

## Unit-IV

### Vehicle Systems

**CO4:** Illustrate various basic parts and transmission system of a road vehicle

*Introduction of chassis layouts, steering system, suspension system, braking system, cooling system and fuel injection system and fuel supply system. Study of Electric and Hybrid Vehicle systems. Study of power transmission system, clutch, gear box (Simple Numerical), propeller shaft, universal joint, differential gearbox and axles. Vehicle active and passive safety arrangements: seat, seat belts, airbags and antilock brake system.*

#### Introduction of Chassis Layout:

Chassis is a metallic structure on which various other components / assemblies are mounted. The chassis contains all the major units necessary to propel the vehicle, guide its motion, stop it and allow it to run smoothly over uneven surfaces.

The chassis includes the following major components,

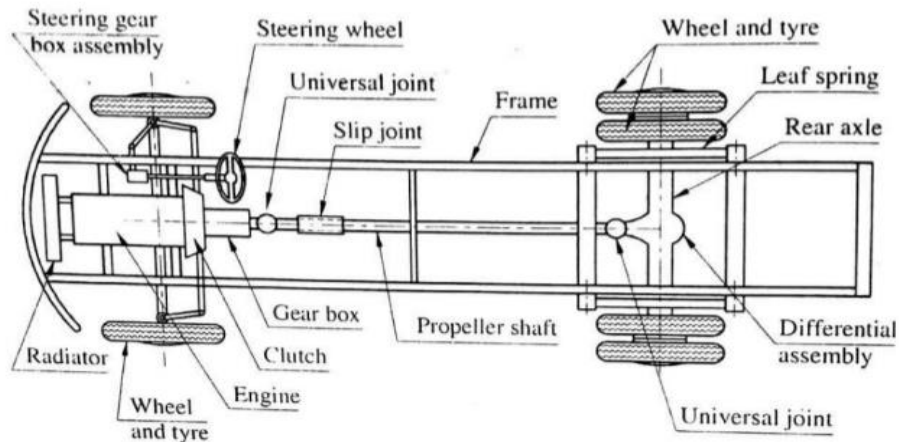
- I. A steel frame, which is a major part.
- II. In case of a passenger car, the whole body is also an integral part of the chassis. However, in commercial vehicles like trucks and buses, the body is not a part of the chassis. Therefore, a chassis is almost a complete vehicle except the body and other accessories, which are not involved in the movement of the vehicle.
- III. Other major components include engine, transmission system, front and rear axle, steering system, suspension system, wheels, tyres and brakes.

#### Functions of the chassis :

The functions of the chassis includes

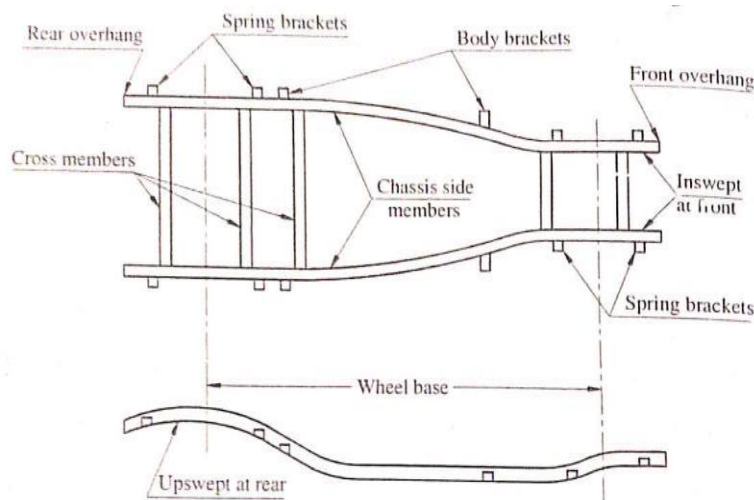
- I. carrying the weight of the vehicle and its passengers,
- II. withstanding the engine and transmission torque and thrust stresses, as well as accelerating and braking torque,
- III. withstanding the centrifugal force while taking a turn and
- IV. withstanding the bending load and twisting due to the rise and fall of the front and rear axles.

## Layout of chassis:



## Vehicle Frame:

- Function: to carry all main components or sub assemblies to make entire automobile systems.
- It is the supporting component of automobile vehicle.
- It is the foundation for carrying the engine, transmission system & steering system by means of spring , axle , rubber pads etc.
- The frame are made of box , tubular channels or U-shaped section , welded or riveted together.



An automobile is made up of mainly two units, these are Chassis and Body.

“Frame” + “Base components” = “Chassis”

“Chassis” + “Body” = “Vehicle”

## Types of Chassis:

- Backward control ( conventional chassis)
- Forward control
- Semi – forward control

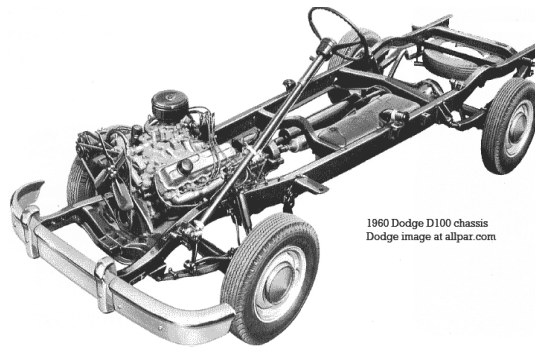
### 1. Conventional chassis:

- Engine is fitted in front of the driver cabin or driver seat such as in *cars*.
- Chassis portion can not be utilized for carrying passengers and goods.



### 2. Semi-forward chassis

- Half portion of the engine is in the driver cabin & and remaining half is outside the cabin such as in *Tata trucks*.
- In this arrangement a part of the chassis is utilized for carrying extra passengers



### 3. Full-forward chassis

- Complete engine is mounted inside the driver cabin
- Driver seat is just above the front wheel



## Types of Automobile Chassis Drive:

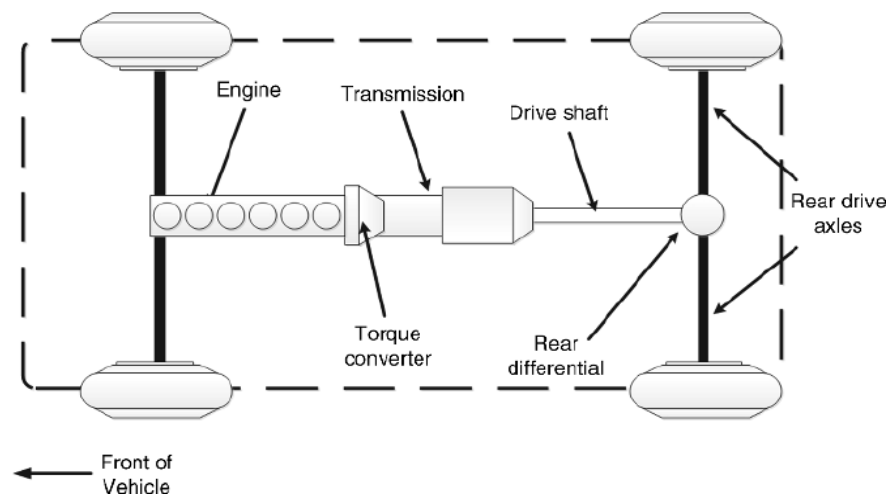
It depends on engine mounting and its power transmission to wheels

1. Front engine rear wheel drive
2. Rear engine rear wheel drive
3. Front engine front wheel drive
4. Four wheel drive
5. Articulated vehicle layout

### 1. Layout of front engine rear wheel drive :

In this drive the engine in the front of the vehicle and the drive is transmitted to rear wheels.

This configuration known as front-engine rear-wheel drive layout.



### Advantages:

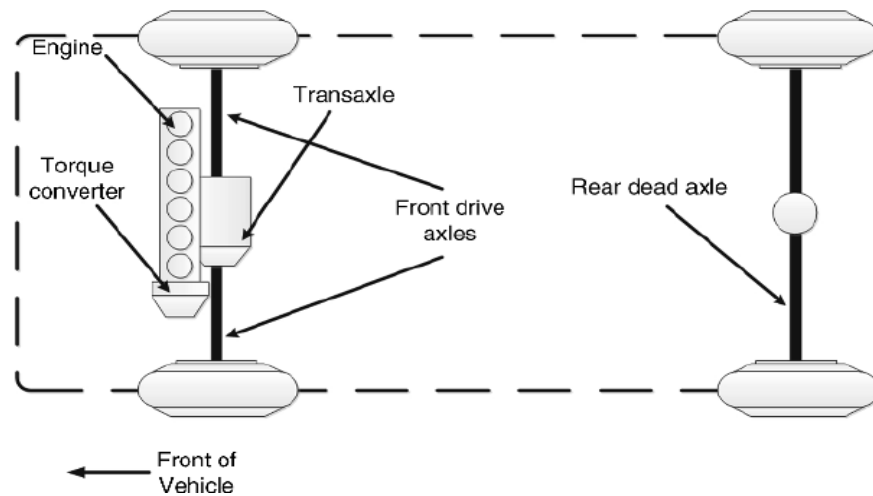
- Balanced weight distribution
- Luggage space available
- Control Linkages are short and simple
- Better engine cooling by taking full benefits of natural air stream flowing across the radiator
- Accessibility to various engine component is easier

### Disadvantages

- It requires long propeller shaft to transmit the power to differential at rear
- Increased weight
- Decrease interior space
- Higher noise transmitted from front engine to driver cabin

## 2. Layout of front engine front wheel drive :

This layout is the most compact layout. It is being popularly used on most cars in India.



### Advantages:

- Compact design of vehicles. Maximum passenger space
- Less weight
- No propeller shaft is required
- Due to higher Weight of the steering wheels , it provides stable steering during turns .
- Better engine cooling by taking full benefits of natural air stream flowing across the radiator

### Disadvantages:

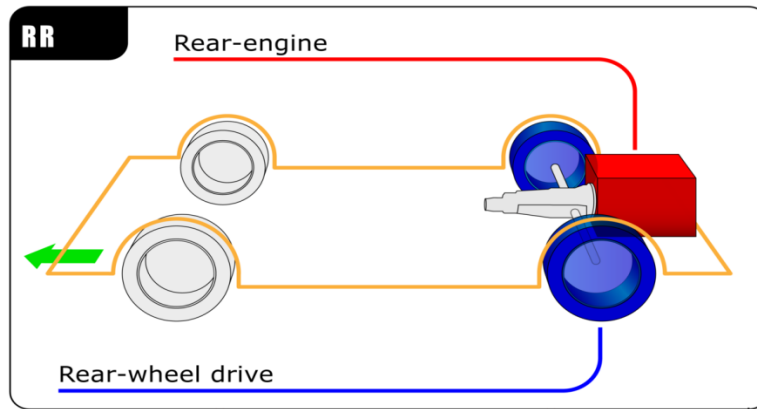
- More tractive effort required( Front wheel design is complicated)

#### Complicated Design

- Less radius of turning
- High noise transmission from engine compartment to cabin
- Poor ability of the vehicle to climb a steep hill because of lower weight on rear wheel

## 3. Layout of rear engine rear wheel drive :

This layout consists of placing the engine, clutch and gearbox in the back. So taking the space of the boot. In these type of layout more than 50% of the weight is on the rear axle. The necessity of the propeller shaft is completely eliminated. The clutch, gear box and engine and final drive form a single unit.



### Advantages :

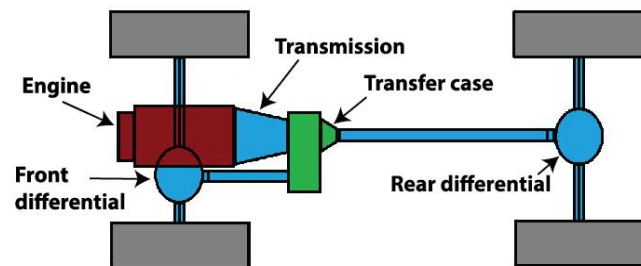
1. Excellent traction is available while climbing hills.
2. A larger passenger space is available for the given length of body.
3. Very compact and accessible power and transmission assembly is provided.
4. Passengers are comfortable from engine noise, heat and fumes.
5. Front of the vehicle provides good visibility and by designing the body to aerodynamic shape gives good streaming lining.

### Disadvantages :

1. Long linkages are required
2. No natural air cooling requires powerful radiator fan
3. Uneven weight distribution
4. Becz. of higher wt distribution at rear the vehicle has tendency to oversteer

### 4. Layout of four wheel drive :

These four wheel drive vehicles are very useful on Hill station if one of the wheel slipping or skidding then the other axle wheel transmit the tractive force to the vehicle. The steering of the four wheel drive is hard to operate compared with other type of drive.



### Advantages :

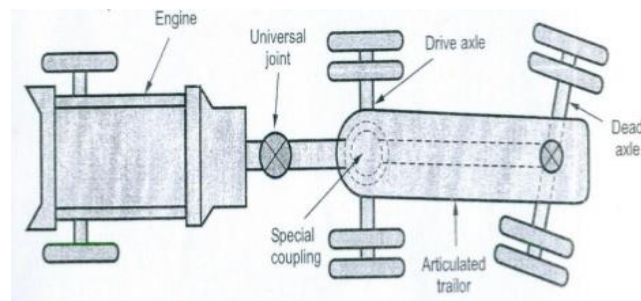
1. Traction is nearly doubled compared to a two-wheel drive layout.
2. Excellent road Handling characteristics
3. Gives sufficient power in unparalleled acceleration and drivability on surfaces with less than ideal and superior engine braking on loose surfaces.

### Disadvantages :

1. The manufacturing cost of the vehicle is high.
2. More component and complicate transmission.
3. Increased power-train mass, rotational inertia and power transmission losses.
4. Increased fuel consumption compared to 2WD.

### 5. Articulated vehicle Layout :

This layout is used for very high load carrying vehicle like truck, tractor. It consist very powerful engine at front. The tractor part of vehicle can be a four wheel or six wheeled and consist of a drive axle.



### Advantages :

1. It provides large luggage / load carrying capacity.
2. Tractor compartment can be easily disengaged & connected to another preloaded trailer, hence reduced loading & unloading time

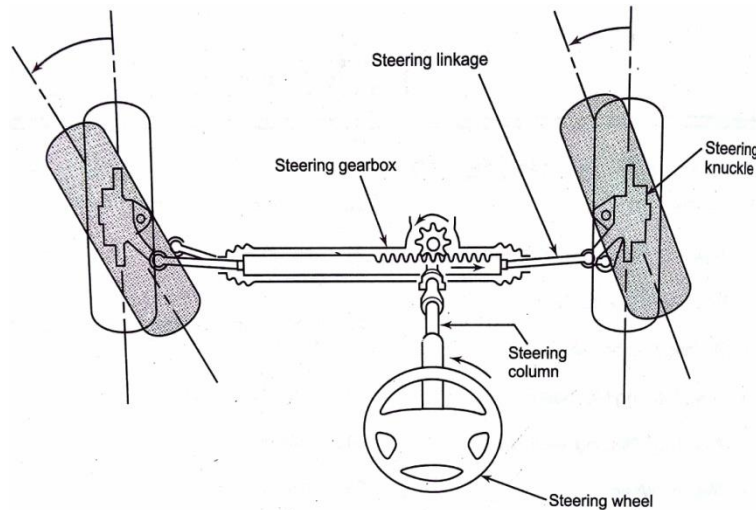
### Disadvantages :

1. Difficult to drive on sharp turn.
2. Heavy vehicle weight is uneconomical for fuel efficiency
3. High cost

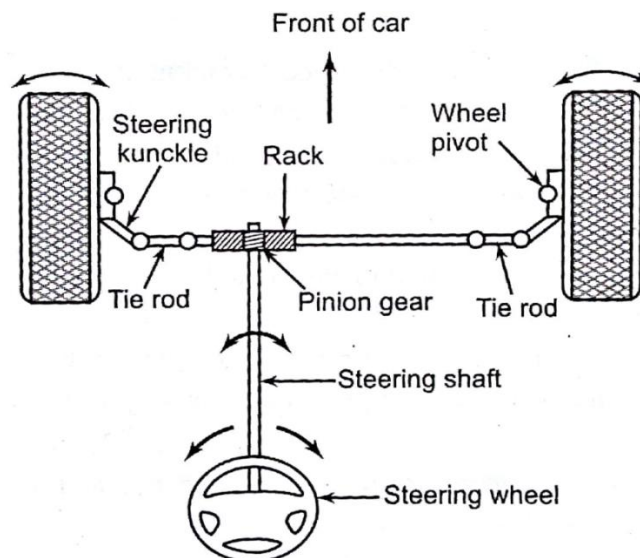
## Steering System:

Steering mechanism is used in the automobile for changing the directions wheels with respect to chassis. So as to move vehicle in desired path.

The steering mechanism includes a steering wheel, which the driver controls, a steering gear, which converts rotary motion of steering wheel in to straight line motion and steering linkages.



When the driver operates the steering wheel, the steering shaft passing through the steering column also rotates with it as it is fixed to steering wheel. This motion of steering shaft is transfer to the steering gear box. It is then converted in to the lateral motion (i.e. straight line motion) by the gear box and transferred to the steering linkages. The left and right linkages are connected to steering knuckles on the left and right wheel respectively. The each knuckle is provided on the suspension's upper and lower arms and rotates about axis when force is applied. This causes wheel to move left or right, allowing the direction of vehicle to be changed.





The steering system should possess the following qualities:

- i. It must be capable of keeping the wheels in true rolling motion at all times without rubbing or scuffing of tyres on road.
- ii. It should have a certain degree of self centering action to keep the vehicle on a straight path.
- iii. It must be easy to operate.
- iv. It should be light i.e. it should not require excessive effort to turn the steering.

#### Function Steering System:

1. To Achieve angular motion of front wheel to navigate turn
2. To provide directional stability while moving ahead
3. To minimize wear & tear of tyres
4. To provide perfect rolling motion of the road wheel all times
5. To facilitate straight ahead recovery after completing turn

#### Steering Mechanism:

For perfect steering, it must always have an instantaneous center about which all the wheels must rotate. To achieve this inner wheel has to turn more than the outer wheel. Two types of mechanism are available, viz., the Davis and the Ackermann steering mechanism. Out of these Ackermann type is more popularly used because of its simplicity. It also lessens wear of tyre and lowers friction.

The major elements of steering mechanism are :

**1.Steering Linkages :** A steering linkage is the part of an automotive steering system that connects to the front wheels. In a commercial vehicle a rigid axle type front suspension system is used.

**2.Steering Wheel:** It is made of polyurethane or hard plastic. It consists of a circular rim with a hub at the center. The rim is slightly elliptical in cross section to maintain strength and provide hand grip. The steering shaft is mated in the undulations cut on the inside of the steering wheel hub.

**3.Steering Column:** It is tubular in nature. It provides switches for horn, light and wiper for easy and quick operation. The collapsible columns are used for safety, which collapse upon impact and reduce the chances of injury to the driver.

**4.Steering Shaft:** It is made from drop forged alloy steel. It connects the steering wheel to the steering gear box and transfers movements of the steering wheel to the steering gear, or to the pinion.

**5.Drop Arm:** It is also called as pitmen arm. It is made up of drop forged steel. It connects the cross shaft with the draglink.

**6. Draglink (Link rod):** It connects the drop arm to the steering knuckle. It is also made up of drop forged steel. The tie rod ends at different parts of the steering linkage will be connected to the ball joints which provide angular motion to the steering system.

**7. Steering Gears:** The steering gear converts the turning motion of the steering wheel into the to-and-fro motion of the link rod of the steering linkage. It also provides the necessary leverage so that the driver is able to steer the vehicle without fatigue.

### Principle of Correct Steering:

The steering gear mechanism is used for changing the direction of two or more wheel axles with reference to the chassis, so as to move the vehicle. Usually, the two back wheels have a common axis, which is fixed in direction with reference to the chassis and the steering is done by means of front wheels.

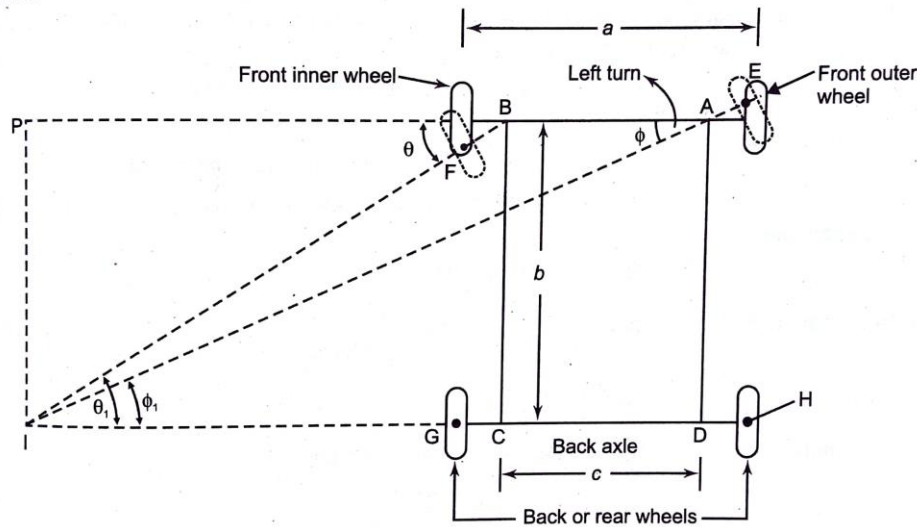


Fig. Steering Gear Mechanism

In automobiles, the front wheels are placed over the front axles, which are pivoted at the points A & B as shown in fig. These points are fixed to the chassis. The rear wheels are placed over the back axle. When the vehicle takes a turn, the front wheels along with respective axles turn about the respective pivoted points. The rear wheels remain straight and do not turn. Therefore steering done by means of front wheels only.

In order to avoid skidding, the two front wheels must turn about the same instantaneous centre I, which lies on the axis of back wheels. If the instantaneous centre of two front wheels do not coincide with the instantaneous centre of rear wheels, the skidding of the front or rear wheel will definitely take place, which will cause more wear and tear of tires.

Thus, condition of correct steering is that the four wheels must turn about the same instantaneous centre. The axis of the inner wheel makes a larger turning angle  $\theta$  than the angle  $\phi$  subtended by the axis of outer wheels.

In order to achieve correct steering mechanism following two types of mechanisms are used:

- (a) Davis steering mechanism
- (b) Ackerman steering mechanism

### Ackerman Steering Mechanism:

The Ackerman steering gearing mechanism consists of four link mechanism ABCD as shown in fig. (a). The shorter links BC and AD are of equal length and are connected with the stub axles BF and AE respectively. The longer link AB and CD are of unequal length. The length of the link CD (the moving link between the stub axles) is shorter than that of the link AB. When the vehicle is moving ahead in straight position, the links BC and AD are parallel and subtend equal angles (i.e.  $\theta = \phi$ ) with the centerline of the vehicle.

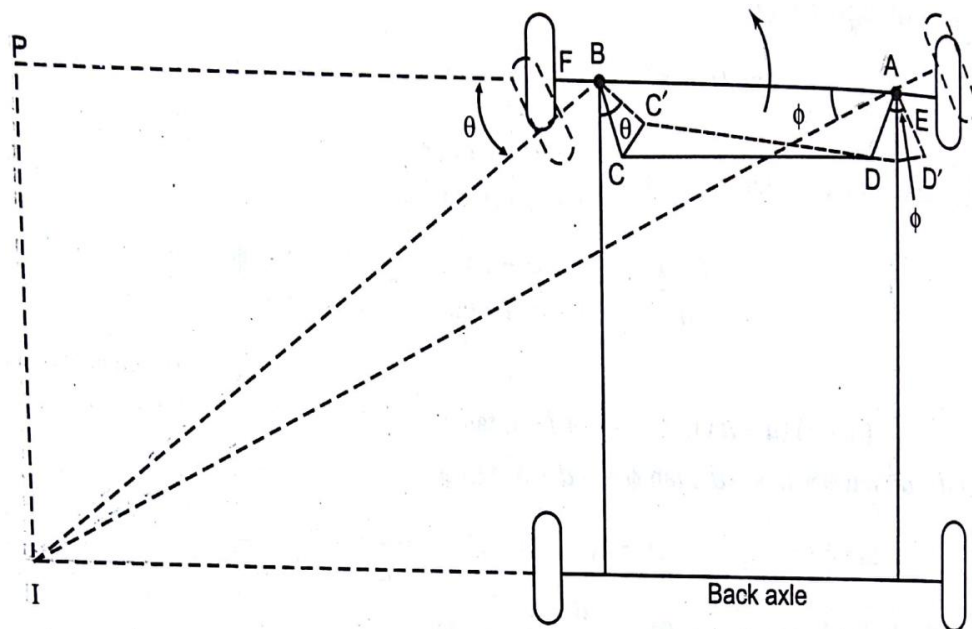


Fig. (a) Ackerman Steering Gear Mechanism.

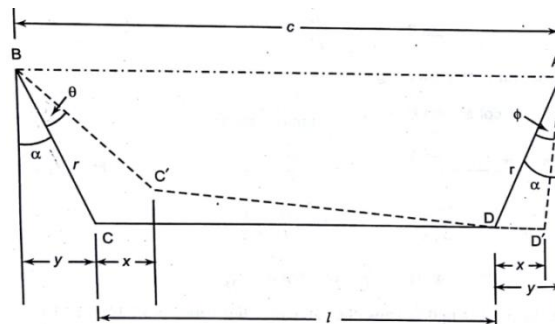


Fig. (b) Ackerman Steering Gear Mechanism

When the vehicle is turned to left, the stub axle AE and BF turn through different angles, in respect to their previous positions. The stub axle BF will turn through a greater angle  $\theta$ , then the stub axle AE, which will turn through an angle  $\phi$  as shown in fig. (b). In this position, the lines from the front wheels axle intersect on the rear wheels axle at the instantaneous centre I. This arrangement is known as Ackerman steering mechanism.

## Suspension System:

A vehicle is run on different type of road conditions. To isolate the passengers and other vehicle compartment from the regular routines of road surface the vehicle chassis is not directly mounted on axle. Spring of suspension system in between passenger compartment and axle isolates the vehicle from road conditions. The suspension system consists of spring and damper assembly.

### Functions of suspension system :

- To safeguard the occupants against road shocks and provide riding comfort.
- To minimize the effects of stresses due to road shocks on the mechanism of the motor vehicle and provide a cushioning effect.
- To keep the body perfectly in level while travelling over rough uneven ground, i.e., the up and down movement of the wheels should be relative to the body.
- To isolate the structure of the vehicle from shock loading and vibration due to irregularities of the road surface without impairing its stability.
- To provide the requisite height to the body structure as well as to bear the torque and braking reactions.

**1.Knuckle:** A knuckle is provided with a king pin and caster angles that helps the front wheels of the vehicle to steer in right or left direction which in turns steers the vehicle.



**2. Springs:** Springs are the critical component in the suspension system that absorb the shocks and bumps while the car is in motion.



**3. Shock absorber:** These are generally fluid filled and work in tandem with the spring to minimize the shocks or vibrations.



**4. Strut:** It joins the spring and shocks. It also provide dampening function as well as structural support for the vehicle suspension.



**5. Anti Sway Bars:** The anti sway bars are used for providing further stability to the moving vehicle.



**6. Spindle:** This part ties the wheel and tyre into the steering system

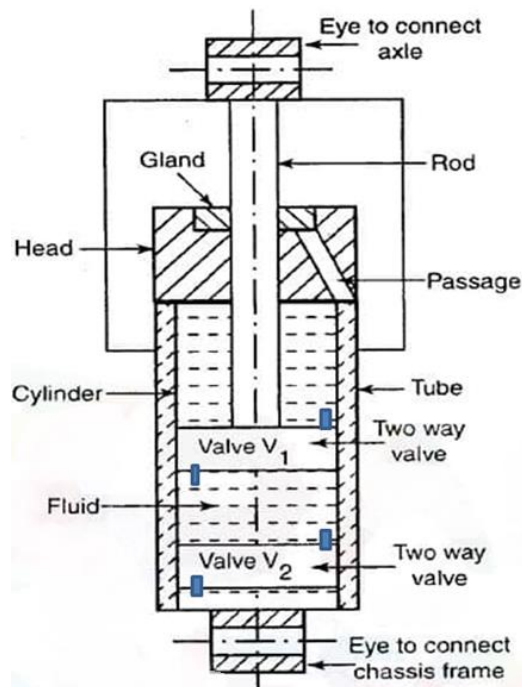


## Telescopic suspension system (hydraulic shock absorber):

It works on the principle that when a piston forces the fluid in a cylinder to pass through a small hole then the fluid offers resistance to the piston movement.

### Construction

Figure shows cut section of hydraulic type telescopic shock absorber the assembly consists of sheet metal body which covers piston rod and cylinder unit. Cylinder C houses the wall A and B. Cylinder C surrounded by outer tube D. Wall A and B have small orifice through it. Upper mount is connected to vehicle frame while the lower mount is connected to the axle. Fluid used in shock absorber is a mixture of 60% transformer oil and 40% turbine oil.



**Working:** When the vehicle comes across a bump the lower mount (eye) pushes the cylinder C upwards. This causes fluid in between valve A and B to move out and enter in chamber above valve A. Since the volume holding capacity of chamber above valve A is less due to presence of piston rod the upward movement of cylinder C is restricted. Then fluid from chamber below valve B is forced out through the small orifice into the outer tube D. The resistance offered by fluid to flow through small openings provides the damping effect.

### Hydraulic Suspension:

Hydraulic suspension combines rubber springs with a damper system, linking the front and rear wheel on the same side of the car. As the front wheel rises over a bump, some of the fluid from its suspension unit (known as a displacer unit) flows to the rear-wheel unit and raises it, so

tending to keep the car level. In each of the displacer units, the fluid passes through a two-way valve, which provides the damping effect. Once the rear wheel has passed over the bump, the fluid returns to the front displacer unit and the original level is restored.

### 1. Hydraulic Shock Absorber:

It is a mechanical device designed to absorb shock impulses. This device is also used for checking or damping out the suspension spring to a comfort level.

### 2. Telescopic Fork Absorber:

A telescopic fork is a form of motorcycle front suspension whose use is so common that it is virtually universal. The telescopic fork uses fork tubes and sliders which contain springs and dampers.

### Air Suspension:

In this suspension, compressed air is used as a spring. This suspension system is operated with air and controlled by a microprocessor. It helps in maintaining self-driving conditions and supports the weight of the vehicle

## Braking System:

- The brake is used to slow-down or stops the motion of the moving member whenever required. In other words brakes are one of the very important control components of vehicle.
- The main function of brake is to stop the vehicle within the smallest possible distance. This is done by converting the kinetic energy of the vehicle into heat energy & this heat dissipated in environment. In braking action, the kinetic energy is converted into heat by friction and the generated heat is ultimately dissipated to the atmosphere.

### Brake performs following functions:

1. It stop the vehicle in minimum possible time.
2. It helps in controlling the speed of the vehicle and to reduce the speed at turnings and other crowded places.
3. It holds the vehicle in its stationary position, without the presence of the operator.
4. To provide mean to stop the vehicle while the engine is running
5. To provide emergency stop of the vehicle within lowest time & distance.

**Classification of Brake system:**

## 1. On the basis of mode of actuation:

- (i) Foot brake (also called the main brake) operated by foot pedal.
- (ii) Handbrake – it is also called parking brake operated by hand

## 2. On the basis of mode of operation

- (i) Air brakes
- (ii) Electric brakes
- (i) Hydraulic brakes
- (ii) Mechanical brakes
- (iii) Vacuum brakes

## 3. On the Basis of Action on Front or Rear Wheels

- (i) Front-wheel brakes
- (ii) Rear-wheel brakes

## 4. On the Basis of Method of Application of Braking Contact

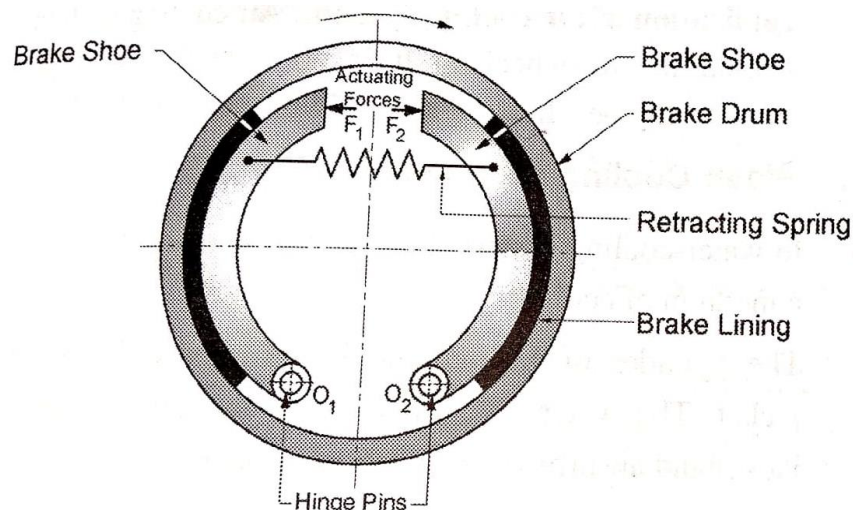
- (i) Externally – contracting brakes
- (ii) Internally – expanding brakes

## 5. By construction –

- (i) Drum type brake,
- (ii) Disc type brake

**Drum Break:**

Drum breaks are the cheapest and most widely used brakes. It consists of a rotating brake drum mounted on the wheel and two semi-circular brake shoes attached in a stationary back plate. The pressing of brake shoes on the rotating drum causes friction resulting in breaking





**Construction:** Figure shows a drum brake system and its component brake drum is a hollow cylinder type construction which is mounted concentric to axle hub and rotates along with wheel. a separate backlit is mounted on stationary axle casing and behind the brake drum consists of semicircular brake shoes mounted on an anchor. The brake plate along with brake shoe assembly remains stationary. The two brake Shoes are pivoted to anchor at one of its end. The other end of brake shoe is held by an expander. The compression type reactor spring connected between the brake shoe try to put them inwards.

**Working:**

The drum mounted on axle hub continues to spin along with the wheel when the brake pedal is pressed the breaking a forth is transferred to the expander true and activation mechanism. This result in a force  $F$  at the expander pushing the brake shoe on the drum against the spring force. The friction between stationary brake shoe and revolving brake drum provides the braking action. When the brake pedal is released the reactive spring pools the brake shoes inward to disengage the brake. An adjuster is also provided to compensate for wear and tear of brake shoes.

**Drum brake advantages**

- Provide better braking
- Design & construction is simple
- Economical
- Drum brakes are cheaper to manufacture.
- Rear drum brakes generate lower heat.
- Drum brakes have a built-in self energizing effect that requires less input force
- Brake shoes can be remanufactured for future use.

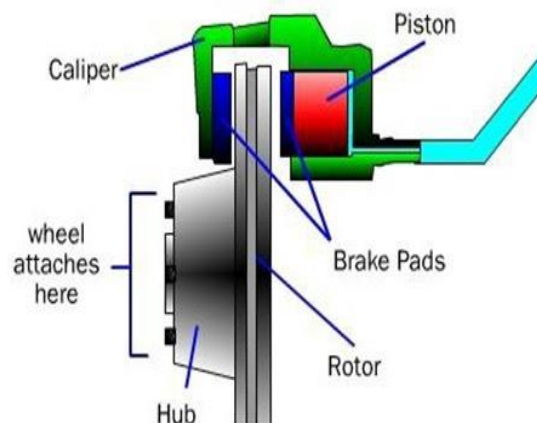
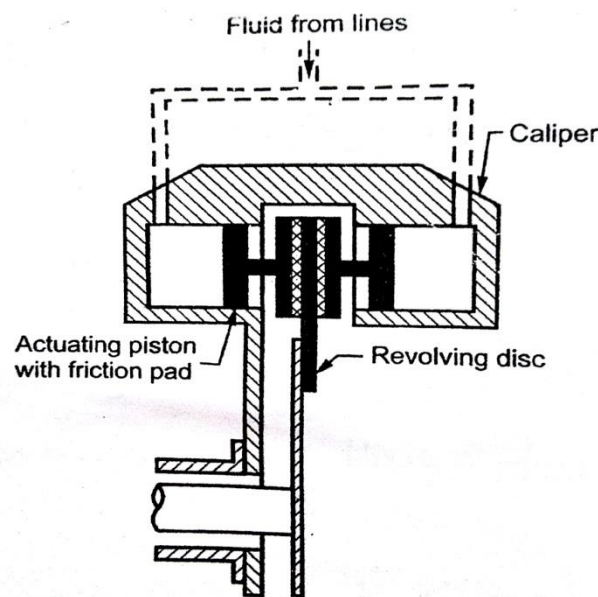
**Drum brake disadvantages**

- Wear & tear is not uniform
- Excessive heating can happen due to heavy braking, which then can cause the drum to distort, and thus cause vibration under braking.
- Under hard braking, the diameter of the drum increases slightly due to thermal expansion, the driver must press the brake pedal farther.
- Brake shoes can overheat to the point where they become glazed.
- Maintenance of drum brakes is more time-consuming, compared to disc brakes.

## Disk Break: (Hydraulic braking system)

The disc brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc (or rotor in U.S. English) is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon-carbon or ceramic-matrix composites.

This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brake caliper assembly usually consisting of one or two hollow aluminum or chrome-plated steel pistons (called caliper pistons), a set of thermally conductive brake pads and a rotor (also called a brake disc) or drum attached to an axle. The system is usually filled with a glycol-ether based brake fluid (other fluids may also be used).



WORKING OF DISK BRAKES

In a hydraulic brake system, when the brake pedal is pressed, a pushrod exerts force on the piston(s) in the master cylinder, causing fluid from the brake fluid reservoir to flow into a pressure chamber through a compensating port. This results in an increase in the pressure of the entire hydraulic system, forcing fluid through the hydraulic lines toward one or more calipers where it acts upon one or two caliper pistons sealed by one or more seated O-rings (which prevent leakage of the fluid).

The brake caliper pistons then apply force to the brake pads, pushing them against the spinning rotor, and the friction between the pads and the rotor causes a braking torque to be generated, slowing the vehicle. Heat generated by this friction is either dissipated through vents and channels in the rotor or is conducted through the pads, which are made of specialized heat-tolerant materials such as Kevlar or sintered glass.

#### Advantages:

- Operation & assembly of disc brake is simpler
- As the friction pads are flat wear & tear is uniform
- Heat dissipation is faster
- Fewer moving parts. ...
- Longer life due to fewer moving parts and more effective heat dissipation.
- Friction pads are easily accessible for replacement or inspection.
- Easy access to caliper for cleaning and maintenance.
- Entire caliper can be removed for maintenance without removing rotor and hub.

#### Disadvantages:

- Overall system cost is higher due to hydraulic caliper & fluid line
- If any air remains in disk brake system, it can be problematic as brakes may not work effectively.
- Disk brake assembly has more moving parts and it is more complex than drum brakes.

### Anti-lock Braking System :

The antilock brake system (ABS) prevents the wheels of a vehicle from locking when the brakes are applied, thus maintaining the ability to steer a vehicle. The locking of front or rear wheels of a vehicle is extremely dangerous.

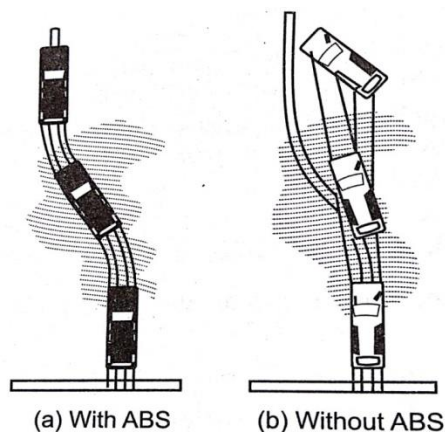


Fig. Antilock braking system

When the front *wheels are locked* (i.e. during hard braking or when the brakes are used on a slippery road surface), the driver loses the control of direction and the vehicle continues to move in its current direction. When the rear wheels are locked, the vehicle can spin around, thereby creating an extremely unstable condition. An ABS controls the brakes in such a way that the wheels do not lock. Fig. shows the effect of ABS a vehicle, on which the brakes are applied on a slippery surface

### Operation of Antilock Brake System :

- 1 . Speed sensors:** It provides the information regarding the wheel lock up to the dedicated electronic control unit (*i.e.* ABS ECU).
- 2. Modulator:** It controls the brake fluid pressure to each wheel.
- 3. Electronic control unit:** It controls the complete system operation. It receives the signals from the wheel sensors and controls the modulator.

The wheel sensors detect any sudden changes in wheel speed. The ECU constantly monitors the vehicle speed and compares signals received from the four wheel speed Sensors. The ECU then judges the slip ratio of each wheel and instructs the modulator to provide optimum braking pressure to each wheel. Thus, as a result, the wheel speed recovers to a level at which locking does not occur. Then the ABS ECU causes the modulator to reapply the brake by increasing the fluid pressure. Thus, the wheel speed drops again to a level at which locking can occur. This operation is repeated very fast and the ABS keeps the wheel close to a lockup condition.

The antilock braking system consist following parts as shown in fig.

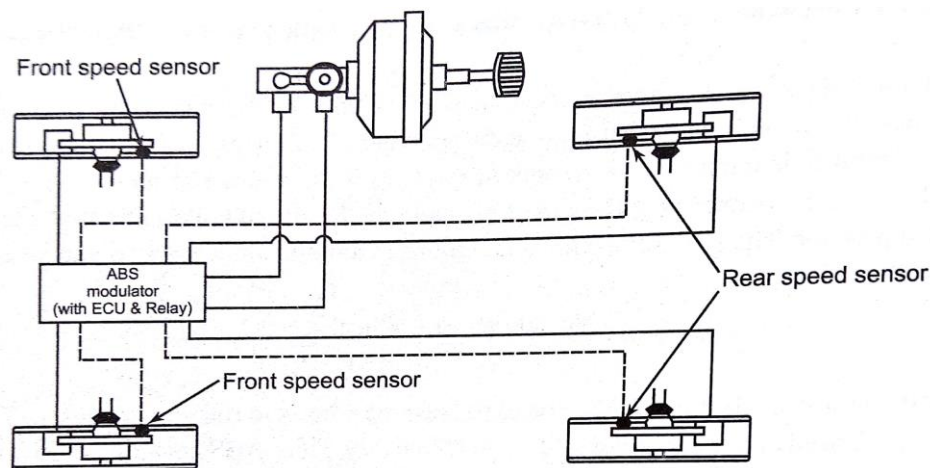


Fig.Operation of Antilock Braking System

**Advantages:**

1. It prevents the locking of the wheel and thus eliminates the chance of skidding.
2. The skidding of the vehicle is completely removed, which results in excellent control during braking?
3. A better steering control is obtained with the ABS system.
4. It reduces the chance of collision by 30 %.

**Disadvantages:**

A vehicle equipped with ABS (Anti-lock Braking System) is costlier as compared with a vehicle without ABS.

**Need of Antilock Braking System**

- The main problem with conventional braking was ,when a driver applies brakes ,all the wheels got lock resulting in loosing control over steering as one can steer vehicle only when the wheels are rotating.
- The second major problem with conventional braking was skidding of vehicle. When the driver applies brakes and all or front wheels or rear wheels are locked there is a major possibility of skidding of vehicle.
- The third major problem with conventional braking system was stopping distance of vehicle while braking. There are many emergency situations while driving , a driver should stop vehicle completely. The stopping distance was not so fair .
- Fourth problem with conventional braking was low directional stability. In the most conditions of emergency braking situations driver loses his vehicle's directional stability.
- Fifth problem which every driver takes a lot care in worst weather conditions like wet and slippery roads.
- Sixth problem is about safety concern of driver as well as of the people who are travelling inside the vehicle.

**Cooling System:**

In case of IC engine the energy input to the engine cylinder is by burning the fuel in engine which increases the temperature up to 2500° C. Therefore cooling of the engine is required to prevent overheating of components & to remove excess heat energy to maintain the practical operating temperature.

The cooling system has three primary functions, which are as follows.

- Remove excess heat from the engine
- Maintain a constant engine operating temperature
- Increase the temperature of a cold engine as quickly as possible by maintaining the thermostat valve in a closed position which is fitted in the path of coolant circulation
- To prevent the damage of vital engine components

#### Necessity of Cooling:

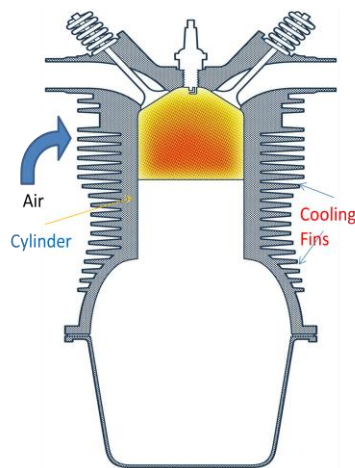
The cylinders of internal combustion engines require cooling because the engine cannot convert all the heat energy released by combustion into useful work. Liquid cooling is employed in most of the IC engines.

#### Types of cooling system:

- Air cooling system (Direct Cooling)
- Liquid cooling system (Indirect Cooling)

#### Air-Cooling System :

The simplest type of cooling is the air-cooled, or direct, method in which the heat is drawn off by moving air in direct contact with the engine. Several fundamental principles of cooling are embodied in this type of engine cooling.



In air cooling object to be cooled have larger surface area surface area is increased by providing cooling fins are having an increased flow of air over its surface or both.

In small capacity IC engine the cylinder block and cylinder head provided with cooling fins on its outside surface and air is allowed to flow over the cylinder allowing it to convey heat by convection process the method of convection employed can be natural convection or forced convection.

The air cooling is mostly applied to small capacity engines like motorcycle scooter etc. Sometimes it is also employed in stationary engines having smaller capacity.

The cooling rate between material and air is lower due to lower heat transfer coefficient the cylinder wall temperatures of air cooled engines are higher than the water cooled engines.

**The amount of heat dissipated depends upon**

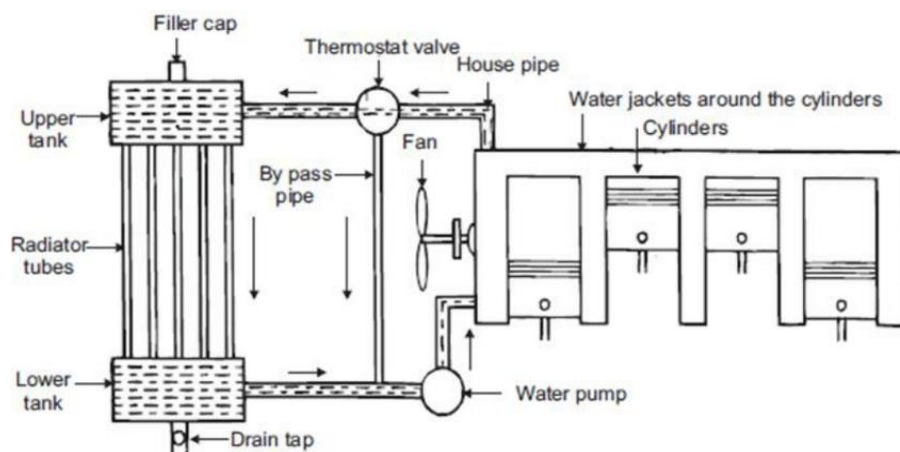
- The cooling surface area in contact with passing air
- Rate of mass flow of air over cooling area
- Effective temperature difference between the cylinder and air
- Coefficient of heat transfer of metal in air

Cooling fins are used to increase heat dissipation of the engine by increasing the cooling surface area. The cooling fins are either cast integrally with the engine or attached separately to external surface of the engine. The heat transfer capacity of fin depends on type of cross section and length of the fin.

### **Water cooling system:**

Water cooling is mainly preferred in medium and large size engines.

Nearly all multi cylinder engines used in automotive, construction, and material-handling equipment use a liquid-cooled system. Any liquid used in this type of system is called a COOLANT. A simple liquid-cooled system consists of a radiator, coolant pump, piping, fan, thermostat, and a system of water jackets and passages in the cylinder head and block through which the coolant circulates. The pump draws the coolant from the bottom of the radiator, forcing the coolant through the water jackets and passages, and ejects it into the upper radiator tank. The coolant then passes through a set of tubes to the bottom of the radiator from which the cooling cycle begins.





The water cooling system shown in figure. Water is circulated through to the water jacket provided around the cylinder wall the water extract the heat from cylinder wall and release it to atmosphere. Water jacket is connected to a radiator through thermostat valve. To avoid over cooling of the engine the thermostat is used. The thermostat maintains the constant temperature of cooling water which in turn maintains the temperature of engine within desirable limit. Radiator is a kind of heat exchanger which cools and hot water coming through water jacket and it recirculates the cold water to engine for cooling purpose.

The radiator is situated in front of a fan that is driven either by the water pump or an electric motor. The fan ensures airflow through the radiator at times when there is no vehicle motion. The downward flow of coolant through the radiator creates what is known as a thermo siphon action. This simply means that as the coolant is heated in the jackets of the engine, it expands. As it expands, it becomes less dense and therefore lighter. This causes it to flow out of the top outlet of the engine and into the top tank of the radiator. As the coolant is cooled in the radiator, it again becomes more dense and heavier. This causes the coolant to settle to the bottom tank of the radiator.

The heating in the engine and the cooling in the radiator therefore create a natural circulation that aids the water pump. The amount of engine heat that must be removed by the cooling system is much greater than is generally realized.

### **Fuel supply system:**

The basic function of this Fuel system is to supply vaporized air fuel mixture to engine cylinder

The basic fuel supply system in an automobile consists following elements

- Fuel Tank
- Fuel Lines
- Fuel Pump
- Fuel Filter
- Air Cleaner
- Carburetor
- Inlet Manifold
- Supply And Return Pipelines

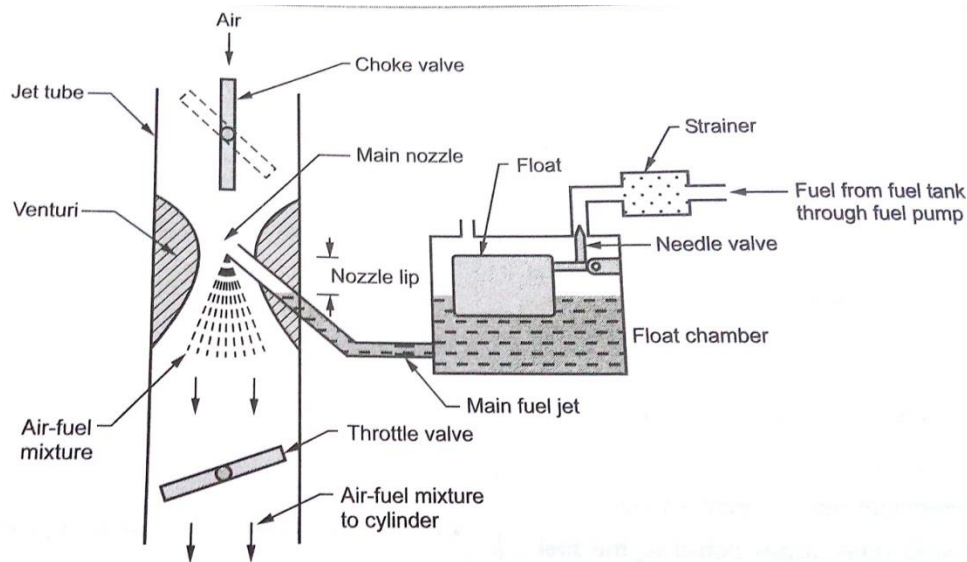


## Simple carburetor:

We know that the purpose of carburetion process is to provide a homogeneous air fuel mixture.

The simple carburetor consists of following elements

1. Float chamber
2. Fuel discharge nozzle
3. A metering orifice
4. A venturi
5. Throttle valve
6. Choke



The float and needle valve maintain the fuel level in the tank

If the fuel level goes down the fluid goes down admitting fuel opening the float needle valve. When the fluid level is optimum the flow is stop. The fuel strainer is used to trap the impurities from the field and prevent choking of the female nozzle. The fuel level in a float chamber is maintained just below the tip of nozzle to avoid fuel flow from the nozzle. The difference between top of nozzle and level in fuel chamber is known as jet tip.

When the piston moves from TDC to BDC it creates vacuum in the engine cylinder due to suction the air flows from intake manifold and carburetor to the cylinder. When air passes through the venturi the velocity of air increases and pressure falls below atmospheric pressure. Due to increase pressure at Venturi a pressure differential is created between nozzle and flow chamber due to this pressure difference the fuel is sprayed into to the air stream which mixes with air. This is air fuel mixture is supplied to engine cylinder. The quantity of air fuel mixture

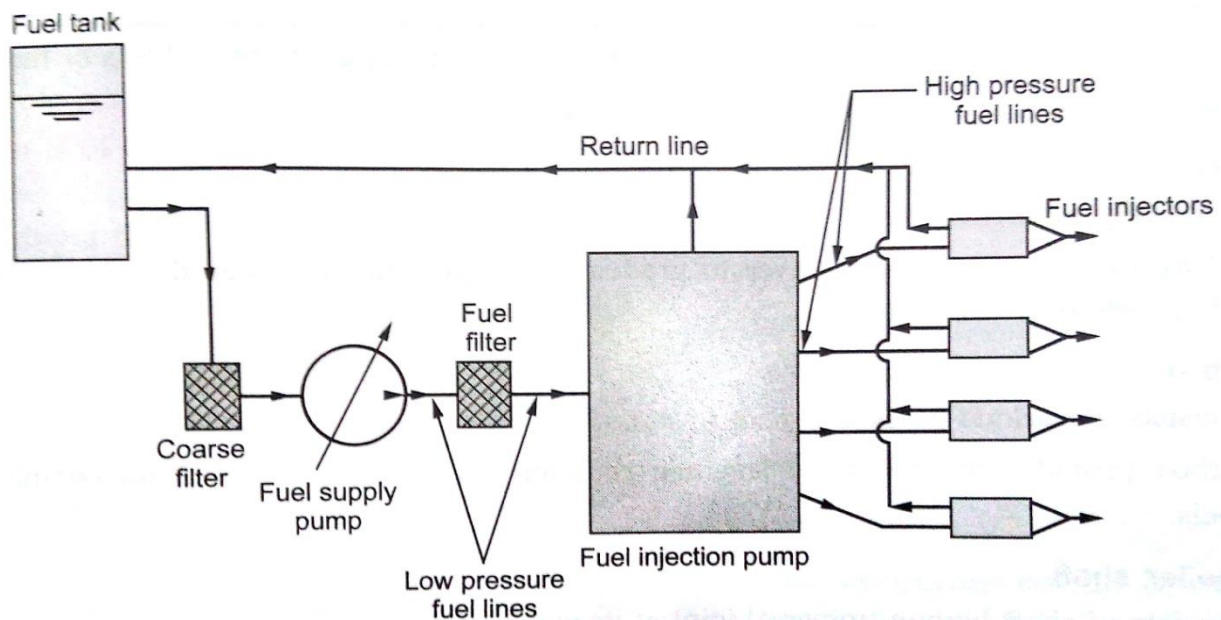
delivered is controlled by throttle valve. The simple carburetor is used in small capacity stationary engine which runs at constant speed.

## Fuel injection system

The fuel injection system is one of the most important part of the diesel engine

It supplies, meters, injects and optimizes the fuel. It is a direct method of introducing fuel into the engine without the use of carburetor for mixing air and fuel.

It is considered to be the heart of the diesel engine as it plays a very important role. The ignition of fuel is depending on the optimization of the fuel and pressure of fuel injection the performance of engine depends on the performance of fuel injection system.



The fuel injection system consists of real tank fuel filter fuel pump fuel supply line and fuel injectors the simple layout of fuel injection system is shown in figure.

The fuel from the fuel tank is drawn into a fuel supply pump through the course filter. In this the pressure of fuel is increased slightly.

Then the fuel supplied to fine filter in which all the particles are removed, then the fuel is supplied to high pressure fuel injection pump where the pressure of fuel is raised to around 250 bars and then it is injected into the cylinder by injectors. The return line collects the extra fuel and returns it to the fuel tank.

## Advantages of Fuel Injection over Carburetor

- Fuel injection has no choke, but sprays atomized fuel directly into the engine.
- Electronic fuel injection also integrates more easily with computerized engine control systems.

- Multi point fuel injection delivers a more evenly distributed mixture of air and fuel to each of the engine's cylinders.
- Sequential fuel injection improves power and reduces emissions.

#### Single Point Injection system:

- The earliest & simplest type of fuel injection, single point simply replaces the carburetor with one or two fuel injector nozzles in the throttle body, which is the throat of the engine's air intake manifold.
- Single point injection system meters fuel better than a carburetor and is less expensive and easier to service.

#### Multi Point Fuel Injection System (MPFI):

- MPFI system is widely used in petrol engine in place of carburetor.
- Purpose of MPFI is supply proper A/F ratio to each cylinder of engine.
- Fuel tank > Pump > High pressure petrol > Distributor > Fuel injector > Cylinder
- Now a days MPFI system control by Electric Control Module (ECM).
- ECM receives signal from different sensors.
- ECM receives signal and send to the solenoid operated fuel injector to meter and inject right amount of fuel at right time.

### Clutch:

A clutch is a mechanical device which provides for the transmission of power (and therefore usually motion) from one shaft (the driving member) to another shaft (the driven member).

It is located between the transmission and the engine.

When the clutch is engaged, the power flows from the engine to the gear box drive transmission and the vehicle moves. When the clutch is disengaged, the power is not transmitted from the engine to the gear box and vehicle stops even if engine is running.

It works on the principle of friction.

The friction depends upon the surface area contact. The friction surfaces are so designed that the driven member initially slips on driving member when initially pressure is applied. As pressure increases the driven member is brought gradually to speed the driving member

#### Purpose of Clutch:

- During initial pickup of vehicle from stationary to moving the engine is running but vehicle is stationary.

- Torque on the vehicles self inertia increasing amount of power is required to be transmitted to the gearbox and hence to the wheels.
- This increasing power transmission should be gradual and should not result in any jerks to the passenger.
- Hence for gradual engagement of rotary motion from engine to gearbox special friction coupling called clutch is used.
- Clutches are also required to disengage the drive from engine to gearbox for changing the gears
- During slowing of vehicle or stopping the clutch is used to disengage engine from the drive wheels.

#### Functions of the clutch:

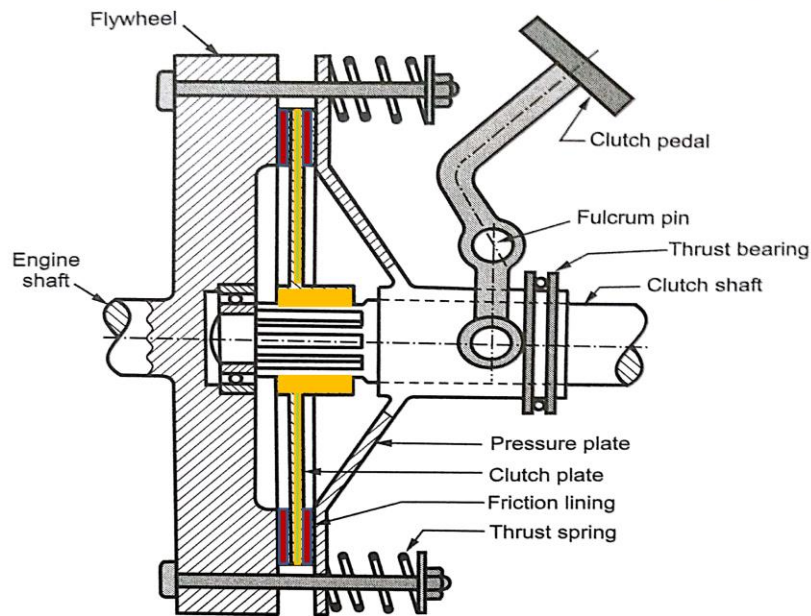
- When the clutch is engaged the clothes transmit maximum power from engine crankshaft to gearbox input shaft.
- When clutch is disengaged the clutch allows the driver to shift the transmission in various gear positions.
- When clutch is disengaged the engine can be crying freely without transmitting the drive to wheel.
- When clutch is engaging the clutch accommodates for minor slippage and hence provides smooth drive transmission without jerk

#### Types of Clutch:

1. Single plate clutch
2. Multi-plate clutch
3. Semi-centrifugal clutch
4. Centrifugal clutch
5. Cone clutch

#### Single plate Clutch:

It is the most common type of clutch plate used in motor vehicles. Basically it consists of only one clutch plate, mounted on the splines of the clutch plate. The flywheel is mounted on engine crankshaft and rotates with it. The pressure plate is bolted to the flywheel through clutch springs, and is free to slide on the clutch shaft when the clutch pedal is operated.



When the clutch is engaged the clutch plate is gripped between the flywheel and pressure plate. The friction linings are on both the sides of the clutch plate. Due to the friction between the flywheel, clutch plate and the pressure plate the clutch plate revolves the flywheel. As the clutch plate revolves the clutch shaft also revolves. Clutch shaft is connected to the transmission gear box. Thus the engine power is transmitted to the crankshaft and then to the clutch shaft.

When the clutch pedal is pressed, the pressure plate moves back against the force of the springs, and the clutch plate becomes free between the flywheel and the pressure plate. Thus the flywheel remains rotating as long as the engine is running and the clutch shaft speed reduces slowly and finally it stops rotating. As soon as the clutch pedal is pressed, the clutch is said to be disengaged, otherwise it remains engaged due to the spring forces.

#### Advantages:

- Simple design of construction & working
- Better heat dissipation from single plate
- Gear changing with single plate is easier
- It has better tensional vibration absorbing capacity.

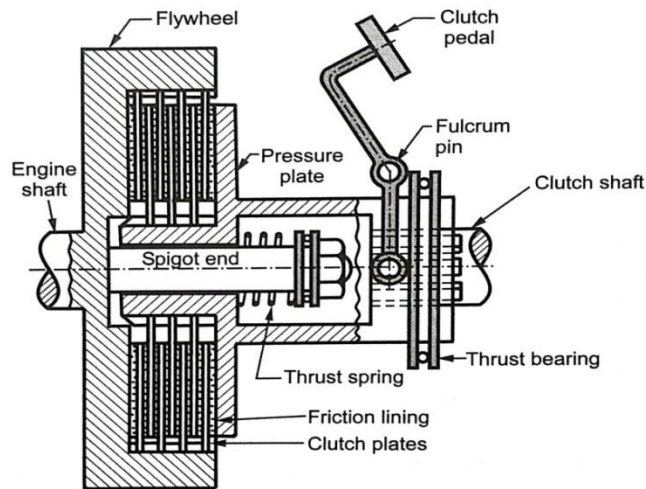
#### Disadvantages:

- For higher transmission overall size of the plate increases
- Pedal force required is higher

**Applications:** These type of clutches are used in trucks, jeeps, cars and buses.

## Multi plate Clutch:

Multi-plate clutch consists of a number of clutch plates instead of only one clutch plate as in case of single plate clutch. As The number of clutch plates are increased, the friction surfaces also increases. The increased number of friction surfaces obviously increases the capacity of the clutch to transmit torque. The plates are alternately fitted to engine and gear box shaft.



They are firmly pressed by strong coil springs and assembled in a drum. The multi-plate clutch works in the same way as a single plate clutch by operating the clutch pedal. The multi-plate clutches are used in heavy commercial vehicles, racing cars and motor cycles for transmitting high torque. The multi-plate clutch may be dry or wet. When the clutch is operated in an oil bath, it is called a wet clutch. When the clutch is operated dry it is called dry clutch

### Advantages:

- The overall size of the clutch is smaller
- It has higher torque transmitting capacity
- Drive transmission is smoother
- Wear and tear of clutch plate is lower

### Disadvantage:

- The design of clutch plate is complicated
- It is difficult to service
- The cost of multi plate clutch is higher

### Applications:

- It is used where high torque transmission is required as such as racing cars etc
- It is also used where all space is constrained motorbikes etc

## Gearbox:

### Introduction to transmission system

Transmission system or gear box is an important element of power train system. Transmission system is referred to the whole mechanism responsible for transmitting power from engine to road wheels. Gearbox is that part of power train system that provides a mean to have suitable variation of the engine torque to the road wheel.

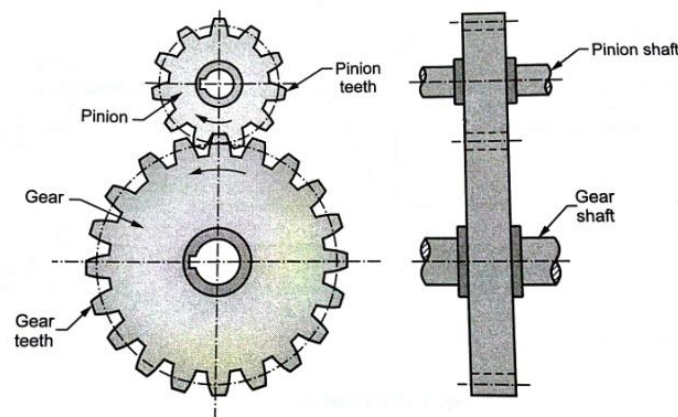
### Functions of gearbox:

- The main function of gearbox is to provide a mean to vary the torque ratio between the engine and the road wheels when required
- Gearbox also provide a mean to move the automobile backward with the reverse gear
- It also enables a neutral position for starting the engine and keep it running without transmitting drive to the road wheel
- To increase the torque and reduce the speed from the input shaft to output shaft.
- To increase the speed & reduce the torque from the input shaft to output shaft
- To change the direction of rotation from one shaft to another shaft.

**Gears** can be defined as the mechanical element used for transmitting power and rotary motion from one shaft to another by means of progressive engagement of projections called teeth.

Gears operates in pairs, the smaller of the pair is called pinion and the larger is called the gear. If pinion rotates in clockwise direction gear rotates in anticlockwise direction and vice versa

### Speed Ratio or Gear Ratio:





Speed ratio or gear ratio is defined as the ratio of pinion speed to the gear speed

It is also defined as the ratio of number of teeth on gear to the number of teeth on pinion or it is the ratio of diameter of gear to the diameter of pinion.

$n_g$  and  $n_p$  = Gear & pinion Speed in rpm

$d_g$  and  $d_p$  = Diameter of gear & Pinion in mm

$Z_g$  and  $Z_p$  = Number of teeth on gear & pinion

$$\text{Gear ratio or Speed ratio} = \frac{n_p}{n_g} = \frac{d_g}{d_p} = \frac{Z_g}{Z_p}$$

### Types of gears:

The gear generally classified as per position of axis of two shafts between which the motion is to be transmitted-

1. Parallel shaft axis gear
2. Intersecting shaft axis gears
3. Non intersecting and perpendicular shaft axis gears
4. Non intersecting and non perpendicular shaft axis gear

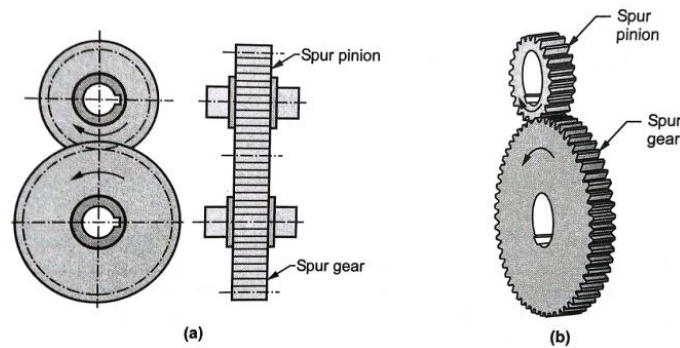
#### 1. Parallel shaft Axis gears:

For the transmitting the motion two parallel shafts are connected by the following types of gears

- a. Spur gears
- b. Helical gears
- c. Herringbone gears
- d. Rack and pinion gear
- e. Internal gears

##### a. Spur Gears:

Spur gears are used to transmit motion between two parallel axis shafts.





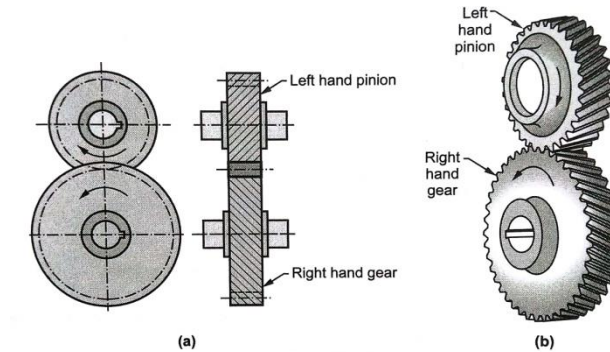
They are the simplest of all the gears and easiest in production. The teeth of spur gears are cut along the periphery and parallel to the axis of gears. Spur gears can be made of steel, brass other metals and plastics

### Applications:

Spur gear commonly used in machine tool gearbox, automobile gearbox, watches, etc

### b. Helical Gears:

Helical gears are similar to spur gear but its teeth are cut at an angle with the axis of rotation of the gear



Helical gears can transmit motion from one shaft to another shaft which is parallel to each other. The helix angle of gear and pinion are same in magnitude but of different hands for example right hand pinion meshes with left hand gear.

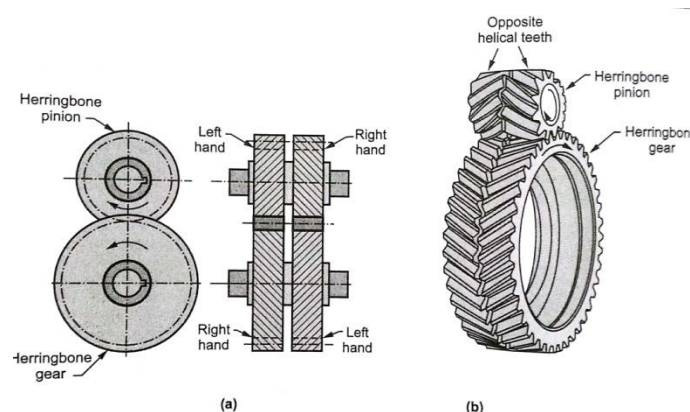
### Application:

Helical gears are commonly used in high speed automobile gearbox, machine tool gearbox, rolling Mills, etc

### c. Herringbone Gears

Herringbone gear look like two single helical gears one right hand and other left and placed side by side.

This gear reduces the and thrust acting on the thrust bearing



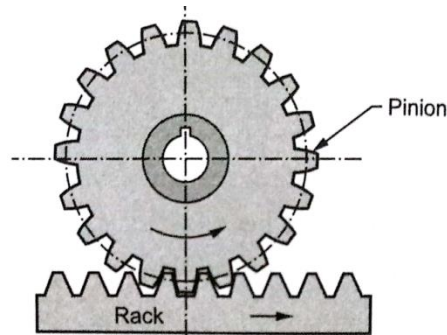
These gears are used to transmit motion from one shaft to another shaft which are parallel to each other.

Herringbone gear is also called as double helical gears.

**Application:** Herringbone gear are used in high speed applications and specially in heavy duty machines.

#### d. Rack and Pinion

Rack is a straight gear which has no curvature and it represents a gear of infinite radius



Rack may have either straight or helical teeth. During the operation rack gear meshes with pinion and converts rotary motion of pinion into reciprocating motion of rack or reverse.

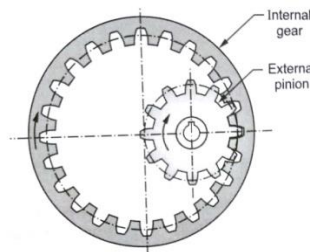
#### **Application:**

Rack and pinion arrangement is used in feeding mechanism, reciprocating drives

They are also used in gauges, small equipments, lathe milling drilling and other machine tools

Also in steering mechanism

#### e. Internal Gear



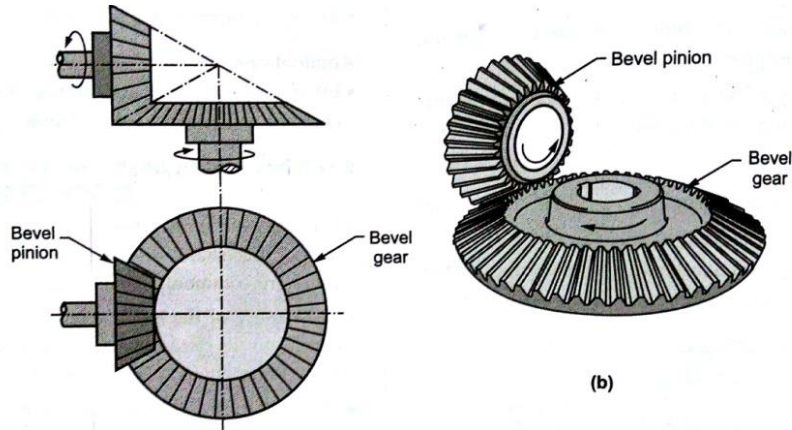
All the above gears carry teeth on their periphery for external surfaces but internal gears have teeth on their inner surface which may be spur, helical, etc

It is important to note that in internal gears both the wheels rotate in the same direction

**Application:** Internal gears are commonly used in internal clutches and heavy vehicle drives

## 2. Intersecting shaft axis gears:

For transmitting the motion between two intersecting shafts or shaft at desired angle bevel gears are used.



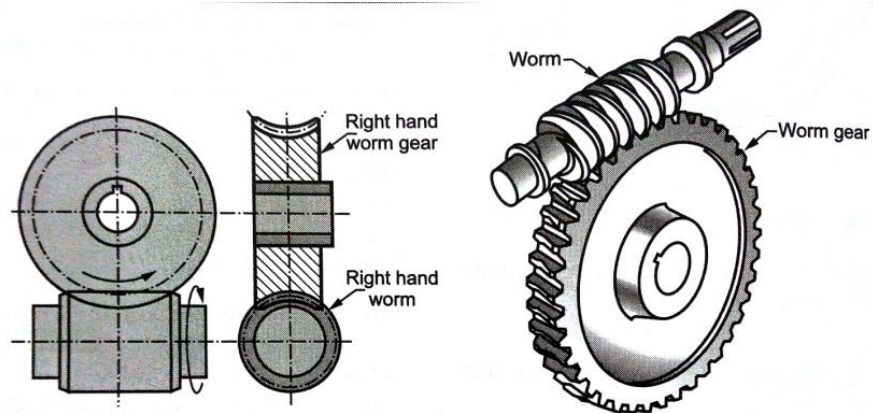
The teeth of wheel gears are so that they radiate from the apex of a cone and lie on the conical surface. Generally bevel Gears are used when two shafts are at right angle to each other but it can be used for your desired shaft angle.

#### **Application:**

Bevel gears are commonly used in differential gearbox of automobile and for connecting two intersecting shafts.

### **3. Non intersecting and perpendicular shaft axis gear:**

For transmitting the motion between two non intersecting and perpendicular shaft worm and worm gears are used.



In worm gears worm is more or less similar to screw having single or multiple start threads which forms the teeth of the worm. Worm gear is a helical gear with a concave face to accommodate a portion of worm periphery. Worm and worm gears are used when large speed reduction ratio is required from one shaft to the other shaft.

#### **Applications:**

Because of self locking and non reversible property worm gears are commonly used in steering mechanism, hoisting devices, cranes, dam gates, lifts, etc.

**Numerical:** **Gear ratio or Speed ratio**  $= \frac{n_p}{n_g} = \frac{d_g}{d_p} = \frac{Z_g}{Z_p}$

1. A pinion with 120 mm pitch circle diameter meshes with a gear of 400 mm pitch circle diameter. The no of teeth on pinion is 18 and it rotates at 1440 rpm. Determine: i) Gear Ratio, ii) Number of teeth on gear, iii) Speed of the gear.

Given:  $d_p = 120$  mm,  $d_g = 400$  mm,  $Z_p = 18$ ,  $n_p = 1440$  rpm

Gear Ratio (i) = ?

Number of teeth on gear  $Z_g = ?$

Speed of the gear  $n_g = ?$

**Calculate the gear ratio:-**

$$\text{Gear ratio} = I = \frac{d_g}{d_p} = \frac{400}{120} = \mathbf{3.3333}$$

**Calculate Number of teeth on gear:-**

$$I = \frac{Z_g}{Z_p}$$

$$\text{Therefore, } 3.3333 = \frac{Z_g}{18}$$

$$\mathbf{Z_g = 60}$$

**Calculate speed the gear:-**

$$I = \frac{n_p}{n_g}$$

$$\text{Therefore, } 3.3333 = \frac{1440}{n_g}$$

$$\mathbf{n_g = 432 \text{ rpm.}}$$

2. A pinion with pitch circle diameter 150 mm meshes with a gear having 80 teeth. Gear ratio is 4 and speed of the gear is 500 rpm. Determine: i) Diameter of gear, ii) Number of teeth on pinion, iii) Speed of pinion.

Given:  $d_p = 150$  mm,  $i = 4$ ,  $Z_g = 80$ ,  $n_g = 500$  rpm

Diameter of gear  $d_g = ?$

Number of teeth on pinion  $Z_p = ?$

Speed of the pinion  $n_p = ?$

**Calculate diameter of :-**

$$\text{Gear ratio} = I = \frac{d_g}{d_p} =$$

$$4 = \frac{d_g}{150} =$$

$$d_g = 600 \text{ mm}$$

*Calculate speed of the pinion:-*

$$I = \frac{n_p}{n_g}$$

Therefore,  $4 = \frac{n_p}{500}$

$$n_p = 2000 \text{ rpm}$$

*Calculate no of teeth on pinion:-*

$$I = \frac{Z_g}{Z_p}$$

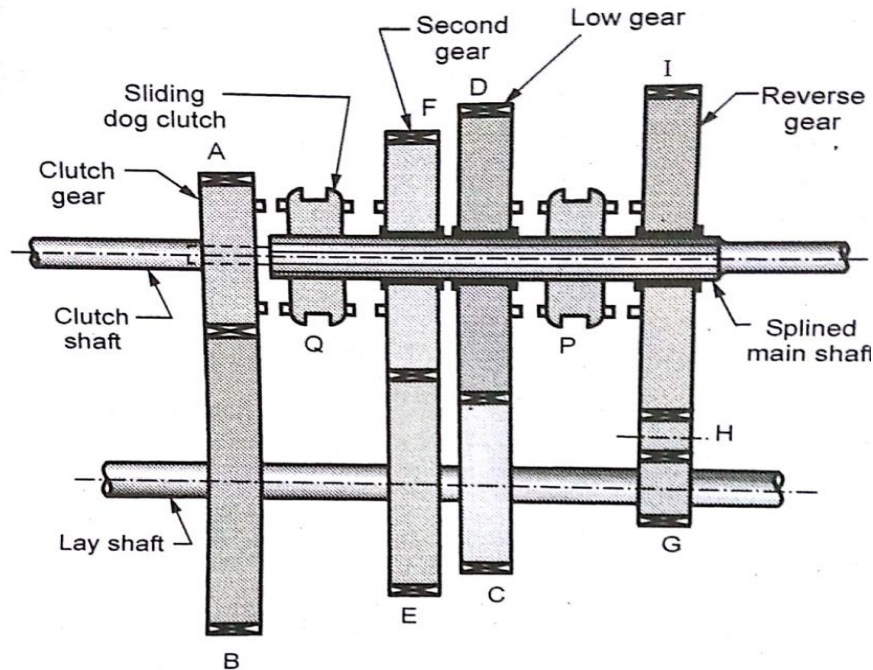
Therefore,  $4 = \frac{80}{Z_p}$

$$Z_p = 20.$$

## Constant mesh gearbox:

As the name indicates in this type all the gears are in continuous constant mesh with each other. Selection of gears takes place by additional sliding dog clutches provided on the main shaft.

Fig. Shows three forward and one reverse gear box configuration



### Construction:

#### Clutch shaft:

It is the input shaft to the gearbox. Its outer end is connected to the clutch disc. It has a gear machine at its inner end (Gear A) that meshes with respect to gear on the lay shaft (in this case it is gear B).

#### Lay shaft:

The lay shaft is freely suspended in bearing mounted on the transmission case. It has gears rigidly mounted on it. (Gears B, E, C, G.)

#### Main shaft:

It is output shaft to the gearbox. It has splines cut across its length to accommodate axial movement of sliding dog clutches on it. Its outer end is connected to the propeller shaft through universal joint.

#### Sliding dog clutches:

These are special coupling with dog teeth provided on its either side. They can slide on the splined main shaft. Dog teeth with respective gears on the main shaft and transmit the drive

### **Working:**

#### **First Gear:**

To engage first gear dog clutch P is shifted towards left side such that it engages with gear D.

**Power Flow:-** Gear A – B – C – D to dog clutch P to Main Shaft

#### **Second Gear:**

To engage the second gear dog clutch P is disengaged.

Then the dog clutch Q is shifted towards right such that it engages with gear F

**Power Flow:-** Gear A – B – E – F then Dog clutch Q to Main shaft.

#### **Third Gear:**

To engage the third gear dog clutch Q is shifted toward left.

It is made to engage directly with gear A.

**Flow:-** Gear A to Dog clutch Q to Main shaft.

#### **Reverse Gear:**

To engage the reverse gear all other dog clutches are disengaged. Then dog clutch P is shifted toward right to engage with gear I rotate in opposite direction.

**Power Flow:-** Gear A – B – G – H -- I then to Dog clutch P to Main shaft.

#### **Advantages:**

- Since gears are in constant engagement, helical gears are used.
- With uses helical gears noise produced during operation is reduced.
- Wear and tear of dog teeth is reduced because all the teeth are in contact during power transmission.

#### **Disadvantages:**

- Since all the gears are in continuous mesh some amount of power is wasted
- Gear box is costly due to sliding dog clutches.

### **Sliding Mesh Gearbox:**

It is simplest type of gear box out of the available gear boxes. In this type of gear box, gears are changed by sliding one gear on the other.

**Components of Sliding Mesh Gearbox are as follows:**

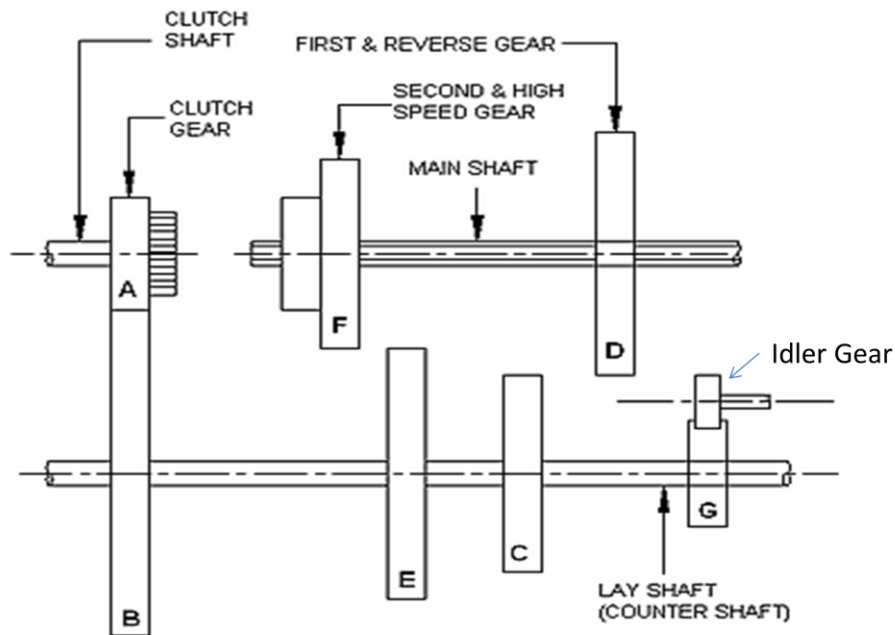
#### **1. Shafts**

- Clutch shaft
- Lay Shaft
- Main Shaft

## 2. Gears

- Fixed Gears
- Movable Gears
- Idler Gear
- Clutch Gear

## 3. Gear Lever



The Sliding Mesh Gear box uses Spur Gears for the transmission of power from the engine shaft to the main shaft. It generally consists of 3 shafts i.e. Clutch shaft, Lay shaft and Main Shaft. It is a transmission mechanism of Just 4 gears and out of these 4, one is the reverse gear. So here we have 1<sup>st</sup> gear, 2<sup>nd</sup> gear, Top gear and the Reverse gear. The power comes from the engine to the clutch shaft and thence to the clutch gear which is always attached at the end of clutch shaft. All the gears on the lay shaft are fixed and are in mesh with the clutch gear and main shaft gears.

### Working:

#### First Gear:

To engage first gear, gear D is shifted towards left side such that it engages & meshes with gear C.

#### Second Gear:

To engage the second gear, First gear is disengaged.

Then the gear F is shifted towards right to mesh with gear E



**Third Gear:**

To engage the third gear the sliding gear F is shifted towards left such that its teeth meshes with teeth on gear A. This is also called as direct drive..

**Reverse Gear:**

To engage the reverse gear all other gears are disengaged. Then the sliding gear D is shifted towards right such that it meshes with reverse idler gear H

**Neutral Gear:**

When engine is running and the clutch is engaged, clutch shaft gear drives the drive gear of the lay shaft and thus lay shaft also rotates. But the main shaft remains stationary as no gears in main shaft are engaged with lay shaft gears.

**Advantages:**

- It is most simplest in construction & working.
- Since it uses simple spur gear, It is cheaper than other types of gears

**Disadvantages:**

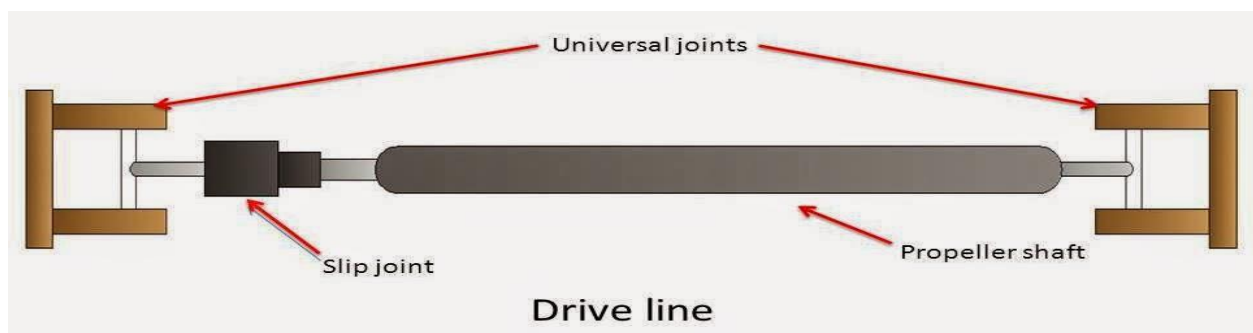
- Spur gear are noisy in operation
- Teeth wear out is more
- Spur gear can not take any trust load

**Propeller shaft:**

The propeller shaft is a driving shaft connected between the gearbox output shaft and differential input shaft.

The main functions of propeller shaft are:

- To transmit rotary motion from gearbox to the differential
- Adjust for variation in the angle between gearbox output shaft and differential

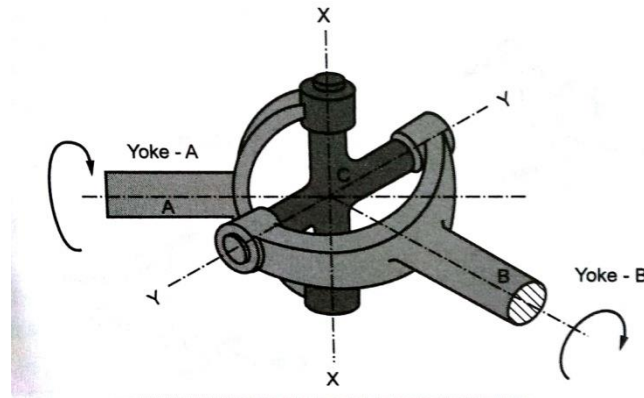


It is subjected to varying torsional load in between gearbox output shaft and differential input shaft. Vehicle with large wheel base have long propeller shaft. Along shaft has tendency to sag and whirl. Whirl can be imagined as the movement of rope revolving when held at its end. At a certain speed the whirling intensity becomes critical and the shaft vibrates violently and can break. Hence to reduce swirl the diameter of shaft is increase for length of shaft is reduced by splitting it.

### Universal Joint:

Universal joint is a special type of joint used to transmit power between two shafts that are inclined to each other.

It also accounts for continuous vibration in the angle between the two connecting shaft. In an automobile the gearbox is rigidly mounted on frame while driving axle usually rear axle continuously varies with respect to gearbox output shaft due to action of suspension system. Therefore, universal joint is used to transmit power from the gearbox output shaft to the differential input shaft. A yoke type is the simplest compact and widely used universal joint



### Construction:

A yoke arrangement is provided at the end of the two shaft to be connected. A Four arm cross spider connects the two yoke. The opposite arm of the cross are supported in the bushes provided in the yoke.

### Working:

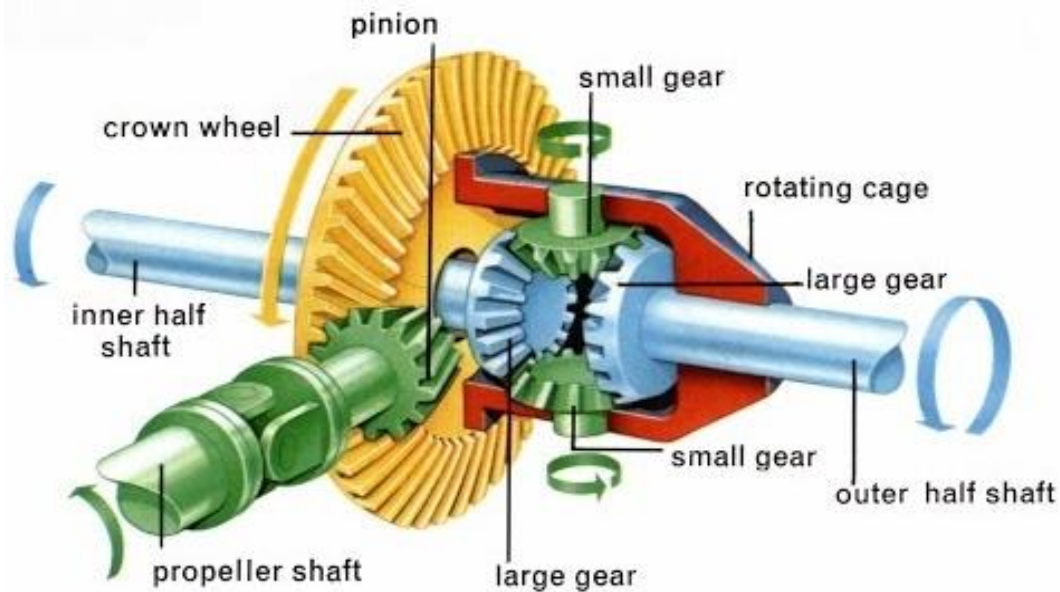
Shaft with yoke A can have angular rotation about Axis X-X while shaft with yoke B can have angular rotation about Axis Y-Y. The rotation of yoke A is transmitted to yoke B through the cross. As the connection between the two connecting shaft is mechanical, a positive drive transmission takes place and still allowing some angular movement between the shaft.

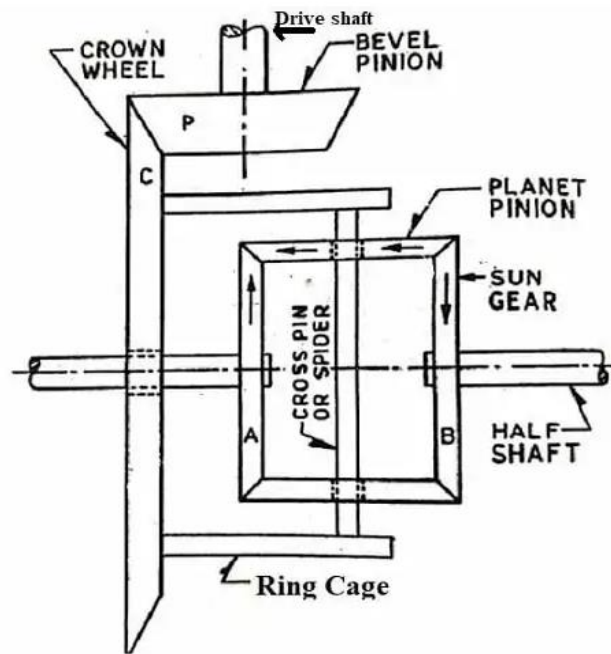
## Differential Gearbox:

The differential gear is a part of the power transmission device. The driving force generated by an engine is transmitted to the tires through various types of bevel gears. Differential gear is representative of the automotive components that incorporate such bevel gears. The differential gear assembly absorbs rotational differences due to the direction change of the rotational axis drive and/or the rotational differences between the right and left wheels that lead to smooth cornering.

In automobiles, the wheels are usually driven by the engine using a bevel gear. This allows the rotational motion from the engine to the wheels to be deflected by  $90^\circ$ . If, however, the wheels were rigidly connected to each other by a common shaft, this would lead to problems when cornering. In such a case, the outer wheel must cover a greater distance than the inner wheel. However, since both wheels must travel around the turn at the same time, the outer wheel must rotate faster than the inner wheel.

The propeller shaft has a small bevel pinion which is in mesh with the crown wheel at right angle this crown wheel rotates the rear axles. The axles are two half shafts. The rotation of propeller shaft converted at right angles to the rear axles. The crown wheel size is larger than the size of the pinion bevel gear hence the speed of crown wheel is lower than bevel pinion





### Components of Differential:

The components of Differential are as follows:

- Ring Gear or Crown Wheel
- Planet Pinion
- Drive Shaft
- Bevel Pinion
- Half Shafts
- Sun Gears – 2 No's
- Ring Cage
- Cross Pin

### Ring Gear or Crown Wheel:

Ring Gear will transmit the power to the Planet Pinions, Sun Gears and finally to the half shafts so that power will be used to drive the wheels.

### Planet Pinion:

Two Planet Pinions or Sometimes Four Planet Pinions are placed opposite to each other and are meshed with the sun gears to transmit the power to the rear wheels via half shafts.

### Drive Shaft:

The power from the Gearbox is transmitted to the propeller shaft or Drive shaft and thereby it will send to Bevel pinion.

**Bevel Pinion:**

The function of Bevel Pinion is to transmit the power from the Propeller shaft to drive the Ring Gear.

**Half Shafts:**

There is not a single shaft which is connecting two rear wheels, but two Half shafts are used to connect two rear wheels in the automobile and the Crown wheel is free to rotate on the half shaft. These axle half shafts are splined to each of the sun gears.

**Sun Gears:**

Two Sun gears are employed for the working of Differential which are opposite to each other and these sun gears are connected to the half shafts to drive the power.

**Ring Cage:**

The Ring cage is attached to the crown wheel which carries a cross pin (if two Planet Pinions are employed) or a Spider (if Four Planet Pinions are employed) in the differential.

**Cross Pin:**

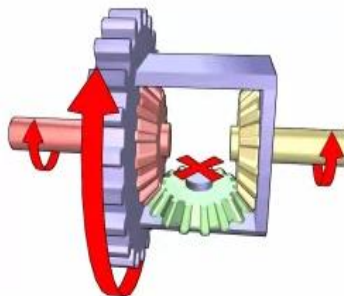
The Cross pin is used to connect two planet pinions opposite to each other so that they can be in proper mesh with the Sun Gears and the Torque will be divided equally on to the rear wheels.

The working Principle of differential when vehicle is moving in STRAIGHT Direction & Vehicle is taking TURN:

Vehicle is moving in Straight Direction :

Condition:  $N_{\text{left}} = N_{\text{right}}$

When the Vehicle is moving in Straight direction, then the speed of Rear wheels is same, in the sense both will rotate at the same speed. In this case, the Sun gears, Planet Pinions and the Ring Cage will act as a single unit and the two half shafts will revolve at the same speed.



In this situation, when all the parts of the differential act as a single unit, there is no relative motion among them and that's the reason all the rear wheels move with the same speed.

i.e.  $N_{\text{left}} = N_{\text{right}}$

### Vehicle is taking a Turn: ( Considering right turn)

**Condition:**  $N_{\text{left}} > N_{\text{right}}$

When the Vehicle is taking the Right Turn, then the distance travelled by the Left wheel is greater than the distance travelled by the Right wheel and the speed (rpm) of Left wheel is greater than the speed (rpm) of Right wheel. Then the turning of one Sun gear will cause the other Sun gear to rotate in the Opposite direction. Which means, if left Sun gear rotates 'n' times in a particular period of time then the right Sun gear will also rotate 'n' times in the same period but, of course, in the opposite direction.

When the vehicle is taking a turn, this rotation is superimposed on the normal wheel speed.

Thus consider a vehicle moving in a straight direction with a speed 'N' rpm and when it takes a turn towards Right, at this time there will be a resistance offered to the motion of the right wheel and as a result of differential action, the right wheels rotate back at 'n' rpm and the left wheel rotate forward at 'n' rpm. This will give the Resultant speed of the Right wheels as  $(N-n)$  and the Left wheels as  $(N+n)$ .

### Axles:

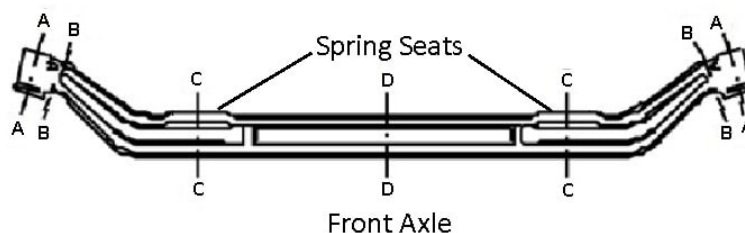
An axle is a non rotating machine elements which is used to support rotating machine elements like- wheels, pulleys, etc

It may be fixed to the wheels, rotating with them or fixed to the vehicle with wheels rotating around the axle.



Ex:- Front axle of car, wheel axle of motor cycle, etc

#### Front Axle:



- Front axle is usually a forged member carrying the road wheels at its ends.
- It carries the front weight of the vehicle.
- It also carries the steering mechanism which is used to direct the vehicle in the desired direction.
- Modern cars have live front axle while heavy vehicles use conventional dead front axle.

#### Rear axle:

Rear axle drives are employed on front engine rear wheel drive vehicles.

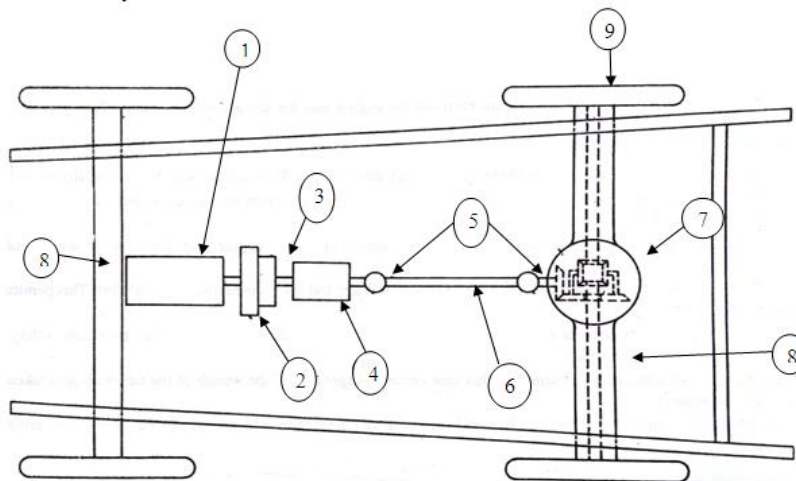
The rear drive axle system consists of important sub- systems such as universal joint, slip joint, propeller shaft, suspension leaf spring, rear axle casing, final drive and differential.

The rear axle drive system subjected to following forces & torques.

1. Weight of the vehicle
2. Driving thrust
3. Torque reaction
4. Side thrust

### Study of Power Transmission System:

In a motor vehicle the **power transmission system** comprises the main components that generate power and deliver it to the road surface. This includes the engine, clutch, gear box, propeller shafts, universal joints, differentials, drive axle and the final drive (drive wheels).



#### Main Components of Power Transmission System:

- |              |                     |
|--------------|---------------------|
| (1) Engine   | (6) Propeller Shaft |
| (2) Flywheel | (7) Differential    |
| (3) Clutch   | (8) Drive axle      |



(4) Gear Box

(9) Wheels

(5) Universal Joints

- 1) Engine or power unit:** Internal combustion engines are employed in automobiles as power units. Since the air fuel mixture is burned inside the engine cylinder to develop power, so these are called as internal combustion engines.

Functions:

- (i) Burn a fuel to create heat which is then used to do work.
  - (ii) The engine provides power to drive the vehicle.
- 2) Flywheel:** Flywheel is heavy disc attached to the rear end of the crankshaft to keep the crankshaft in regular motion. The flywheel tends to keep the crankshaft turning at the constant speed.

Functions:

- (i) To store the energy received in power stroke & keeps the crankshaft rotating in idle stroke.
  - (ii) It maintains the speed of crankshaft.
  - (iii) It transmits the engine power to gearbox through a clutch.
- 3) Clutch:** Clutch works on the principle of friction because when the two rough surface clutch plates are comes in contact with each other then they become rotating as a single unit. This is possible due to the friction between the two plates.

Functions:

- (i) A clutch engages & disengages power transmission from engine to gearbox.
  - (ii) To transmit power from engine to drive train
  - (iii) Smooth transmission.
  - (iv) Protect drive train from engine jerks.
  - (v) It delivers the power to wheels via gearbox without stopping during gear change.
- 4) Gear box:** This is a component which houses the complete gear mechanism. The gear box provides the necessary power variation between engine and road wheels.

Functions:

- (i) To provide sufficient torque at starting, ascending, accelerating, braking, etc
- (ii) To provide low speed to high speed driving capability
- (iii) To change the direction of wheel rotation (forward or reverse).

- 5) **Universal Joint:** A universal joint is a joint connecting rigid rods whose axes are inclined to each other and is commonly used in shafts that transmit rotary motion.

Functions:

- (i) It enables the drive shaft to transmit power at varied angles.
- (ii) To transmit power from gear box to differential via propeller shaft.

- 6) **Propeller shaft:** The propeller shaft is a driving shaft which connects the transmission main shaft to the differential of the rear axle. It transmits the power from gear box to rear axle with the help of universal joints

Functions:

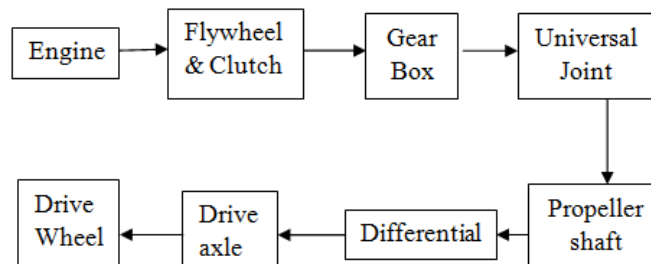
- (i) Power from the transmission is transmitted to the driving axel at rear at varied lengths and varied angles.

- 7) **Differential:** The differential generates the difference in the inner and outer wheel speed when the vehicle takes a turn.

- (i) Further reduces the rotations coming from the gear box before the same are passed on to the rear axles.
- (ii) To distribute power equally to both the rear driving axles when the tractor is moving in straight ahead direction.
- (iii) To distribute the power as per requirement to the driving axles during turning i.e. more rotations are required by the outer wheel as compared to the inner wheel – during turns.

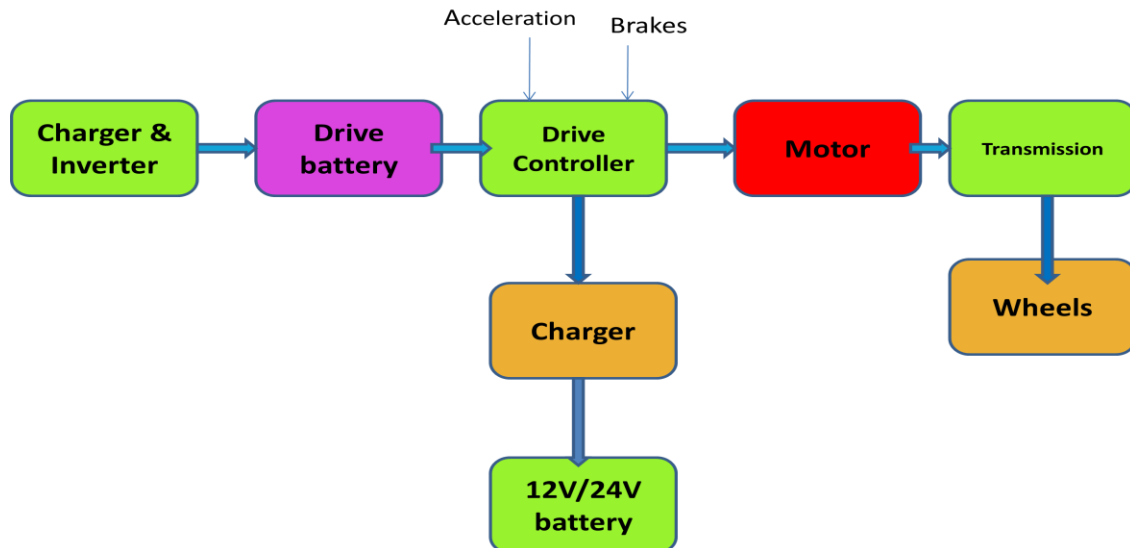
- 8) **Drive axle:** The purpose of the drive axle is to transfer the torque from the differential to the wheels. Accordingly, one end of each shaft is splined to the differential's pinion drive gear (or side gear), while the other end is splined to the wheel stub axle. The drive axles are connected to the differential and the wheel stub axles through universal joints.

- 9) **Wheels :** The wheel along with tyre has to take the vehicle load, provide a cushioning effect and cope with the steering control.



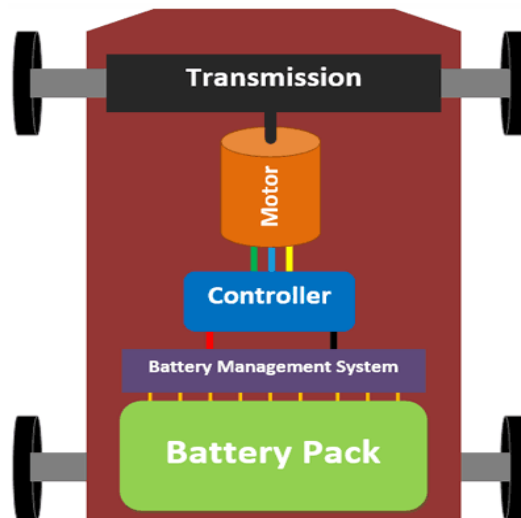
## Electric Vehicle:

- Electric cars are the automobile vehicle which are powered by electric engine and electric energy
- Electric vehicles are powered by electric motor instead of heat engine.
- An electric vehicle (EV) is a vehicle that uses one or more electric motors or traction motors for propulsion.
- Components:
  - Battery pack
  - Electric Motor
  - Transmission
  - Inverter
  - Power electronic controller
  - DC/DC converter
  - Wheels



## Working:

- High Capacity battery is used which can be lead based nickel based or lithium ion based.
- It is charged from the electric electric plug point outside vehicle
- Battery provide high current energy to inverter. It converts Ac to DC current.
- Motor used with DC shunt winding
- When pedal of the car is pressed, then Controller takes and regulates electrical energy from batteries and inverters
- With the controller set, the inverter then sends a certain amount of electrical energy to the motor (according to the depth of pressure on the pedal)
- Electric motor converts electrical energy into mechanical energy (rotation)
- Rotation of the motor rotor rotates the transmission so the wheels turn and then the car moves.



- **Advantages:**
  - Simple design and limited no of Components
  - Minimum running cost.
  - Highly reliable
  - Doesn't create any type of pollution
  - Noise free operation
  - Reduce dependence on oil and gasoline
  - No fire hazards.
- **Disadvantages:**
  - Battery need Frequent charging
  - High replacement cost of battery
  - Distance travel range limitations
  - Due to battery pack vehicle weight is more
  - High speed range is low in case of electric vehicle.

### Hybrid Vehicle:

Hybrid vehicle is automobile propelled by two power sources electric motor & I C engine. Hybrid electric vehicle is a progressive transformation from conventional automobile vehicle powered by only I C engine to battery electric vehicle power by electric motor.

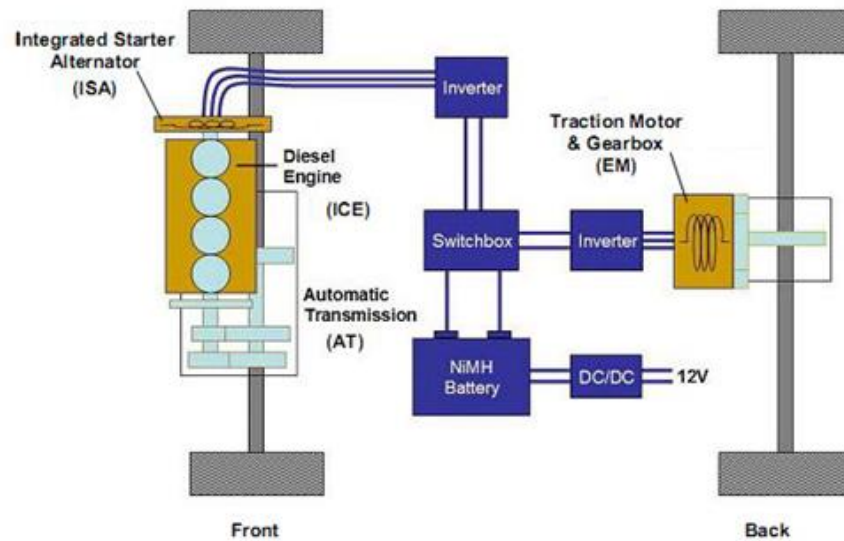
Hybrid vehicle minimizes the drawback of I C Engine powered vehicle and retains the advantage of it.

A **hybrid vehicle** uses two or more distinct types of power, such as internal combustion engine to drive an electric generator that powers an electric motor, e.g. in diesel-electric trains using diesel engines to drive an electric generator that powers an electric motor.

### Components:

- (i) Engine
- (ii) Transmission System
- (iii) Switch Box
- (iv) Inverter

- (v) Battery
- (vi) Electric Motor
- (vii) Wheels



The combination of Internal combustion engine & electric motor results in a hybrid vehicle. The optimum strategy for hybrid vehicle is to use electric drive during slow moving areas in city & IC engine during high speed on highway. This would result in reduced pollution in cities and improve mileage.

This type of hybrid cars is often called as standard hybrid or parallel hybrid. HEV has both an ICE and an electric motor. In this types of electric cars, internal combustion engine gets energy from fuel (gasoline and others type of fuels), while the motor gets electricity from batteries. The gasoline engine and electric motor simultaneously rotate the transmission, which drives the wheels.

- **Advantages:**

- Efficiency is more than that of IC Engine vehicle
- Highly reliable
- Reduce fuel cost & harmful emission from it while run on battery.
- Battery is continuously recharged by motor generator
- Lower emission and better mileage
- It does not use energy during idle state when it run on battery.
- It reduces dependency on fuel

- **Disadvantages:**

- High Cost of Vehicle
- High replacement cost of battery
- Due to battery pack vehicle weight is more
- Poor handling: as smaller engine and heavy battery pack takes extra space in vehicle
- Higher maintenance cost.

## Vehicle Safety:

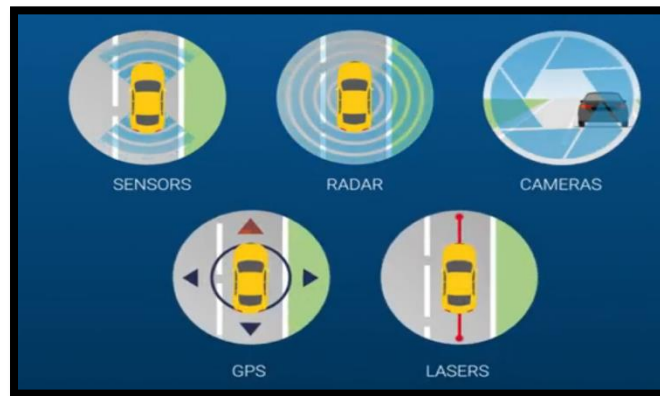
Vehicle safety is the study and practice of design, construction, equipment and regulation to minimize the occurrence and consequences of traffic collisions.

The consideration for safety of an automobile is of two type;

1. Active Safety
2. Passive Safety

### 1. Active Safety :

Active safety system are those that improve driving safety through technology designed to prevent accidents before they happen. They are also referred as primary safety system. Modern vehicle has various electric sensors and microprocessor controlled actuators that assist driver to better control on the vehicle.

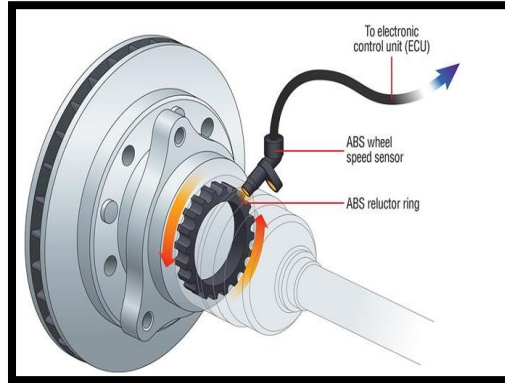


It plays the Preventive role in avoiding crashes and accidents by providing advance warning to the driver with additional assistance. Its features works silently in background

Examples:

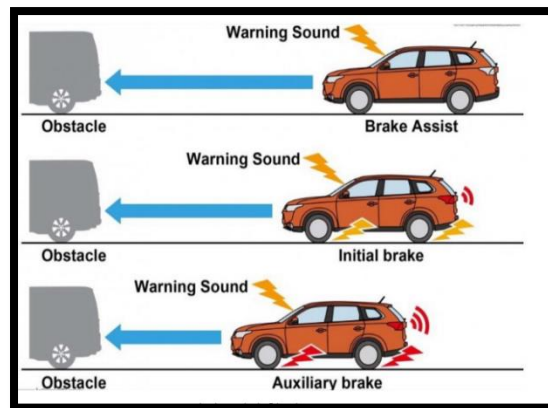
- ABS- Antilock breaking system
- TCS- Traction Control System
- ESP -Electronic Stability Program
- Cruise Control

## 1. Antilock Braking System



ABS is an automobile safety system prevent the wheels of vehicle locking as brake pedal pressure is applied.

## 2. Collision Warning System



This sensors recognize the danger of collision. It's working based on speed of vehicle and distance to obstacle

## 3. Electronic Stability program

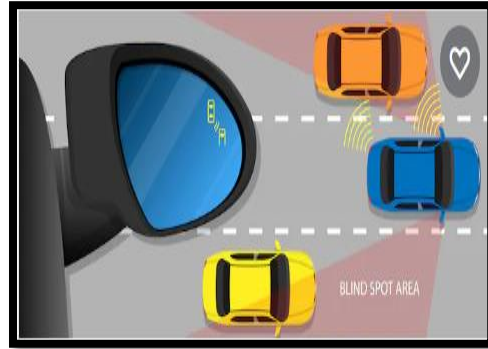


A function is to prevent Vehicle Skidding.

It contains wheel speed sensors, accelerometer, yaw sensors, steering wheel sensors, brake force control, EBD

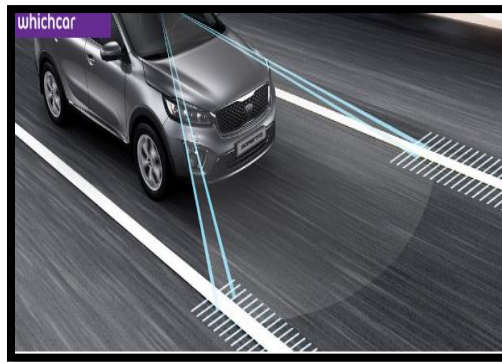


#### 4. Blind Spot Detectors



Blind spot area is the area around the vehicle that can not be direct observed. It shown by flashing warning or vibration in wheels. i.e. visibility and audibility warning.

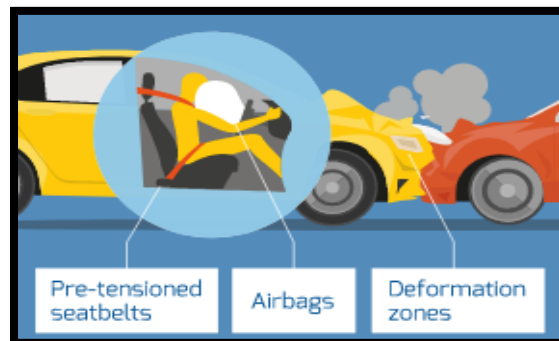
#### 5.Lane Departure Warning System :



It can prevent a car from unintentionally running off the road, had lowered the rate of single-vehicle sideswipe and head-on crashes.

#### 2. Passive safety system:

Passive safety systems are those that protect the passenger once an accident hands occurred by reducing the risk and severity of injury. The Passive safety system for reducing the impact of crash on passengers. They are also referred as secondary safety system. These systems are only deployed on in response to a vehicle accident.



Examples of passive safety systems include:- Seat belt, Airbags

## Seatbelts:

A seat belt is a safety harness design to secure the occupants of vehicle against harmful effect resulting during a collision or a sudden stop.



The seatbelt is something also referred as safety belt. A seat belt reduces the severity of injury in a traffic collision by stopping the vehicle occupants from hitting hard against interior element of the vehicle or other passengers. The seatbelt keeps occupants positioned correctly on its seat for maximum benefit from the impact.

### Need of seat belt:

Any moving or stationary element has inertia that is a tendency to continue in its state of motion or raised unless some external forces disturbs its state.

If a car is speeding along at 50 miles per hour then the compartment and passenger inside the car also keeps moving along the car at 50 miles per hour. But if the car crash into a stationary pole the force of the pole would bring the car to an abrupt stop. Without a seatbelt occupants would either slam into a steering wheel at 50 miles per hour or go flying through the windshield at 50 miles per hour. If occupants hit the windshield with its head the stopping power is concentrated and causing severe injury or fatal death.

A seat belt applies the stopping force to more durable parts of the body or a longer period of time.

The basic idea of a seat belt is to keep the occupants from flying through the windshield or hurdling towards the dashboard when the car comes to an abrupt stop.

## Airbag

Airbag was invented to perform a safety cushion between the passengers and the hard surface of the car. It is also referred as supplemental restraint system (SRS), air cushion restraint system (ACRS), and supplemental inflatable restraint (SIR).

### Airbags inflated



It consists of flexible envelope design to inflate rapidly during an automobile collision. its purpose is to cushion occupants during a crash and provide protection to their bodies when they strike interior objects are charged the steering wheel or window. The airbag is design to only in flat in moderate-to-severe frontal crashes. They are normally design with the intention of supplementing the protection to an occupant who is correctly restraint with a seat belt. Most designs are in plated through pyrotechnic. This airbag inflation is controlled by the airbag electronic control unit AECU. After deployment the inflated airbag need to be replaced and the ECU needs to be reset.

#### **Components of airbag system**

- Crash sensors
- Airbag electronic control unit AECU
- Detonator
- Inflatable airbag