Systems in Mechanical Engineering

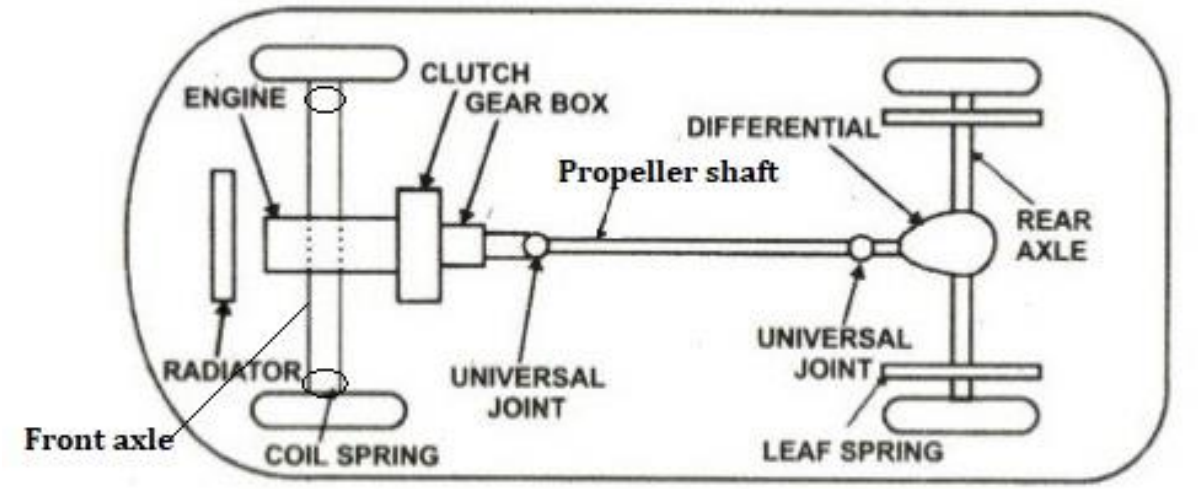
Unit IV

Vehicle Systems

A. Y. 2019-20

Chassis Layout

- The layout indicates the various components / assemblies that transfer the drive from the engine to the wheel.
- The layout also indicates the relative positioning of all drive related components.



- The various components, their relative location and purpose are as follows:

1. **Chassis (Frame):** Chassis is a skeleton frame of a vehicle on which various components or systems of vehicle (radiator, engine, gearbox, suspension system, steering system, fuel tank, etc.) are mounted.
2. **Engine:** It consists of an internal combustion engine which converts thermal energy of fuel into mechanical rotary energy at the engine flywheel.
3. **Clutch**: It is connected after the engine and transfers the drive from engine to gearbox at the will of driver. The clutch and hence the drive can be easily engaged and disengaged by a pedal provided at foot region in the driver's cabin.
4. **Gearbox**: The gearbox is the next element is the drive chain. It provides the necessary variation of torque available from the engine to the propeller shaft.
5. **Propeller shaft**: It is the drive element in between the gearbox output shaft and the differential on the rear axle.
6. **Differential**: The differential transfers the drive from the propeller shaft to the rear wheel axle. It ensures equal distribution of torque between the two wheels irrespective of their relative speeds.
7. **Rear axle**: The rear axle consists of driving shaft enclosed in a tubular structure. On the extreme end of the axle are mounted the wheels. In this case, the rear axle is the drive axle.

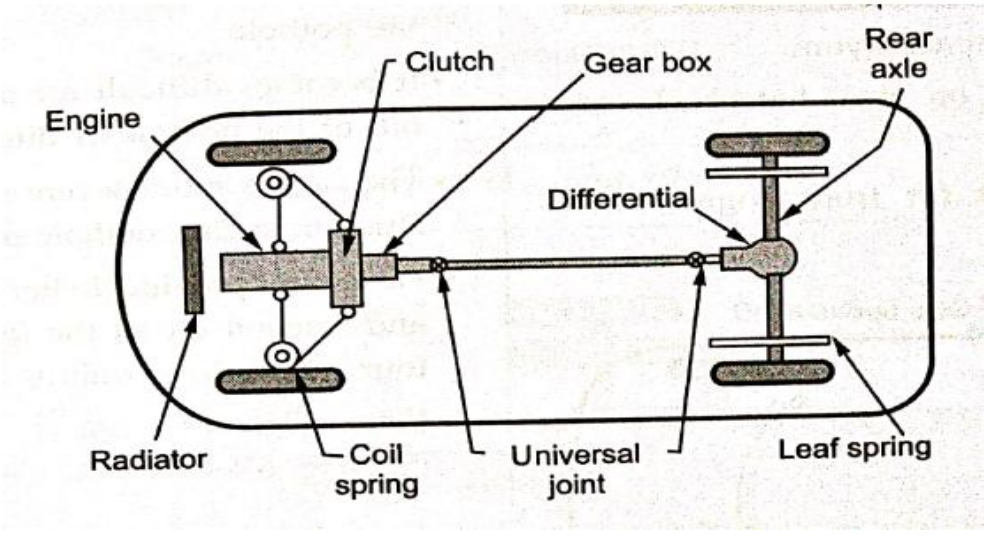
8. **Front axle**: The front axle consists of the steering mechanism, the stub axle and wheels mounted on the extreme ends.
9. **Wheels:** The wheels are the last link in the drive chain. The wheels support the load of vehicle and passengers.
10. **Suspension System**: Chassis is mounted on the axles not directly but through the suspension system. The suspension system isolates the vehicle body and passengers from road shocks.
11. **Steering System**: Steering system is used for turning the wheels or vehicles in desired direction. It is mounted on front axle.
12. **Radiator**: Radiator is a heat exchanger engine placed at the front of the vehicle. It cools the hot coolant coming from the engine and sends it back to the engine.

- **Types of Layout in an Automobile:**

Based on relative positioning of engine and drive axle, layout of an automobile can be grouped as:

1. Front engine rear wheel drive
2. Rear engine rear wheel drive
3. Front engine front wheel drive
4. Four wheel drive

1. Front Engine Rear Wheel Drive:



- It is the most conventional type of layout and as the name suggests, the engine is mounted in the front part of vehicle and the drive is transmitted to the rear axle.
- The drive chain in this layout is :

Engine -> clutch -> gearbox -> universal joint ->
Propeller shaft -> differential -> rear axle -> Wheels

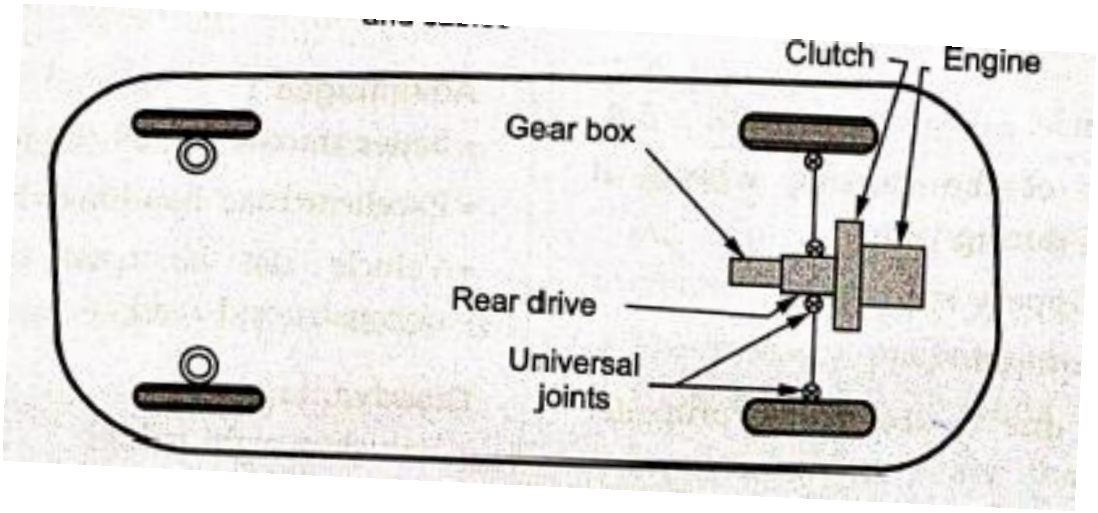
- **Advantages:**

i. Balanced weight distribution in a vehicle.
ii. Simple front axle design with steering mechanism.
iii. Increased luggage carrying capacity at rear.
iv. Linkages controlling the engine are short, simple such as clutch, accelerator linkages, etc.
v. Accessibility to various engine components is easier.
vi. Better engine cooling by taking full benefits of natural air stream flowing across the radiator.

- **Disadvantages:**

i. It requires long propeller shaft to transmit the drive from gearbox to differential.
ii. The rear floor houses the propeller shaft and hence rear leg space is limited.
iii. Higher noise transmitted from front engine to driver cabin.
iv. It requires larger brake pads at front wheels because of higher weight being transferred on front wheels while deceleration.

2. Rear Engine Rear Wheel Drive:



- This type of layout eliminates the necessity of a propeller shaft.
- The engine is mounted at the rear and drive is also transmitted to the rear axle.
- The drive chain for this layout is.

  Engine —» clutch —» gearbox —» universal joints—»differential —» rear axle—»wheels

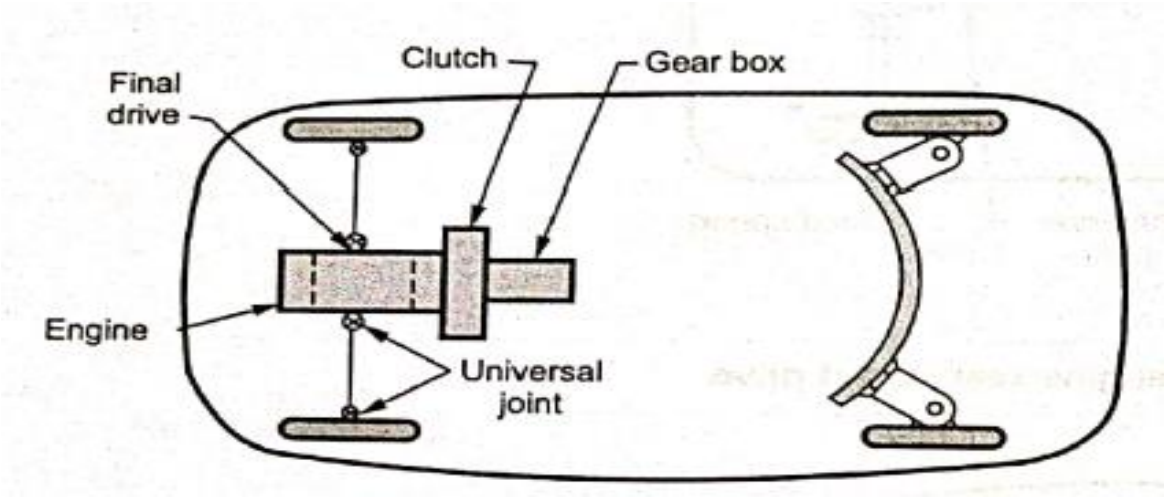
- **Advantages:**

i. The front axle consists of a very simple design and houses the steering mechanism only.
ii. Because of high weight on the driving axle provides excellent traction and grip on steep hill.
iii. The rear floor can be made flat due to absence of propeller shaft.
iv. Driver cabin is well isolated from engine noise.
v. Because of elimination of front engine, the front body can be designed as per styling.

- **Disadvantages:**

i. Natural air cooling of engine is not possible, hence.
ii. It requires a powerful radiator fan.
iii. The clutch and gear shifting mechanism is long and complex.
iv. Because of higher weight concentration at rear, the vehicle has a tendency to over steer while taking a sharp turn.
v. Luggage space at front is restricted due to small compartment of fuel tank and spare wheel.

3. Front Engine Front Wheel Drive:



- This layout is the most compact layout.
- It is being popularly used on most hatchback cars in India.
- The drive chain for this layout is :

  Engine —» clutch—»gearbox —»universal joints—» differential —» front axle —» wheels

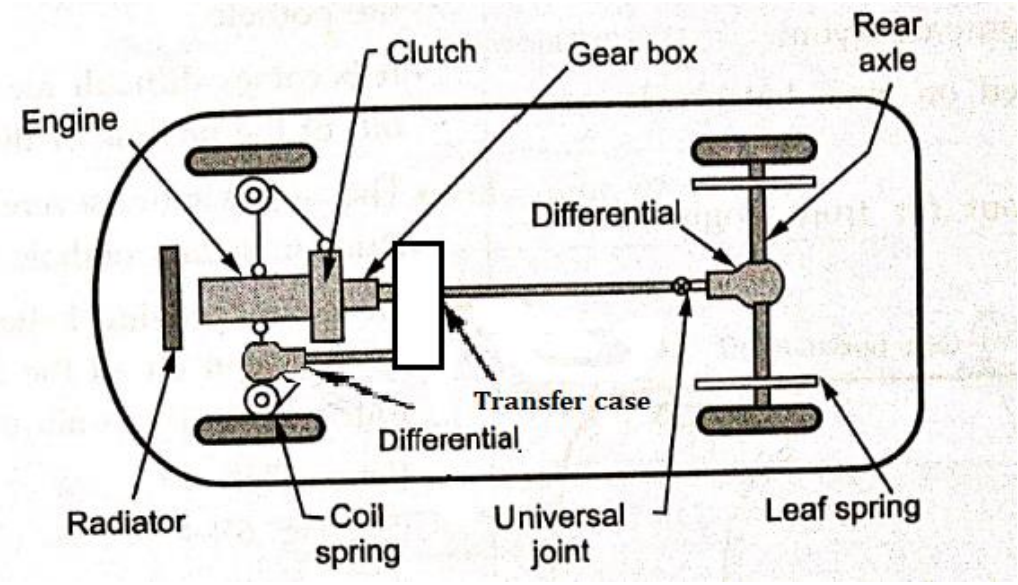
- **Advantages:**

i. Compact design of vehicle.
ii. Due to higher weight of the steering wheels, it provides stable steering during turns.
iii. Reduced skidding on slippery roads.
iv. No propeller shaft is required.
v. It has a flat rear floor due to absence of propeller shaft.
vi. Better engine cooling takes place due to natural air stream flowing across the engine radiator.

- **Disadvantages:**

i. The front wheel design is complicated because it supports the engine, differential and steering mechanism.
ii. High noise transmission from engine compartment to driver cabin.
iii. Poor ability of the vehicle to climb a steep hill because of lower weight on rear wheel.

4. Four Wheel Drive:

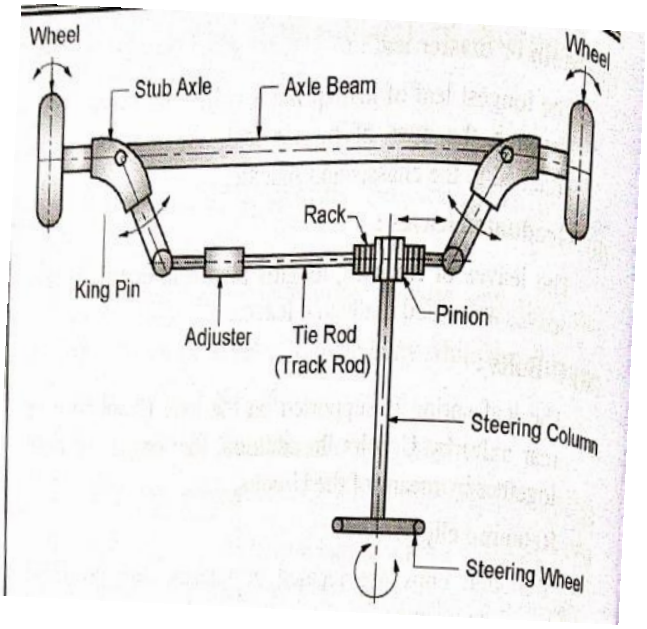


- Sometimes while driving on rural or uneven rough unconstructed roads, automobile with conventional layout (2 - wheel drive) gets stuck the pothole.
- It becomes difficult for driver to get the automobile out of the pothole or ditch.
- The case is more severe if the drive wheel itself gets stuck in such a pothole or ditch.
- To provide better drive and traction on all four wheels of the vehicle, a four wheel drive is used.
- The drive chain for this layout is: A vehicle with four wheel drive is denoted as 4 WD or all - wheel drive.
- An additional lever is provided in the driver cabin to engage or disengage the 4 WD.

- **Advantages:**
  i. Better traction on all the four wheels.
  ii. Excellent road handling characteristics.
  iii. Vehicle can be used on uneven or rough or unconstructed road.

- **Disadvantages:**
  i. Vehicle weight is high.
  ii. Vehicle cost is higher.
  iii. Accessibility to various components is difficult due to complicated design.
  iv. It requires special transfer case.

Steering System (Ackermann Steering Mechanism)



- Steering system is a mechanism used for converting the rotary motion of steering wheel into angular motion of front wheels to turn the vehicle in desired direction.
- The most commonly used steering mechanism is Ackermann steering mechanism.
- **Functions of Steering System:**
  i. To change the direction of vehicle
  ii. To provide the directional stability to vehicle when moving along straight path
  iii. To facilitate straight motion recovery after completing the turn
  iv. To achieve perfect rolling motion of wheels on road
  v. To minimize the tyre wear and tear.

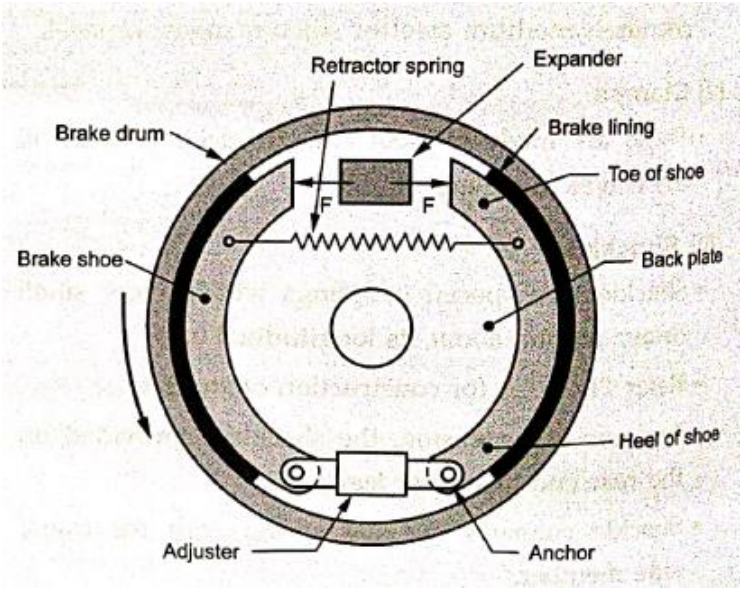
- **Components and Working of Steering System (Ackermann Steering Mechanism):**
  1. **Axle Beam:** Vehicle chassis is supported on axle beam through suspension system. Axle beam takes the weight of stub axle. Vehicle and transmit to stub axle.
  2. **Stub Axle:** Stub axles are pivoted at two ends of the axle beam by king pins. One end of stub axle carries wheel and brake drum while other end of the stub axle is connected to the tie rod.
  3. **King Pin (Swivel Pin):** King pin pivots the stub axle on axle beam.
  4. **Tie Rod:** Two stub axles are connected to each other by tie rod. With the help of adjuster, the length of tie rod can be adjusted. Tie rod is important part of steering mechanism.

5. **Rack and Pinion:** To turn of the wheels, the stub axles need to be oscillated about the king pin. The oscillatory motion of stub axles can be achieved by giving the linear motion to the tie rod. Rack mounted on the tie rod engages with pinion mounted on steering column.
6. **Steering Column:** When steering column rotates, the pinion mounted on steering column also rotates. The rotary motion of pinion is converted into linear motion of rack and tie rod.
7. **Steering Wheel:** Driver rotates steering wheel so as to rotate the steering column. The rotary motion of steering wheel is converted into angular motion of front wheels.

Braking System

- Braking system is an arrangement of various linkages and components used to slow down or completely stop the moving vehicle within the shortest possible time by applying artificial frictional resistance.
- During process, the brake absorbs the kinetic energy of moving vehicle and converts it to heat energy. The heat generated by brake is unwanted energy which is dissipated to surrounding air.
- **The main purpose / functions of the braking system are as follows :**
  i. To provide a mean to slow the vehicle without affecting the engine speed.
  ii. To provide a mean to stop the vehicle while the engine is still running.
  iii. To provide emergency stop of the vehicle within lowest time and distance.
- Types of Brakes:
  1. Drum brakes
  2. Disc Brakes

1. Drum Brakes/ Internally expanding Brake:



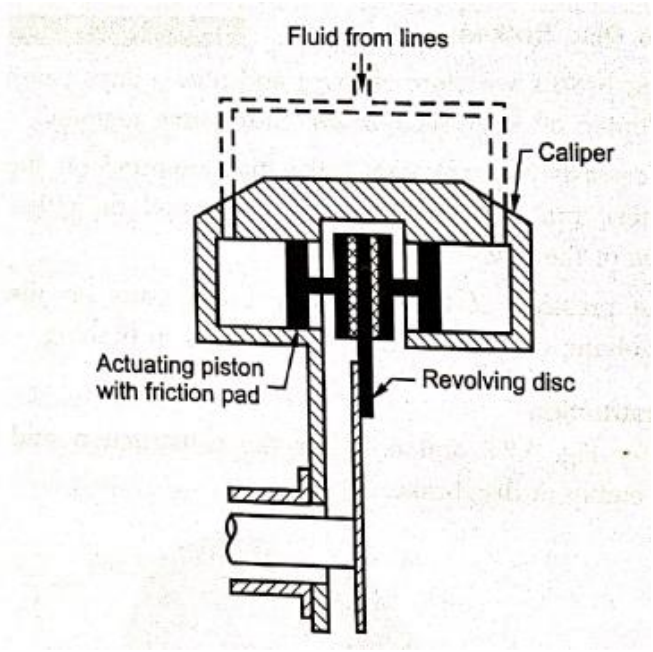
- **Brake drum:** The brake drum is a hollow cylinder type construction made of cast iron. It is mounted concentric to the axle hub and rotates along with the wheel. It consists of a rotating brake drum mounted on the wheel and two semi-circular brake shoes attached on a stationary back plate.
- **Back plate:** A separate back plate is mounted on the stationary axle casing and behind the brake drum. The back plate houses the assembly of semi-circular brake shoes mounted on an anchor. It also covers the entire brake assembly, thereby protecting it from dirt, dust and mud.
- **Brake shoe:** The two brake shoes are pivoted to the anchor at one of its ends. The other end of brake shoe is held by an expander. The pressing of brake shoes on the rotating drum causes friction resulting in braking.
- **Expander:** It can be mechanical cam type or a hydraulic piston type.
- **Retractor spring:** The compression type retractor spring connected between the brake shoes always try to pull shoes inwards.

- **Working:**
  i. The drum mounted on the axle hub continues to spin along with the wheel.
  ii. When the brake pedal is pressed, the braking effort is transferred to the expander through an activation mechanism, pushing the brake shoes on the drum, against the spring force.
  iii. The friction between the stationary brake shoes and the revolving brake drum provides the braking action.
  iv. When the brake pedal is released, the retractor spring pulls the brake shoes inward to disengage the brakes.
  v. An adjuster is also provided to compensate for the wear and tear of the brake shoes.

- **Advantages :**
  i. It consists of large friction shoes providing better braking.
  ii. The overall system design and construction simple.
  iii. The drum brakes are most economical at cost.

- **Limitations:**
  i. The wear and tear on brake shoes is not uniform.
  ii. Overall size of the system is more.
  iii. Replacement of brake lining requires dismantling of entire brake drum and back plate assembly.

2. Disc Brakes:



- **Principle:** It consists of a rotating brake disc mounted on the wheel and two friction pads positioned on either side of the disc. The pressing of the stationary brake pads on the revolving disc causes friction, resulting in braking.

- **Construction:**
  i. **Rotating Disc:** It consists of a cast iron disc bolted on the wheel hub. The brake disc revolves along with the wheel. The outer circumference of brake disc is housed in the hydraulic calliper.
  ii. **Calliper:** The hydraulic calliper consists of two sliding pistons. The outer surface of sliding pistons is provided with friction pad riveted on it.
  iii. **Fluid lines:** Fluid lines are connect the calliper to the brake lever or pedal.
  iv. **Retractor springs:** These are mounted in between the piston and calliper housing.
  v. **Brake pads:** These are stationary pads mounted on piston.

- **Working :**
  i. When the vehicle is running, the brake disc revolves along with the wheel.
  ii. When the brake lever or pedal is operated, the braking effort is transmitted to the hydraulic calliper through pressurized fluid.
  iii. The fluid pressure pushes the two pistons towards the brake disc.
  iv. The friction between the brake pads and rotating brake disc causes the braking of the vehicle.
  v. When the brake lever is released, the two pistons are pushed back by the retractor springs.

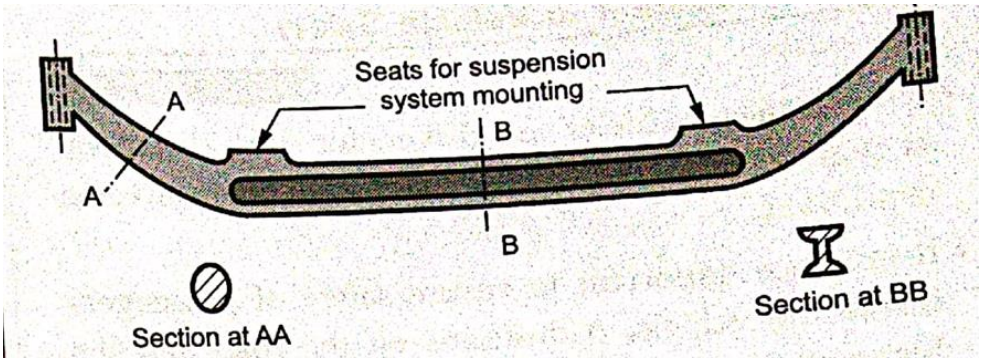
- **Advantages :**

i. The operation and assembly of disc brake is much simpler.
ii. As the friction pads are flat, the wear and tear is uniform.
iii. Heat dissipation is faster.
iv. More efficient.

- **Limitations :**

i. The overall system cost is higher due to hydraulic calliper and fluid lines.
ii. The frictional area of pads is less, thereby requiring high pressure intensity fluid.

Axles



- Axle is a member which carries the wheels at its ends. It is central shaft for rotating a wheel.
- It may be fixed to the wheels, rotating with them or fixed to the vehicle with the wheels rotating around the axle.

1. Front Axle:

- Front axle is usually a forged member carrying the road wheels at its ends.
- Modem cars have live front axle while heavy vehicles use conventional dead front axle.
- The front axle has to take vertical vehicle load, bending loads due to weight, and torque loads due to braking and acceleration.
- The front axle assembly includes stub axles, brake assembly and tie rod units.
- The central portion of front axle is given a downward sweep to keep a low chassis height.
- **Functions of Front Axle:**

i. It carries the front weight of the vehicle.
ii. It carries the steering mechanism which is used to direct the vehicle in the desired direction.
iii. It houses front suspension which absorbs shocks produced due to road surface variations.
iv. In case of front wheel drive, it also carries the differential unit. Seats for suspension system mounting.
v. Front axle is used for steering the front wheels carried on the stub axle.

2. Rear Axle:

- Rear axle drives are employed on front engine rear wheel drive vehicles.
- The rear axle drive system consists of important sub-systems such as universal joints, slip joint, propeller shaft, suspension leaf springs, rear axle, rear axle casing, final drive and differential.
- The rear axle drive system is subjected to the following forces and torques.

i. Weight of the vehicle: It acts vertically downward and causes bending moment in the axle shaft.
ii. Driving thrust: It acts in the longitudinal direction of the vehicle.
iii. Torque reaction: It acts in longitudinal direction of the vehicle and is caused due to acceleration or braking of the road wheels.
iv. Side thrust: It acts from the sides of vehicle due to force etc.

Suspension System

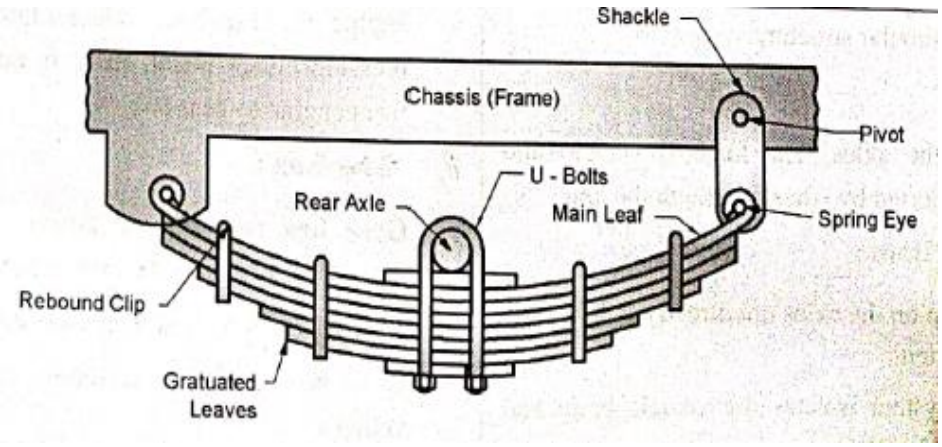
- Suspension system is mounted between the automobile chassis and the axles (front axle and rear axle) to isolate the vehicle body from road shocks.
- Suspension system consists of spring and damper. The damper, which is known as shock absorber, consists of piston cylinder arrangement filled with oil.
- **Function of Suspension System:**

i. To isolate the vehicle body from road shocks
ii. To safeguard passengers and cargo from the road shocks
iii. To maintain the contact between the tyres and road.
iv. To maintain the level of vehicle body while travelling on rough or inclined road.

- **Types of Suspension Systems:**

1. Leaf Spring
2. Telescopic Suspension System (Coil Spring and Damper)

1. Leaf Spring (Semi-Elliptic Leaf Spring):



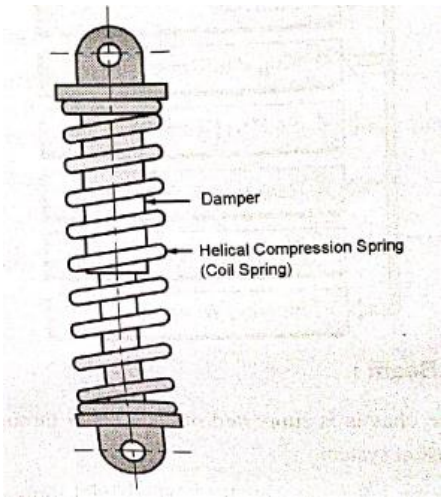
- **Component and working:**

1. **Main or master leaf:** The longest leaf of leaf spring is called the master leaf. Through the eyes of master leaf, the leaf spring is attached to the chassis and shackle.
2. **Graduated leaves:** The leaves of reducing lengths placed after full length.
3. **U-Bolts:** The leaf spring is supported on the axle (front axle or rear axle) by U-bolts. In addition, the leaves are held together by means of the U-bolts.
4. **Rebound clips:** Rebound clips are located at intermediate positions along the length of the spring so that the graduated leaves share the rebound load with main or master leaf.
5. **Shackle:** One end of the leaf spring is directly mounted on the chassis while the other end is connected to the chassis through the shackle. The shackle provides flexibility for movement of end of leaf spring. When vehicle is subjected to road shock, the wheel and axle move upward, deflecting the spring. The spring absorbs the shock. Due to deflection of spring, the length of spring increase. The increase in length of spring is accommodated due to angular movement of shackle about the pivot.

- **Application of leaf spring :**

  Leaf springs are used in heavy motor vehicles (buses, trucks, etc.)

2. Telescopic Suspension System (Coil Spring and damper):

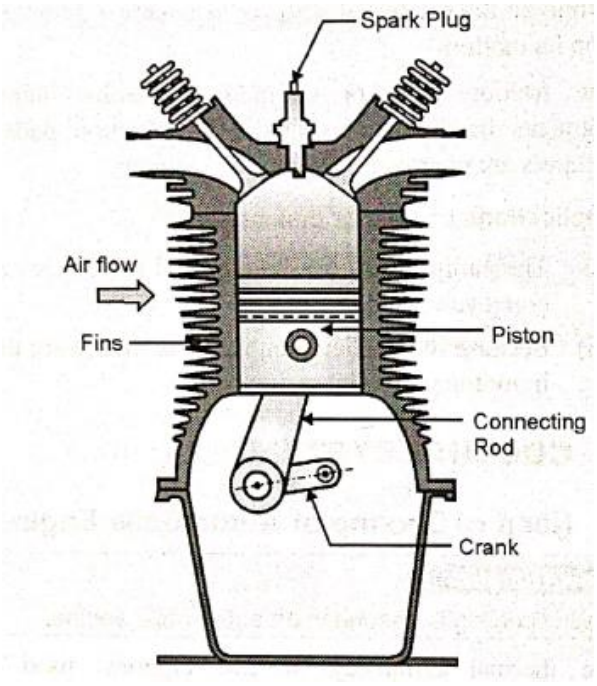


- **Components and working of telescopic suspension system:**
  1. **Helical compression spring (coil spring):** The helical compression spring absorbs the energy of road shock. Due to this, the spring tends to oscillate.
  2. **Damper (shock absorber):** The damper consists of piston cylinder arrangement filled with the oil. The oil in damper restricts the oscillation of helical compression spring (coil spring).
- **Application of telescopic suspension system:** The load carrying capacity of coil spring and damper is less than the leaf spring. It is used in two wheelers and light motor vehicles (cars).

Cooling system

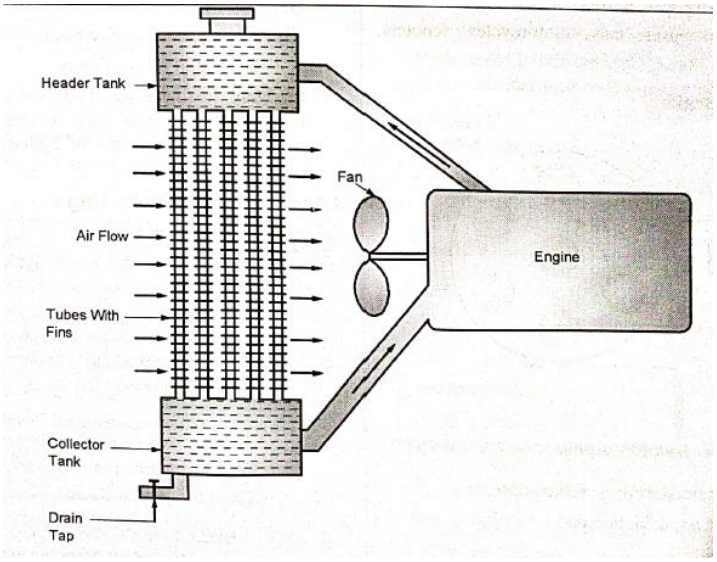
- The thermal efficiency of I.C. engines, used in automobile vehicles, is around 30 %. Therefore, the total heat produced by combustion of fuel in I.C. engines is not converted into mechanical power at the crank shaft.
- About 30% of the total heat produced by combustion of fuel in I.C. engine is lost to cylinder walls. If heat lost to cylinder wall is not dissipated or removed is leads to:
  i. damage of cylinder due to overheating
  ii. seizing of piston due to overheating
  iii. burning of lubricating oil
- Therefore, it is necessary to provide the cooling system to dissipate the heat form cylinder wall so as to maintain the temperature of cylinder wall within the limits.
- Methods of Cooling:
  i. Air cooling system
  ii. Water cooling system

1. Air cooling system:



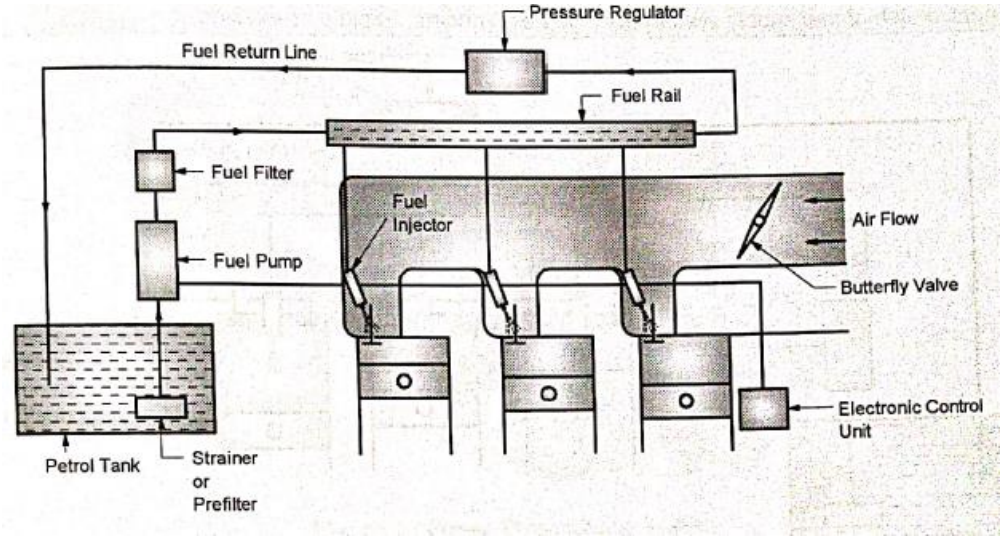
- In air cooling system, the fins are provided on the surface of the cylinder.
- The fins increase the surface area available for dissipation of heat.
- The air flowing over the surface of the cylinder helps to dissipate the heat from the cylinder wall.
- Application of air cooling system: Air cooling system is used in two-wheelers. It is not effective in high capacity engines, like engines used in four wheelers.

2. Water cooling system:



- In water-cooling system, the water or coolant is used as a medium of cooling.
- The cylinder of I.C. engine is surrounded by water jacket. The water or coolant flows through the water jacket and absorbs the heat from cylinder. The hot water from engine jacket flows through the radiator.
- The radiator consists of header tank, collector tank and tubes with fins. The hot water or coolant flows through the radiator tubes where it loses its heat to air. The cold water or coolant is again supplied to engine jacket.
- The fan induces the air to flow over the radiator tubes, which helps to cool the coolant flowing through the radiator tubes.
- Application of water cooling system: System is highly effective. Hence, it is used in four wheelers.

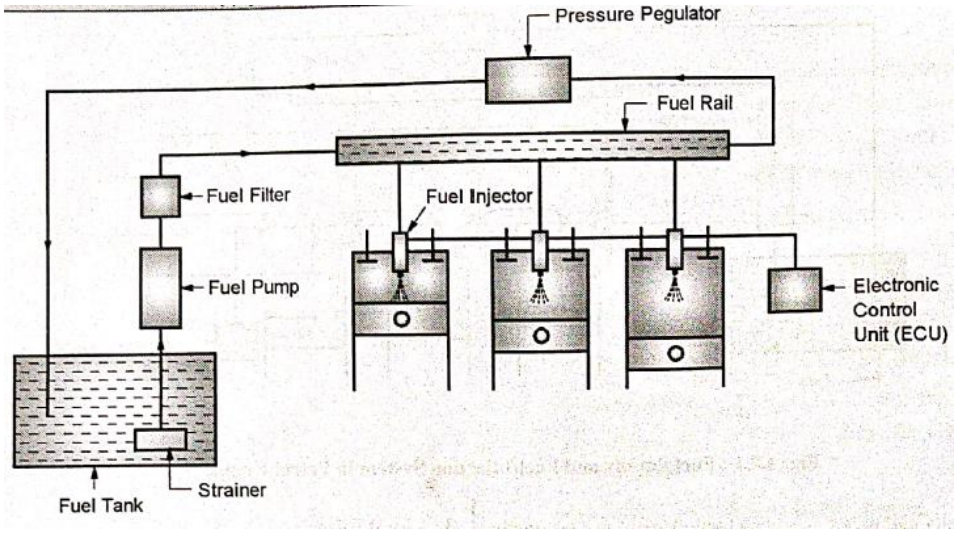
- **Fuel supply and fuel injection system in petrol engine:**



- Traditionally carburettor is an essential element of fuel supply system in petrol engine. It is now being replaced in petrol four-wheelers by multi-point fuel injection (MPFI) system.
- **Elements of Fuel Supply and Fuel Injection System in Petrol Engine (MPFI):**

1. **Petrol Tank:** Petrol is stored in petrol tank.
2. **Fuel Pump:** Fuel pump increases the pressure of the petrol before feeding it to the fuel rail. The fuel pump is driven by engine camshaft or electric motor.
3. **Fuel Filter:** The high pressure petrol passes through the fuel filter, where it is filtered so as to remove the dust and dirt particles.
4. **Fuel Rail:** The high pressure petrol is then supplied to the fuel rail.
5. **Fuel Injector:** A fuel injector is placed in intake manifold of each cylinder. The high pressure petrol enters the fuel injector and fuel injector injects the petrol into intake manifold at high velocity. The air is flowing though the intake manifold. The homogenous air and petrol mixture then enters the engine cylinder through the inlet valve.
6. **Pressure Regulator:** The pressure regulator controls the pressure of petrol in fuel rail.
7. **Electronic Control Unit (ECU):** The ECU controls the fuel injection system. ECU decides the amount of fuel injected and timing of fuel injection in each cylinder.

- **Fuel supply and fuel injection system in Diesel engine:**

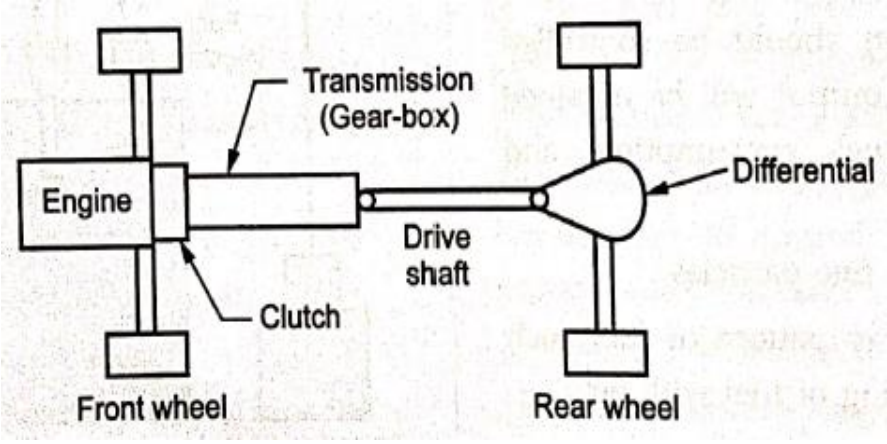


- Fuel supply and fuel injection system of diesel engine consist of following components:

1. **Diesel Tank:** Diesel is stored in diesel tank.
2. **Fuel Pump:** The fuel pump increases the pressure of diesel before feeding it to the fuel rail. The fuel pump is driven by engine camshaft or electric motor.

3. **Fuel Filter:** The high pressure diesel passes through the fuel filter where it is filtered so as to remove the dirt particles.
4. **Fuel Rail:** The high pressure diesel is then supplied to the fuel rail.
5. **Fuel Injector:** The fuel injector is placed in a cylinder head of each cylinder. The high pressure diesel enters in injector and the fuel injector injects diesel in cylinder at the end of compression stroke.
6. **Pressure Regulator:** The pressure regulator controls the pressure of diesel fuel rail.
7. **Electronic Control Unit (ECU):** The ECU controls the fuel injection system. It decides the amount of fuel injected and timing of fuel injection.

Power Transmission System



- The function of power train system is to transfer power from engine to the wheels of the vehicle. It consists of a clutch, a gearbox, a propeller shaft, and a differential.

1. **Clutch:** It is usually a friction device. Its purpose is to enable the driver to gradually engage road wheels when required and disengage the drive from engine to road wheel when required.
2. **Gearbox:** It consists of various types and sizes of gears. .Gearbox provides the necessary leverage variation between the torques from engine to the road wheels.
3. **Propeller shaft:** It consists of shaft having universal joint at its ends. Its function is to transmit power from output shaft of gearbox to input shaft of the differential.
4. **Differential:** It consists of bevel pinion and crown wheel and a set of internal gears. Its purpose is to permit the two wheels on the axle to run at different speeds while cornering a turn.

Clutch

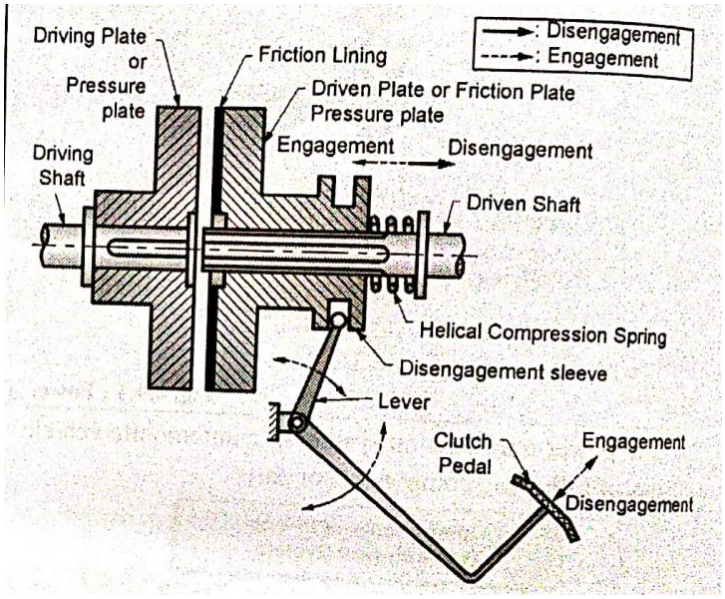
- Clutch is mounted between the engine and the gear box. It is used to engage or disengage the engine from gear box as per the will of the driver.
- When clutch is engaged, power is transmitted from engine to gear box. When clutch is disengaged by pressing the clutch pedal, there is no power transmission from engine to gear box.
- **Classification of clutch:**
    1. Plate or Disc Clutches: The plate clutch consists of a set of driving plates and driven plates arranged alternately.

       Types of plate clutch depending upon number of driven plates used:
       i. Single plate clutch: A single plate clutch consists of only one driven plate
       ii. Multi-plate clutch: A multi-plate clutch consists of more than one driven plates
    2. Types of plate clutches depending upon use of cooling oil :
       i. Wet Clutch: If the cooling oil is used for heat dissipation, the clutch is called wet clutch
       ii. Dry Clutch: The cooling oil is not used, the clutch is called dry clutch

A. Cone Clutches: The cone clutch consists of a cup keyed to the driving shaft and a cone with friction lining free to slide axially on the splined driven shaft.

B. Centrifugal Clutches: The centrifugal clutch works on the principle of centrifugal force.

• Single plate clutch:



- A single plate clutch consists of following components driving (pressure) plate:

1. **The driving plate:** It is rigidly keyed to the driving shaft, while the driven plate is free to slide axially on the splined driven shaft. The driving plate is also known as pressure plate.

2. **Driven (friction) plate:** The friction lining, made of friction materials like asbestos, is riveted or pasted to the driven plate. The driven plate is also known as friction plate or clutch plate.
3. **Helical compression springs:** The helical compression spring exerts the axial force on the driven plate or friction plate or clutch plate.
4. **Disengagement mechanism:** The disengagement mechanism, which consists of disengagement sleeve, lever and clutch pedal, is used for disengaging the clutch.

- **Working of Single Plate Clutch:**
  1. Engage position: Normally the clutch is in engaged position. Both plates are in contact with each other due to spring force. Hence torque is transmitted from driving plate to driven plate and finally to driven shaft (Output shaft).
  2. Disengage condition: When clutch pedal is pressed clutch is disengaged, the drive plate or clutch plate moves away from driving plate and there is no torque or power transmission from driving shaft to driven shaft.
  3. Heat is generated during engagement of the clutch due to friction between driver and driven surface. This heat must be dissipated to avoid overheating.
- **Applications of Single Plate Clutch:**

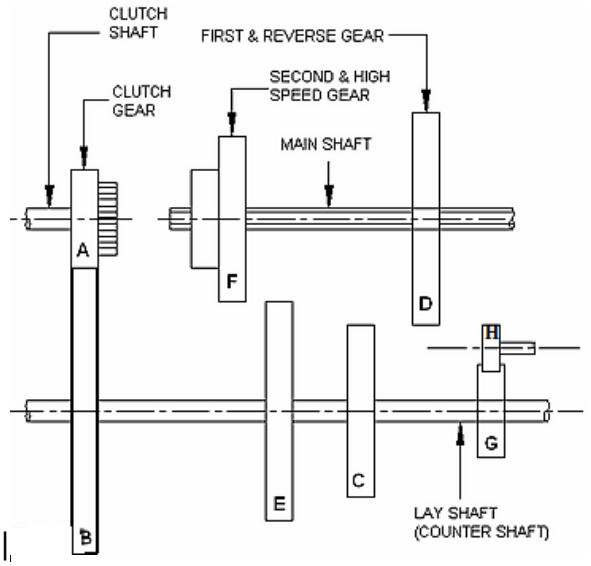
  The single plate clutches are used where large radial space is available: trucks, buses, cars, etc.

Gear Box

- Gear box receives the power from engine through clutch and transmits the power to the propeller shaft.
- In gear box, torque is increased and speed is reduced.
- Gear box produces different speed ranges for the vehicle.
- **Need of Gear Box in Vehicles :**
  1. In automobile vehicle, the I.C. engine operates at high speed but the torque produced by I.C. engine is not very high. If I.C. engine is directly connected to the wheels, the engine torque may not be sufficient to drive the vehicle. *The gear box receives the power form engine at high speed. It reduces the speed and increases the torque, which is adequate to drive the vehicle.*
  2. I.C. engines operate over limited speed range. So, automobile vehicle has to run over wide range of speeds and torque. *The gear box provides wide range of speeds and torque to vehicle.*
- **Functions of Gear Box:**
  1. Gear box reduces the speed and increases the torque.
  2. Gear box provides wide range of speeds and torque to the vehicle
  3. With reverse gear, gear box provides the means to move the vehicle in reverse direction.

4. In neutral position, the gear box disconnects the I.C. engine from the wheel even with the clutch in the engaged position.

- Types of Gear Boxes: Three types of gear boxes are used in automobile vehicles
    1. Constant Mesh Gear Bo
    2. Sliding Mesh Gear Box
    3. Synchromesh Gear Box
- **Sliding mesh Gearbox:**



- **Construction:**

  Sliding mesh gearbox consists of 3 shafts that are:

1. **Main shaft:** It is the shaft used as an output shaft in a sliding-mesh over which the sets of gears with internally splined grooves are arranged in an organised fashion. The outer surface of this shaft is made splined so that the gears can easily slide over this shaft in order to mesh with the appropriate gear.
2. **Clutch shaft:** It is the shaft that is used to carry engine output to the transmission box with the help of engaging and disengaging clutch which is mounting at the engine end, gear or a pair of gear is mounted over this shaft which is used to transmit rotational motion to the lay shaft.
3. **Lay shaft:** It is the shaft having gears mounted over its outer surface and is in continuous rotation with the clutch shaft as one gear of this shaft is always in contact with a gear on the clutch shaft, it is used as an intermediate shaft (between main shaft and clutch shaft)that provides the meshing of the gears of the main shaft in order to transmit appropriate output to the final drive.

- **Working:**

i. The shifting of gears is obtained by the meshing of the gears on the main shaft with the gears on the lay shaft by right or left sliding of gears on the main shaft in order to obtain appropriate gears.

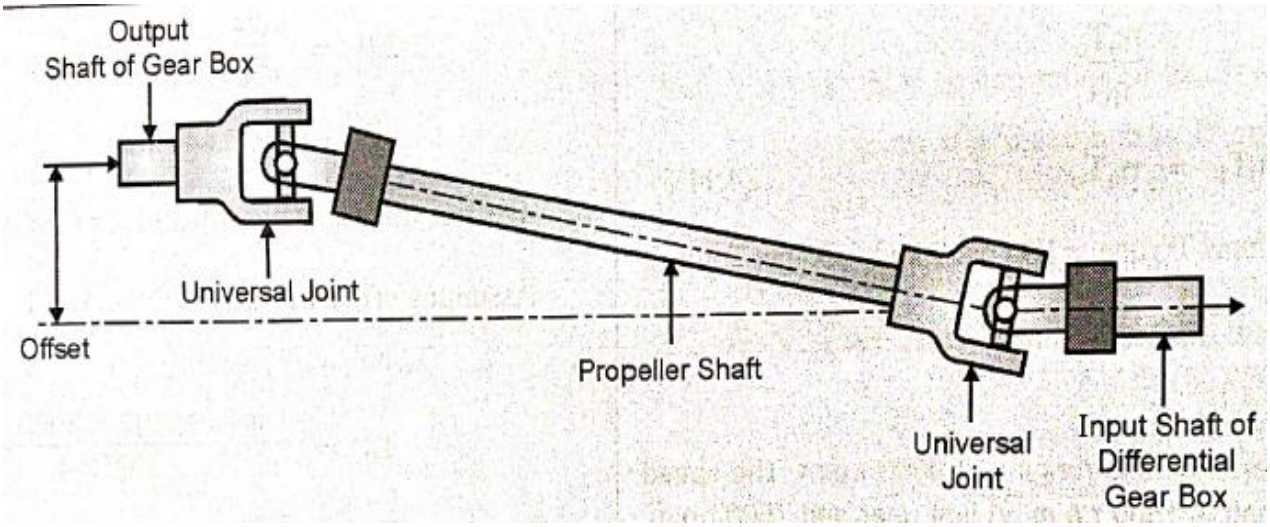
ii. **First gear:** First gear provide maximum torque at low speed which is obtained when the smallest gear on the lay shaft meshes with the biggest gear on the main shaft in order to provide high torque.

iii. **Second gear:** Second gear provides less torque and higher speed than first gear and is obtained when the middle size gear of the main shaft meshes with the second smallest gear on the lay shaft and high speed and second high torque is transmitted to the final drive.

iv. **Third gear:** Third gear provides maximum speed and minimum torque to the final drive and is also known as high speed gear or top gear in sliding mesh gearbox, this gear is obtained when the smallest gear of the main shaft meshes with the biggest gear of the lay shaft. Or we can say that the drive obtained maximum speed of the clutch shaft.

v. **Reverse gear:** When the reverse gear is selected, the rotation of the output shaft is reversed which is made possible by using an idler gear between the main shaft and lay shaft that changes the rotation of the output shaft and the vehicle starts moving in reverse direction.

Propeller Shaft and Universal Joint:



- Gearbox is located in front part of vehicle; whereas differential gear box is located in rear part of vehicle.
- The power is transmitted from the gear box to the differential gear box through a long shaft called as propeller shaft or drive shaft.
- The position of input shaft of differential gear box is at much lower level as compared to output shaft of the gear box.
- The axes of two shafts are parallel but there is some offset. Therefore, to connect these two shafts through propeller shaft, universal joint is used at each end of the propeller shaft.

- **Function of propeller shaft:**

i. It transmit rotary motion of gear box output shaft to differential and then to the wheels through axle shaft.

ii. It transmits motion at some angle which varies frequently.

iii. The propeller shaft changes the length between gear box and rear axle.

- **Construction of propeller shaft:**

i. It is made of steel or hollow tube shaft which are connected with slip joint which are flexible.

ii. It is having diameter 50 to 70 mm and the thickness ranges from 1.5 to 7.5 mm depending upon application type.

iii. It is manufactured from tube so it is light in weight and stronger than solid shaft.

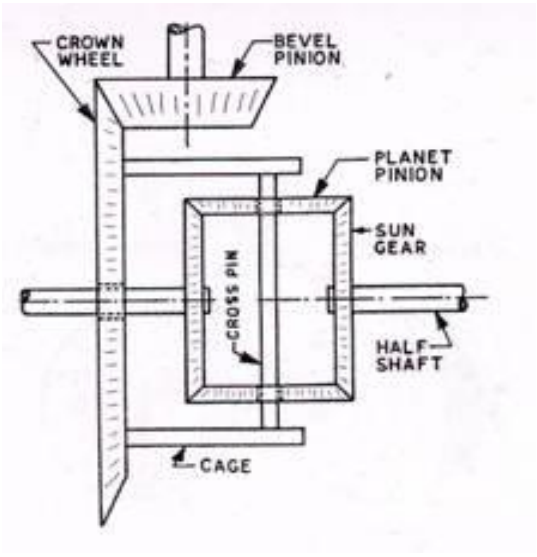
iv. Slip joint is formed by internal splines on the sleeve attached to universal joint at left and external spline on propeller shaft.

- **Universal Joints:**
- Functions of Universal joints:

i. For transmitting power from horizontal main transmission shaft to the propeller shaft which is normally at an angle with the horizontal because the rear axle is usually lower than the main transmission shaft.

ii. In this type of joint there is flexibility which withstands the irregularities. Due to that there is possibility of changing angle constantly. Since input bevel pinion shaft differential are parallel but not in the same axis. Therefore two joints are required al both the ends of propeller shaft for power transmission.

Differential Gear Box



- Differential is located between two half shafts of the rear axle. The rear axle is classified into two parts each part is known as half shaft.

- **Functions of Differential Gear Box:**
  1. To increase the torque the differential gives a constant reduction in speed.
  2. The shaft of rear axle is at right angles to the propeller shaft. The differential gear box transmits the power at right angles.
  3. The differential gear box allows the two wheels to at different speeds when vehicle is taking the turn. Differential gear box increases the torque and reduces the speed from propeller shaft to rear axle shaft.
- **Construction and working:**

1. It consists of a mechanism having epicyclic gear train. Due to epicyclic gear train outer wheel rotates at high speed than inner wheel at the turning of vehicle (or car).
2. In straight running both outer and inner wheel run at the same speed.
3. **Ring gear:** It is also called crown wheel of final drive. It drives cafe.
4. **Differential cage:** It is used to carry pinions of planet.
5. **Differential cage:** It is firmly fixed on the crown wheel face. The two pinions of planet which drive the sun gears are mounted on cage with the help of a pin.
6. **Sun gears:** Both sun gears and planet pinions form the gear train which is called as epicyclic gear train. Sun gears are mounted with keys over the inner ends of both half rear axles. The drive from planet pinion is given to sun gears.
7. **Planet pinions:** The cage which is comprising of a long pin on which the two planet pinions are mounted with their teeth meshed with sun gears. The pinions of planets are free to rotate around the pin and which also drive the sun gears.
8. When vehicle running straight the drive from bevel pinion of propeller shaft is transmitted at 90° to the crown wheel. Along with crown wheel the differential cage also rotates at the same speed. The cage carries two pinion planets which also rotate with cage at the same speed. The teeth of pinion of planet engaged with teeth of sun gears which transmit power to both rear axle halves through sun gears at uniform speed.
9. In straight running conditions the planet pinions do not rotate on their own axes or at pin. The crown cage and wheel pin with planet pinions rotate at a single unit with crown wheel. The same amount of rpm and torque are transferred to the driving wheels.
10. Differential transmits torque to both drive axles depending on the speed ratio across it.

Vehicle Active and Passive Safety Arrangements

- It is very important to consider safety of an automobile vehicle. Safety of an automobile vehicle can be ensured by following two parameters.
    1. The design of vehicle should be such that the chances of accidents should be as minimum as possible.
    2. Secondly if there is accidently any chance the injury to the occupants including driver should be minimum.

- **Active safety:**

- It comes under design automobile vehicle for minimum injury at the time of accidents.
- Passive safety features are the features by which there is minimum injury and crashing for occupants at the time of accidents.
- Some of passive safety features help to absorb crash forces collision of vehicle. The following points come under passive safety features.

i. There should have rigid boxes for occupants with weaker ends which crumble on collision thereby absorbing the energy of impact and bringing the vehicle to stop instantly.

ii. For protecting against side sweeps the doors of the vehicle must be/should be strengthened by using steel bars. To reduce the risk of spilled fuel and consequent fire in case of near end collision fuel tank should be located at suitable positions.

iii. In case of accident it is very important to consider the doors closing after car comes to rest otherwise there are chances of person to thrown out and being killed are increased so the doors should be fitted with safety lock.

iv. Various switches controls etc. should be so shaped that they are not producing excessively so as to cause injury to the occupants at the front at the time of front side collision.

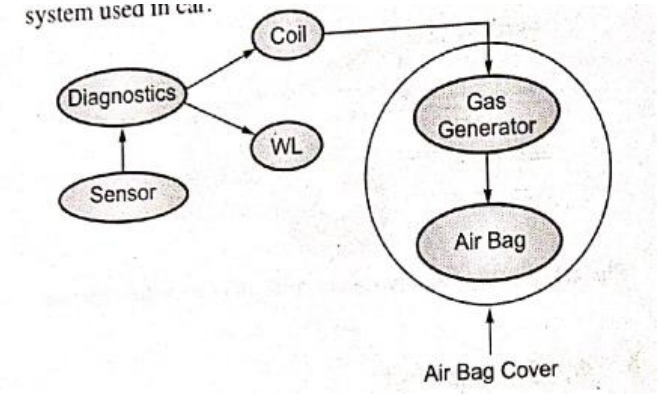
v. To minimize the leg injuries to occupants of front seats, a knee bolster must be provided knee absorbing crushable barrier under dashboard that steps occupant knees from striking hard components under and surfaces below and behind the dash.

vi. Seat belts should be worn both by passenger as well as driver.

1. Seat belts:

- Seat belts are a safety device used in four wheelers for the safety of driver and the person seating near the driver. These are also known as safety belts.
- Seat belts reduce the injury in a traffic collision by stopping the vehicle occupant from hitting hard against interior elements of the vehicle or other passengers.
- Safety belts keep the passengers and driver positioned correctly on its seat for maximum benefit from the impact.
- When passenger and vehicle are travelling at same speed, the seat belt is fairly loose and passenger can make comfortable movements.

2. Air bags:



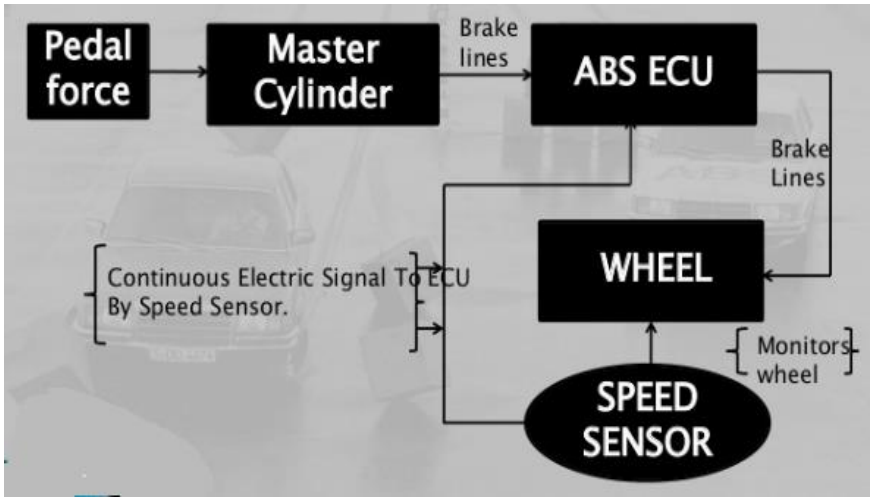
- Stopping an object's momentum requires force acting over a period of time.
- When a car crashes the force required to stop an object is very great becomes the car's momentum has changed instantly while the passenger's has not much time to work with.
- The goal of any supplement restraint system is to help for stopping the passenger while doing as little damage to him or her as possible.
- The air bag has the space between the passenger and the steering wheel or dashboard and a fraction of a second to work with.
- Even that tiny amount of space and time is available, however, if the system can slow the passenger evenly rather than forcing an abrupt half to his or her motion.
- Main parts of air bag system are:

1. Bag:

- The bag itself is made of a thin, nylon fabric which folded into the steering wheel or dashboard or more recently the seat belt or door.
- The powdery substance released from their sir bag by the way is regular corn starch or talcum powder which is need by the air bag manufacturers to keep the bags pliable and lubricated while they are in the storage.

2. **Sensor:**
    - The sensor is the device that tells the bag to inflate. It works with the control module to discriminate between crash and non-crash events.
    - These sensors measure the severity of the impact. Inflation happens when there is a collision force equal to running into a brick wall at 16 to 24 km. per hour.
    - They are setup so that sudden negative acceleration will cause the contacts to close, telling the control module that a crash before airbag deployment.
3. **Inflation system:**
    - The air bag's inflation system reads sodium amide (NaN3) with potassium; nitrate (KN03) to produce large volume of nitrogen gas. Hot blasts of the nitrogen inflate the air bag from its storage site up to 322 kmph.
    - A second later the gas quickly dissipates through tiny holes in the bag hence deflating the bag so you can move.
    - Nitrogen gas is filled in air bags.

3. **Anti-Skid Brake System or Anti-Lock Brake System (ABS):**



- One of the important requirements from a brake system is that the wheels should not lock or skid while the brakes are slowing down the vehicle. A wheel that is locked or skids on the road, loses its traction and the vehicle becomes non-controllable. An Anti-lock Brake System (A.B.S.) is a safety system which prevents the wheels from locking during braking operation.
- The anti-lock braking system ensures:
    i. Maintains vehicle control
    ii. Directional stability
    iii. Optimum deceleration while braking

- **Principle:** The system monitors the rotational speed of each wheel continuously and controls the brake line pressure to each wheel during braking. This prevents the wheel from locking up.
- **Construction:**
  i. **Speed sensor with toothed ring:** A circular toothed ring is mounted at each of the wheels. A magnetic speed sensor is located perpendicular to the toothed ring. The speed sensor transmits this speed data of each wheel to the E.C.U. of A.B.S.
  ii. **Valves:** The valve regulate air pressure to brakes during ABS action. It allows the pressure from master cylinder to brakes intermittently.
  iii. **E.C.U. (Electronic Control Unit):** The E.C.U. is the heart of the A.B.S. The E.C.U. receives speed input of each wheel and computes the state of rotation of each wheel.
  iv. **Hydraulic control unit:** It receives signal from ECU to apply or release brake under antilock conditions.
- **Working:**
  i. While braking, if wheel locking situation is detected, the ECU alerts Hydraulic control unit by sending commands it to release brake pressure, allowing wheel velocity to increase and wheel slip to decrease.
  ii. When wheel velocity increases, ECU reapplies the brake pressure and restricts the wheel slip to certain degree.
  iii. Hydraulic control unit controls the brake pressure in each wheel cylinder based on inputs from system sensor. As a result it controls wheel speed. This process is repeated for next braking operation.
- **Advantages:**
  i. ABS provides safety to the passengers.
  ii. It provides best traction during the operation of brake.
  iii. It also time of turns.
  iv. Controls directional stability of vehicle at the time of turns.
- **Disadvantages:**
  i. Under slipping surface (slippery surface) the stopping distance is high.
  ii. During braking vibration feeling is there pedal at the brake.
  iii. Its cost is very high.

***Note:

- ***Electric Vehicle:*** *refer notes of Unit no. III*
- ***Hybrid Vehicle:*** *refer notes of Unit no. III*