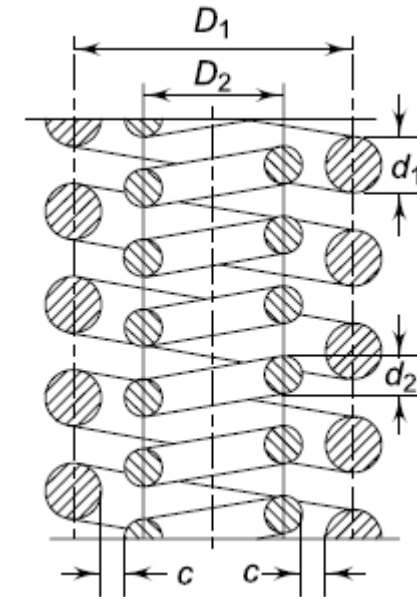
LEAF SPRING

- 1) **Semi elliptical leaf spring** is widely used in heavy vehicles for rear suspension.
- 2) it consists of a number of **semi-elliptical flat plates** of rectangular cross-section.
- 3) The leaf springs vary in length which is arranged lower to each other having reducing the length.
- 4) Upper leaf is known as the **Master Leaf** & other leaves under Master Leaf are known as **Graduated leaves**.
- 5) **U-shape** bolt is used to hold the rear axle to leaves.
- 6) One end (Left eye) of the Master leaf is fixed to the frame & Another end (Right eye) of the Master leaf is connected to the shackle.
- 7) The **shackle** is used to compensate for the deflection of leaf spring.
- 8) When leaf spring moves upward due to bumping, The shackle rotates about the fulcrum to compensate for horizontal deflection.
- 9) The **Rebound Clips** are used which hold the Master Leaf & Graduated Leaves together. Hence the stresses are distributed over the complete length of each leaf.
- 10) In Leaf Spring, [Stresses](#) due to bear the load are distributed over the complete length of each leaf. Hence it has the ability to withstand the higher working load



COIL SPRING

- the coil spring are used mainly with independent suspension though they have also been in conventional rigid axle suspension as they can be accommodated in small spaces. the energy stored per unit volume is almost double in the case of coil spring than leaf spring
- Coil spring do not have noise problem ,nor they do have static friction causing harshness of ride as in case of leaf spring
- The spring takes the shear as well as bending stresses. the coil springs ,however cannot take torque reaction and side thrust ,for which alternative arrangements have to be provided



SPRING SHACKLE

- **Leaf spring shackle** helps to get the best ride quality and suspension travel of a vehicle. Leaf springs are a crucial component of the automobile manufacturing industry. They are the default suspension system for off-road vehicles or trucks or other heavy vehicles. They help to balance the weight of the car during pick up while absorbing vibrations from speed bumps and uneven surface. But if there's no shackle, the leaf springs are quite ineffective.
- Leaf spring shackles help the vehicle's springs to travel through long ways when you drive through different road surfaces like rocks, bumps, potholes, uneven dirt and rocks. It ensures the length of the leaf springs changes appropriately during the movements of the suspension.
- Another purpose of this component is to keep the vehicle balanced. Shackles are located at the rear end of each leaf spring in the suspension system of any vehicle. They link the springs and the vehicle frame with the help of an eye spring bolt.
- Since a leaf spring cannot take on all the load, they depend on shackles to flex and adequately run the suspension system.

<https://www.youtube.com/watch?v=iMqE-NCrWIg>

AIR SUSPENSION

- **An air suspension system is a suspension system in which an air spring or airbag is used instead of a metal spring (coil or leaf) to support the vehicle on the axles with an organization of the airbags.**
- **The air suspension system works on the principle of using compressed air to vary the height of the suspension system of the vehicle.** In simple words, air suspension is a suspension where the properties of air are used for cushioning effect.
- The bumps on the road compress airbags and they bounce up and down allowing the wheels to move. The airbags are nothing but a rubber bladder that holds air, usually made from textile-reinforced rubber or a composite of rubber and [polyurethane](#).
- ADVANTAGES
- Optimum space utilisation
- Change in head lamp alignment is avoided
- Reduces dynamic loading
- Improves ride comfort and noise reduction
- Reduces driver and passenger fatigue

<https://www.youtube.com/watch?v=gEe-Wa6GZ6Y&t=1s>

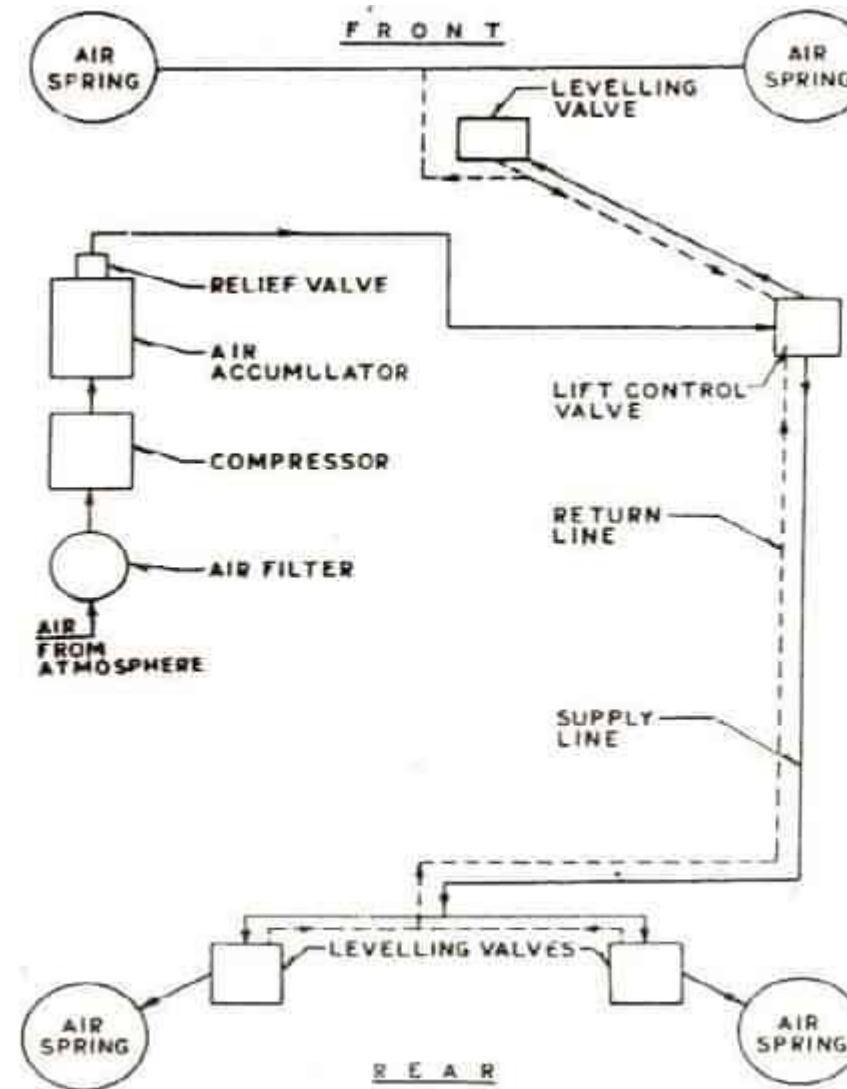


Figure: Schematic diagram showing the layout of an air suspension system.

STEERING SYSTEM

Functions

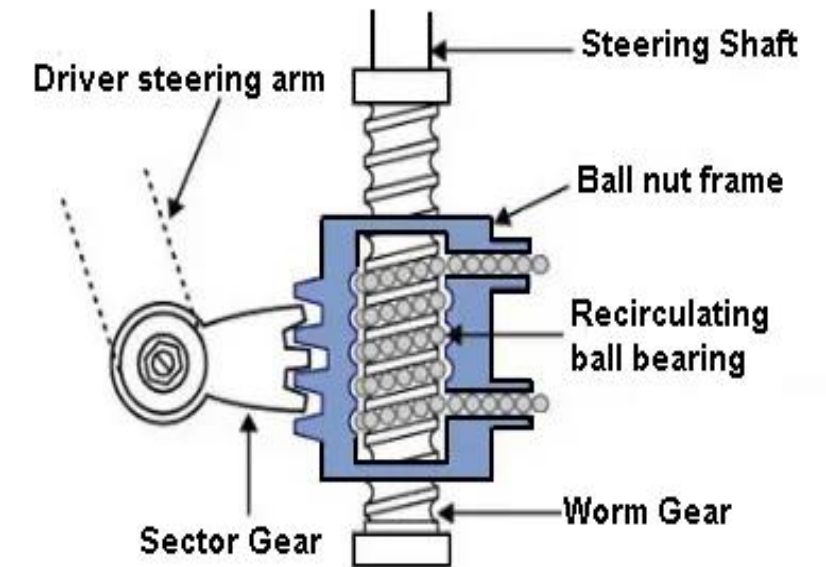
- With the help of the steering system, the driver can control the vehicle however he wants
- The steering provides stability to the vehicle on the road.
- It minimizes tyre wear and tear.
- It prevents road shocks from reaching to the driver.
- The steering provides self-rightening effect after taking a turn

Recirculating Ball Steering Gear

- The circulating ball gear is similar to the worm and ball bearing not steering gear.

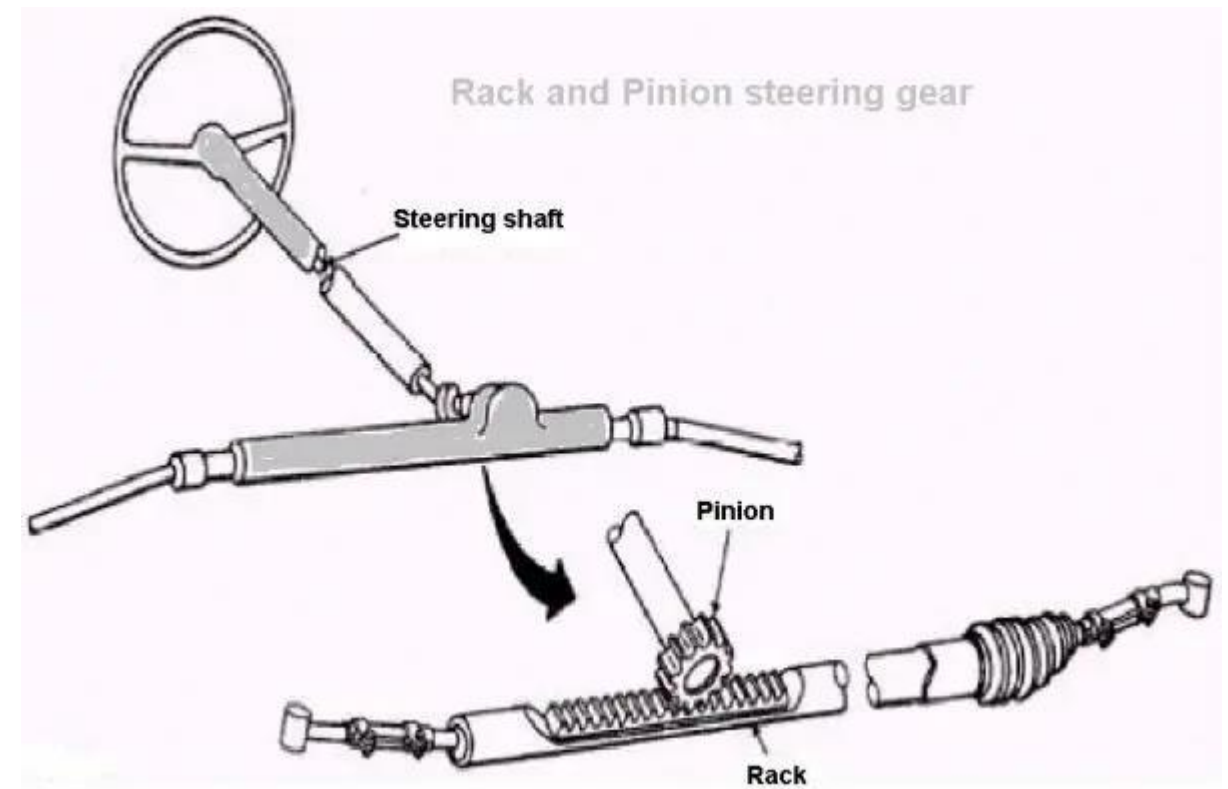
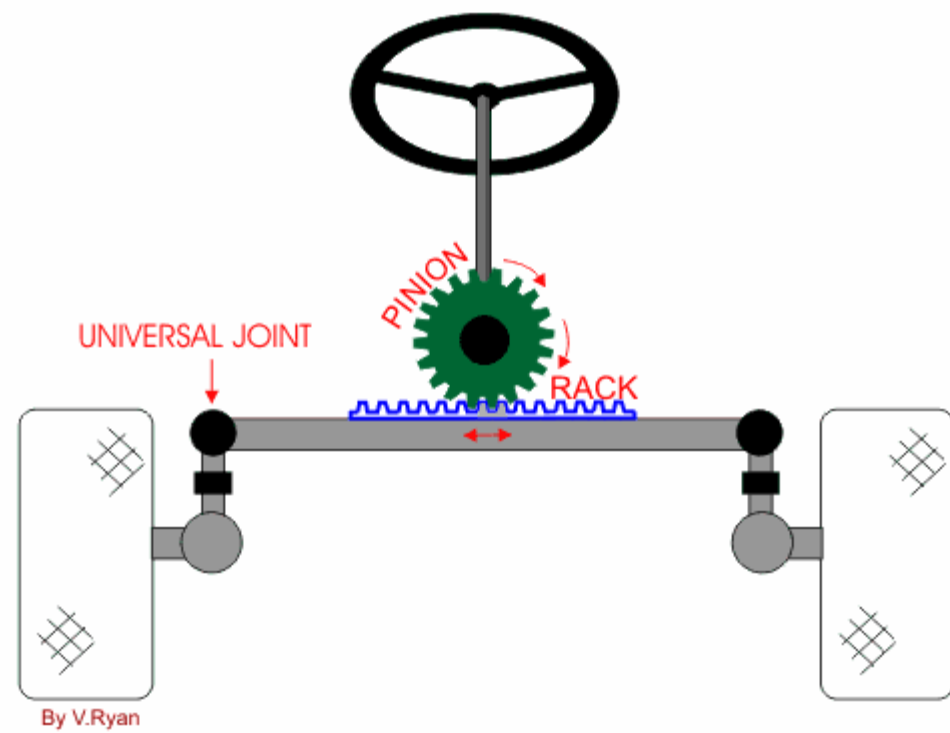
Working

- The recirculating ball steering mechanism contains a worm gear inside a block with a threaded hole in it
- This block has gear teeth cut into the outside to engage the Sector shaft (also called a sector gear) which moves the arm.
- As the cam or worm rotates, the balls pass from one side of the nut to the transfer tube to the opposite side.
- The steering wheel connects to a shaft, which rotates the worm gear inside of the block.
- Instead of twisting further into the block, the worm gear is fixed so that when it rotates, it moves the block, which transmits the motion through the gear to the arm, causing the road wheels to turn.
- The worm gear is similar in design to a ball screw; the threads are filled with steel balls that recirculate through the gear and rack as it turns.
- The balls serve to reduce friction and wear in the gear, and reduce stop.



Rack and Pinion Steering Gear

- Rack-and-pinion steering is the most common type of steering on cars, small trucks and SUVs. It is actually a pretty simple mechanism. A rack-and-pinion gear-set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod, connects to each end of the rack. The pinion gear is attached to the steering shaft. When you turn the steering wheel, the gear spins, moving the rack. The tie rod at each end of the rack connects to the steering arm on the spindle .
- The rack-and-pinion gear set does two things:
 1. It converts the rotational motion of the steering wheel into the linear motion needed to turn the wheels.
 2. It provides a gear reduction, making it easier to turn the wheels.
- On most cars, it takes three to four complete revolutions of the steering wheel to make the wheels turn from lock to lock (from far left to far right). The steering ratio is the ratio of how far you turn the steering wheel to how far the wheels turn. For instance, if one complete revolution (360 degrees) of the steering wheel results in the wheels of the car turning 20 degrees, then the steering ratio is 360 divided by 20, or 18:1. A higher ratio means that you have to turn the steering wheel more to get the wheels to turn a given distance. However, less effort is required because of the higher gear ratio



Worm and Sector Steering Gear

- In the worm and sector steering gear, the worm on the end of the steering shaft meshes with a sector mounted on a sector shaft. When the worm is rotated by rotation of the steering wheel, the sector also turns rotating a sector shaft. Its motion is transmitted to the wheel through the linkage.
- Note that the sector shaft is also known as pitman arm shaft, pitman shaft, roller shaft, steering arm shaft, cross shaft.

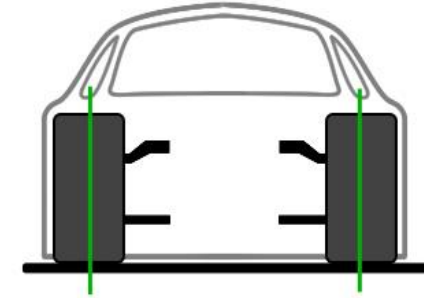


- **Camber**

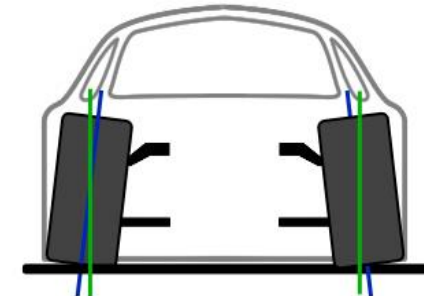
- The angle between the centerline of the tyre and the vertical line, when viewed from the front of the vehicle, is known as camber. When the wheels are tilted outwards at the top is called positive camber, and if tilted inward at the top is called negative camber. An equal camber angle is provided on both the front wheels.
- With the positive camber, wheels become verticle under load on the tyre will have full contact with the road, hence the tyre wear will be uniform. If the positive camber is excessive then tyres outer edge will rear will wear out faster. If the negative camber is excessive the tyres inner edge will wear out faster.
- Unequal camber on both the front wheels will result in wheels vibration at low speed.

**Camber, as seen from
the front of the car**

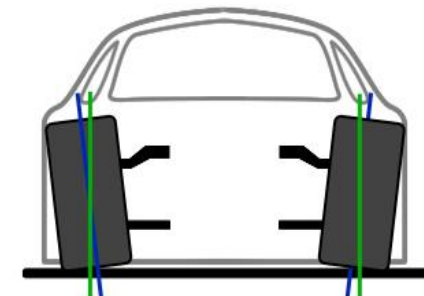
Zero camber



Negative camber

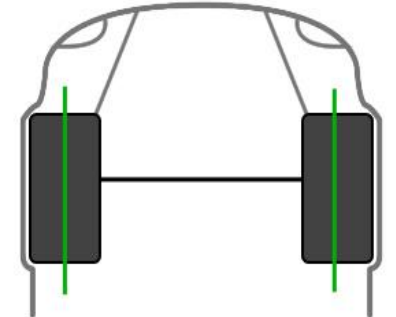


Positive camber

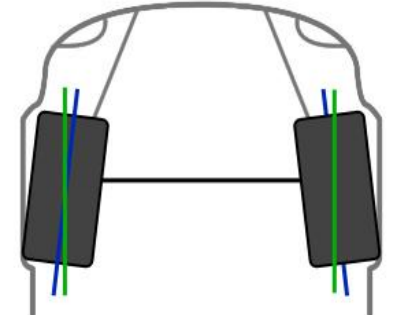


**Toe, as seen from
the top of the car**

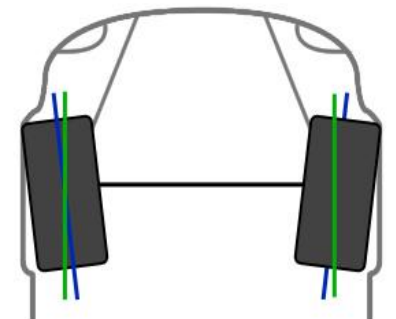
No toe



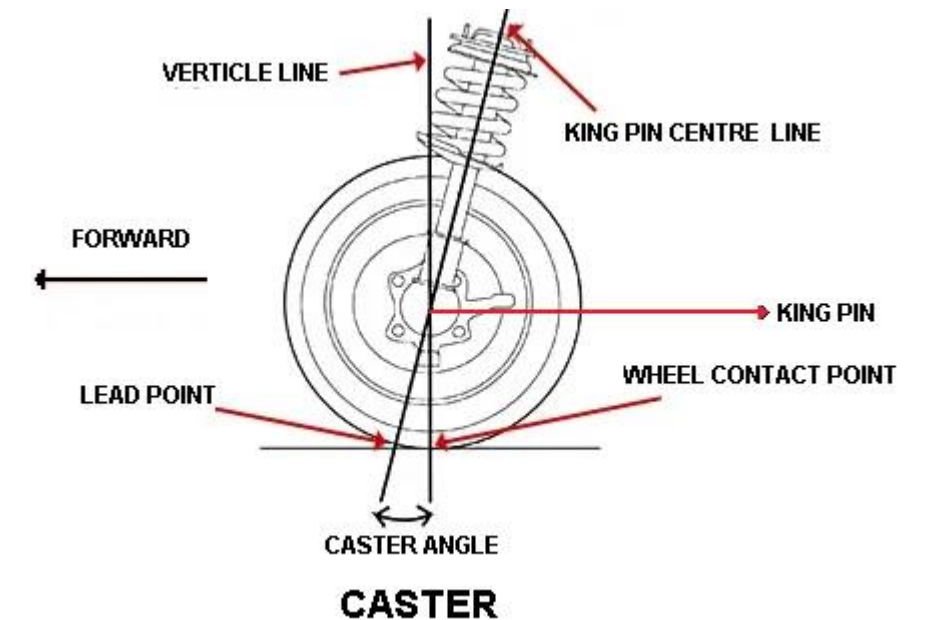
Toe-in



Toe-out

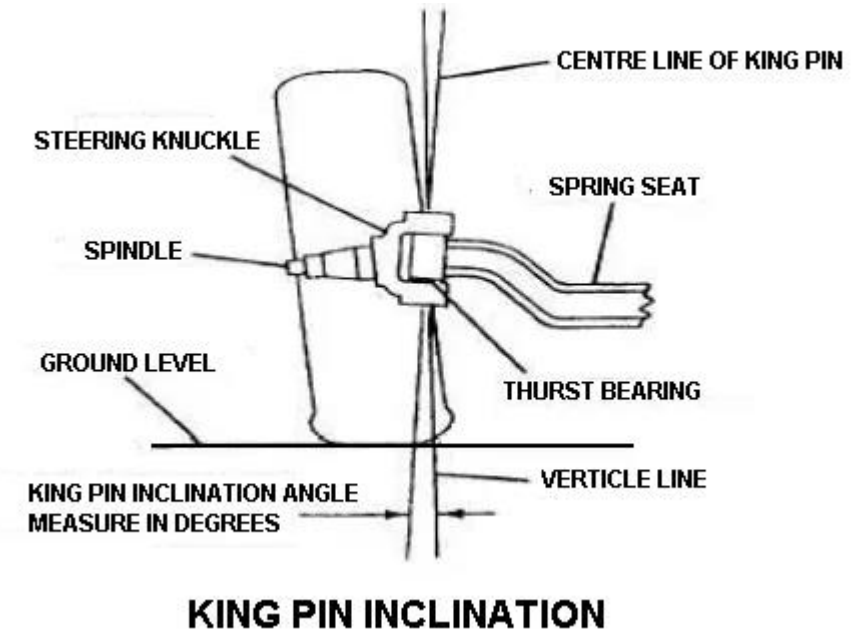


- **Caster**
- The Kingpin axis or steering axis may be tilted forward or backward from the vertical line. This tilt is known as Caster. Caster Angle: The caster angle is the angle formed by the forward or backward tilt of the steering axis from the vertical when viewed from the side of the wheel.
- A backward tilt is known as a positive caster and a forward tilt is known as a negative caster. If the caster is not equal on both sides it will cause the vehicle to pull to the side of the wheel having a lesser caster angle. The caster angle in modern vehicles varies from 2° to 8° .
- **Purposes of Caster**
- To maintain directional stability and control.
- To increase steering stability.
- Reduce driver's effort to turn the vehicle.



- **King Pin Inclination**

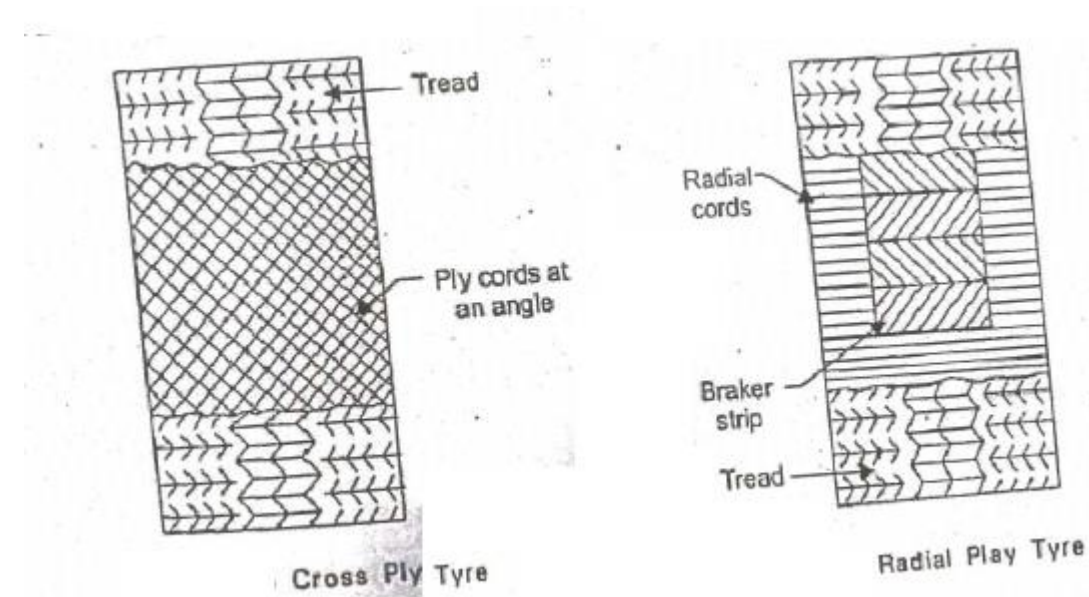
- The angle between the vehicle line and center of the kingpin or steering axis, when viewed from the front of the vehicle, is known as Kingpin inclination.
- The Kingpin inclination in modern cars varies from 7° to 8° . It must be equal on both sides. It is greater on one side than the other, the vehicle will tend to pull to the side having a greater angle.
- **The main functions of Kingpin inclination are as follows,**
- It helps in self-centring of wheels after taking a turn.
- To provide directional stability.
- It reduces steering effort.



- **Toe-in**
- Front wheels are slightly tilted inward at the front of the distance between the front wheels at the front (A) is less than the distance at its rear (B) measured at the height of the hub level and at the center of the wheel tread.
- The difference in its distance is 'Toe-in' (B-A). it is usually 2 to 3 mm. The purpose of the toe-in is to overcome the bad effect of camber. The toe-in is adjusted by tie-rod ends.
- **Toe-out**
- Whenever the vehicle is taking a turn with Ackerman steering geometry the inner wheel turn more degrees than the outer wheel so that the perpendiculars of all four wheels at a point when produced. This point is called the instantaneous center so that all the wheels roll very easily without scuffing.

TYRES

- The tyre is a cover for the tube and provides protection. These are placed around the rims of the wheel as a cushion between the wheel and the road. The casing is made up of a number of fabric layers. The casing resists expansion of the tube when road shocks are experienced. Rubberized cards are used to form sheets of the layers. Each sheet is placed at an inclination to the adjacent layer so that a strong casing is formed. The tyre casing is made of Rayon and Nylon materials to form a strong, flexible and heat resisting tyre. A number of hoops of steel wire are used in the bead of the tyre to place the tyre on the rim. The tyres are made of natural or synthetic rubber. These are compounded with chemicals.



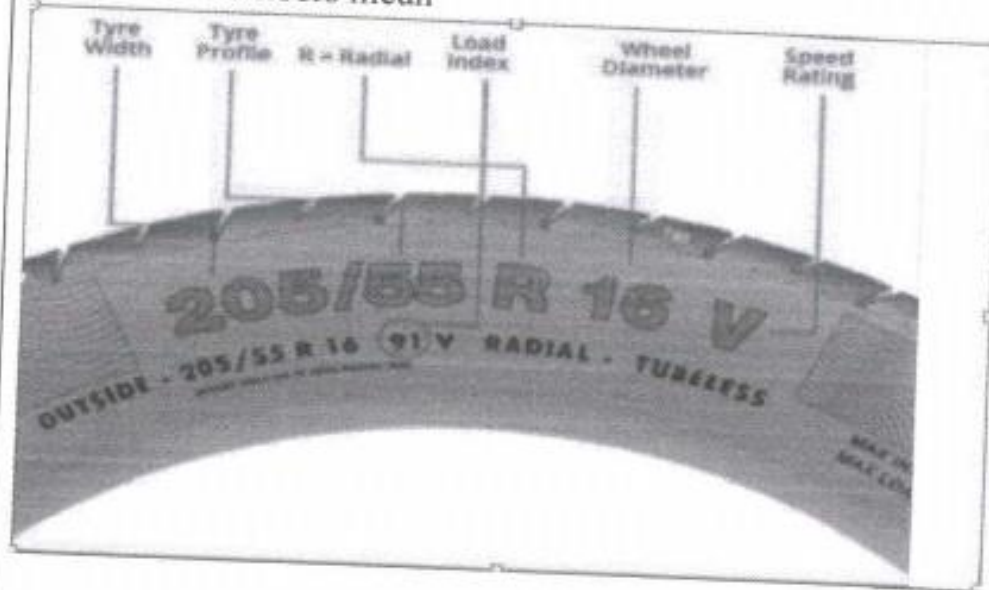
	TUBED TYRE	TUBELESS TYRE
	A tube inside a tire would simply collapse in case of puncture and the air in the tyre goes out in no time.	Tubeless tyre retains air pressure and helps avoid sudden air loss in the case of a puncture.
Fuel Efficiency	Tube tyres are not so fuel efficient. When compared to Tubeless tyres.	Tubeless tyres are more fuel efficient.
Weight	Tube tyres weigh more because of the tube placed inside them.	Tubeless tyres are light weight because of no tube inside the tyre.
In case of puncture	The tube in the tube tyres will explode suddenly in case of puncture causing loss of control of the vehicle which may result in accidents.	Tubeless tyres make driving safe and easy and there is no loss of control of the vehicle in case of puncture.

	TUBED TYRE	TUBELESS TYRE
Repair Process	The puncture repairing process of tube tyre involves a complicated process of removing the tyre from the vehicle and removing tube from the tyre, etc.	The puncture repairing process of a Tubeless tyre can be Done without removing the tyre and is very simple compared to a tubed tyre.
Cost of Tyre	The tube tyres are of less cost and are available in every size for every vehicle.	The tubeless tyres are costly and are not available for all types of vehicles.
Punctures	The tube tyres are more prone to punctures because of the tubes placed in them.	The tubeless tyres are durable and last longer because of no tube is placed in them.
Repair Cost	The tube tyre puncture repair cost is less when compared to that of the tubeless tyre.	The tubeless tyre Puncture repair cost is very high and can be repaired instantly.

<u>Radial ply type</u>		<u>Cross ply type</u>	
1.	In radial ply type, the cords of tyre run in radial direction.	1.	In cross ply type, alternate layers of cords run in opposite direction.
2.	The cord ply are woven in radial direction of tyre axis.	2.	The cord ply are woven at angle (30 - 40°) to the tyre axis.
3.	Radial tyre are provided with breaker strip, thus a continuous flat contact is possible with road surface.	3.	There is no breaker strip in this tyre. Thus continuous grip with road surface is not possible.
4.	This tyre has low rolling resistance, thus better fuel efficiency.	4.	The cross ply has more rolling resistance as compared to cross ply.
5.	This tyre provides better directional stability.	5.	This tyre has wobbling characteristics.
6.	This tyre has greater sidewall flexibility & treads stiffness.	6.	Sidewall flexibility & tread stiffness is lesser as compared to radial ply tyre.

TYRE SIZE

Along with the manufacturer's name and the name of the tyre (i.e. Bridgestone Ecopia), there's always a set of numbers and letters that relate to the size of the tyre. Here's a rundown on what those numbers mean



Example: 215/60R15

215 is the width of the tyre in millimetres. 60 is the aspect ratio or tyre profile. R means it is radial construction. 15 is the diameter of the wheel rim in inches.

WHEEL SIZE



The wheel size is the size designation of a wheel given by its diameter, width, and offset. ... For example, 17x8.5 +35, the wheel's diameter is 17 inches, its width is 8.5 inches, and it has a +35 positive offset.

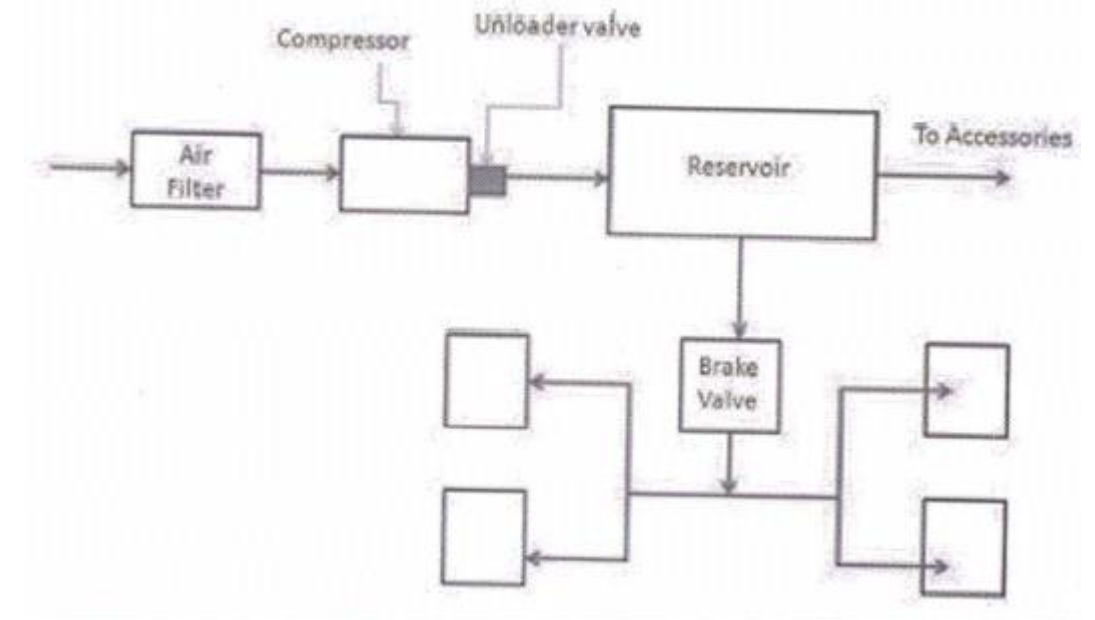
TYRE MATERIAL

- **Natural rubber** -is made from a white liquid called latex from certain plants when you cut them. There are over 200 plants in the world that produce latex. The most plentiful amount of latex can be found in the rubber tree.
- **synthetic rubber** -is any artificial elastomer. The elastomers that go into tires are a petroleum byproduct. produced through the petroleum refining process and containing unique ingredients that are added to make the tire last longer, grip better or to improve rolling resistance for better fuel economy.
- **carbon black** -Most tires are black. This is because a key ingredient that is added to the mix of natural and synthetic rubber is carbon black. Carbon black are tiny dust-like particles that act like a bonding agent for the other ingredients in the tire.. Carbon black has the added feature of catching ultraviolet rays and absorbing the heat of the sun. This helps protect the tire against ozone and UV damage.
- **steel cords** -An estimated 15% of the material in a tire is steel, mainly in the form of cord. Rubber is vulcanized to steel cords that are spirally wrapped to form bead wire. The bead is the part of the tire that attaches to the rim. It takes a lot of pressure to mount a tire on the wheel.
- **fabric belt** -An important element in tires is the fabric belt that forms the casing of the tire and helps the tire maintain its shape even at high speeds. The casing forms the main body of the tire, and it is made of strips of cloth-like fabric that are covered with rubber: Each strip of rubberized fabric is used to form a layer called a ply
- **Nylon & Steel** — steel meshes and the nylon meshes are also used as a liner between plies in the form of belts.

PNEUMATIC BRAKE

Working

- The pneumatic brake is used in heavy vehicle where large braking force is required to stop the vehicle.
- In Pneumatic braking system the compressed air is used to operate the brake shoes toward the drum to slower down or stop the vehicle.
- It consists of a compressor which sucks the air from atmosphere through a filter element.
- The compressed air is store in a reservoir with a unloader valve which sets or control the pressure of compressed air in the reservoir.
- From the reservoir the compressed air send to the brake valve which is controlled by the driver when the braking action is performed.
- The amount of opening or closing the brake valve controls the braking force acting on the brake shoes toward drum.
- Applying of brake causes the decrease in pressure in the reservoir and the compress air is filled in the reservoir through unloader valve.
- The hose pipe or delivery pipe is used to deliver the compressed air from the compressor to the brake shoes.



master cylinder

1. The required hydraulic pressure is built up to operate the system.
2. It maintains a constant volume of fluid in the system.
3. To bleed or force air out of the brake line and wheel cylinder, a pump is used.

wheel cylinder.

1. It actuates the shoes outward to contact the brake drum.
2. It converts the hydraulic pressure of very low value into a significant value of mechanical force of higher value.

Brake shoe adjustor

1. The purpose of adjustor is to compensate the wear of brake leather due to regular use of vehicle.

DISC BRAKE

- Cast iron Disc bolted to wheel hub and stationary housing called the caliper.
- Caliper is connected to some stationary part of vehicle like axle casing or the stub axle.
- Caliper consists of two parts, each part contains a piston.
- in between the piston and the disc, friction pads are placed.
- passages are drilled in the caliper for fluid to enter or leave each housing.
- Hydraulically actuated pistons move the friction pads to bring them in contact with disc applying equal and opposite forces on the disc.
- On releasing brakes piston and friction pads retract them away from disc.

