AUTOMOTIVE

Student Handbook
Class XII

Acknowledgements

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UNIT – 1

Measuring and Service Equipment

Learning Outcome

Session 1 : Measuring and Service Equipment				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students shall be able to identify components of each service equipment and able to operate the equipments.	Explain the construction and working of different service equipments.	Demonstrate how to operate all service equipment accurately.	**Interactive Lecture:** 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the operation technique of different service equipment.

Objectives

After attending this session, you should be able to:

- *Explain the construction, working and application of Air Compressor.*
- *Explain the construction, working and application of Car Washer.*
- *Explain the construction, working and application of Tyre Inflator.*
- *Explain the construction, working and application of Spark Plug Cleaner and Tester.*
- *Explain the construction, working and application of Wheel Balancer.*

1.1 Air Compressor

An air compressor is a machine that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off.

The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

There are many methods of air compression and can be divided into either positive-displacement or negative- displacement type compressors.

❖ Positive Displacement

Positive-displacement compressors work by forcing air into a chamber whose volume is decreased to compress the air. Common types of positive displacement compressors are:

- Piston-type air compressors
- Rotary screw compressors
- Vane compressors

Piston-type air compressors type of air compressors uses the principle in which pumping of air into an air chamber takes place because of the use of constant motion of pistons. They use one-way valves to guide air into a cylinder chamber, where the air is compressed.

Rotary screw compressors use positive-displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is decreased as the screws turn.

Vane compressors use a slotted rotor with varied blade placement to guide air into a chamber and compress the volume. Vane compressors deliver a fixed volume of air at high pressures.

❖ Negative Displacement

Negative-displacement air compressors include centrifugal compressors. These use centrifugal

force generated by a spinning impeller to accelerate and then de-accelerate captured air, which pressurises it.

Compressors can also be classiJfied according to the type of pressure:

- Low-pressure air compressors , which have a discharge pressure of 150 psi or less
- Medium-pressure compre0ssors, which have a discharge pressure of 151 psi to 1,000 psi
- High-pressure air compressorsz which have a discharge pressure above 1,000 psi

Fig. 1.2 Air Compressor

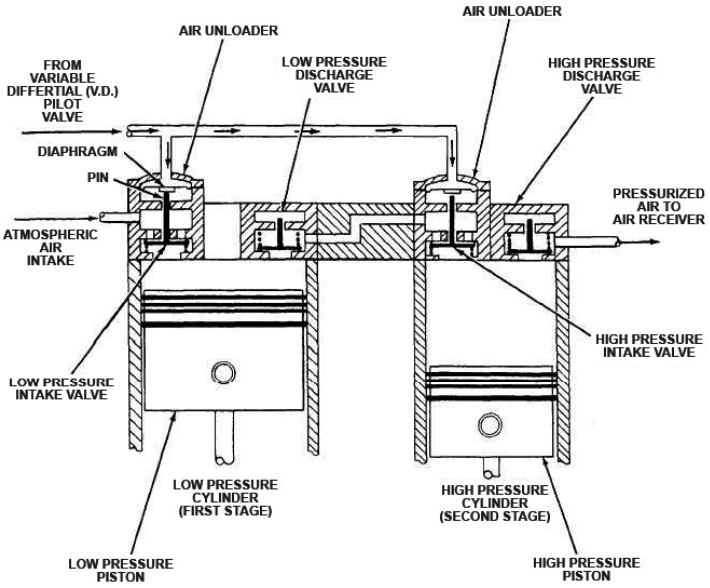


Fig. 1.1.1 Two Stage Reciprocating Air Compressor

❖ Working principle of Air Compressor

Air compressors collect and store pressurized air in a tank, and use pistons and valves to achieve the appropriate pressure levels within an air storage tank that is attached to the motorized unit. There are a few different types of piston compressors that can deliver even air pressures to the user.

Automotive compressors are combustion engine compressors that use the up-and-down stroke of the piston to allow air in and pressurize the air within the storage tank.

Other piston compressors utilize a diaphragm, oil-free piston. These pull air in, and pressurize it by not allowing air to escape during the collection period.

These are the most common types of air compressors that are used today by skilled workers and craftsmen. Before the day of motorized engines, air compressors were not what they are today.

Unable to store pressurized air, a type of antique air compressor may be found in the blacksmith's foundry bellows.

Now the air compressor is capable of building extreme pressures in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

❖ Applications of Air Compressor

- Portable air compressor for powering tools, such as jack-hammers
- To supply high-pressure clean air to fill gas cylinders
- To supply moderate-pressure clean air to a submerged surface supplied diver
- To supply moderate-pressure clean air for driving. Some office and school building pneumatic HVAC control system valves
- To supply a large amount of moderate-pressure air to power pneumatic tools, such as jack-hammers
- For filling tyres
- To produce large volumes of moderate-pressure air for large-scale industrial processes (such as oxidation for petroleum coking or cement plant bag house purge systems).

Most air compressors either are reciprocating piston type, rotary vane or rotary screw type. Centrifugal compressors are common in very large applications.

The power of a compressor is measured in HP (Horsepower) and CFM (cubic feet of air per minute).

The gallon size of the tank tells you how much compressed air "in reserve" is available. Gas/diesel powered compressors are widely used in remote areas with problematic access to electricity. They are noisy and require ventilation for exhaust gases.

Common workshop/ garage compressors are 110-120 Volt or 230-240 Volt. Compressor tank shapes are: "pancake", "twin tank", "horizontal", and "vertical". Depending on a size and purpose compressors can be stationary or portable.

1.2 Car Washer

Car washer is a most commonly used equipment in a garage. It supplies the water under high pressure through a flexible pipe and nozzle.

A commonly used car washer has following main parts:

- Electric motor
- Reciprocating water pump
- Water tank
- Spray nozzle
- Flexible water pipe
- Control valve
- Safety valve
- V-belt and pulley
- Pressure gauge

Car washers can be classified as:

- Manual car washers, and
- Automatic car washers (which are generally computerised and costlier)

❖ Manual Car Washer

A manual car washer consists of an electric motor which moves the crank and piston with the help of a V-belt. A pressure control valve is provided to adjust the pressure of water. The nozzle at the delivery pipe is able to adjust the amount of water. A storage tank is provided to store the water.

Fig. 1.3 Manual Car Washer

❖ Automatic Car Washer

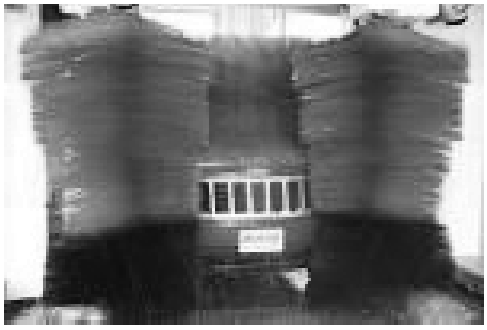
The first automatic car washes appeared in the late 1930s. Automatic car washes consist of tunnel-like buildings into which customers (or attendants) drive. In this, car is parked on the platform and is manually pre-washed by jet spraying at high pressure and under chassis wash. Further ph neutral shampoo is spread in form of foam, structure moves on rails along with rotating brush which cleans the car from top as well as from sides. Drying is done manually with cloth. Water used is directly dumped into sewage or water recycling plant.

❖ Applications of Car Washer

Car washers are used for cleaning the cars and other vehicles. The washing is carried out to remove mud, dust, dirt, grease, wax, oil, fat and other sticky chemicals from the cars.

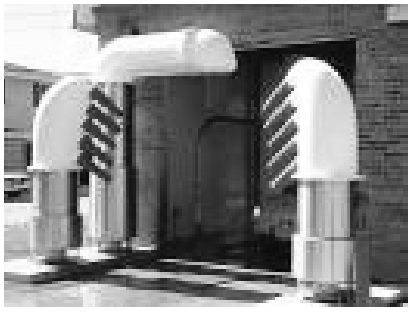
High pressure pre-wash

Foam Wash



Brushing

Rinsing



Drying

Fig. 1.4 Different Stages of Automatic Car Washing System

1.3 Tyre Inflators

Tyre inflators are used for vehicle tyre inflation, deflation and checking up the air pressure. The tyre inflator is connected to air compressor and has a dial for reading the air pressure. The dial is generally Bourdon's pressure gauge.

Tyre inflators can be classified as:

- Manual type tyre inflators, and
- Automatic tyre inflators (Digital type)

❖ Manual Type Tyre Inflators

These tyre inflators require more human effort to operate them while inflating, deflating and checking air pressure of tyre. There is hardly any automatic cut to ensure the required pressure is achieved. If the pressure is lesser than the prescribed value or vice-versa, the operator is required to fill again and again followed by checking the same. These manual type inflators can be digital as well as analogue type and can be wall mounted as well as portable type. Wall mounted Tyre inflators are ideal for fuel filling stations, small workshops and garages.

Fig. 1.5 Analogue Type Manual Wall Mounted

Fig. 1.6 Digital Type Manual Wall Mounted

❖ Automatic Type Tyre Inflators

These tyre inflators are normally digital type and can be electronic pre set type with built in compressor also. Electronic pre set type tyre inflators has microcontroller based system for setting and regulating Tyre pressure with digital backlit display. These Inflators inflates /deflates Tyre as per the preset pressure as the accurate pressure ensures proper grip and extends the life of tyre. These are very easy to handle.

Fig. 1.7 Automatic Type Tyre Inflators

❖ Applications of tyre inflators

- Tyre inflators are used for inflate/ deflate air pressure in tyres.
- Tyre inflators are used for checking air pressure in tyres.
- Tyre inflators are used in fuel retail outlets, service stations, garages and tyre shops.

1.4 Spark Plug Cleaner and Tester

Spark plug is an important component in petrol and gas fuelled engine. It produces an electric spark to ignite the air fuel mixture inside the combustion chamber. Due to its continuous exposure to the heat and gases in the combustion chamber, gets dust and debris on it. Spark plug cleaner and tester is designed to sandblast clean and make spark gap test. This equipment operates on 220V AC power source. Battery clips are provided for this purpose and an external source of compressed air is required for sand blast cleaning purpose.

Fig. 1.8 Spark Plug Cleaner and Tester

❖ Construction of Spark Plug Cleaner

A push button is located on the body of the equipment is pushed to supply ignition voltage to the spark plug during gap test.

Air valve control, is a wing type handle on the top of the equipment and “Air” is marked on it. This valve control has three positions “OFF”, “AIR” and “SAND”. This control is used to control the flow of air and sand during sand blast cleaning of spark plugs.

One needle valve is located to increase or decrease the air pressure during spark test by rotating it anti clockwise and clockwise respectively.

Pressure gauge is provided on the equipment to record the pressure applied during the spark plug gap test.

Mirror, a metal mirror is mounted at an angle to the rear of the plug test opening, is used to observe the action of the spark during the gap test.

Adaptor and gasket are provided to install different size spark plugs in the test opening.

Gap gauge, is provided for the purpose of checking and adjusting spark plug gaps.

❖ Working of Spark Plug Cleaner

Connect the air line from 125-150 psi air supply to the rear of the air control valve. Ground the equipment properly otherwise the spark gap test won't be up to the mark.

- **Sandblast Cleaning:** clean the spark plug of any excess oil or water and insert in the opening. With the left hand, turn air control valve to "sand" position. Oscillate outer end of the plug with a circular motion, so that cleaner blast can penetrate all crevices, for about 5 seconds. Without removing plug from the opening, turn valve to "Air" position and again oscillate plug for a few seconds to clean out all particles of loosened carbon. Return the air valve to "off" position and remove the cleaned plug. Shake out any particle of abrasive remaining between plug porcelain and shell.
- **Gap Testing:** Adjust gap of the old plug and screw old plug in the openings. Clip high tension lead to the plug to be observed. Regulate air pressure to correct amount for plug being tested. Press the test button, gradually opening needle valve until the pressure has been around 20psi above normal. While pressure is being increased, observe action of the spark in the mirror to see if the spark remains bright and steady, without flickering or missing.

1.5 Wheel Balancing

Tyre/wheel assembly balancing is a very basic service. Modern automobiles are highly tuned vehicles. Their performance, driver comfort, fuel economy and tyre life all can be negatively affected by even the slightest imbalance. Current wheel balancing machines are much easier to use than earlier machines. Latest wheel balancing machines are equipped with many automatic and computer-generated features designed to give excellent balance. There are three basic times when balancing should be done:

- When a tire is replaced or repaired,
- When a balance weight is moved or falls off,
- When new tires are purchased.

❖ Advantages of wheel balancing

- Wheel balancing can eliminate vibration and wobbling.
- Wheel balancing will improve tyre wear.
- Wheel balancing will increase fuel mileage.
- Wheel balancing will remove stress from a vehicle.

❖ Type of wheel balancing

- Static balancing and
- Dynamic balance.

Fig. 1.9 Computerised Wheel Balancing Machine

Fig. 1.10 Clip-on lead weight (Standard)

Fig. 1.11 Stick-on weight (for alloy rims)

- **Static Balancing**

  Tyre manufacturers' measure static balance by the use of a sensor mounted to the spindle assembly.

- **Dynamic Balancing**

  Dynamic balance of a tyre/ wheel is checked and measured by mounting a tyre on a test wheel, accelerating the assembly to 300 rpm or higher and then measuring the forces of imbalance as the tyre rotates. Now a day's computerised wheel balancing machines are commonly used in automobile garages and tyre shops. Dynamic balancers not only determine the location of any imbalance, but also point out the exact amount of counter weight that must be added to correct the imbalance.

❖ Procedure of Wheel Balancing/ Working of Wheel Balancing Machine

- Turn on the balancer.
- Clean the tyre, rim flange and wheel.
- Mount the tyre/wheel assembly on a balancer.
- Enter the wheel dimensions.
- Enter width wheel dimensions.
- Lower the hood to spin the wheel and check dimensions.
- Raise the hood after the tyre stops rotating.
- Note when the inboard centre bar blinks.
- Attach inboard corrective weight.
- Press NEXT, which rotates the wheel.
- Note when the outboard centre bar blinks.
- Attach outboard corrective weights.
- Lower the hood to re-spin and check balance.

Disclaimer:

Operating any of the above mentioned garage equipment is a serious business. This information is not meant as a substitute for proper training by respective manufacturers. The recommendations made here are consistent with practises used in the industry. These articles are meant purely for educational purposes. Those who use method recommended are solely responsible for any injuries or losses resulting from their application. Authors and Publisher may not be held responsible.

QUESTIONS

Very Short Answer Type Questions

1. An air compressor can be driven by_____
   a. using electric motor. b. using diesel engine.
   c. using gasoline/ petrol engine. d. all of above.
2. The nozzle at the delivery pipe is able to adjust the _____ of water, in a car washer.
3. Tyre inflation gauges can be of _____
   a. analog type. b. digital type.
   c. either a or b. d. neither a nor b.
4. Spark plug cleaner and tester is used for _____.
   a. sandblast cleaning. b. gap testing.
   c. both a and b. d. none of the above.
5. Proper wheel balancing can _____.
   a. eliminate vibration and wobbling. b. improve tyre wear.
   c. increase fuel mileage . d. all of above.

Short Answer Type Questions

1. Define air compressor.
2. Give broad classification of compressors.
3. Define Dynamic Balancing.

Short Answer Type Questions

1. What are the main advantages of balancing of wheels in a car?
2. Why it is essential to clean a spark plug after regular interval?
3. What are advantages of maintaining correct tyre pressure in a vehicle?
4. Briefly describe different stages of automatic car washing system.
5. Write different safety precautions to be observed while operating a hoist.

Long Answer Type Questions

1. Write procedure to balance a wheel on computerized wheel balancing machine.
2. Why it is essential to clean a spark plug after regular interval? Explain.
3. How we can classify tyre inflators. Write advantages & disadvantages of automatic tyre inflators over manual tyre inflators.
4. With a neat sketch explain the construction and working of an air compressor.
5. With a neat sketch explain the construction and working of spark plug cleaner and tester.

UNIT – 2

Steering System

Learning Outcome

Session 1 : Steering System				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students shall be able to: 1. Understand the Ackerman Principle of Steering. 2. Understand Toe-in, Toe-out, Castor, Camber and Kingpin inclination. 3. Draw the steeing geometry. 4. Understand the construction and operation of steering gear linkages. 5. Understand the construction and operation of power steering.	Explain: 1. Understand the Ackerman Principle of Steering. 2. Understand Toe-in, Toe-out, Castor, Camber and Kingpin inclination. 3. Draw the steeing geometry. 4. Understand the construction and operation of steering gear linkages. 5. Understand the construction and operation of power steering.	Able to: 1. Draw the steering geometry. 2. Demonstrate steering system and their gear and linkages. 3. Demonstrate Toe-in, Toe-out, Castor, Camber and Kingpin inclination.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the different components of steering system.

Objectives

After attending this session, you should be able to:

- *Explain the Ackerman Principle of Steering.*
- *Explain toe-in, toe-out, castor, camber and king pin inclination.*
- *Draw the steering geometry.*
- *Explain the operation of steering gears and linkages.*
- *Explain the construction and operation of power steering.*

2.1 Concept of Live and Dead Axles

In one way the rear axles are classified as:

- **Live Axle:** It is the type of axle which drives the vehicle. It consists of hollow axle casing through which drive is transmitted, passing from the final drive to the differential, then to the half shafts (or axle shafts) and finally to the road wheels. The axle shaft rotates with the road wheels and is supported in bearings mounted in or on the axle casing.
- **Dead Axle:** It does not rotate with the road wheels but supports the vehicle load and provides mounting mechanism for wheels. The rear axle of a front wheel drive is a dead axle.

2.2 Ackerman's Principle of Steering

Before explaining the Ackerman's Principle of Steering students must have an idea about **Pure Rolling, Pure Sliding and a combination of Rolling and Sliding.**

In the fig. 2.1 three arrow heads are shown through X, Y and Z. Travel in X-X direction indicates pure rolling and Y-Y direction indicates pure sliding of the wheel on the travel surface. When the wheel is turned the travel of wheel is along the Z-Z, the result is a combination of pure rolling and pure sliding.

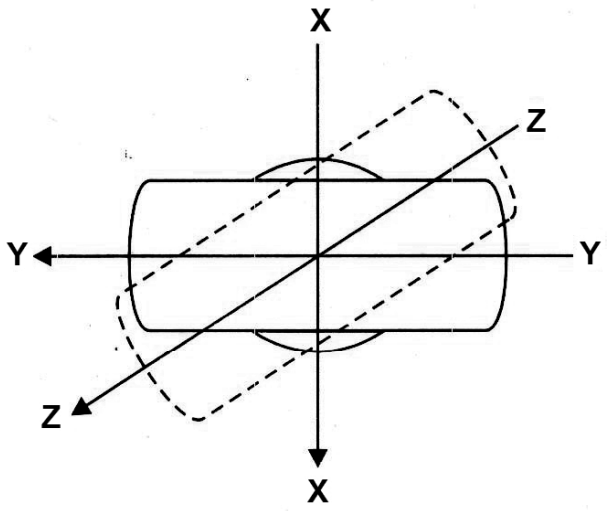
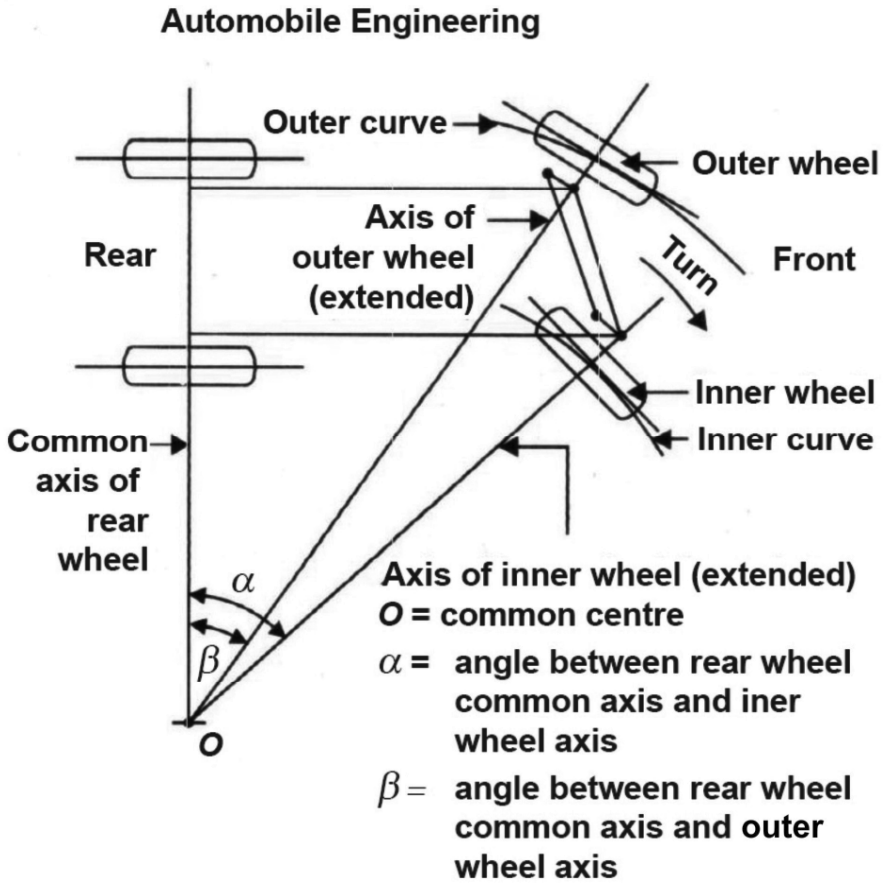
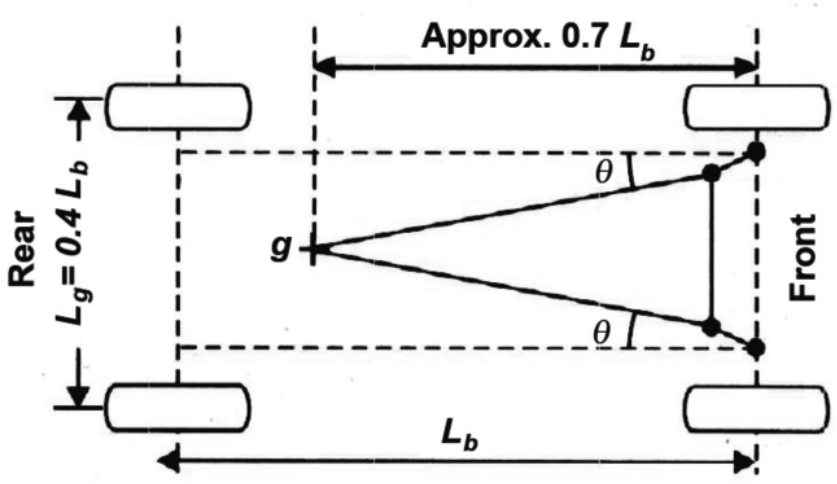


Fig. 2.1 Result of Pure Rolling and Pure sliding

When a vehicle with four wheels is negotiating a curve the third condition as explained above with a combination of pure rolling and pure sliding prevails. But there should be only rolling motion on the wheels while taking a turn. ***To ensure that all the wheels only roll but do not slide on the travel surface, the kinetic linkages of all four wheels should be arranged in such a way that the centre of rotation of all the four wheels in plan coincide. In other words, the centre of rotation should be common to all the four wheels. This is the Ackerman's Steering Principle.***



(a) Ackerman's sttering principle (right turn)



(b) Ackerman's steering linkage geometry

Fig. 2.2 Ackerman's Steering Linkage in principle

The Ackerman's steering geometry is shown in the fig. 2.2. In this linkage, which is a kinematic four bar chain, the two short links are equal in length and two long links are unequal in length. When the vehicle is moving straight ahead on the road, two long links are parallel to each other and all the four links form a trapezium [fig. 2.2 (a)]. The shorter links make an angle, ɵ with the wheel base line as shown in the diagram.

While taking a turn, in order to satisfy the condition that the axes of all four wheels coincide at a common centre, O as shown in the fig. 2.2 (b), the links in the mechanism should have a proper proportion for a given angle, ɵ.

- It has been found that the point of intersection g, of the two short arms in the linkage as shown in fig. 2.2 (a), should be at a distance of about 0.7 times the vehicle wheel base from the common axis of the front wheels. This condition and proportion offers very good results for steering with minimum sliding of the steered wheels.
- It is also observed that for a given relationship between angle, ɵ and location of point g, wheel base Lb and wheel gauge (track) Lg, there will be a single value of α which will give the best result. Normally, the ratio of wheel gauge to wheel base in most of the passenger cars is approximately 0.4.

2.3 Steering Geometry

The front axle and the steering linkage are connected to the wheel axles (stub axles). The wheels should be made to travel true and straight to avoid excessive and non-uniform tyre tread wear to ensure proper steering characteristics. To describe the linkages, there is need for simple geometry to specify the angles and inclinations & linier dimensions at the road wheels of an automobile. The topic related to this part of automobile is known as **Steering Geometry or Wheel Geometry.** The wheel alignment in practice is the adjustments of these angles which are listed below.

- Camber
- Caster
- King Pin Inclination
- Toe Angles (Toe-in and Toe-out)
- Centre point Steering and Scrub Radius
- Turning Radius

❖ Camber (or Wheel Rake)

Camber is the tilt of car wheels from the vertical when viewed from the front of the vehicle. Camber is **positive** if **the** tilt is outwards at the top and is **negative** if the tilt is inwards at the top of wheels. If the top of a wheel is not tilted in either direction, it **is** called **Zero Camber**. The Camber is also called **Wheel Rake** and is measured in degrees.

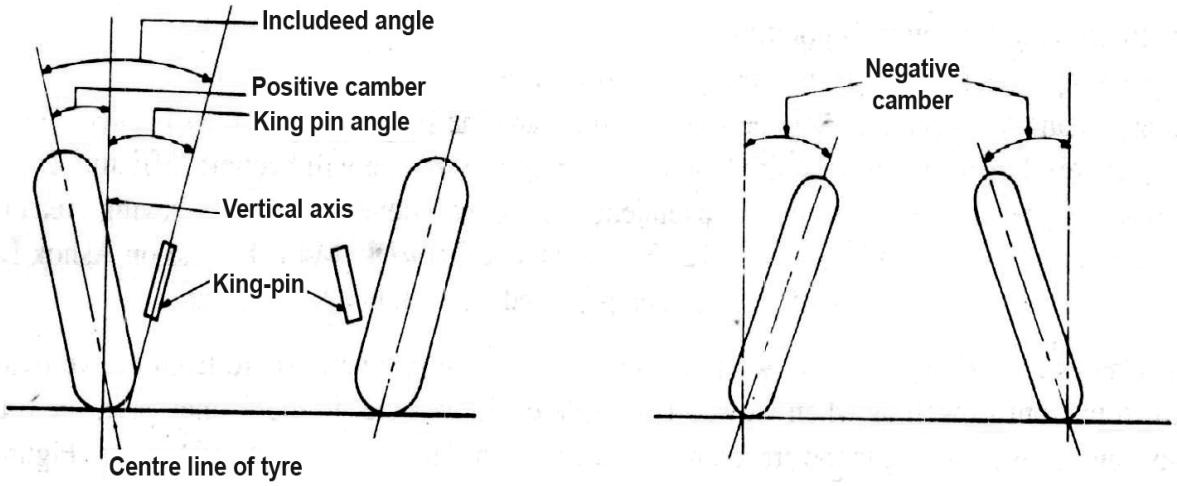


Fig. 2.3 Showing Positive Camber, Negative Camber and King Pin Inclination

It is always desirable that tyres should roll on the ground vertically so that the wear is uniform. If tyres are inclined inwards or outwards from the vertical while running, they will wear out more on one side than the other. The positive camber or camber on an automobile without pay load or passengers load becomes almost nil with load. This ensures uniform contact of the wheel tread on the road surface and a better distribution of wheel load on the wheel outer and inner bearings. However, the value of the camber angle when the vehicle is at rest varies from the camber values at various speeds of the vehicle.

The vehicles, which are generally running in hilly-roads, are given negative camber to improve cornering performance.

A positive camber causes the wheel to toe-out. Therefore if the camber on the two front wheels is not equal, the vehicle will try to pull towards the side where the camber is higher.

On the conventional rigid axle, the camber remains almost fixed. However in independent suspension system usually the change of spring height changes the camber angle.

- **Amount of Camber**

  The amount of camber is generally kept in between 0° to 2°. However, the exact amount of camber is depending on the amount of King Pin Inclination.

❖ Caster

The angle between the king pin centre line (steering axis) and the vertical, in the plane of wheel is called the **Caster Angle**. If the king pin centre line meets the ground at a point ahead of the vertical wheel centre line (top of the king pin is inwards towards the rear of the vehicle), [fig. 2.4 (a)], it is called **Positive Caster**. If the king pin centre line meets the ground at a point behind the vertical wheel centre line (top of the king pin is outwards towards the front) [fig. 2.4 (b)], it is called **Negative Caster**.

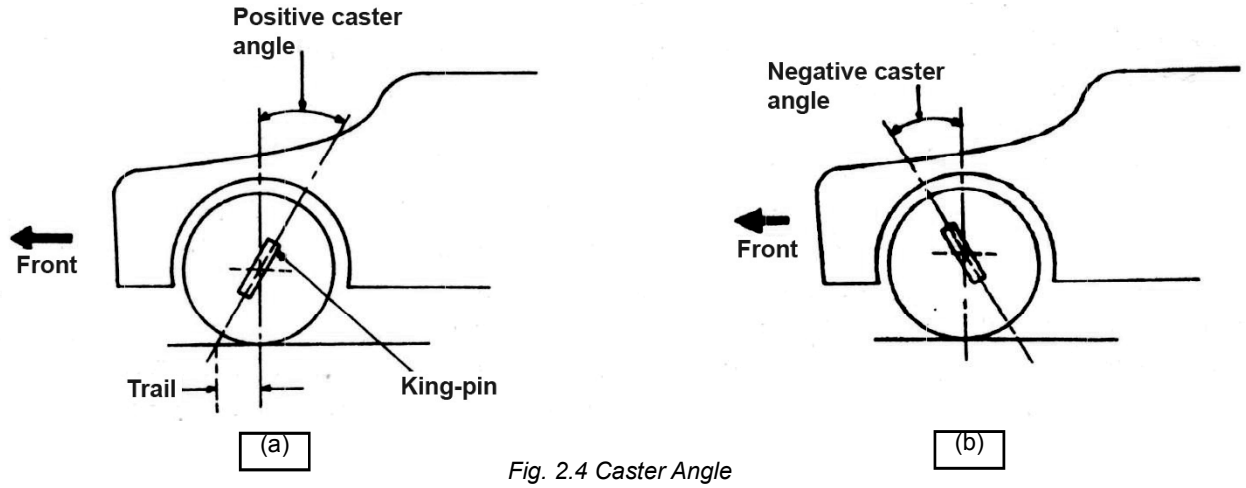


Fig. 2.4 Caster Angle

Caster has negligible effect on wheel tread wear but it effects the steering.

a. Negative caster makes the steering too light and difficult to control.

b. Too positive caster angles results in hard steering causing road shocks to be felt at the steering.

c. Caster angle once set, it becomes permanent and cannot be adjusted like camber angle.

d. If on an automobile, which is in use, the caster angle is different on both sides, indicates damage due to an accident and should immediately be replaced or corrected by repair.

- **Amount of Caster**

  It is about 3°, which gives best results.

❖ King Pin Inclination (Steering Axis Inclination)

A king pin has two plane inclination. The inclinations are from the vertical when viewed from the side as well as when viewed from the front of the vehicle. In former case, the inclination is called caster, which we have already discussed and in later case it is called king pin inclination. A king pin is mounted in such a way that it remains inclined inward with respect to the vertical axis when viewed from the front

Inclination of king pin from vertical when viewed from the front of vehicle is called King Pin Inclination or King Pin Rake.

Modern cars employ ball joints instead of a king pin. In these cases, a term **Steering Axis Inclination** is referred instead of king pin inclination. Thus the Steering Axis inclination is the angle made by the ball joints axis with the vertical.

- **Purpose:** At the time of steering the road wheels, the steering linkages rotate about the king-pin or the axis of ball joints since they act as pivot. This causes a rise in C.G. of the vehicle when the vehicle is taking a turn. Thus the purpose of giving an inward inclination to king-pin or ball joint axis are

  i) To keep the front wheels pointing forward.

ii) To bring back the wheels in a straight position after a turn.

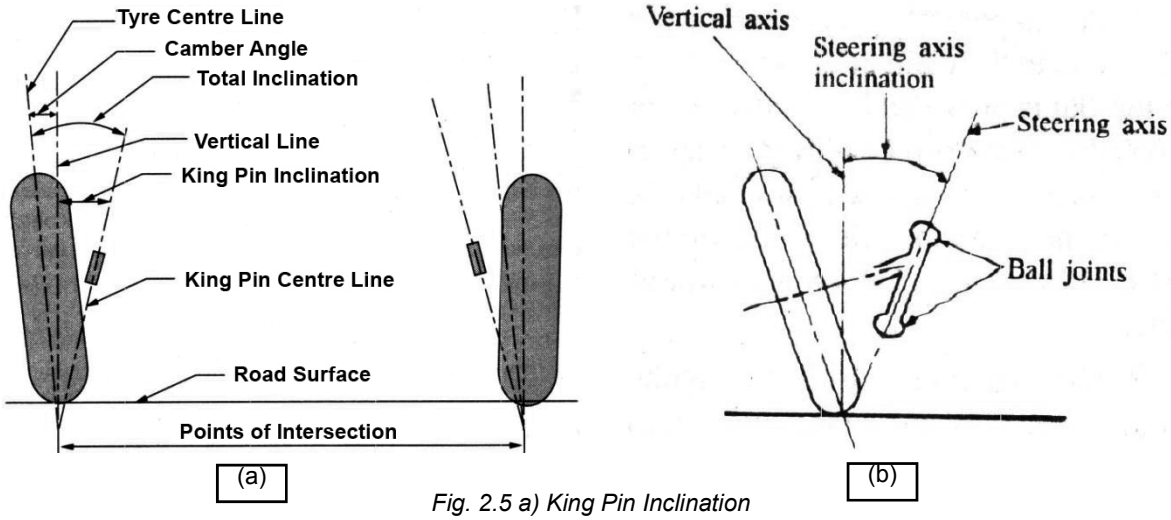


Fig. 2.5 a) King Pin Inclination

b) Steering Axis Inclination (When ball joints are provided in place of king pin)

- Amount of king-pin inclination: between 3° to 9°.
- Amount of steering axis inclination: between 5° to 12°.

❖ Toe Angles (Toe-in and Toe-out)

Toe-in is the amount by which the front wheels are set closer together at the front than at the rear when the vehicle is stationery. Toe-in is shown in the Fig. 2.6 (a) i.e.; Toe-in = B – A.

On the other hand, the wheels may be set closer at the rear than at the front, then it is called toe-out. Toe-out is shown in the Fig. 2.6 (b) i.e.; Toe-out = A – B.

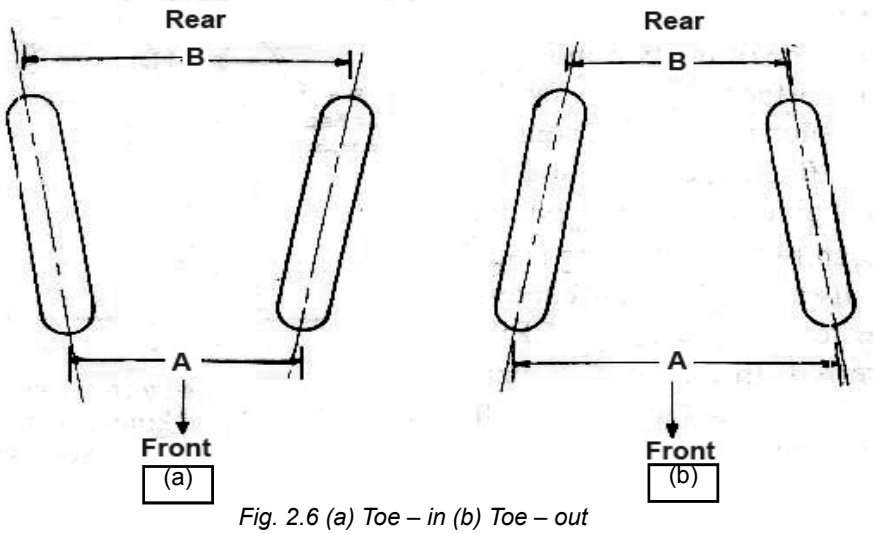


Fig. 2.6 (a) Toe – in (b) Toe – out

- **Purpose:** The toe-in is provided on all kinds of vehicles except tractors and some front wheel drive cars.

The purpose of providing toe-in is to offset the tendency of wheel rolling

i) On the curves due to the limitation of correct steering

ii) Due to possible play in the steering linkages

iii) Due to camber effect

The toe-out is provided to counter the tendency of inward rolling of the wheels

i) Due to soil condition on agricultural land.

ii) On account of side thrusts and cross wind effect.

- Amount of toe-in and toe-out varies from 0 to 6 mm. depending upon the type of vehicles.

Centre point Steering, Scrub (or roll) radius and combined angle:

- **Centre Point Steering:** The point, at which the axis of the road wheel and axis of king-pin (or steering axis) intersects at a point on the ground, is called the centre point of steering.
- **Scrub Radius:** The distance between the steering axis and the axis of the road wheel at the point where they intersect the road surface is called as scrub radius.
- **Combined Angle (Total or included angle):** Combined angle or included angle is the angle formed in the vertical plain between the road wheel axis and the axis of king-pin (steering axis). Combined angle is equal to camber angle plus king pin inclination (or steering axis inclination), refer fig 2.5 (a).

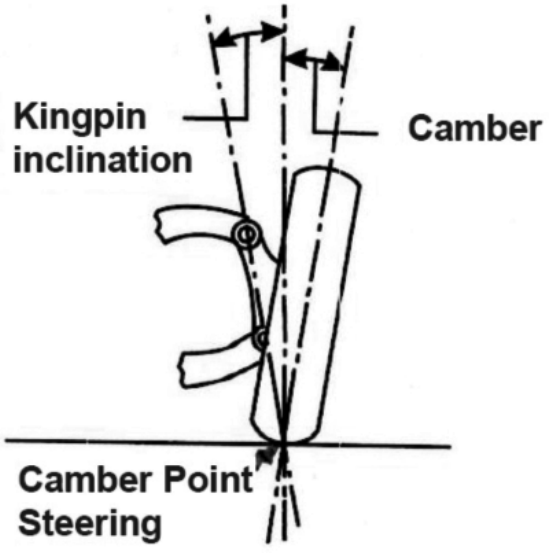


Fig. 2.7 a. Centre point steering

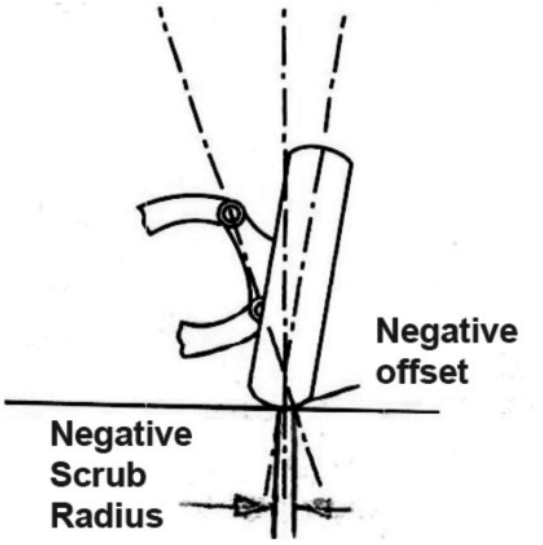


Fig. 2.7 b. Negative scrub radius

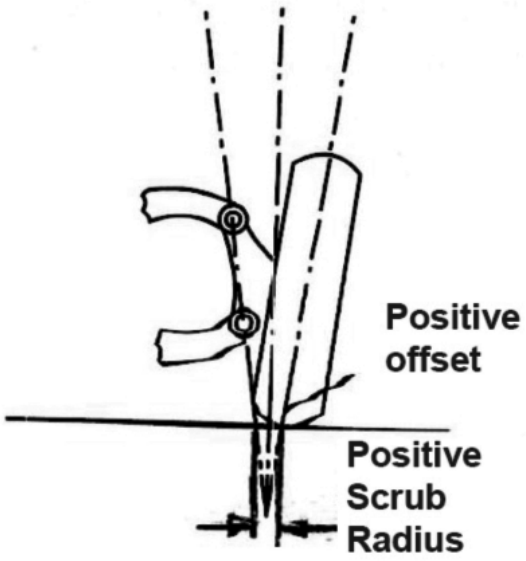


Fig. 2.7 c. Positive scrub radius

To reduce steering effort, the steering geometry can be arranged to give centre-point steering. In the 2.7 (a) layout the axis of the road wheel and of the steering axis intersect where the tyre touches the road.

In the layout 2.7 (b), the axis of the road wheel and the steering axis intersect slightly above ground level. It has been found that this arrangement improves stability and reduces the pull on the steering wheel if there is a tyre blow-out or front brakes become unbalanced. It is now widely used on cars. It is called negative scrub radius.

In another layout, the axis of the road wheel and the steering axis meet below ground level as shown in Fig. 2.7 (c). It is called positive scrub radius and gives plenty of “feel” to the steering, but can make it heavy.

❖ Turning Radius

The steering turning angle is the angle of each front wheel when the car is turning. The inner front wheel always turns sharper than the outer wheels as shown in fig. 2.8, resulting in toe-out condition. The design of the steering arms in relation to the wheel base of the car provides the proper turning of each wheel.

The radius of the circle on which the outside front wheel moves when the front wheels are turned to their extreme outer position is known as turning radius. The turning radius is generally proportional to the wheel base of the car.

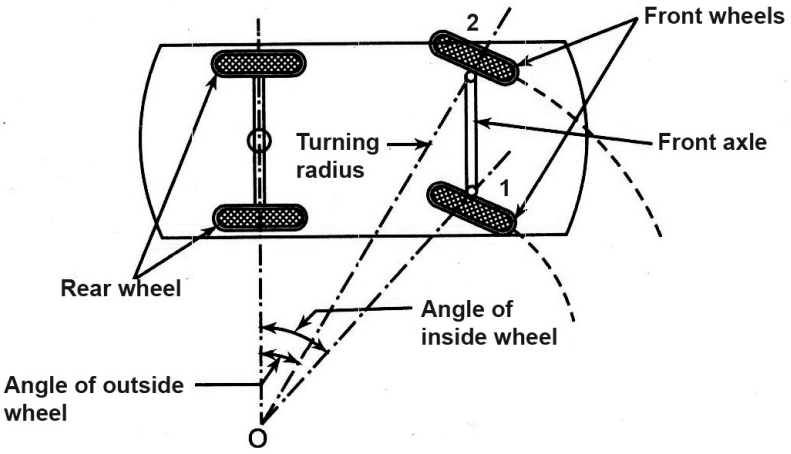


Fig. 2.8 Turning Radius

2.4 Steering Gear Box

The gear in the steering gearbox assembly not only steer the front wheels but, at the same time, they act as reduction gears, reducing steering wheel turning effort by increasing the output torque. The reduction ratio is called the steering gear ratio. A larger ratio reduces the steering effort but makes it necessary to turn the steering wheel more when going around a curve.

Passenger cars usually have a steering reduction ratio of between 10 and 20 to 1. On trucks, the figure is in excess of 20 to 1.

❖ Types of Steering Gearbox

Over the years a number of different types of steering gearbox have been used. These include:

1. Worm and sector
2. Screw and nut
3. Worm and peg
4. Worm and roller
5. Rack and pinion
6. Worm and nut with Re-circulating ball

However in this chapter we are going to explain only last two types of steering gearbox which are widely used in the modern vehicles.

- **Rack and Pinion Gear Box:** The rack and pinion steering gear, used mostly on smaller cars, has pinion connected to the lower end of the steering main shaft. The pinion is meshed with a rack of gear teeth cut on the underside of the major cross member of the steering linkage. When the steering wheel is turned, the pinion turns. This moves the rack to the left or right. The movement of the rack is transmitted through the tie rods and spindle arms to steer the front wheels.

Advantages

- Construction is compact, simple and light in weight since the gearbox is small, and the rack itself acts as the steering linkage.
- Gear meshing is direct, so steering response is very sharp.
- There is little sliding and rotational resistance, and torque transmission is better, so steering is very light.
- The steering gear assembly is completely sealed, so it needs no maintenance.

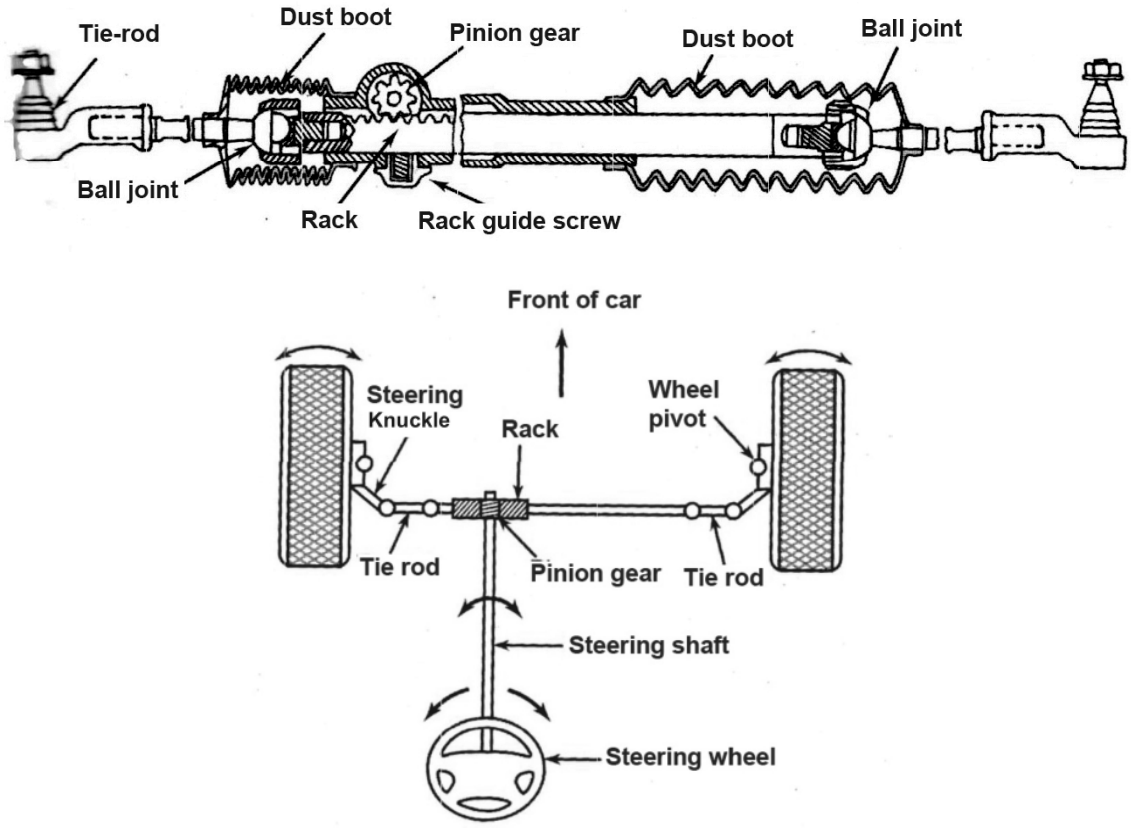


Fig. 2.9 Rack and Pinion Steering Gear

- **Worm and nut with re-circulating ball steering gear box:** In this type of steering gear, a ball nut is mounted on the worm as shown in fig. 2.10. The steel balls are provided between the worm grooves and ball nut. The steel balls ensure a smooth and frictionless drive. The teeth on the ball nut meshes with the teeth of the sector gear mounted on the shaft (sector shaft). When it is desired to turn the vehicle the steering wheel is move. As the steering shaft rotates, the worm forces the ball to roll in the grooves. The balls as they roll, forces the ball nut to move up or down the worm. The up and down movement of the ball nut is transmitted to the sector shaft, which will make the sector shaft to rotate.

  This type of steering gear produces a light steering feel but has a complicated construction. This type of steering gear box is widely used in heavy vehicles.

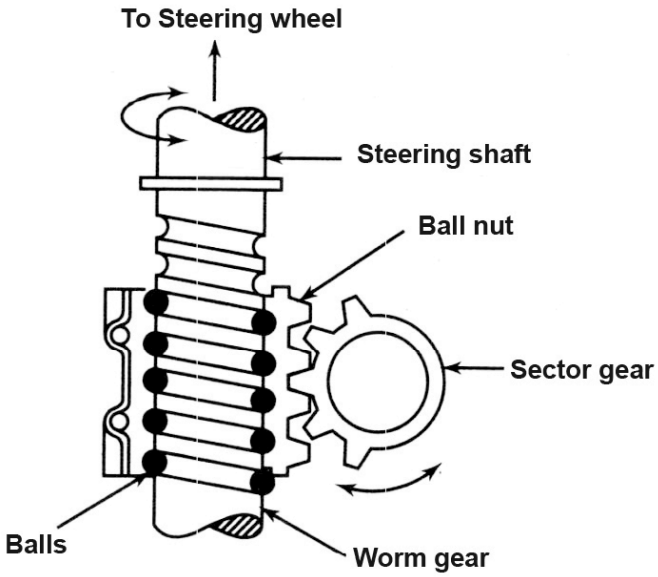


Fig. 2.10 Worm and nut with re-circulating ball steering gear

2.5 Steering Linkages

Steering linkage depends upon the type of the vehicle, whether it is a car which has independent front suspension or a commercial vehicle having generally a rigid axle type front suspension. Each of these linkages will now be described.

❖ Steering Linkage for Vehicle with Rigid Axle Front Suspension

Fig 2.11 and 2.12 shows such steering linkages. The drop arm (also called Pitman arm) is rigidly connected to the cross-shaft of the steering gear at its upper end, while its lower end is connected to the link rod through a ball joint. To the other end of the link rod connected the link rod arm through a ball joint. Attached rigidly to the other end of the link rod arm is the stub axle on which the road wheel is mounted. Each stub axle has a forged track rod arm rigidly bolted to the wheel axis. The other ends of the track rod arms are connected to the track rod by means of ball joints. The design of these ball joints is such that the expanding spring compensates for wear or mis-adjustments. An adjuster is also provided in the track rod to change its length for adjusting wheel alignment.

The steering gear provides mechanical advantage so that only a small effort is required at the steering wheel to apply a much larger force to the steering linkage. Moreover it also provides the desired velocity ratio so that much smaller movement of the stub axle is obtained with large angular movement of the steering wheel. When the steering wheel is turned, the swinging action of the drop arm imparts near linear movement to the link rod. This movement is transmitted through the link rod arm to the stub axle so as to turn the later about its pivot, which may be a king pin or ball joints. The other wheel is steered thorough the track rod. Thus only one wheel is positively steered.

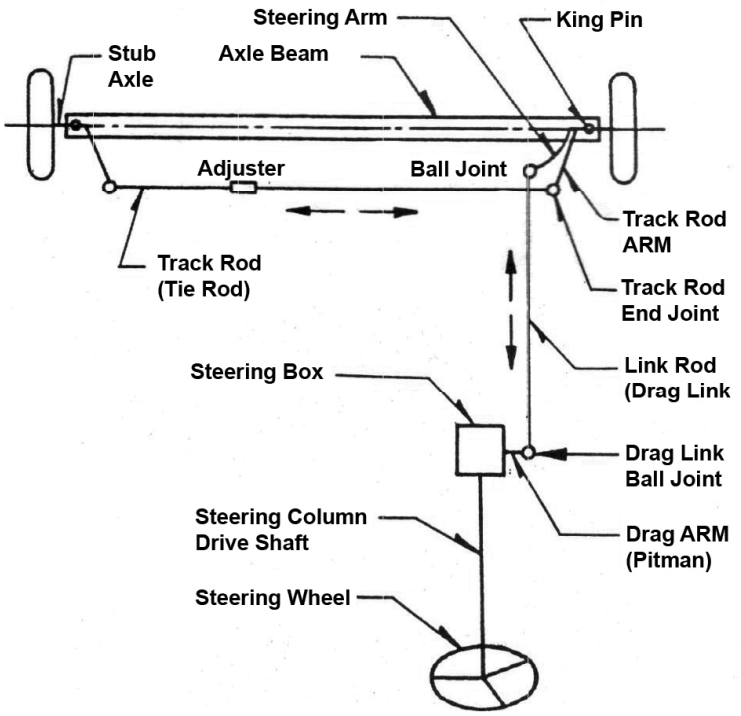


Fig. 2.11 Steering Linkage for rigid axle suspension (line diagram)

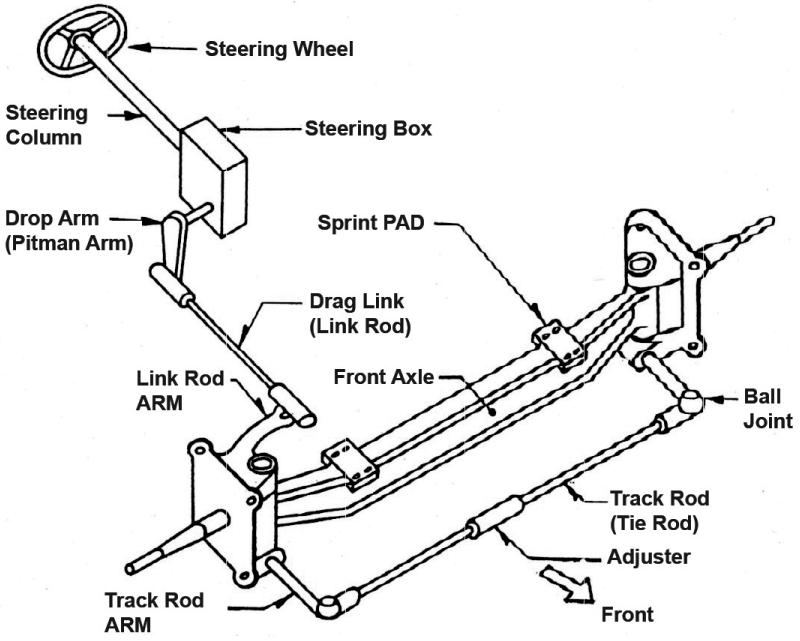


Fig. 2.12 Steering Linkage for rigid axle suspension

❖ Steering Linkage for Vehicle with Independent Front Suspension System

In case of conventional rigid axle suspension, the main axle beam ensures the movement of stub axle in the horizontal plane only. In this therefore, there is no vertical deflection of the suspension

and hence there is no change in effective track-rod length. However, in the case of independent suspension, the two stub axles can move up or down independent of each other due to which distance between ball-joint ends of the two track rod arms is continuously varying. On account of this a single track rod as in conventional system described above, cannot be used.

Fig. 2.13 depicts one linkage for independent suspension where the above difficulty is avoided. Here three-piece track rod is used, the centre portion being called the relay rod, which is connected at one end to an idler arm supported on body structure and to the drop arm of the steering gear at the other end through ball joints. The relay rod is restricted to move in horizontal plane only. Movement in vertical plane is provided by the outer portions, viz, the tie rods about the end ball joints.

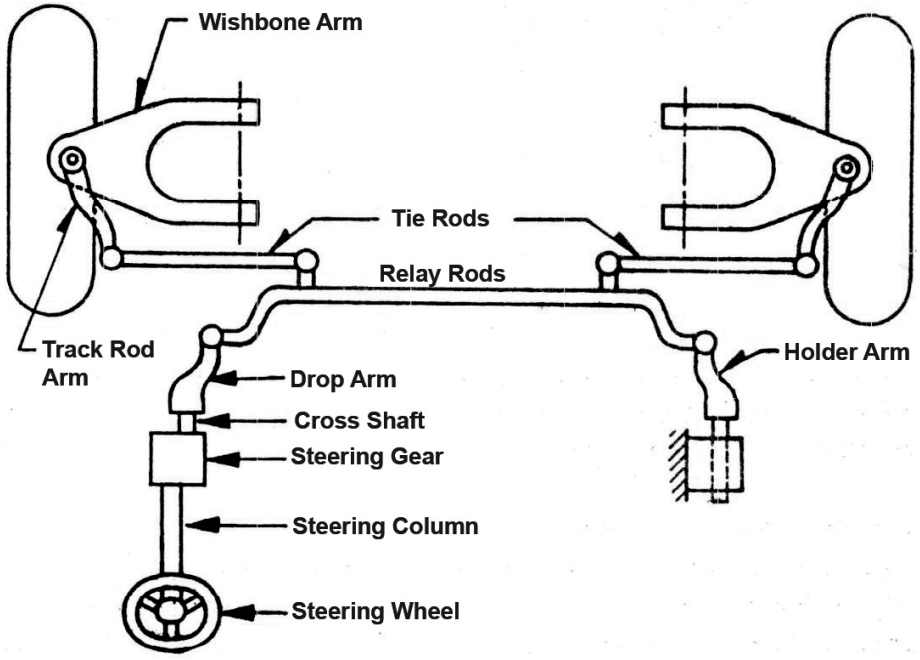


Fig. 2.13 Steering linkage for vehicle with independent front suspension system

2.6 Power Steering

The power steering system is the system employed in automobiles to reduce the effort required to operate the steering wheel. This feature adds to the comfort while driving, as less effort is required to turn the steering by the driver.

The following are the advantages and disadvantages of the power steering system.

Advantages

1. The power steering system reduces the number of turns of steering wheel required to move it from lock to lock (i.e. steering ratio on a vehicle having power steering us usually less).
2. Easy steering while parking, at low speeds or tight turns.

Disadvantages

The components used in the power steering assembly are more costly than the ones used in the normal steering.

The most commonly power steering systems employed in automobiles are

1. Hydraulic power steering systems, and
2. Electrically assisted, electronic power steering systems (or simply electronic power steering systems).

Types of Power Steering

There are two types of power steering system

- Hydraulic Power Steering
- Electronic Power Steering

Hydraulic Power Steering System: The hydraulic power steering, as discussed above, is the system having a hydraulic booster that reduces the force required to operate the steering wheel.

Components

The hydraulic power steering system consists of the following major components, as shown in fig. 2.14.

1. **Pump:** It generates hydraulic pressure.
2. **Control Valve:** It switches the oil passage to the power cylinder according to the rotational direction of the steering wheel.
3. **Power Cylinder:** It moves the piston in the cylinder to the right or left with hydraulic force and thereby assists the steering wheel operation.
4. **Fluid Reservoir:** The power steering fluid reservoir stores fluid and cleans it using a built in filter.

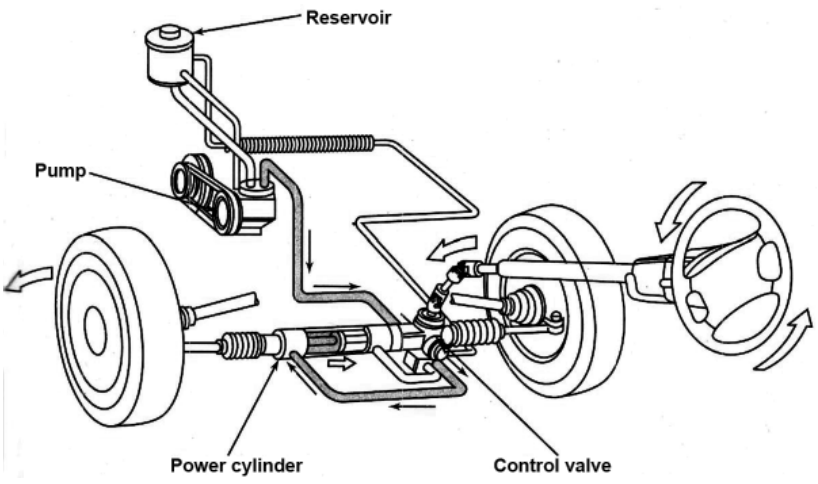


Fig. 2.14 Hydraulic Power Steering system

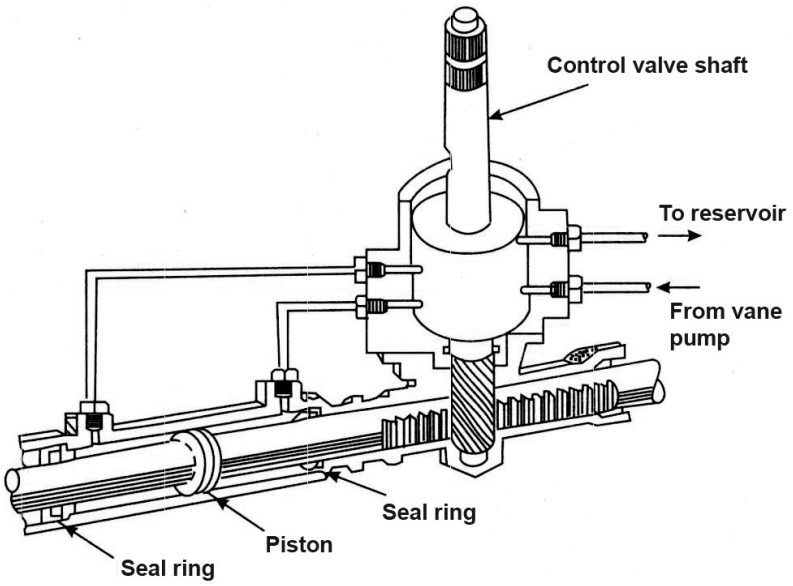


Fig. 2.15 Rack and Pinion Hydraulic Power Steering

Working Principle

- **Neutral (Straight-Ahead) Position:** Fluid from the pump is sent to the control valve. If the control valve is in the neutral position, the fluid will flow through the control valve into the relief port and back to the pump. At this time hardly any pressure is created and because the pressure on the cylinder piston equal on both sides, the piston will not move in either direction.

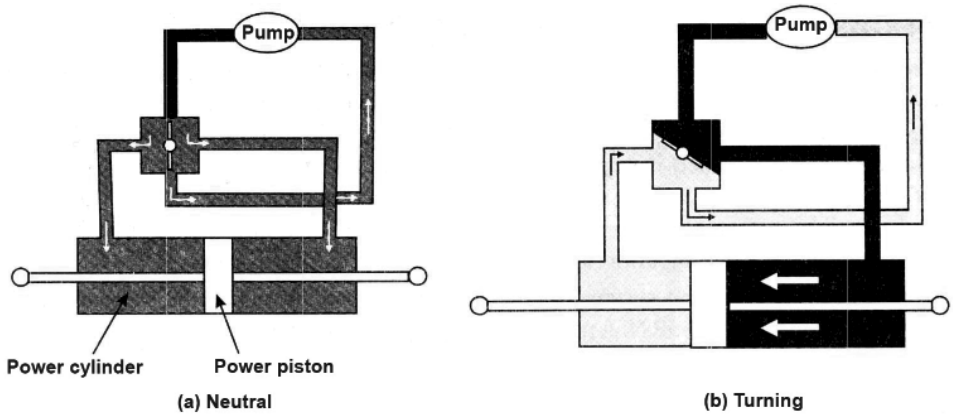


Fig. 2.16 Working Principle of Hydraulic Power Steering.

- **While Turning:** When the steering main shaft is turned is either direction, the control valve also moves, closing one of the fluid passages. The other passage then opens wider, causing a change in fluid flow volume and, at the same time, pressure is created. Consequently, a pressure difference occurs between both sides of the piston and the piston moves in the direction of the lower pressure so that the fluid in the cylinder is forced back to the pump through the control valve.

- **Electronic Power Steering System:** In electronic power steering, a magnet and a magnet torque sensor are mounted at the end of the steering shaft. The torque sensor senses the amount and direction of turning moment the driver is putting on the steering wheel. By the turning effect the magnet moves. The signal, the strength of which depends on the amount of torque applied on the steering shaft, is sent to an electronic control module (ECM). The ECM sends currents in varying magnitude to the electric motor. The rotation of the motor forces the ball nut to move. This produces a force on the rack. The steering effort is then supplied by the electric motor and the driver is relieved.

2.7 Trouble Shooting and Remedies

S. No.	Problem	Probable cause	Action or Items to be checked
1.	Hard Steering	i. Low tyre pressure	Inflate the tyre to correct pressure.
		ii. Too tight steering gear	Adjust the tightness.
		iii. Incorrect wheel alignment (specially incorrect steering axis inclination and too much caster)	Correct the wheel alignment.
		iv. Broken or bent steering arms, or knuckles, or suspension arm.	Replace the bent or broken parts
		v. Insufficient lubricant steering gear box system.	Apply sufficient amount of lubricant in
2.	Vehicle pulls to one side	i. Incorrect wheel alignment (unequal left and right wheel alignment).	Correct the wheel alignment
		ii. Bent steering knuckle.	Replace the steering knuckle
		iii. Inoperative stabilizer	Repair the stabilizer.
3.	Electric steering on braking.	i. Incorrect caster	Correct the caster.
		ii. Bent steering knuckle.	Replace the steering knuckle.
		iii. Defective brake linings	Wipe off oil, grease and brake oil from brake linings. Change the linings if required
		iv. Improper adjustment of brakes	Adjust the brakes properly.

4.	Excessive play or looseness in steering system	i. Loose column or steering gear box mounting bolts and nuts.	Tighten the bolts and nuts.
		ii. Loose steering wheel.	Tighten the steering wheel
		iii. Damaged or worn out steering linkages	Replace the parts.

QUESTIONS

Very Short Answer Type Questions

1. Normally the ratio of wheel gauge to wheel base in most of the passenger cars is approximately _____.

   a. 0.2 b. 0.4 c. 0.5 d. 0.6

2. The amount of camber is generally kept between _____.

   a. $0 – 2^{\circ}$ b. $0 – 4^{\circ}$ c. $0 – 6^{\circ}$ d. $0 – 8^{\circ}$

3. The exact amount of Camber is depending on the amount of _____ _____ _____.

4. The vehicles which are generally running in hilly-road, are given.

   a. Positive camber b. Zero camber
   c. Negative camber d. None of the above

5. A positive camber causes the wheels to _____.

6. If the camber on the two front wheels is not equal, the vehicle will try to pull towards the side where.

   a. The camber is higher. b. The camber is lower
   c. Both (a) & (b) d. None of the above

7. The amount of caster angle is about _____.

   a. 1° b. 2° c. 3° d. 5°

8. Too positive caster angle results.

   a. Steering too light and difficult to control
   b. Hard steering and causing road shocks to be felt at the steering.
   c. Continuous vibration on the vehicle
   d. None of the above

9. Amount of Toe-angle (Toe-in or Toe-out) varies from _____ to _____mm., depending upon the type of vehicle.

10. Steering gear reduction ratio for car is between

    a. 10 and 20 to 1 b. 20 and 30 to 1

    c. 30 and 40 to 1 d. 40 and 50 to 1

11. Steering gear ratio for trucks is _____.

12. Which type of steering gear box is widely used in car?

    a. Worm and sector b. Worm and roller

    c. Rack and Pinion d. Re-circulating ball type

13. Which type of steering gear box is widely used in heavy vehicles?

    a. Worm and sector b. Worm and roller

    c. Rack and Pinion d. Re-circulating ball type

Short Answer Type Questions

1. Write the purpose of providing King Pin inclination or steering axis inclination.
2. What is the amount of King-pin inclination and steering axis inclination?
3. Define Centre point of steering.
4. Define Scrub (or roll) radius
5. Define Combined angle.
6. Name different types of power steering.

Short Answer Type Questions

1. Explain Pure Rolling, Pure Sliding and combination of both.
2. Define the camber with sketch.
3. Define caster angle with sketch.
4. Write the effects of caster angle on steering.
5. Define Toe-angle (Toe-in and Toe-out) with diagram.
6. What are the purposes of Toe-in and Toe-out?
7. Name different types of steering gear boxes.
8. Write the advantages and disadvantages of Power Steering.
9. Write short note on Electronic Power Steering system.

Long Answer Type Questions

1. Explain the Ackerman's Principle of Steering.
2. Explain with diagram the wheel Rake (camber).
3. Explain Caster with diagram.
4. Explain with sketch, the king pin inclination and steering axis inclination.
5. Explain the following with neat sketches:
    a. Centre point of Steering
    b. Scrub or roll radius
    c. Combined angle.
6. Explain construction of Rack and Pinion type steering gear box with its advantages.
7. Explain construction of Worm and nut with re-circulating ball type steering gear box.
8. With neat sketch write the construction of steering linkages for rigid axle suspension system.
9. With neat sketch write the construction of steering linkages for vehicle with independent front suspension system.
10. Explain the function of different components of Hydraulic Power Steering.
11. Explain with diagram the working principle of Hydraulic Power Steering.
12. Write the causes of following trouble shooting of steering system and their remedial action
    a. Hard steering
    b. Vehicle pull to one side
    c. Excessive play or looseness in steering system
    d. Electric steering on braking.

UNIT – 3

Suspension System

Learning Outcome

Suspension System				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students should be able to understand: 1. The function of suspension system. 2. Different terminologies related to the suspension system. 3. Different components of suspension system. 4. Different types of leaf spring, their construction, characteristics and use. 5. Coil spring, their construction, characteristics and use. 6. Torsion bar spring, their construction, characteristics and use. 7. Function and working of different types of shock absorber.	Explain: 1. The function of suspension system. 2. Different terminologies related to the suspension system. 3. Different components of suspension system. 4. Different types of leaf spring, their construction, characteristics and use. 5. Coil spring, their construction, characteristics and use. 6. Torsion bar spring, their construction, characteristics and use. 7. Function and working of different types of shock absorber.	Demonstrate: 1. Different components of suspension system such as leaf spring, coil spring and torsion bar with their construct-ional features.	**Interactive Lecture:** 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the different components of suspension system for different types of vehicles.

Objectives

After attending this session, you should be able to:

- *Explain the functions of suspension system.*
- *Explain different terminologies related to the suspension system.*
- *Explain different components of suspension system.*
- *Explain different types of leaf springs, their construction, characteristics and use.*
- *Explain coil spring, their construction, characteristics and use.*
- *Explain torsion bar spring, their construction, characteristics and use.*
- *Explain the function and working of different types of shock absorber.*
- *Explain the function, working and advantages of Mac Phenson Strut Suspension.*

3.1 Introduction

To isolate the vehicle body from the road shocks the automobile chassis is mounted on the axle through some form of springs, shock absorber, etc. All the parts which perform the function of isolating the automobile from the road shocks are collectively called a suspension system.

The suspension system serves the following functions:

- It connects the vehicle body and the wheels, and thus supports the weight of the vehicle.
- During running it acts together with the tyres to absorb and damp the various vibrations, oscillations and shocks received by the vehicle due to irregularities of the road in order to protect the passengers and cargo, and improve driving stability.
- It transmits the driving and braking forces, which are generated due to friction between the road surface and the wheels, to the chassis and body.

3.2 Types of Suspension System

Before we go into the details of suspension we should understand that there are basically two types of suspension front wheel suspension and rear wheel suspension. These two are independent of each other except that they are both connected to the rigid structural frame of the vehicle.

Then again at the front wheels or the rear wheels there is scope for rigid suspension and independent suspension

❖ Rigid Suspension

An example of rigid suspension at the front wheels of a truck shown in the following figure, for the convenience of the students.

In this rigid suspension the front axle beam is connected to the steering knuckles with the help of kingpins. On top of the front axle beam there are two coil spring seats closer to the wheels for locating and supporting coil springs. The springs support the frame. The disadvantage here is that

the two wheels are not independent of each other connected as they are by the rigid front axle. As a direct consequence the vehicle will tilt when one of the front wheels passes over a bump or falls into a ditch or a pothole or when the vehicle is running on an uneven surface or in rough terrain. Obviously, this causes lot of discomfort to the driver in steering and to the other passengers.

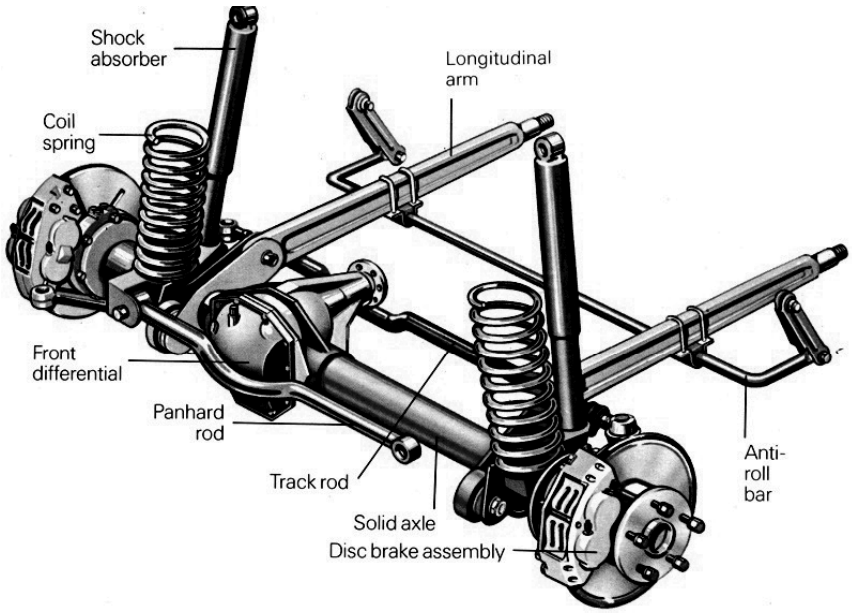


Fig. 3.1 Rigid Axle Suspension System with coil springs and shock absorber

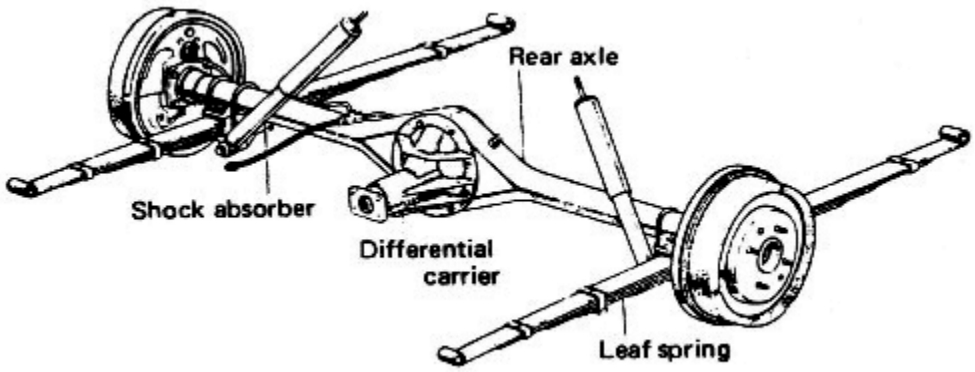


Fig. 3.2 Rigid Axle Suspension System with leaf springs and shock absorber

❖ Independent Suspension

The difficulty with the rigid suspension as explained above can be overcome by making the two front wheels independent of each other. This arrangement is used passenger cars by dispensing with the front axle beam. In the absence of the front axle beam the two front wheels are made independent of each other and the vehicle does not tilt when one of the wheels passes over a bump or falls into a pot hole on the road. Following figure shows the principle of independent suspension system.

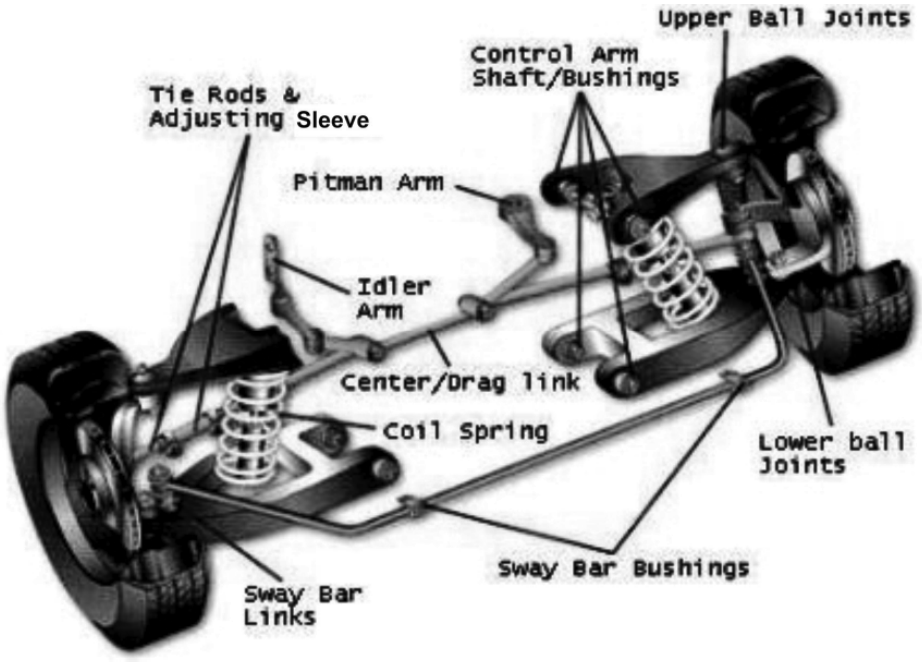


Fig. 3.3 Independent Suspension System

At both ends of the steering knuckle there are ball joints for connecting the upper link and lower link to the structural frame to ball joints. In this arrangement as compared to a rigid axle the wheel is independent of the vehicle body. The spring between the two upper and lower links is compressed and the ball joints accommodate all the three motions of the vehicle – rolling, pitching and yawing, when the vehicle is running on an uneven surface.

Note: The different variations of independent front wheel and rear wheel suspensions may be of following categories;

- With Coil Spring
- With Leaf Spring
- With Torsion Bar Spring
- Shock Absorber with any of the above.

3.3 Description of Suspension System

❖ Sprung and Un-sprung Weight

The **sprung weight** refers to the weight which is supported by the suspension springs. The weight of the vehicle's body, frame, engine, transmission, interior, fuel, and passengers constitute the sprung weight.

The **un-sprung weight** refers to the weight which is not supported by the suspension springs i.e. weight of the components between the springs and road surface. The un-sprung weight includes the weight of wheels, axles, steering linkage, and some suspension components. It may be noted that un-sprung weight should be kept as low as possible to achieve pleasant ride.

❖ Oscillation of the Sprung and Un-sprung Weight

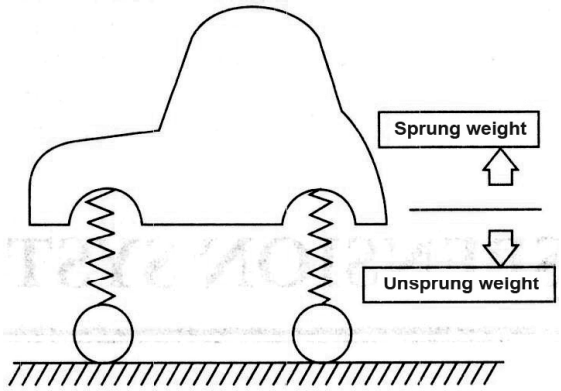


Fig. 3.4 Sprung and Un-sprung Weight

Oscillation and jolting of the sprung and un-sprung parts of the vehicle have a particularly gear effect on riding comfort. The oscillation and jolting can be classified as follows:

- **Oscillation of sprung weight**

  Pitching: Up and down oscillation of the car, at front and rear, in relation to its centre of gravity is called pitching.

  Rolling: When turning or when driving on a bumpy road, the springs on one side of the vehicle expand, while those on the other side contract. This results in body rolling in the lateral (side-to-side) direction.

  Bouncing: Bouncing in the up and down movement of the auto body as a whole. When a car is running at high speeds on an undulating surface, bouncing is likely to occur. Also, it occurs easily when the springs are soft.

  Yawing: Yawing is the movement of the car's longitudinal centreline to the right and left, in relation to the car's centre of gravity. On roads where pitching occurs, yawing is also likely to occur.

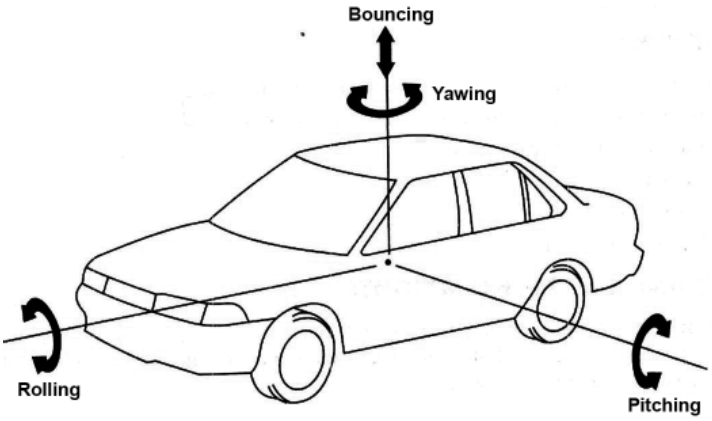


Fig. 3.5 Oscillation of Sprung Weight

- **Oscillation of Un-sprung Weight**

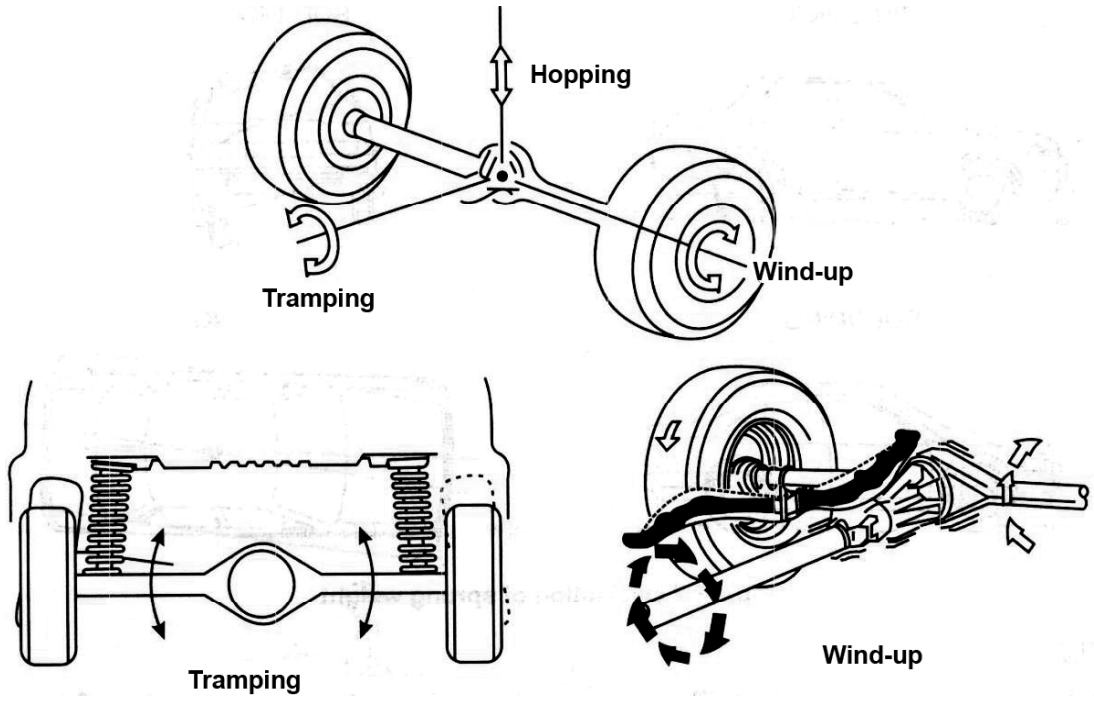


Fig. 3.6 Oscillation of Un-sprung Weight

Hopping: Hopping is the up and down bouncing of the wheels which usually occurs on corrugated roads while driving at medium and high speeds.

Tramping: Tramping is the up and down oscillation in opposite directions of the left and right wheels, causing the wheels to skip over the road surface. This occurs more easily in vehicles with rigid axle suspension.

Wind-up: Wind-up is the phenomenon in which the leaf springs attempt to wind themselves around the axle due to the driving torque.

- **Other Suspension Terms**

Bounce: The vertical (upward and downward) movement of the suspension system is called bounce.

Jounce: Jounce literally means 'bump'. In suspension terminology, it is the most compressed condition of a spring due to the upward movement of suspension system.

Rebound: The downward movement of the tyre and wheel that extends the spring is called rebound.

Dive: The lowering of the front end of the vehicle along with a raising of the rear end during braking is known as dive.

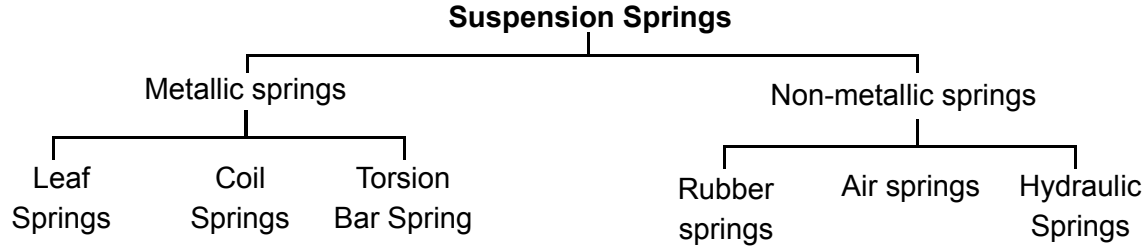
3.4 Components of a Suspension system

It consists of the following principle components:

1. Springs, which neutralize the shocks from the road surface.
2. Shock absorbers (dampers), which act to improve riding comfort by limiting the free oscillation of the springs.
3. Stabilizer (sway or anti roll bar), which prevents lateral swaying of the car.
4. A linkage system, which acts to hold the above components in place and to control the longitudinal and lateral movements of the wheels.

❖ Suspension Spring

The suspension springs are classified as follows:



In this chapter we are going to study about only metallic springs i.e. Leaf springs, Coil springs and Torsion bar springs

❖ Leaf Spring

Leaf springs are made of a number of curved bands of spring steel called “leaves”, stacked together in order from shortest to longest. Stack of leaves is fastened together at the centre with a centre bolt or a rivet. To keep the leaves from slipping out of place, they are held at several places with clips. Both ends of the longest (main) leaf are bent to form spring eyes, used to attack the spring to the frame or structural member of a body.

Generally, the longer a leaf spring, the softer it will be. Also, the more leaves in a leaf spring, the greater the load they will withstand. But on the other hand, the spring will become firmer and riding comfort will suffer.

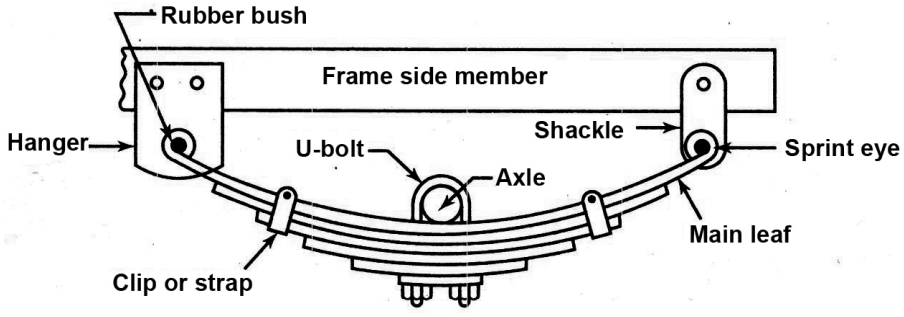


Fig. 3.7 Leaf Spring

Types of Leaf Springs:

a. **Full elliptical leaf spring:** This type of leaf spring refers to two semi-elliptical springs connected at their ends, to form the shape of an ellipse as shown in Fig. 3.8(a).

b. **Three quarter elliptical leaf spring:** This type of leaf spring refers to one semi-elliptical spring connected over a quarter elliptical springs as shown in Fig. 3.8(b).

c. **Semi-elliptical leaf spring:** This type of leaf spring refers to forming the shape of half ellipse as shown in Fig. 3.8(c). It is most commonly used in all types of heavy vehicles.

d. **Quarter elliptical leaf springs:** This type of leaf spring refers to forming the shape of half of semi-elliptical spring as shown in Fig. 3.8(d). This type of system is also called as cantilever spring system, the thick end of which is bolted rigidly to the frame.

e. **Transverse leaf Spring:** This type of leaf spring refers to a semi elliptical spring mounted in a inverted manner, and has saddle at above forming a bow and is attached parallel to the wheel axle as shown in Fig. 3.8(e).

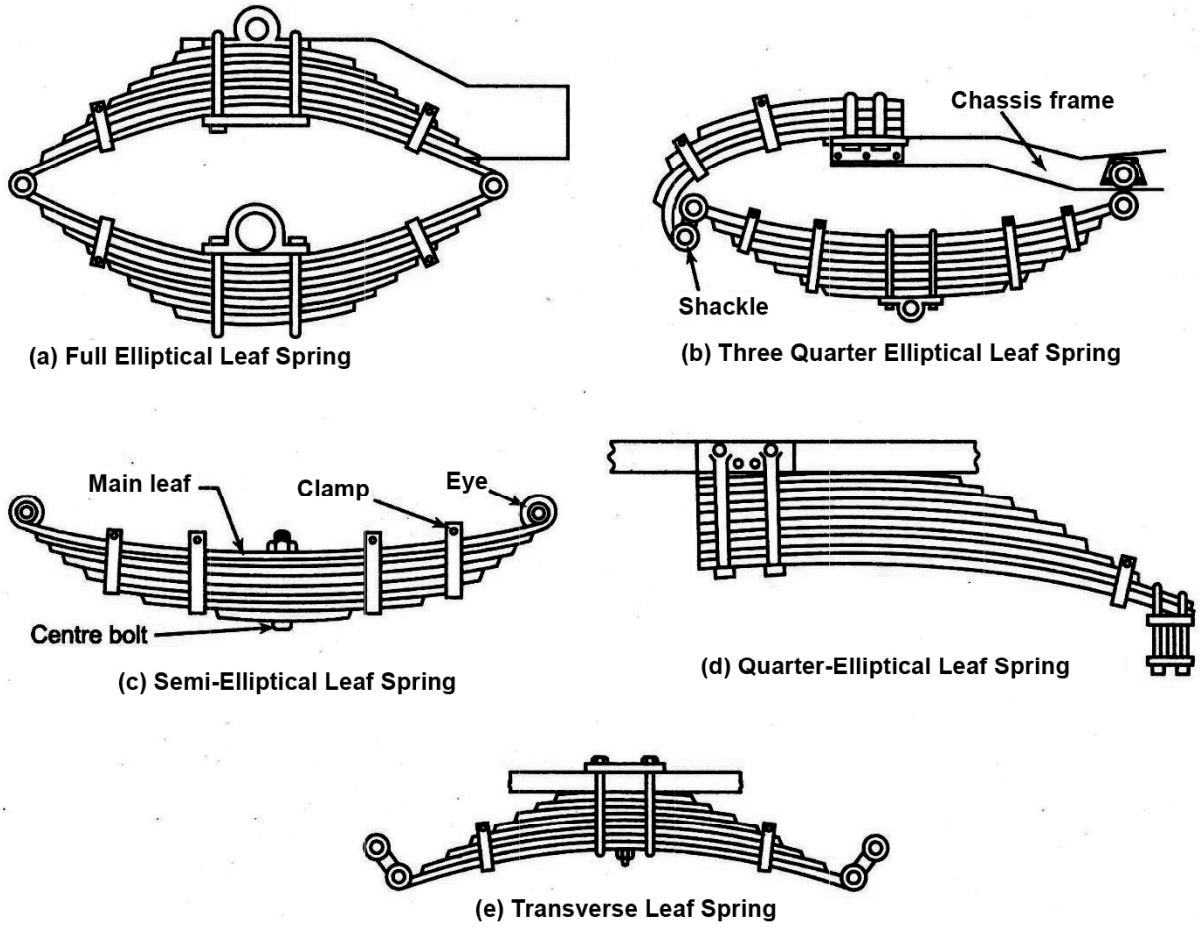


Fig. 3.8 Different types of Leaf Springs

❖ Helper Springs

The helper springs are mounted directly on the main springs and are used in the commercial vehicles such as trucks and buses to provide additional support for heavy loads, at the rear end only. The helper springs are fixed on top of the rear main springs with the help of a centre bolt and then clamped with U-bolts to the rear axle, whereas the ends are left loose.

When the vehicle is lightly loaded, only main springs are active. In case of heavy loads, the helper springs rest against the brackets on the frame and then both the springs share the load.

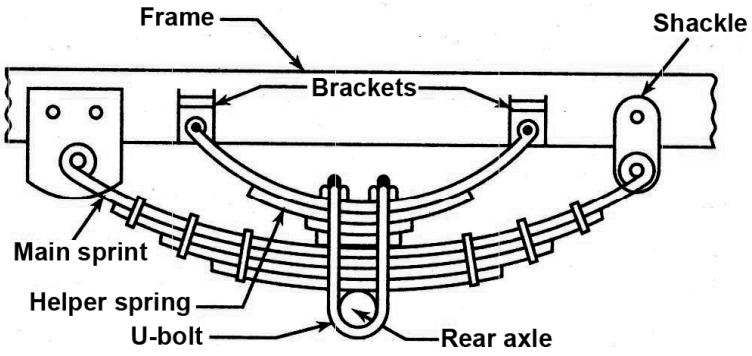


Fig. 3.9 Helper Springs

- **Features of Leaf Springs**

  The curvature of each leaf is called **"nip"**. The overall curvature of the leaf spring is called **"camber"**. When a spring is flexed, nip causes the leaves in the spring to rub against together and the friction created by this rubbing quickly damps the oscillations of the spring. This friction is called inter-leaf friction and is one of the greatest features of the leaf spring. However, this friction also causes a decrease in riding comfort, since it prevents the spring from flexing easily.

  When the spring rebounds, nip prevents gaps from occurring between each of the leaves, thus preventing dirt and sand, etc., from penetrating between the leaves and causing wear.

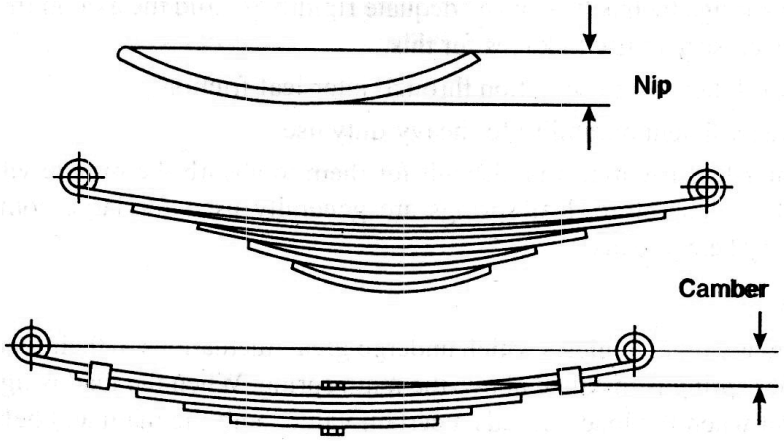


Fig. 3.10 Springs Nip and Camber

- **Techniques to reduce inter leaf friction**

Since riding comfort deteriorates if the inter-leaf friction is great, measures are taken in actual leaf springs to reduce this friction. Silencer pads are inserted between each of the leaves at their ends to improve the sliding of the leaves against each other.

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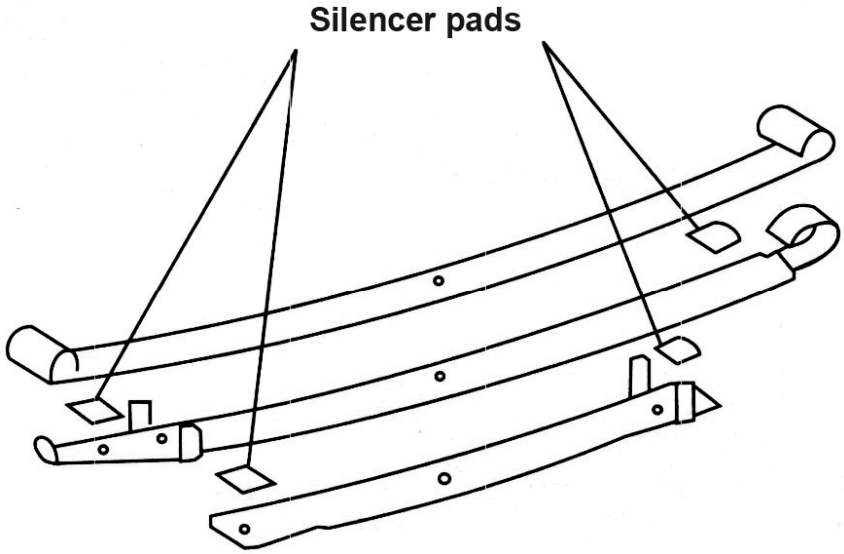


Fig. 3.11 Silencer Pads

Each of the leaves is also tapered at the ends so that they exert the proper amount of pressure when they come in contact with each other.

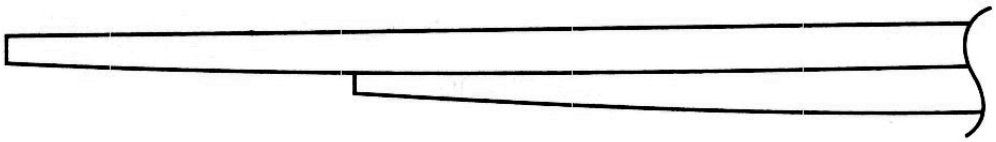


Fig. 3.12 Tapered at the ends of each Leaf

- **Characteristics of Leaf Springs**

1. Since the springs themselves have adequate rigidity to hold the axle in the proper position, it is not necessary to use linkages for this.
2. They control their own oscillation through inter-leaf friction.
3. They have sufficient durability for heavy-duty use.
4. Due to inter-leaf friction, it is difficult for them to absorb the minute vibrations from the road surface. Therefore, leaf springs are generally used for large commercial vehicles which carry heavy loads.

❖ Coil Springs

The coil springs are extensively used in suspension system of automobiles. A standard coil spring is made from a length of special spring steel, usually round in section. It is wound in the shape of a coil. The ends of a coil spring are kept flat so that they seat properly. The coil spring is very elastic and compresses when a load is put on it. When a vehicle goes over a bump or a pot hole, the spring compresses or expands to absorb the shock.

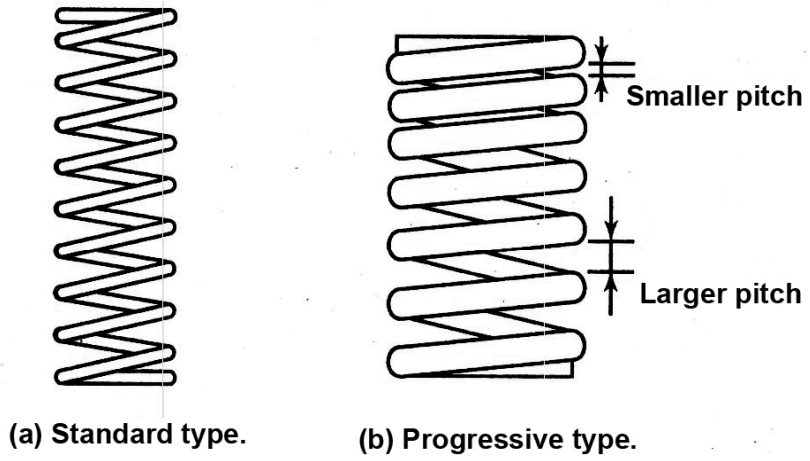


Fig. 3.13 Coil Spring

Sometimes, instead of standard type of coil spring, progressive type coil springs are used in automobiles. In progressive type coil springs, the wire is wound into coils of progressively increased pitches. When the wheel hits a hole or bump, the larger pitch section absorbs shocks or impacts with the smaller pitch section of the spring completely compressed. The coil springs are mostly used in the independent suspension system. The advantage this type of springs is that they can be assembled in compact space and are capable of storing twice the energy than that of a leaf spring.

- **Characteristics of Coil Springs**

1. The energy absorption rate per unit of weight is greater in comparison with leaf springs.
2. Soft springs can be made.
3. Since there is no inter-leaf friction, there is no control of oscillation by the spring itself. So it is necessary to use shock absorbers along with them.
4. Since there is no resistance to lateral forces, linkage mechanisms to support the axle (suspension arms, lateral control rod, etc.) are necessary.

❖ Torsion Bar Spring

A torsion bar spring is a spring-steel rod that uses its torsional elasticity to resist twisting. One end of the torsion bar is anchored to the frame or other structural member of the body and the other end to suspension arm that is subjected to torsional load.

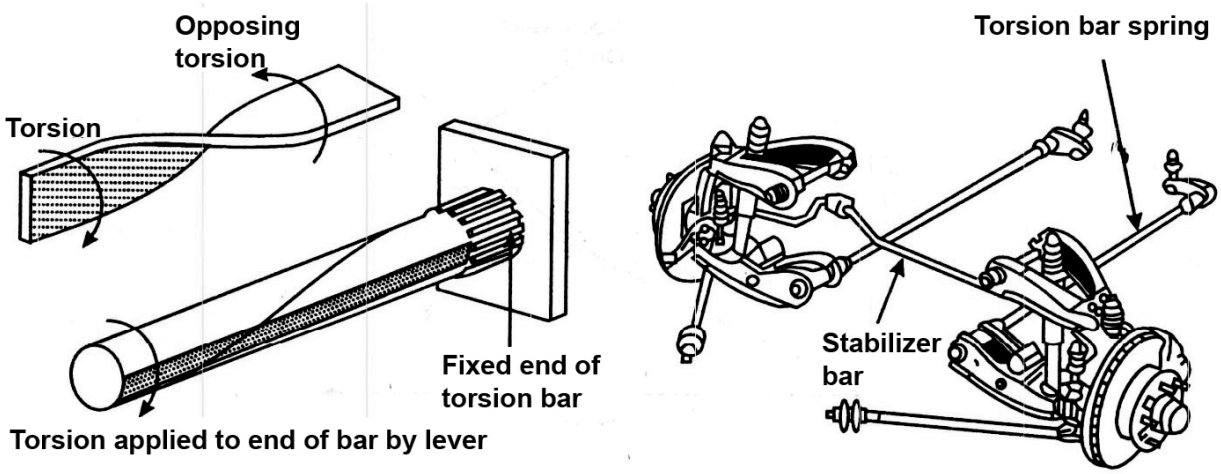


Fig. 3.14 Torsion Bar Spring

- **Characteristics of Torsion Bar Springs**
  1. Since the energy absorption rate per unit weight is great as compared to other springs, the suspension can be lightened.
  2. The layout of the suspension system is simplified.
  3. As with coil springs, torsion bar springs do not control oscillation, so it is necessary to use shock absorbers along with them.

❖ Shock Absorber

Shock absorbers are normally used in conjunction with springs and in particular with coil springs. Shock absorbers serve the purpose of quickly dampening the oscillations of coil springs caused by uneven wheel loads during travel on bumpy ground. The force introduced by the shock absorber opposes the force causing abnormal motion of the suspension at any particular instant. Shock absorbers are also called telescopic dampers.

In principle a shock absorber consists of a cylinder and a piston and a hydraulic fluid working inside the cylinder. The upper end of the shock absorber is fitted with a suitable mount for connecting to the vehicle body or the frame. The lower end is usually provided with an eye which fits with a pin and forms a hinged connection on a moving part like wheel axle or a control arm as the case may be.

Types of shock absorbers

The shock absorbers may be classified as:

1. Mechanical shock absorbers; and
2. Hydraulic shock absorbers

In mechanical shock absorbers, the friction action of metallic discs is utilized to control the spring action whereas in hydraulic shock absorbers fluid is used to resist the spring action. These shock absorbers are discussed in detail in the following articles.

- **Mechanical shock absorbers**

  The mechanical shock absorber consists of two links which are connected with each other by means of a pin. The one link is connected to the frame whereas the other link is fixed with axle. A number of friction discs of different metals are placed in between the links. These frictional discs control the spring action due to their frictional effect and thus help in absorbing the road shocks. This type of system has almost become obsolete due to its non predictable damping characteristics.

- **Hydraulic shock absorbers**

  The hydraulic shock absorber uses a fluid, which is passed through an orifice, which resists the movement of fluid. It is the resistance force that is created at this time which is used to suppress the motion of the spring. The hydraulic shock absorbers are of following three types;

  - Telescopic shock absorber;
  - Cam actuated piston type shock absorber; and
  - Rotary vane type shock absorber.

  Among above types the telescopic shock absorber is generally used in automobile suspension system.

❖ Telescopic Shock Absorber

- **Construction**

  This is formed by two concentric tubes, the inner tube being the pressure cylinder and the outer a reservoir for hydraulic fluid a piston and a piston rod assembly work in the cylinder. A valve assembly is fitted in the bottom of the cylinder and abuts a cap welded to the lower end of the reservoir. The top piston rod passes through an oil seal in a cap welded to the top of the reservoir. The top piston rod passes through an oil seal in a cap welded to the top of the reservoir tube. The top of the piston carries a further cap to which is attached a dust cover. Rubber bushed mounting eyes are welded to the top and bottom caps. The piston is drilled with too rings of holes, the outer ring controlled by a spring loaded flap valve, the inner ring is controlled by another flap valve backed by a support ring a helical spring abutting a shouldered nut which retains the piston and valves on the piston rod. In the lower end of the pressure cylinder is the valve assembly. The valve body has a large central hole and a ring smaller hole. A spring loaded recuperation valve is fitted over the large over the large central hole and spring discs cover the ring of smaller holes.

- **Operation**

  Compression Cycle (Bound): As the shock absorber is compressed by rising wheel the piston rod assembly moves down in relation to the cylinder thus creating a pressure below the piston. The oil flows through the outer ring of holes lifting the flap valve against its spring the volume of the piston rod entering the cylinder displaces an equal volume of oil which is forced through the holes in the valve, past the spring discs and into the reservoir.

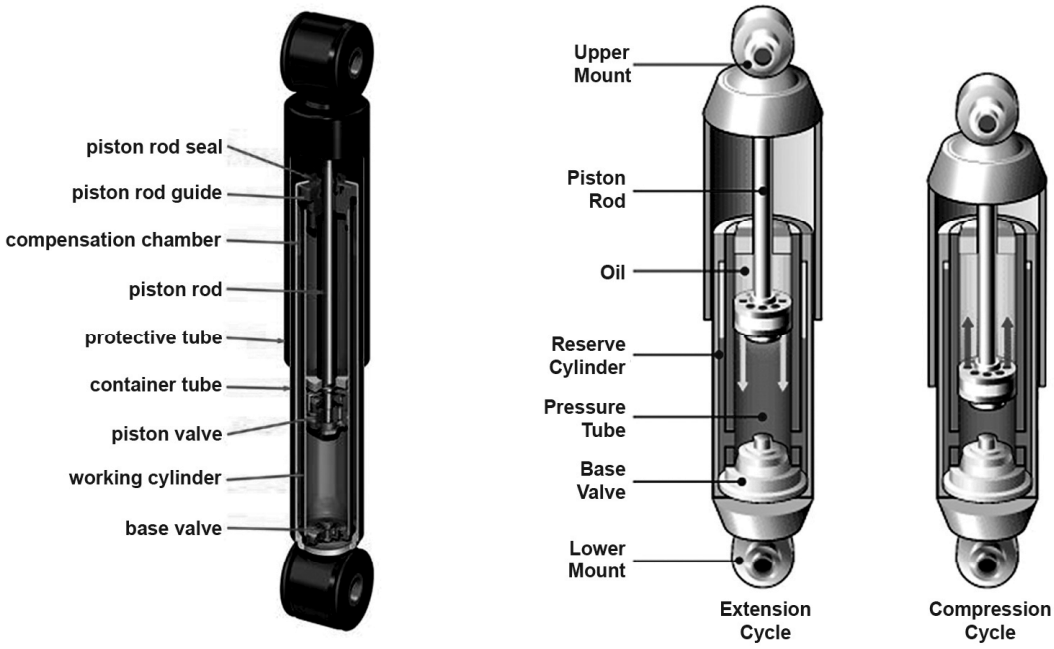


Fig. 3.15 Telescopic Shock Absorber

Extension Cycle (Rebound): On the rebound the shock absorber is extended reversing the flow of oil. The lower flap valve moves against the helical spring uncovering the inner ring of holes and allowing oil to flow through. As the piston rod is withdrawn from the cylinder an equal volume of oil is recuperated from the reservoir through the central orifice in the valve assembly.

- **Servicing of shock absorber**

  Servicing of this type of shock absorber is confined to renewal of the rubber bushes in the mounting eyes if the existing bushes are worn or perished

  The internal mechanism of the shock absorber is inaccessible because of the welded construction of the tubes; for the same reason the working fluid cannot normally escape and no means of replenishment is provided. If examination shows that the shock absorber has leaked, it should be removed from the vehicle and a serviceable shock absorber is fitted.

3.5 Mac Pherson Strut Suspension

This Suspension system was developed by an American engineer, Earle S. MacPherson. Nowadays, it is the most popular independent front wheel suspension used on all passenger cars.

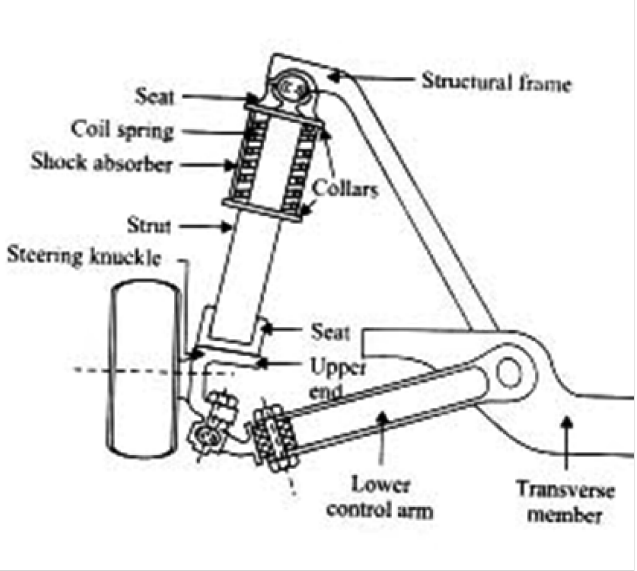


Fig.3.16 Mac Pherson Strut Suspension

In this system of arrangement, a shock absorber inside a long and thin coil spring is used at each wheel. The lower end of the shock absorber rests on a strut mounted on the upper end of the steering knuckle on proper seat. The upper end of the shock absorber and the top of the coil spring are made to sit on a seat provided on the structural frame. The coil spring is restrained between two collars on the body of the shock absorber. The upper control arm is absent and the steering control is done by connection to the upper end of the steering knuckle. The lower control arm is connected to the transverse member of the frame.

- Advantages of MacPherson Strut Suspension

1. This type of suspension gives the maximum room in the engine compartment due to the absent of upper control arm.
2. It is simple in construction and light in weight.
3. Due to its light weight, road irregularities are easily countered and hence provide increased road safety.
4. It improves the ride comfort and gives a light and self-stabilizing steering, also the wheel camber is more stable.
5. In addition to its relatively low initial cost, its maintenance, repair or replacement is less expensive.

3.6: Trouble shooting Chart for Suspension System

Complaint	Causes	Remedies
1. Suspension too flexible	a. The manufacturer might have indicated that the springs should not be lubricated. By mistake, these springs are lubricated against this precaution. Then the friction in the springs may decrease	Clean the springs completely
	b. A few leaves of the springs may be broken	Replace the springs
	c. Some defects may be noted in the shock absorber	Replace the shock absorber
	d. The springs may become weak due to constant use	Replace the spring
2. Rough ride	**A. In the conventional rigid axle suspension:**	
	a. The leaves of the spring may be rusted. This will result in excessive friction	The spring should be lubricated to reduce friction
	b. The pins in the shackles may be seized	This defect should be set right
	c. Defect will be in the shock absorber.	Replace the shock absorber
	B. In the independent suspension:	
	a. The pivots on the suspension arms may be seized.	Lubricate the pivots
	b. The adjustment in the torsion bars may not be correct.	Adjust the torsion bars properly
3. The vehicle may sag on one side due to the sagging springs.	a. Due to constant use, the spring on the sagging side may be weak	Replace the weak spring
	b. A few leaves of the sagging spring may be broken	Replace the spring
	c. The coil spring may be adjusted incorrectly in case of independent suspension	Adjust the coil spring correctly
4. Squeaking or rattling noises	a. Lubrication may not be sufficient. This may develop spring noise.	Lubricate the springs
	b. Shackles may have side play	Rectify the side play
	c. U-bolts may be loose	Tighten the U-bolts correctly
	d. The shackle pins and the bushes may be loose	Rectify suitably
	e. Shock absorbers may have some defect	Replaced the shock absorber

QUESTIONS

Very Short Answer Type Questions

1. Define pitching, during oscillation of sprung weight of a car.
2. Define **rolling,** during oscillation of sprung weight of a car.
3. Define **bouncing,** during oscillation of sprung weight of a car.
4. Define **yawing,** during oscillation of sprung weight of a car.
5. Define **hopping,** during oscillation of un-sprung weight of a car.
6. Define **tramping,** during oscillation of un-sprung weight of a car.
7. Define **wind-up,** during oscillation of un-sprung weight of a car.
8. Define the suspension term **bounce.**
9. Define the suspension term **jounce.**
10. Define the suspension term **rebound.**
11. Define the suspension term **dive.**
12. What is nip of a leaf spring?
13. What is camber of a leaf spring?
14. Springs are made of

    a. Mild steel b. Carbon steel
    c. High speed steel d. Spring steel

15. The reason why a laminated spring is made up of a series of leaves is to

    a. Reduce interleaf friction
    b. Soften the spring action and increase the maximum deflection
    c. Allow the leaves to slide during the bump movement
    d. Overcome the weakness at the centre spring.

16. During the rebound stroke, the load is transmitted from the main leaf from the shorter leaves by a

    a. U – Bolt b. Spring clip
    c. Centre bolt d. Shackle pin

17. The provision made to allow a leaf spring to vary its length is a

    a. Swinging shackle b. Rubber U – bolt mounting
    c. Sliding centre bolt d. Splines in the spring eye

18. The purpose of a suspension damper is to

    a. Resist the road shocks
    b. Reduce the 'bump' stroke of the spring
    c. Absorb the energy stored in the spring
    d. All above.

Short Answer Type Questions

1. What are the functions of suspension system?
2. Define sprung and un-sprung weight.

Short Answer Type Questions

1. Explain sprung and un-sprung weight with a sketch.
2. Name different principal components of suspension system.
3. Draw the sketch of a semi-elliptical leaf spring and show its different parts.
4. How the suspension springs are classified?
5. With neat sketch explain Nip and Camber of a leaf spring.
6. Explain the technique to reduce the inter leaf friction of leaf spring.
7. Write different characteristics of leaf springs.
8. Write different characteristics of torsion springs.

Long Answer Type Questions

1. Explain the oscillations of sprung and un-sprung weight of a vehicle.
2. Draw the sketch of different types of leaf springs and write their uses.
3. Explain the constructional features of suspension coil springs.
4. Explain with diagram the torsion spring suspension.
5. Explain with sketch the construction of telescopic shock absorber.
6. Explain with sketch the operation of telescopic shock absorber.

UNIT – 4

Transmission & Final Drive System
(Propeller Shaft & Universal Joint)

Learning Outcome

Session 1 : Transmission & Final Drive System (Propeller Shaft & Universal Joint)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students shall be able to understand: 1. The function of propeller shaft and universal joint. 2. Construction and working of propeller shaft and universal joint.	Explain: 1. The function of propeller shaft and universal joint. 2. Construction and working of propeller shaft and universal joint.	Demonstrate the propeller shaft and universal joint with deassembled parts	**Interactive Lecture:** 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the technique of servicing propeller shaft and universal joint.

Session 2 : Transmission & Final Drive System (Differential and Rear Axle)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students shall be able to understand: 1. Function of final drive, differential and rear axle. 2. Types of final drive and their features. 3. Principle of differential and its construction & operation. 4. Classification and construction of rear axle.	Explain: 1. Function of final drive, differential and rear axel. 2. Types of final drive and their features. 3. Principle of differential and its construction & operation. 4. Classification and construction of rear axle.	Demonstrate: 1. Each component of final drive, differential and rear axle. 2. Construction and working of differential and rear axle.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the different parts and their working of differential and rear axle assembly.

Objectives

After attending this session, you should be able to:

- *Explain the function of Propeller Shaft.*
- *Explain the construction and working of Propeller Shaft.*
- *Explain the function and type of Universal Joints.*
- *Explain the construction and operation of Universal Joints.*
- *Explain the function of Final drive.*
- *Explain the types of final drive and their features.*
- *Explain the principle of differential.*
- *Explain the construction and operation of differential.*
- *Explain the function of rear axle.*
- *Explain the construction of rear axle and its classification.*

4.1: Difference between Manual and Automatic Transmission

1. The primary difference between an automatic and a manual transmission is the method of shifting (engaging or disengaging) different gears. In an automatic transmission, the car decides when to shift and automatically changes gears as per the requirement, but in manual transmission the driver (operator) is responsible for shifting gears using the clutch and accelerator pedals.
2. The fuel economy is better with manual transmission system because the engines is not having to work as hard to shift between gears and therefore the car does not consume as much.
3. Automatic transmissions are much more complicated, therefore may be more difficult and expensive for mechanics to fix.

4.2 Propeller Shaft

In four wheel drive and rear wheel drive vehicles, it is the propeller shaft that serves to transmit the drive force generated by the engine to the axles. The propeller shaft is made of steel tube having a high resistance against torsional or bending forces. It is dynamically balanced, some time a balance weight is welded outside the tube for the purpose of balancing dynamically.

❖ Function

The functions of propeller shafts are:

- To transmit torque
- To allow different drive shaft angles
- To allow changes in length
- To reduce rotary vibrations

❖ Construction

The propeller shaft is normally made by seamless steel tubing method with universal joint yokes welded to both ends of the shaft. Some drivelines have two propeller shafts and three universal joints and use a center support bearing. Four wheel-drive wheels use two propeller shafts, one to drive the front wheels and the other to drive the rear wheels.

In practice, propeller shaft should always be short and as stiff as possible, this enable the shaft to resist the bending loads and torque reactions which are imposed during operation. If the shaft cannot be made in a short length, then its stiffness can be improved by making the diameter larger. Propeller shafts are either solid

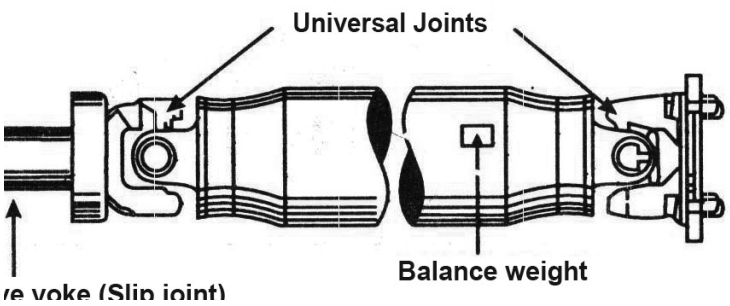


Fig. 4.1.1 Propeller Shaft Assembly

or tubular in construction. A tubular shaft is stronger than a solid shaft of the same weight and therefore offers advantages of reduced weight and low manufacturing costs.

Components of Propeller Shaft Assembly

- **Universal Joint:** A universal joint forms a mechanical connection between the two shafts and allows angular movement of one or both shafts. Also it transmits power smoothly from the gearbox to the differential.

  Road shocks due to road irregularities will deflect the springs, which will alter the angle of the propeller shaft, relative to the gear box and final drive and unless a universal joint is fitted to each end of the propeller shaft, the shaft will bend and fracture.

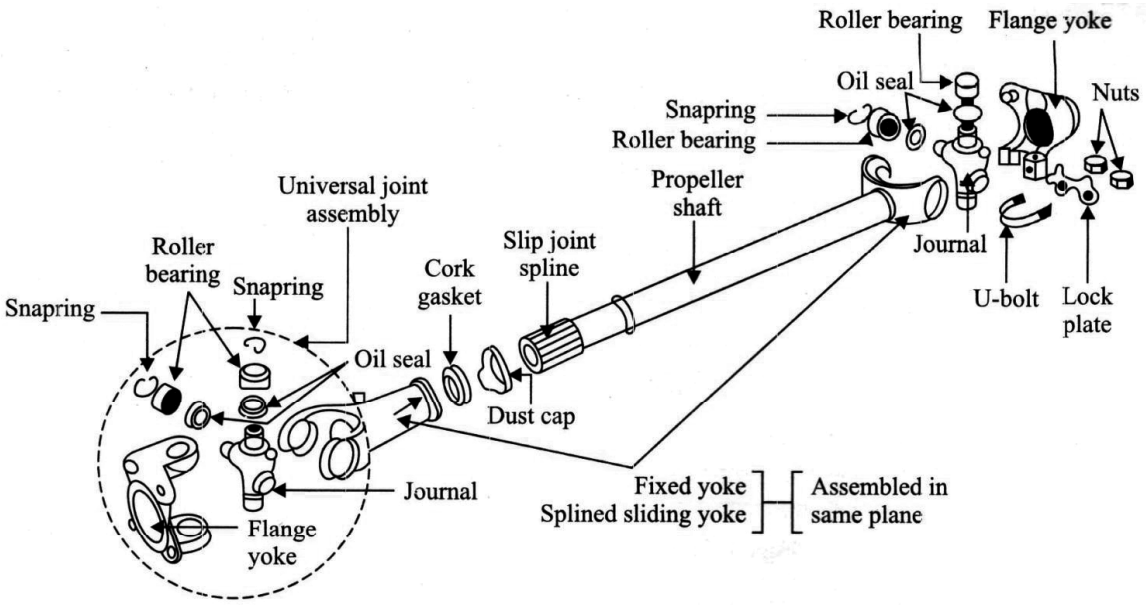


Fig. 4.1.2 Exploded view of various components of Propeller shaft and Universal Joint.

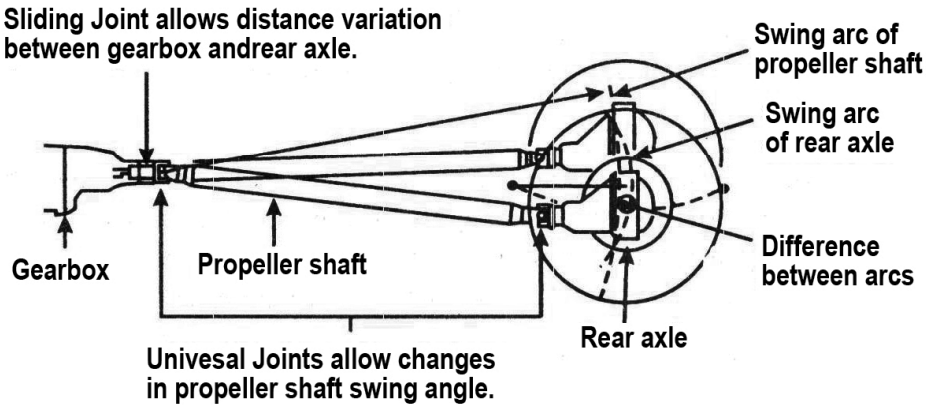


Fig. 4.1.3 Components and Swing Arc of Propeller shaft and Rear Axle.

- **Slip Joint (or Sliding Joint):** Propeller shaft use a slip joint at one end, which allows it to lengthen or shorten. It permits the effective length of the propeller shaft to change due to up and down movement of the wheels.

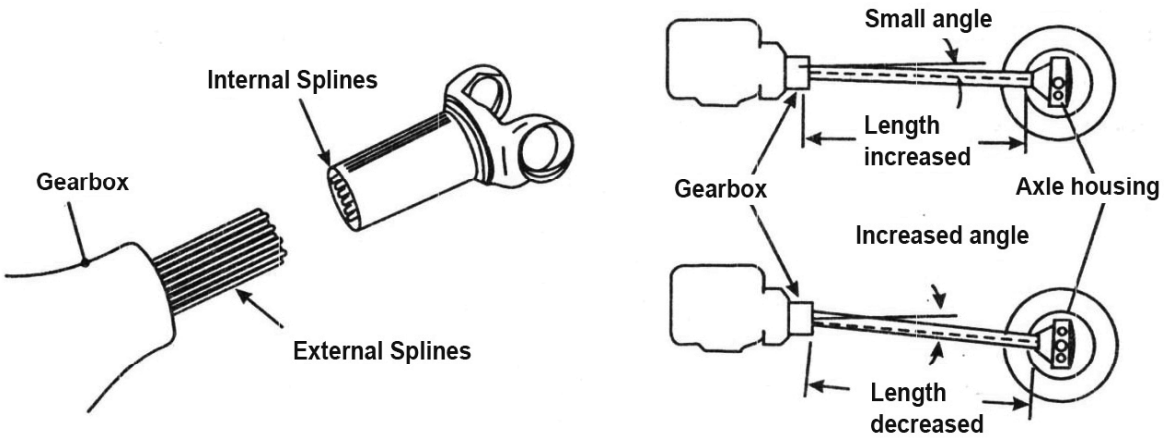


Fig. 4.1.4 Slip joint and its function

- **Centre Bearing:** Vehicles having long wheelbase i.e. bus, truck, etc. have propeller shaft in two sections, supported by intermediate bearings fitted in a cross member of chassis frame. In this type of arrangement there are three universal joints and two slip joints.

  The advantage of fitting divided propeller shaft to a long wheel base vehicle is to avoid the propeller shaft sag and whirl at high speed and in turn reduces the vibration caused by the rotation of the propeller shaft.

  The centre bearing consists of a rubber collar contained within a steel casing, which is mounted on the vehicle's chassis cross member. The centre bearing normally uses self-aligning bearings, which allow for slight misalignment of the shaft caused by the gearbox moving on its mountings.

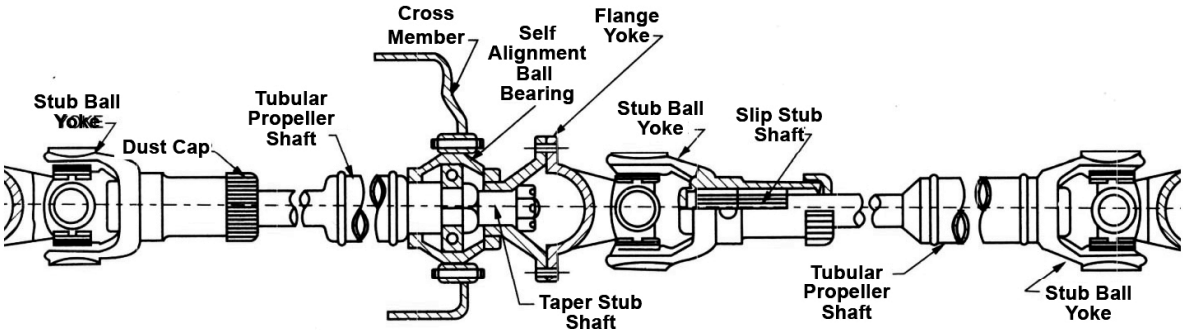


Fig. 4.1.5 Two-piece Propeller shaft with self alignment Centre Bearing.

4.3 Universal Joint

It may be noted that in case of front engine, rear wheel drive, the power is transmitted from the gear box to differential via the propeller shaft. The transmission is connected to one end of the propeller shaft by means of universal joint. The differential is connected to the other end of the propeller shaft by means of another universal joint. The universal joints are required because the rear end of the propeller shaft is constantly rising and falling due to the up and down flexing of the rear springs.

- **Function:** The functions of universal joint is to
  - transmit power at varied angles
  - allow rear axle assembly to twist due to the driving and braking torque application.
- **Requirements:** A modern universal joint is expected to meet the following requirements:
  - **Strength:** High torque must be transmitted with the minimum energy due to friction.
  - **Compactness:** Space is limited so the joint must be small and robust.
  - **Large drive angle:** Modern road springs allow large wheel deflections so the joint must be able to accommodate the large drive angle given by this movement.
  - **Shaft balance:** Severe vibration occurs if the shaft runs out-of-true, so the joint must maintain good alignment.
  - **Operating speed:** The joint must operate efficiently at higher speed under the conditions of high torque and variable drive angle. This requirement must be combined with the need for the joint to have a long life and minimum maintenance.

Types of Universal Joint

The universal joints are classified as follows:

1. Variable velocity joints and 2. Constant velocity joints.

   The variable velocity joints are further classified as:

   (a) Cross or spider type and (b) Flexible Ring type

   The constant velocity joints are further classified as:

   (a) Rzeppa joint and (b) Tripod joint.

1. Variable Velocity Joints

In variable velocity joints, the driving and driven members do not turn at the same speed through each part of a revolution although they turn at the same r.p.m. The driven and driving shaft should therefore, be in a straight line so that they may turn at same speed through each part of a revolution. But in a automobile, it is not feasible as the drive shaft is inclined.

When there is an angle between the driven and driving and driving shafts, the driven shaft turns slower than the driving shaft through half a revolution and faster than the driving shaft through the other half of the revolution. Thus, the average speed of the driven shaft is equal to the driving shaft. The speed variation in the driven shaft increases when the flex angle of the universal joint is increased. It is owing to this fact that variable velocity joints are usually used when the flex angle is small.

It may be noted that when two variable velocity universal joints are used in one drive line, the yoke on the shafts connecting the universal joints should be in the same plane. It helps in balancing the shaft.

Two types of variable velocity joints are explained below:

a. **Cross or spider type:** It is also commonly known as Hooke's joint. It is most common type of universal joint widely used in automobiles because of the fact that it is simple in construction and reasonable efficient at small angles (generally up to 20^0 angle) of up and down movement of propeller shaft.

It consists of two Y-shaped yokes connected at right angles to each other by means of a cross or spider. The arms of the cross are called as trunnions. The needle type bearings are employed between the yokes and cross ends and the bearing cups are locked with yokes with the help of circlips.

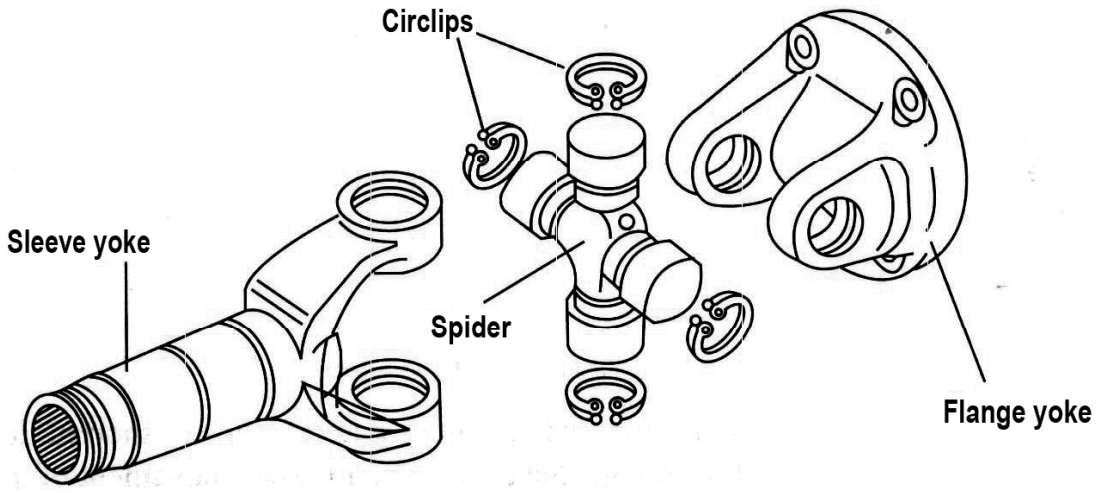


Fig. 4.1.6 Cross or Spider type Universal Joint

b. **Flexible Ring type:** This type of joint employs a flexible ring and acts due to its flexing. The shafts are provided with two or three armed spiders, the arms of which are bolted to the opposite faces of flexible ring. The arms of one spider are arranged midway between the arms of the other.

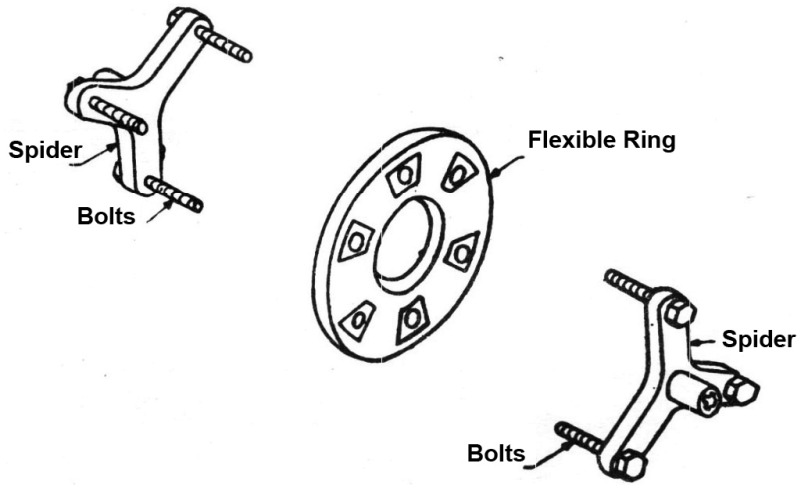


Fig. 4.1.7 Flexible Ring type Universal Joint

The flexible ring is usually made of one or more rings of rubberized fabric made in a special way for providing necessary strength. It may be noted that sometimes a number of this steel discs are used instead of fabric rings. When the shafts are revolving about their axes, there is a continuous flexing of the ring to enable drive through varied angles

The following are the advantages and disadvantages of this type of joint.

Advantages:

- This joint can accommodate a considerable amount of axial movement of the shaft.
- It helps in smoothing out of torque fluctuations.
- It needs no lubrication

Disadvantages:

- The ring does not withstand for a long period.

1. Constant Velocity (CV) Universal Joint

A constant velocity joint is a type that provides an output shaft speed equal to that of the input in all shaft positions within the working range of the joint. Constant-velocity conditions are achieved when the connecting device between the driving and driven yokes is positioned in a plane that bisects the angle of drive.

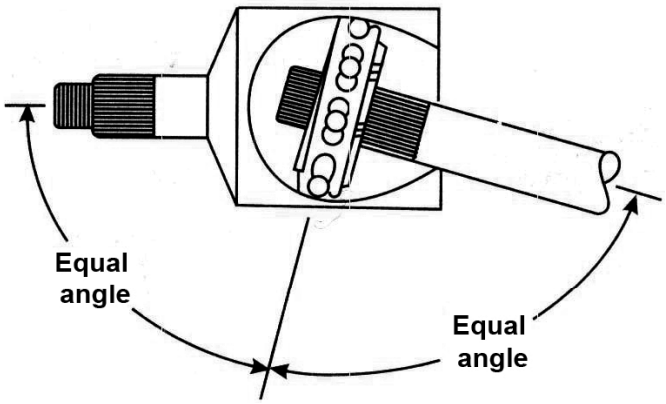


Fig. 4.1.8 Constant Velocity Joint

One method of achieving a constant speed output from the propeller shaft is to mount two universal joints back-to-back (double Carden type) or positioned in a certain way at each end of the propeller shaft. In both configurations the relative positions of each joint must be arranged so that the speed change of one joint is counteracted by the other.

a. **Rzeppa Joint:** A Rzeppa joint (or Birfield Rzeppa joint) consists of an inner race, a set of six spherical ball, a cage to position the balls, and an outer housing as shown in fig. These joints are used as outboard joints (i.e. wheel end of the axle shaft or drive shaft).

The steel balls are held in the grooves on the spherical recess. The torque is transmitted from one race to another by the balls. The circular pattern of balls results in both shafts to turn at the same velocity.

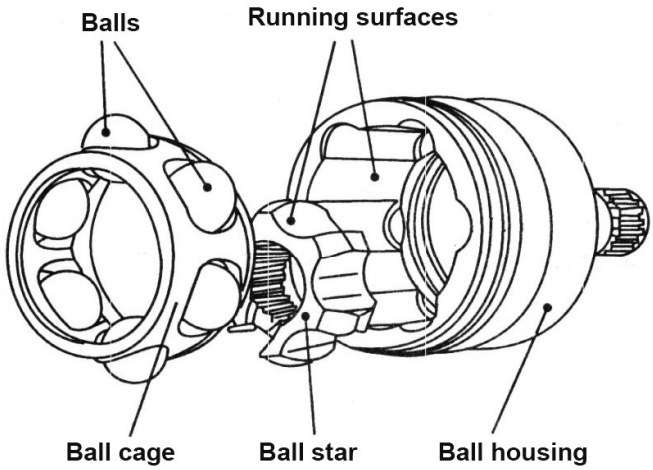


Fig. 4.1.9 Rzeppa Joint

b. **Tripod Joint:** A tripod joint consists of a housing, a spider, and a set of three rollers as

shown in Fig. The spider and rollers can slide in the axial direction to compensated for any change in drive shaft length caused as a result of variation of the drive shaft angle. The tripod joints are commonly used as inboard joints (i.e. differential end of axle shaft or drive shaft).

Note: *Both types of CV joints are covered with boots so that water, dust etc, can be kept out of the mechanism so that the lubricant can be packed inside while assembling.*

4.4 Final Drive

The final drive is the last stage of power transfer from the engine to wheels. The final gear of the differential assembly consists of the drive pinion and ring gear (crown wheel). The purpose of final drive is to:

- Provide a constant permanent speed reduction, irrespective of what gear is engaged in the gearbox to increase the torque available.
- Turn the drive through 900, where an in-line engine is employed.

Types of Final Drive:

The final drive is classified in the following two types:

(a) **Chain type:** Now a day, this type of final drive is obsolete in cars and trucks. In this type, the drive wheel is connected with the gearbox by means of chains and sprockets. The motor cycles employ this type of drive.

(b) **Gear type:** The gear type final drive consists of a ring gear and a drive pinion. The ring gear is riveted with the differential cage and the drive pinion is connected with the propeller shaft (drive shaft). The power from the propeller shaft flows towards the axle shafts through the drive pinion and ring gear.

The gear type final drive is of the following main types:

i. **Worm and wheel type:** This type of final drive is particularly used in heavy vehicles, where the final reduction is greater than about 6. This gives a quiet, efficient and very strong drive. The worm can be mounted either below the wheel axis level giving low chassis height or above the wheel axis level allowing more ground clearance.

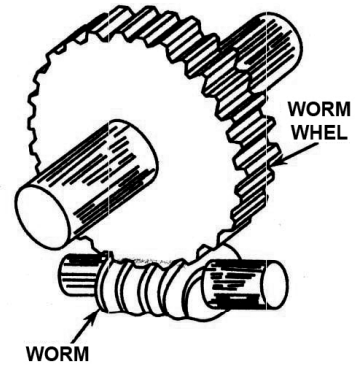


Fig. 4.2.1 Worm and worm wheel drive.

The following are the disadvantages of this type, which restricts its practical usage:

- The cost of manufacturing and weight is higher than bevel gears.
- The mechanical efficiency is lower than that of bevel gears for a single stage bevel drive.
- The lubrication of worm is difficult.

ii. **Straight bevel gears:** This type of gear consists of the drive pinion and ring gear. These rotate at right angles to each other and their faces are beveled. Therefore, they are the simplest and cheapest of all.

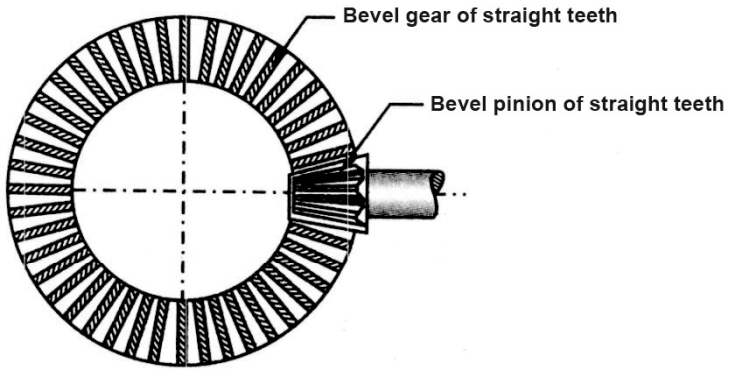


Fig. 4.2.2 Straight bevel gear drive

In this type, at one instant, only one pair of teeth of pinion and the crown wheel will be in contact, which results in the uneven transmission of motion. Hence high wear and noise occurs during transmission.

iii. **Spiral bevel gears:** The difference between the straight bevels hears and spiral type of bevel gears is that in this type, the teeth are helical or spiral in shape. This results in greater contact of teeth. These are stronger and silent in operation.

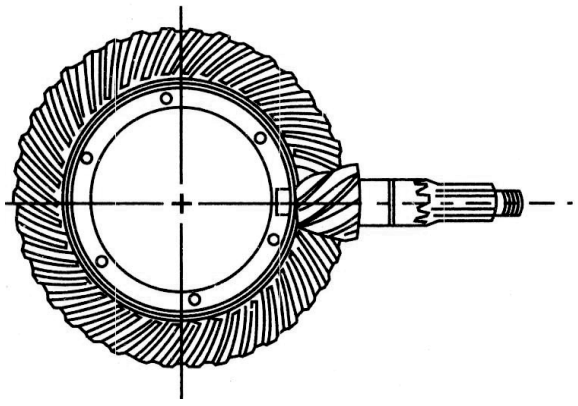


Fig. 4.2.3 Spiral bevel gear drive

iv. **Hypoid gears:** In this type of final drive gears, the teeth are cut in a hyperbola curve. This type of teeth shape provides a greater area of contact, and therefore greater strength. The pinion shaft is placed below or above the axis of the crown wheel.

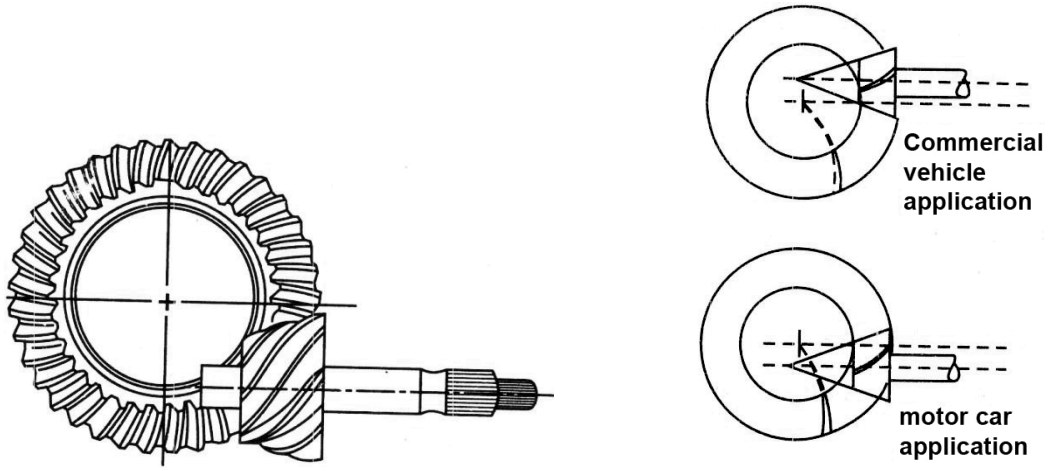


Fig. 4.2.4 Hypoid gear drive

If pinion shaft is placed below the axis of crown wheel it makes possible a lower position of the propeller shaft, thus allowing a low chassis height. This type is used for light cars.

If pinion shaft is placed above the axis of crown wheel it makes possible an upper position of the propeller shaft, thus allowing a more chassis height. This type is used for heavy vehicles like truck.

4.5 Differential

❖ Principle of Differential

When a vehicle is moving rounding a corner, the turning radii of inner and outer wheels differ. It may be noted that a difference also exists in the distance travelled by the inner and outer wheels. As both sets of wheels complete the corner in the same period of time, it follows that their respective speeds will also differ.

The differential is responsible for generating this difference of speed in inner and outer wheels. If the left and right wheels are connected directly without differential, turning would not be possible unless one of the wheels started to slip. Thus, cornering in such a condition would be extremely difficult and would also result in an increased amount of tyre wear.

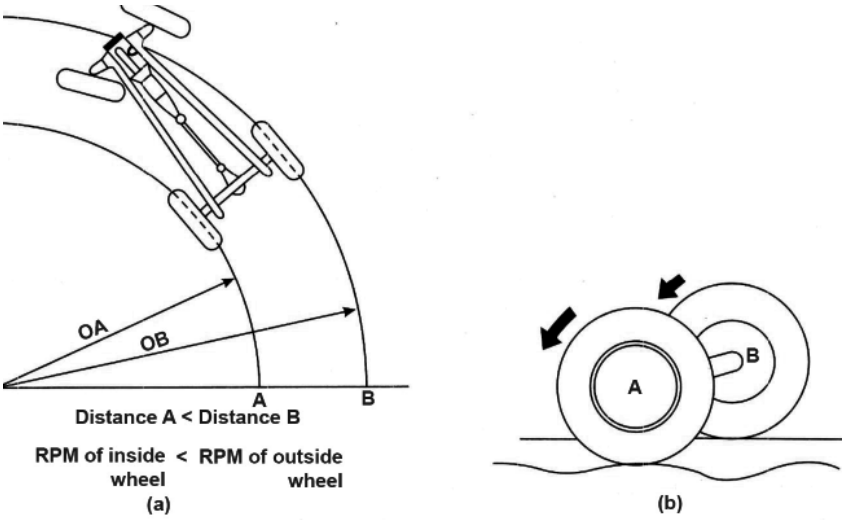


Fig. 4.2.5 Principle of Differential

Thus, in simple works, differential is a mechanism by means of which outer wheel runs faster than the inner wheels while taking a turn or moving over upheaval road. The differential consists of a system of gears arranged in such a way that connects the propeller shaft with the rear axles. The differential is a part of rear axle housing assembly, which includes differential, rear axles, wheel and bearings.

The differentials are used in

- The rear drive axle of front engines, rear wheel drive vehicles.
- The transaxle of front engine, front wheel drive vehicles or rear engines, rear wheel drive vehicles.
- The front drive axle and rear drive axle of four wheel drive vehicles.
- The transfer case of some four wheel drive vehicles, have a third differential.

❖ Construction

The general constructional detail of the final drive and differential assembly is shown in fig.3.2.6.

The ring gear (crown wheel) of the final drive is attached to a differential case which contains four bevel type gear pinions all facing inwards, meshing with each other in the form of a box. Two of the bevel pinions opposite each other are splined to the half shafts and are referred to as the sun gears. The other opposed pair of pinions are free to rotate upon a pinion shaft and are known as pinion shaft which acts as a pivot for the pinion gears in mounted in the differential housing which is driven by the ring gear. There is no direct connection between the ring gear and the half shafts.

The final drive gears must function precisely in correct relationship with each other. At the same time they will be transmitting very high torque. For this reason, the final drive and differential assembly is located in the axle casing and supported on taper roller bearings.

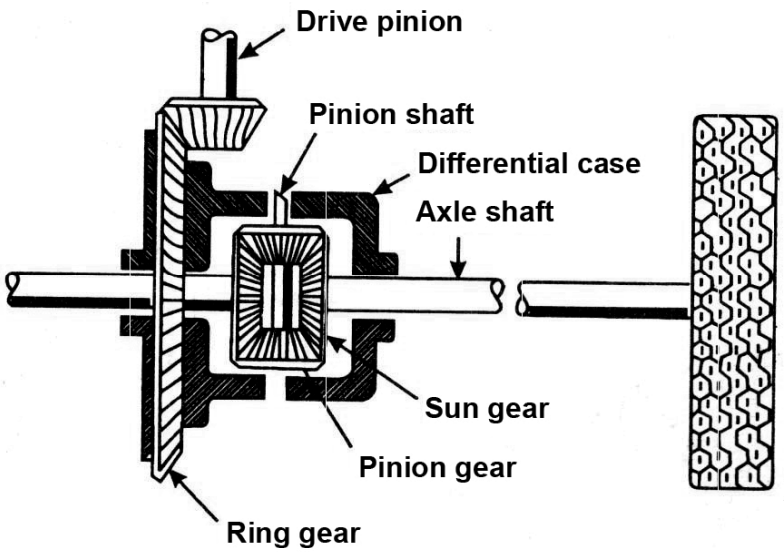


Fig. 4.2.6 Differential Assembly

❖ Operation

- **Straight Ahead Travel:** The rolling resistances of the two drive wheels are almost identical when the vehicle is travelling straight ahead on a level road. When resistance is equal in both axle shafts, the differential pinions themselves do not rotate but turn as a unit with the ring gear, differential case and pinion shafts. In this case, the differential pinions only function to connect the right and left sun gears. As a result, the two sun gears rotate as a unit with the revolution of the pinion gears, causing both drive wheels to turn at an equal rpm.

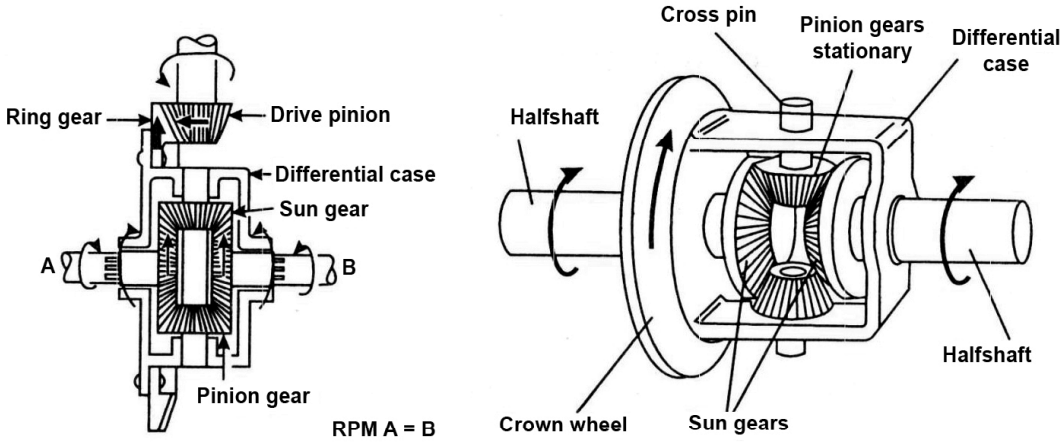


Fig. 4.2.7 Operation of Differential while vehicle moving on straightahead

- **Turning:** When the vehicle is turning, the inside wheel travels less distance (i.e., in a shorter arc) than the outside wheel in comparison with when the vehicle is travelling in a straight line.

  Since a resistance is therefore applied to the left-hand sun gear while taking left turn, as illustrated above in fig. 4.2.8 each differential pinion rotates around its own shaft (axis) and also revolves around the rear axle. As a result the rpm of the right-hand sun gear increases.

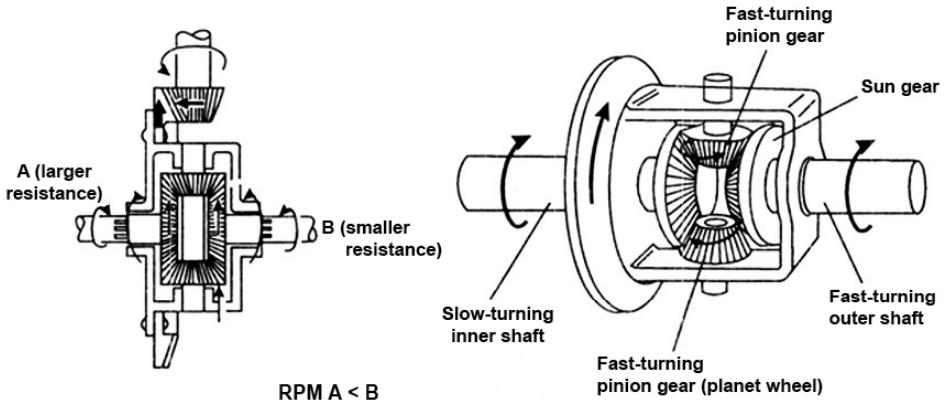


Fig. 4.2.8 Operation of Differential while vehicle taking a turn

4.6 Rear Axle

❖ Functions of Rear Axles

The following are the functions of the rear axles:

- They support the weight of the vehicle.
- They drive the rear wheels via the final drive.
- They rotate the power flow at the final drive by 90° on either side for driving the wheels.
- The rear axle casing offers space for filling the lubricant for the final drive components.
- The rear axle casing serves as protective guard for the complete mechanism of final drive and differential.

❖ Construction

The rear axle is installed to the chassis springs through axle housings. The basic layout of a conventional live axle used on rear-wheel drive vehicles, which comprises the following main components:

- Axle housing or casing
- Final drive
- Differential unit
- Half shaft to each road wheel
- Support bearings
- Two hub assemblies.

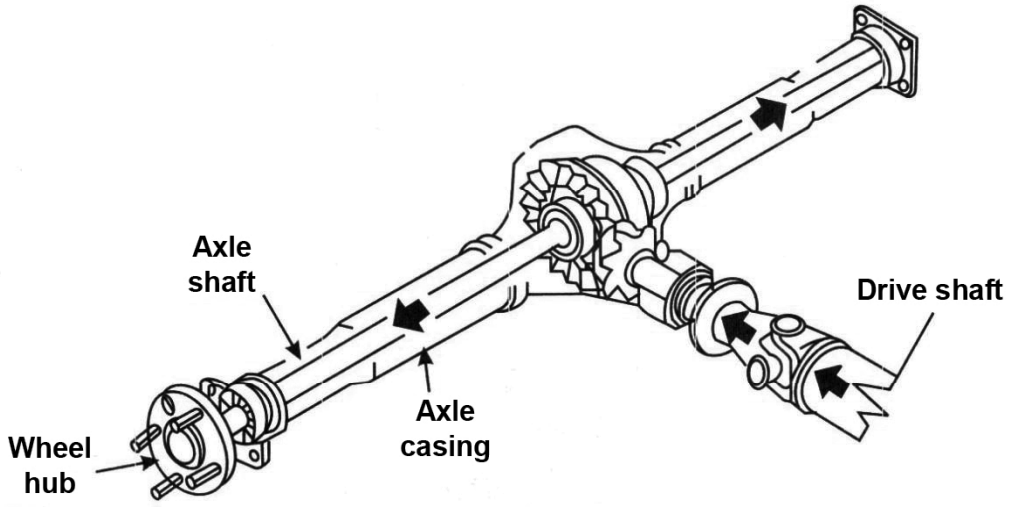


Fig. 4.2.9 Rear Axle Assembly

The axle housing is a single-piece construction and has the brakes installed at both ends. The centre part of the axle housing is made to allow installing the differential and also serve as an oil well. Drive from the propeller shaft is transmitted via the crown wheel and pinion, to both rear

wheels by means of the half shafts. The axle housing itself acts as a beam to support the weight of the rear of the vehicle and provide a mounting for the final drive and differential gears. The axle housing must also act as a reservoir for lubrication purposes. Each half shaft is supported at its inner end by the differential sun wheel and bearing while their outer ends are carried in hub bearings. An oil seal is provided on the outer end of each axle shaft to prevent the oil from leaking into the brakes.

On front-wheel drive vehicles, the rear axle is considered a dead axle. In a dead axle, bearings are used to support the vehicle. However, since there is no differential, the axle is not connected to a differential and is not used to transmit power.

The rear live axles are classified as:

- **Semi floating type:** Bearing is installed between the axle housing and the axle shaft and the wheel is fitted directly to the shaft. For this reason, the shaft is required to support all of the vehicle weight as well as lateral loads during turning. This type of rear axle is not preferred due to following drawbacks.
  - i. The axle shaft has to bear the driving torque.
  - ii. The axle shaft has to take the vehicle load.
  - iii. The axle shaft has to take the cornering load when the vehicle is turning.
  - iv. In case of breakage, the axle shaft of the vehicle will fall to one side of the ground.

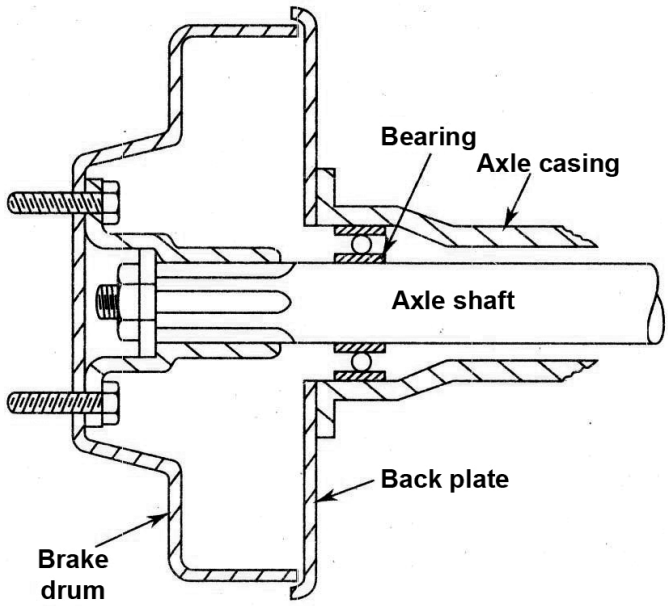


Fig. 4.2.10 Semi-floating Rear Axle

- **Three quarter floating type:** A single bearing is installed between the axle housing and the wheel hub and the wheel is fitted directly to the shaft. Most of the vehicle weight is supported by the housing, although lateral loads during turning are applied to the axle shaft.

The axle takes care of driving and cornering torque. This type of rear axle is used in small and medium vehicles.

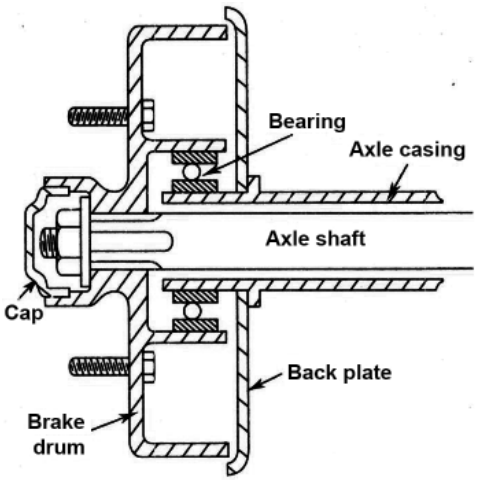


Fig. 4.2.11 Three-quarter floating Rear Axle

- **Full-floating type:** Bearings are placed between the axle housing and the wheel hub and the wheel is fitted to the wheel hub. Since the load of the vehicle is supported completely by the axle housing in this type of suspension system, the axle only needs to drive the wheels. Therefore, the shaft is prevented from excessive force. This type is often used with trucks since it supports heavy loads well.

  The advantages of this type of axle are as follows:

  i. The axle shaft can be removed by removing the bolts without removing the wheel and wheel hub.

  ii. This type of axle is very strong and is used for heavy vehicles.

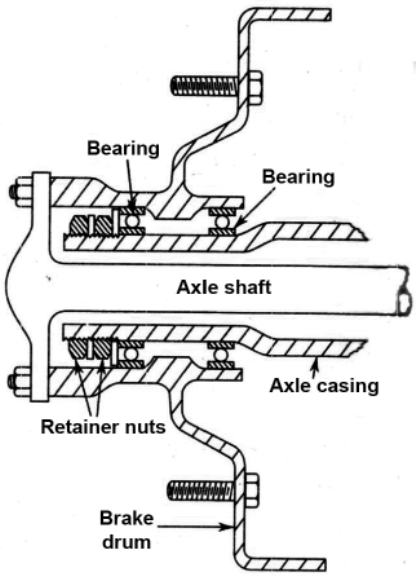


Fig. 4.2.12 Fully-floating Rear Axle

4.7: Trouble shooting chart for Transmission and Final Drive System:

Trouble Shooting Chart for Clutch

	Causes	Remedies
Clutch slips	a. Oil on the lining because of leaks in engine seal or gear box	Replace the lining and correct
	b. Too small a clearance of clutch	Adjust the clearance to the required back-lash of pedal
	c. Worn out facing	Install a new clutch friction plate
	d. Weak clutch springs	Install a new set of springs
Clutch fails to disengage	a. Excessive clutch clearance	Properly adjust the clearance
	b. Friction plate not moving freely on splined shaft	Clean the splined shaft and hub and see that they move freely
	c. Friction plate facing worn out.	Replace the facing on the friction plate or fit a new clutch plate
Clutch grabs, i.e., the hub of the friction plate binds on the clutch shaft	a. Scored contact surfaces of flywheel or pressure plate.	Reface the surfaces to make them smooth
	b. Warped friction plate	Straighten or replace the friction plate
	c. Release levers not evenly placed	Adjust the levers properly
Clutch is noisy	a. Clutch pedal bush is dry	Lubricate the bush
	b. Clutch release bearing is dry	The bearing should be filled with grease
	c. Torsion spring is damaged	Replace the torsion springs
	d. Pilot bearing is damaged	Replace the pilot bearing
Clutch judder or vibration	a. Rivets of clutch plate are loose	Replace the clutch facing or replace the complete clutch plate
	b. Clutch facings are worn out	Replace the facing or renew the clutch plate.
	c. Splined clutch shaft is bent	Replace the clutch shaft

Trouble Shouting Chart for Gearbox

Fault	Causes	Remedies
Oil leaks	a. Too high lubricant level	Use just the right amount of oil
	b. Broken or missing gaskets	Replace the gaskets
	c. Damaged oil seals	Replace the oil seals
Gears clash while they are shifted	a. Defective synchronizer	Repair or replace the synchronizer
	b. Incorrect lubricant	Replace with correct lubricant
	c. Clutch is not releasing	Adjust the clutch
	d. Incorrect pedal lash	Suitably adjust the pedal lash
Transmission is noisy in the neutral speed position	a. Worn out bearing	Replace the bearing
	b. No lubricating oil bearing	Lubricating the bearings
	c. Worn out gear; broken or chipped teeth	Replace the damaged gears
	d. Worn out counter shaft	Replace the worn out parts
	e. Bent or damaged counter shaft	Replace the damaged parts
Transmission sticks in gear	a. Clutch is not releasing	Adjust clutch pedal linkage from time to time
	b. Insufficient lubricant in gear box; incorrect lubricant	Add sufficient amount of lubricant; replace with correct lubricant
	c. Stuck synchronizing unit	Free the synchronizing units. Check for damage; if damaged, replace them
Transmission slips out of gear	a. Worn out or defective synchronizer	Repair and, if necessary, replace the defective parts
	b. Worn out bearings	Replace the bearings
	c. Gear shift linkage is out of adjustment	Adjust the gear shift linkage
Clutch spin, i.e. difficulty in changing the gear from neutral to first as a result of depressing the clutch pedal for a short period when the engine is running	a. Pedal of clutch not travelling the full length	Adjust the travel of the clutch pedal to give 2.5cm. free travel, follow the specification of the manufacturer
	b. Worn out clutch plates or traces of oil on facing of clutch plates	Remove the clutch outside, check and replace

Worn out faulty gear selector mechanism	a. The interlock pin of the third speed fork rod	Replace the interlock pin
	b. Bending of striking fork	Remove the bend of the striking fork
	c. Insufficient side clearance of striking fork pads	Check for sufficient side
Development of noise on engagement of synchromesh gear	a. Worn out synchronizing ring and cone	Replace the worn out parts
	b. Damaged synchronizing ring or cone	Replace the damaged parts
	c. Weak or broken springs in clutch hub	Replace the weak or broken springs
Gear jumps out	a. Worn out rollers and bearings in gear box	Replace the worn out parts
	b. Worn out shafts of the selector mechanism	Replace the worn out parts
	c. Incorrect setting of gear shift	Set the gear shift correctly
	d. Excessive wear of gear shift control	Replace the gear shift control

Troubleshooting Chart for the Rear Axle

Fault	Causes	Remedies
Humming noise	a. Due to worn out bearings	Replace the worn out bearings
	b. Due to worn out gear	Replace the worn out gear
	c. In some cases, this noise may be due to the excessive clearance between the pinion and the crown wheel	Backlash (It is clearance between two meshing gear teeth) between pinion and crown wheel to be adjusted.
Knock	a. Worn out splines of the axle shaft may cause knocking or clicking sound	Replace the defective shaft
	b. Chipped teeth of some gear in the rear axle may cause the knocking sound	Replace the gear with chipped teeth
Drive may not be transmitted	a. Out of two half shafts, any one may be broken	Replace the broken shaft
	b. There may be stripped splines on the axle shafts	Replace the axle shafts
	c. The teeth of some gear in the rear axle drive may be stripped	Gear with such defect may be replaced
	d. There may be fractured taper key in the hub	

QUESTIONS

Very Short Answer Type Questions

1. If four wheel drive and rear wheel drive vehicles _____.
2. Sometime a _____ is welded outside the propeller shaft tube for the purpose of balancing dynamically.
3. Maximum inclination of propeller shaft fitted with Hooke's Joint (cross or spider type Joint) is

   a. 10° b. 15°

   c. 20° d. 25°
4. The type of universal joint which provides an output shaft speed equal to that of the input in all shaft positions within the working range of joint is called _____.

Short Answer Type Questions

1. What are the functions of propeller shaft?
2. Name different major components of propeller shaft assembly.
3. What is the function of slip or sliding joint used in the propeller shaft?
4. Write the function of Universal Joint.

Short Answer Type Questions

1. Explain why and where the centre bearing support is provided with the propeller shaft.
2. What are the requirements of Universal Joint?
3. Write the advantages and disadvantages of flexible ring type Universal joint.

Long Answer Type Questions

1. Explain with diagram the construction of propeller shaft
2. With sketch explain the operation of slip or sliding joint used in propeller shaft.
3. Explain Hooke's Joint (cross or spider joint) with diagram.
4. Explain Flexible Ring type universal joint with diagram.
5. Explain with diagram any one type of constant velocity universal joints. (Either Rzeppa Joint or Tripod joint).

QUESTIONS

Very Short Answer Type Questions

1. _____ is the last stage of power transfer from the engine to wheels.
2. Which type of final drive is used in motor cycle?
3. Spiral bevel gears have _____ contact of teeth.
4. One of the disadvantages of _____ drive is difficult to lubricate gears.

Short Answer Type Questions

1. Write the purposes of final drive.
2. Write the disadvantages of Worm and Worm wheel final drive.
3. Write the advantages of spiral bevel gear.
4. What are the advantages of hypoid gear drive?
5. Write the advantages of Fully Floating type rear axle.

Short Answer Type Questions

1. Name different types of final drive.
2. Name different types of rear axle.
3. Write at least three functions of rear axle.
4. What are the drawbacks of Semi-Floating type rear axle.

Long Answer Type Questions

1. Explain with diagram the Hypoid gear fina drive, with its advantages.
2. Explain with diagram the principle of differential.
3. Write the construction of differential assembly with neat skitch.
4. Explain the operation of differential with diagram when the vehicle moving on straight ahead path.
5. Explain the operation of differential with diagram when the vehicle taking a turn.
6. Write functions of rear axle.
7. Explain the construction of rear axle.
8. With neat sketch explain Semi-Floating type rear axle.
9. With neat sketch explain Three-Quarter type rear axle.
10. With neat sketch explain Fully-Floating type rear axle.

UNIT – 5

Automotive Electrical & Electronic System

Learning Outcome

Automotive Electrical & Electronic System (Introduction and Battery)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students should be able to understand: 1. Different purposes of Automobile electrical system & battery. 2. The Layout of different components of Automobile Electrical System. 3. Construction and working of Lead Acid Battery & to identify the main components of the Battery. 4. Maintenance of Lead Acid Battery. 5. Concepts of maintenance free Battery.	Explain: 1. Different purposes of Automobile electrical system & battery. 2. Draw the layout diagram of Automobile Electrical System. 3. Construction and working of Lead Acid Battery. 4. Different maintenance carried out on Lead Acid Battery. 5. Concept of maintenance free battery.	Demonstrate: 1. Different components of Automobile Electrical System and their layout. 2. Different components of Lead Acid Battery. 3. How maintenance carried out on Lead Acid Battery. 4. Constructional features of maintenance free battery.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the layout of complete electrical system, battery etc.

Automotive Electrical & Electronic System (Charging & Stating System & Different Electrical Circuit)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Automobile Lab / Automobile workshop.	Students should be able to understand: 1. Charging circuit and its different components. 2. Construction and operation of DC Generator or Dynamo. 3. The function of regulator unit (cut-out voltage regulator and current regulator). 4. Construction and operation of AC generator or alternator. 5. Advantages of Alternator over Dynamo. 6. The starting circuit and its different components. 7. Construction and operation of Starter motor. 8. Lighting circuit, Horn circuit, wind screen wiper circuit and their different components.	Explain: 1. Charging circuit and its different components. 2. Construction and operation of DC Generator or Dynamo. 3. The function of regulator unit (cut-out voltage regulator and current regulator). 4. Construction and operation of AC generator or alternator. 5. Advantages of Alternator over Dynamo. 6. The starting circuit and its different components. 7. Construction and operation of Starter motor. 8. Lighting circuit, horn circuit, wind screen wiper circuit and their different components.	Demonstrate: 1. Charging circuit and its different components. 2. Exploded views of AC & DC generators, cut-out voltage regulator and current regulator. 3. Starting circuit and its different components. 4. Exploded views of starting motor. 5. Different electrical circuit such as Lighting circuit, horn circuit, wind screen wiper circuit. Also these circuits to be drawn by the students for evaluation.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Automobile workshop & observe the exploded parts of different electrical components.

Objectives

After attending this session, students should be able to:

- *Explain the different purposes of Automobile Electrical System.*
- *Understand the layout of different components of Automobile Electrical System.*
- *Understand the charging circuit and its different components.*
- *Explain the Principle, Construction and Operation of DC Generator or Dynamo.*
- *Understand the function of regulator unit (Cut-out, Voltage regulator and Current regulator).*
- *Explain the Principle, Construction and Operation of AC Generator or Alternator.*
- *Explain the Advantages of Alternators over Dynamo.*
- *Understand the starting circuit and its different components.*
- *Explain the Principle, Construction and Operation of Starter Motor.*
- *Understand the Lighting circuit, Horn circuit, Wind screen wiper circuit and their different components.*
- *Undertand the engine management system - sensors and actuator.*

5.1 Introduction

Every automobile of toda y contains an electric power plant under its hood, which produces and stores electrical energy that is delivered either at low voltage or in the form of high voltage surges. Electrical equipments fitted on automobile are required to operate without failure for long periods with little attention. Further, it is made to operate under widely varying climatic conditions.

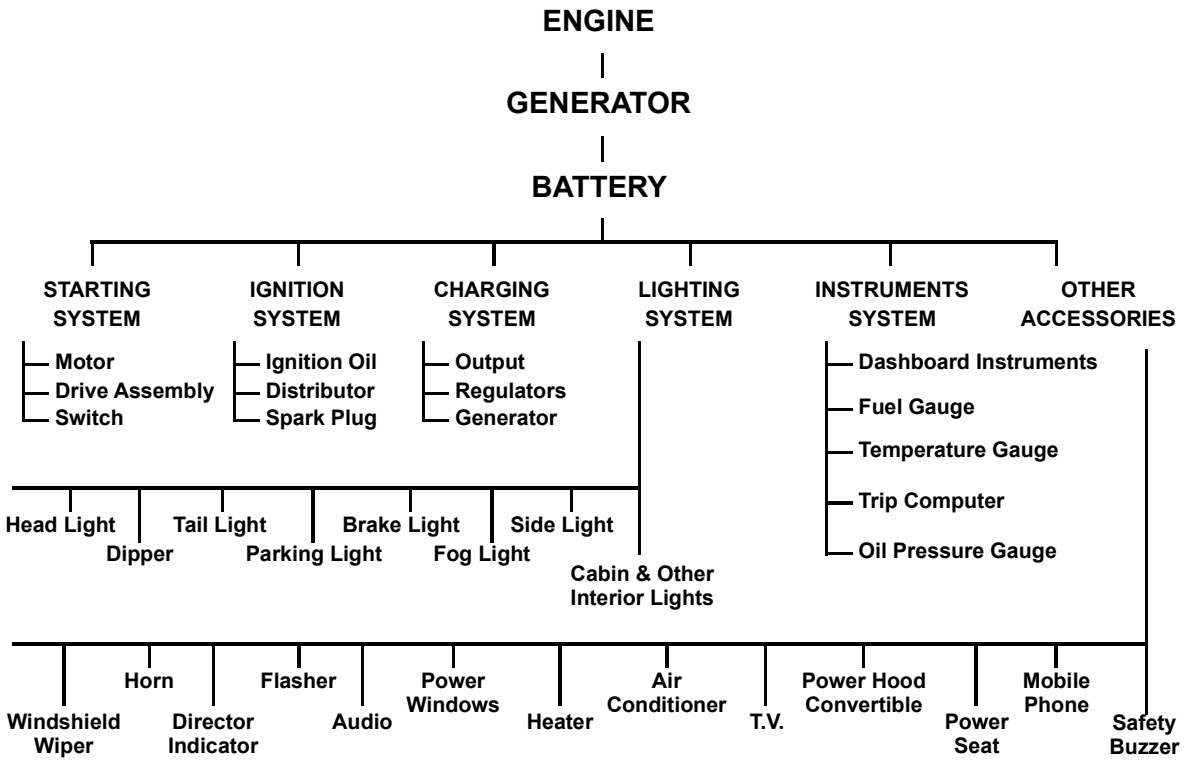
5.2 Purpose of Automotive Electrical System

The auto electrical system has various electrical equipments and wires and serves the following purposes:

- To generate the electricity for charging of battery.
- To supply current to starting motor for cranking the engine.
- To charge the battery and supply the current to various units of an automobile.
- To supply current to the lighting system for operation of head lights, brake lights, flashers, fog lights, dippers, direction indicators etc.
- To supply current to the ignition coil for fuel ignition in petrol engine.
- To supply current to horn, wipers, meters, gauges and dash board instruments.
- To supply current to various other electrical accessories.

5.3 Layout of an Automotive Electrical System

The layout of an electrical system varies widely for different types of vehicles. It is different for two – wheelers and four – wheelers. This layout for a luxury – car is more complicated. A typical layout is shown. The layout has various equipment, meters, gauges, lights and other items connected with wires.



Layout of Typical Automotive Electrical System

5.4 Charging System

The charging system consists of

1. Battery
2. Ignition switch
3. A.C Generator (Alternator) or DC Generator (Dynamo)
4. Relay Switch
5. Indicator Lamp

In the previous session we have already discussed about the battery. In this session students are going to learn about the generators (ac and dc) and different important circuits.

During cranking, the battery supplies most of the vehicle's electrical energy. However, once the engine is running, the charging system is responsible for producing enough energy to meet the demands of all the loads in the electrical system, while also recharging the battery.

For many years the automotive charging system produced direct current using a belt driven DC generator. The DC charging system offered limited voltage output, particularly at low speeds or idle. For this reason, alternating current, or AC charging systems were developed and are now universally used. Alternators (AC generators) are compact light weight, and efficient at all engine speeds.

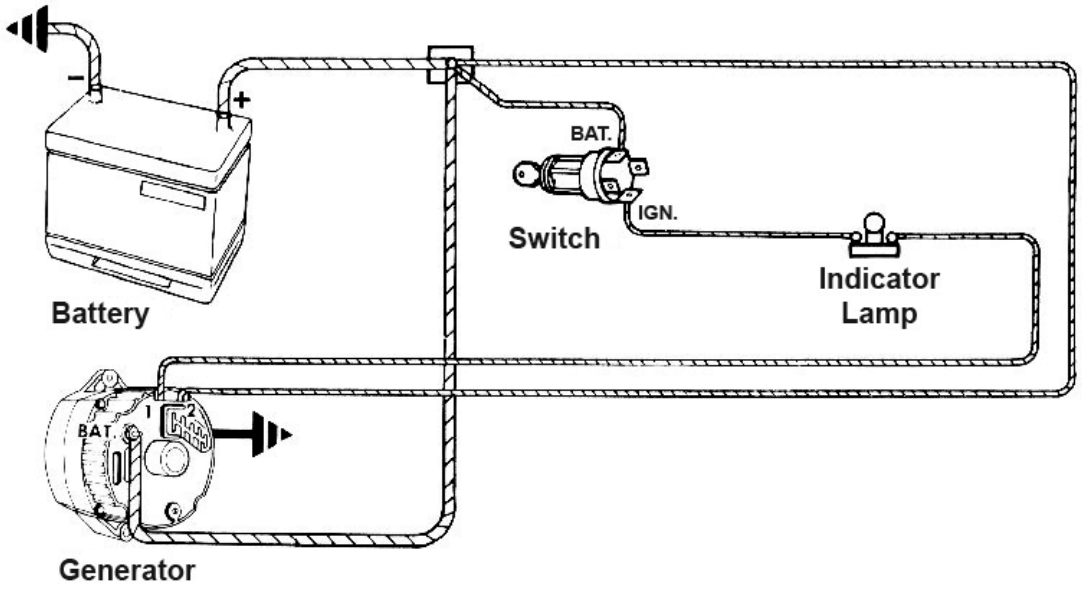


Fig. 5.1 Charging System Circuit.

5.4.1 Principle and Operation of DC Generator or Dynamo

❖ Principle

When a conductor is placed between a U – shaped permanent magnet and moved in the direction as shown in the figure 5.2 (a), electromotive force (e.m.f) is induced in the conductor and an electric current occurs in the conductor in the direction as shown by arrow.

The direction of magnetic lines from the permanent magnet, the direction of the movement of the conductor and the direction of induced electric current follows the ***Fleming's right hand rule which states that when the thumb forefinger and middle finger of the right hand are positioned right angle to each other, as shown in the figure 5.2 (b), then the thumb points the direction of the force which moves the conductor, the forefinger points the direction of the magnetic lines and the middle finger indicates the direction of induced electric current.***

The principle of DC generator is further elaborated by considering the action taking place in two conductors moving through a magnetic field in opposite direction, as shown in the fig. 5.3, current induced will be in the opposite directions, as indicated there.

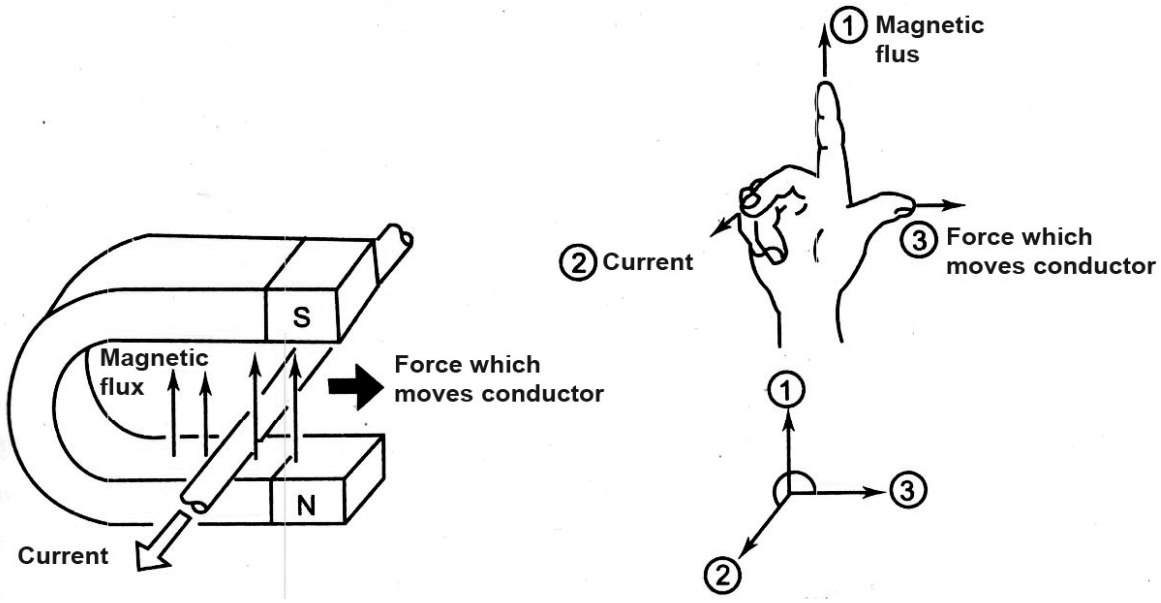


Fig. 5.2 Fleming's Right Hand Rule

Figure 5.4, shows these two conductors formed into a loop. The ends of the loop are connected to two segments of a commutator. Two brushes have been provided at the segments to take off the current generated in the loop. When the loop is rotated in the clockwise direction as shown in the fig. 5.4, the current will flow through the commutator segments, brushes and the lamp.

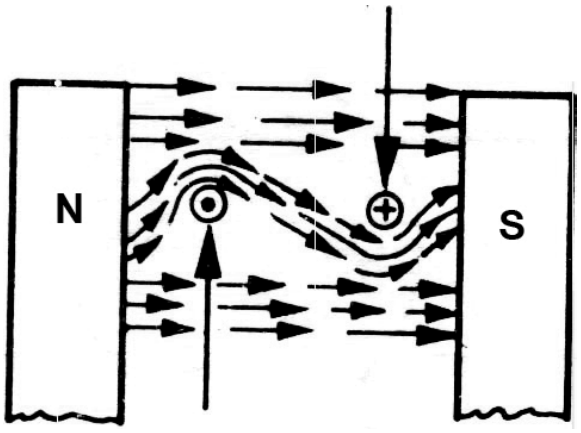


Fig. 5.3 Distortion of magnetic field due to movement of two conductors in opposite directions

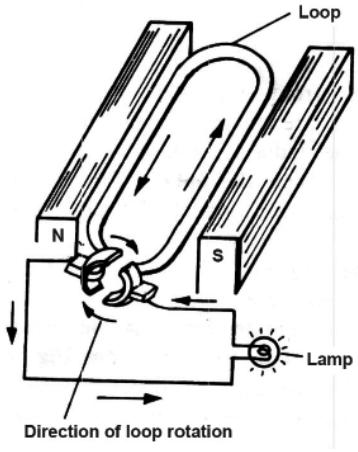


Fig. 5.4 Simple Generator

When the loop is rotated through 180°0, the two sides of the loop will change position without affecting the direction of the current flow since the commutator segments also change positions.

Fig. 5.5 shows the three different positions a, b and c of the coil. When the conductors are moving parallel to the field the induced voltage in the coil is zero and maximum when moving at right angles to the field. The induced voltage depends upon the rate at which the conductors cut the magnetic lines of force.

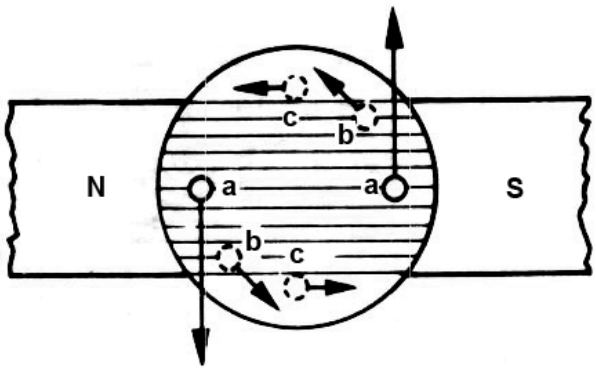


Fig. 5.5 Conductors at various positions with respect to magnetic field.

As seen from fig. 5.5, the conductors at position c are moving parallel to the field and hence the induced voltage is zero since they are not cutting the lines of force. The induced voltage in each conductor at any time is proportional to sine θ, where θ is the angle between the direction of motion and the magnetic field. Hence, the **voltage induced in the coil will follow a sine wave.**

❖ Function of Commutator

In order to charge a battery, the current should be unidirectional. Therefore, there must be some way of reversing the connections of the external circuit to the generator in order to make the current unidirectional in that circuit. This is the job of commutator. A simple commutator consists of a metal ring divided into two segments. The unidirectional current curve is shown in fig. 5.6(b).

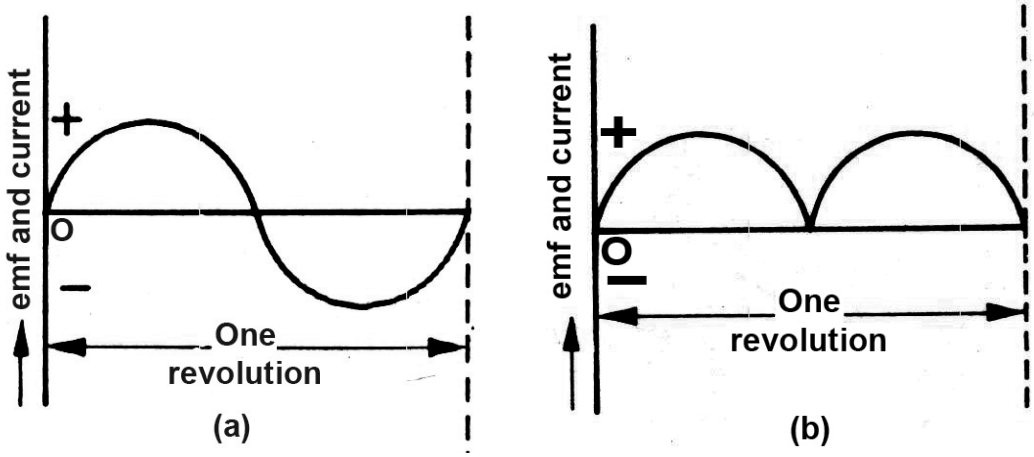


Fig. 5.6 Curves of e.m.f. induced in a coil

❖ Elimination of Voltage Fluctuation

In automobile dc generator the voltage fluctuation has been reduced to almost nil by increasing no. of coils in series sufficiently, which is shown in the fig. 5.7.

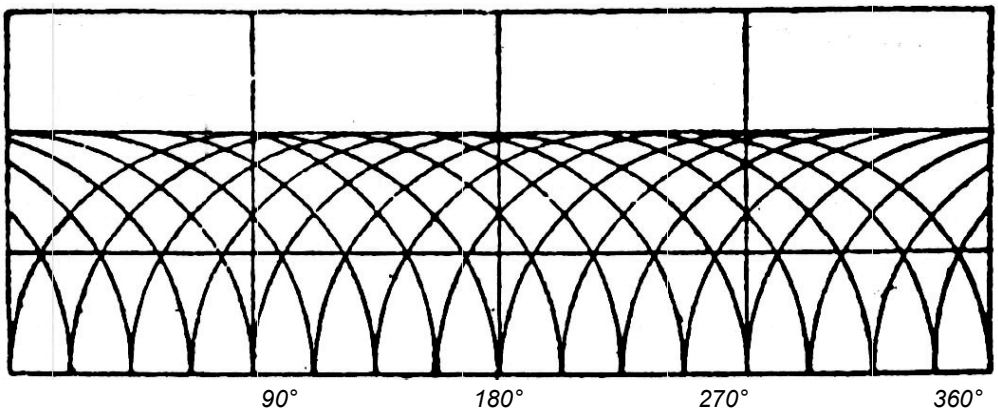


Fig. 5.7 Production of Smooth Current Wave.

Note:

1. *In actual condition, electromagnets are used instead of permanent magnets, the energy for which is taken from the current produced by the generator itself.*
2. *The amount of current induced in a conductor depends upon the strength of the magnetic field, the number of turns, cutting the field and speed with which they pass through the field.*
3. *If the rotating coil is connected to the external circuit through brushes and slip rings instead of the com**mutator, the current generated will be alternating in character.***

5.4.2 Automobile DC Generator

Modern automobile generator are the two-pole, two-brush, shunt wound type. This type is one of the three types available, viz. Series, shunt and compound. The shunt type is quite suitable for battery charging purposes since its polarity remains constant irrespective of whether the battery is being charged or discharged. Moreover, the exciting current can be kept constant or varied as required by adding resistance to the field circuit. Fig. 5.8 shows, simple diagrams of three types of generator field winding connections.

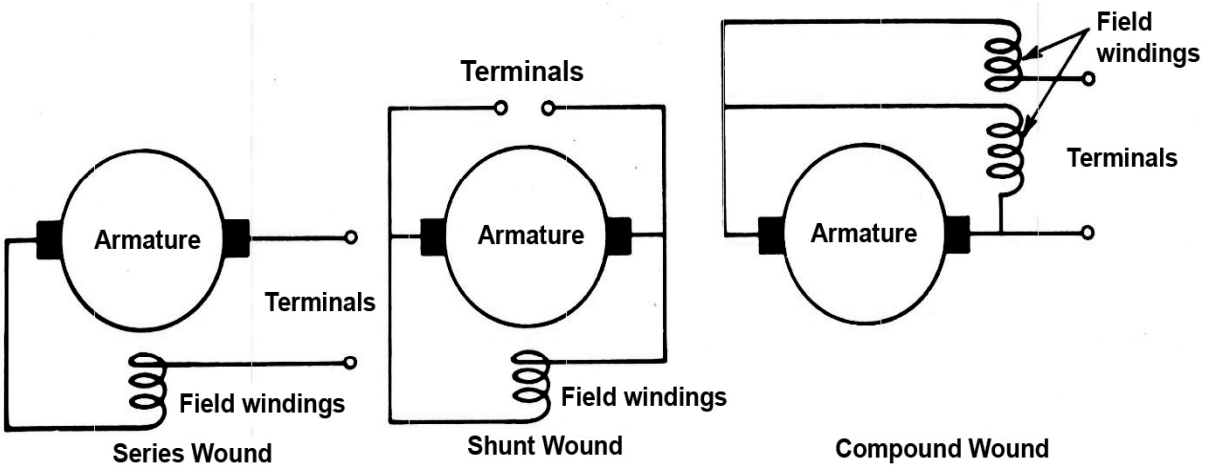


Fig. 5.8 Generator Field Winding Connections

The figure 5. 9 shows the exploded view of automobile dc generator which has following main components.

1. Frame
2. Armature
3. Field coils

❖ Frame

Generator frame is made of steel and is of cylindrical form. It is machined on the inner surface to accommodate pole shoes. The end covers support the bearings for the armature shaft. The end cover on the side of the commutator carries the brushes and the generator output terminals. Openings are provided for inspection as well for dissipation of the heat produced while the generator is running.

❖ Armature

The major parts are – shaft, core, commutator and coil windings. The shaft is made of mild steel, whereas soft iron laminations are used to make up the core. The core has longitudinal slots over it which contains the coil windings. The windings are secured in position in the slots by wedges of insulation. Sometimes a band or steel wire is tightened around the armature to protect the armature windings against the centrifugal force which tries to fly these out. The windings are coated with insulation (mica). Sometimes a band or steel wire is tightened around the armature to protect the armature windings against the centrifugal force which tries to fly these out. The windings are coated with insulating varnish and dried. Commutator consists of copper segments insulated from each other and from the shaft by mica. It is pressed on the armature shaft. Armature coils are wound in two distinct ways, the lap winding and the wave winding. Two spring-loaded carbon brushes held in brush holders are employed to connect the armature coils to the outside circuit.

❖ Field Coils

As mentioned previously the field magnets used are not permanent, but they are electromagnets energized by the generator current itself. The generator field coils are wound as shunt windings, as this method is best suited for the attainment of nearly constant voltage with varying speed, and for current regulation. About one fifth of total output is consumed as the field current and the generator output is controlled by the field circuit regulation. Field coils are in the form of many turns o, insulated fine wire.

The field magnets, though not permanent ones, have a small residual magnetism which provides the initial field to start the generator operation.

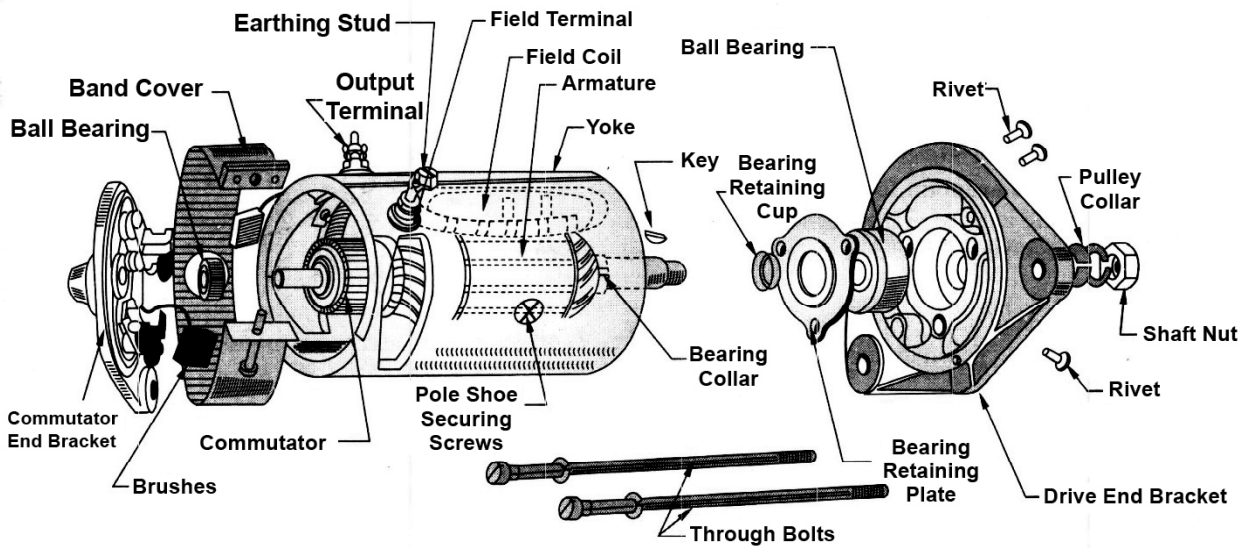


Fig. 5.9 Exploded view of Automobile DC Generator.

5.4.3 Cut out and Regulator

The most widely used type of regulator is the combined current and voltage vibrating regulator. It consists of following three main units.

1. Cut-out Relay
2. Current Regulator
3. Voltage Regulator

❖ Cut-out Relay

The D.C. generator is connected to the battery through a cut-out relay and an ammeter. The cut-out relay is a safety device for battery. When the generator speed is very low, due to which the output is not sufficient to balance the battery voltage, the necessity to cut out the generator from the battery arises, because otherwise the battery would discharge into the generator. When the engine and hence the generator speed has reached a sufficiently higher value to match its output to the battery voltage the generator should be automatically connected to the battery. ***The speed of the generator at which its output voltage just rises above voltage of the battery being charged is called cutting in speed.***

A simple cut-out relay is shown in Fig. 5.10. The electromagnet consists of two coils, the shunt (voltage) and the series (current). When generator is producing sufficient voltage so that the field due to both the current and the voltage coils support each other, the electromagnet pulls down the armature, the contacts are closed and the generator-battery circuit is completed. However, when due to low engine speeds the generator voltage falls below the battery voltage, the current flows from the battery to the generator. Then the fields due to current and voltage windings become opposed to each other. Hence the pull on the armature decrease, the contacts open out and the battery is cut from the generator.

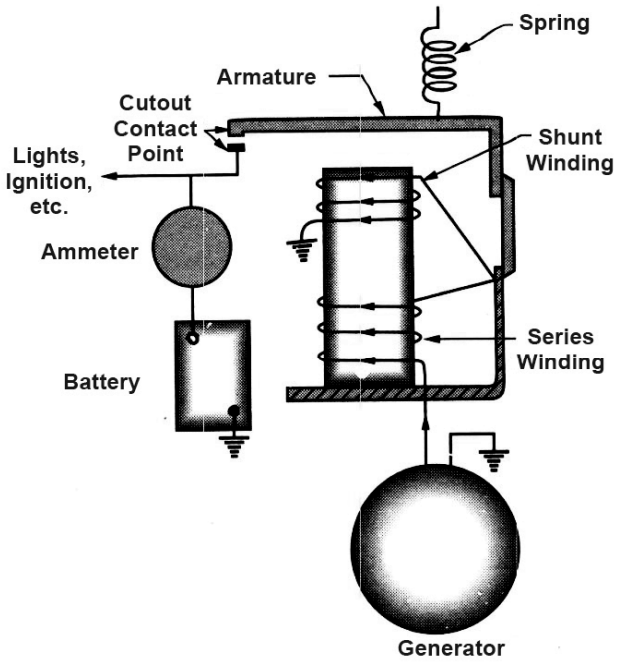


Fig. 5.10 Wiring Circuit of a cut-out relay.

❖ Voltage Regulator

- **Principle**

  The principle is that of inserting a resistance in the shunt field whenever the voltage exceeds certain value and removing the resistance from the field whenever the voltage falls below the pre-determined value. This principle is known as "TIRRIL" principle.

  This consists of an operating solenoid and a pair of contacts connected across the resistance and in series with the field. The contacts are kept closed by a spring.The solenoid consists of a coil with a soft iron core. It is placed beneath the armature and is connected directly across the generator terminals. The armature carries the movable contact. The contacts are in sireis with the field and normally it short circuits the field resistance.

❖ Operation

As the generator speed rises the current flowing through the shunt coil of the regulator increases. At a pre-determined voltage. The magnetic pull of the iron core attracts the movable arm against the spring tension, the contacts open and insert the resistance in siries with the generator field coils. The field current is reduced and the generator voltage falls, the pull of the regulator solenoid is then weakened allowing the spring to close the contacts again. This sequence of operation is repeated rapidly, causing the contacts to vibrate, alternately inserting and short circuiting the field resistance. The period of the time during which the contacts are open increases with the generator speed, therefore the resistance is inserted in circuit for longer period as more control

is necessary. The regulator maintains the generator voltage at a constant level at varying engine speeds and the current output can vary considerably.

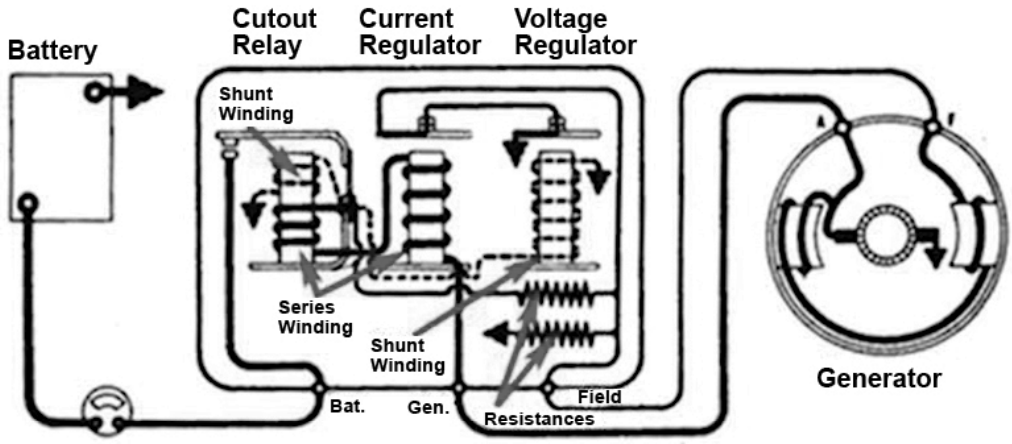


Fig. 5.11 Three unit Regulator.

❖ Current Regulator

The current regulator consists of a heavy series winding. When the regulator is not operating, the contact points are closed and the generator field circuit is grounded. When the load on the generator increases and the generator voltage is not sufficient to operate the voltage regulator, the generator current continues to rise till the stage is reached where the current in the regulator coil is sufficient to pull the armature down separating the contacts, thus inserting the resistance in the generator field circuit which armature down separating the contacts, thus inserting the resistance in the generator field circuit which brings down the generator output, until the current decreases to a value such that the series winding in the current regulator cannot exert enough force to keep the contacts separated. The contacts then close and the generator field circuit is grounded again thus increasing its output. In this way the current regulator continues vibrating at a frequency of about 200 times per second, and maintains the current output at a preset constant value.

5.4.4 AC Generator or Alternator

The DC generators were not able to produce the sufficient amount of current required when the engine is running at low speeds, specially in cities where vehicles have to move at very low speeds due to heavy traffic. In modern vehicles, there is an addition of more electrical accessories and components like electrically operated power windows, air-conditioners, electrical equipment for automatic transmissions, overdrives etc. which requires sufficient amount of current at slow speed of vehicle. So, the DC generators is replaced with alternators (or AC generators).

❖ Principle of Operation

In alternator the magnetic field is rotated and the conductors are held stationary (just opposite to DC generator). The current first flows in one direction and then in the other direction alternately.

When an electromagnet (or permanent bar magnet) is rotated around a U shaped conductor, the

magnetic lines of forces cut the stationary conductor to produce current in it. The conductor is also called as **stator** as it is stationary and since the magnet in an alternator rotates, therefore it is also called as **rotor**.

It may be noted that as the magnet is rotating continously and the direction of lines of force is also changing continuously, then the current induced in the conductor is an alternating current. In order to convert this alternating current into direct current, the diodes (or rectifiers) are used, which allows the current to pass through them in only one direction.

The amount of current produced depends upon the following factors:

- The strength of the magnetic field,
- Rotating speed of magnetic field and
- The number of conductors passing through the magnetic field.

❖ Construction of Alternator

- **Housing (frame):**

  The housing of the alternator assembly is made of cast aluminium in two pieces. The aluminium is used because it is non-magnetic, and a light weight material that provides good heat dissipation. The front part of the housing (also called as drive end housing) holds a ball bearing to support the front of the rotor drive shaft. The rotor drive shaft extends through the dirve end housing and holds the drive pulley and colling fan.

  The rear part of the housing (also called as slip ring end) holds the rotor drive shaft to support a roller bearing. It also contains the brushes and has all the electrical terninals. If the alternator has an integral regulator, it is also contained in this housing.

  The cooling fan draws air into the housing from the openings at the rear part of the housing. The air leaves through the openings behind the cooling fan.

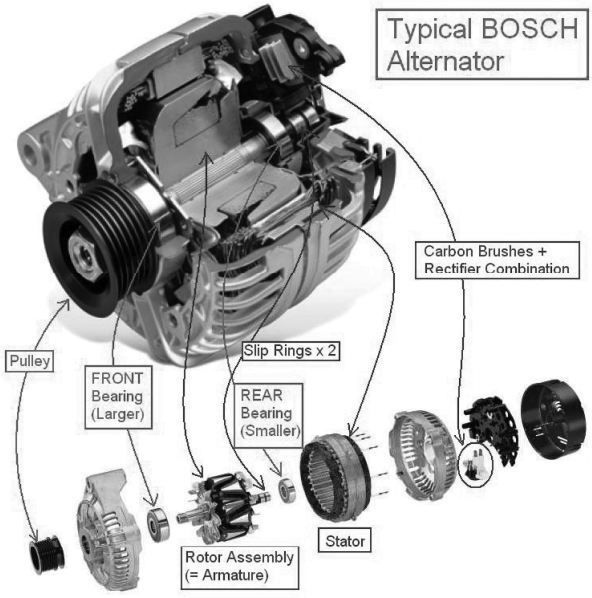


Fig. 5.12 Sectional & Exploded Views of Alternator Assembly

- **Rotor**

The rotor creates the rotating magnetic field of the AC generator. It consists of a drive shaft, a field winding (i.e. winding around an iron core), two pole pieces, and two slip rings, as shown in the figure. The drive shaft is pressed into the core. The rotor turns when a pulley mounted on the dirve shaft is driven by the crankshaft pulley via the drive belt.

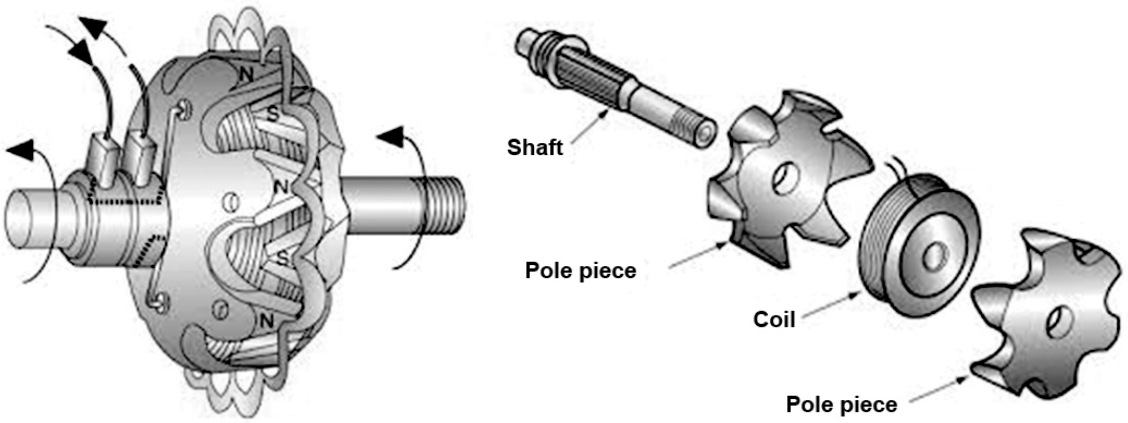


Fig. 5.13 Rotor Assembly of Alternator.

The field winding consists of many turns of copper wire wrapped around an iron core. The iron core is located between the two pole pieces. The each end of the field winding is attached to one of the slip rings. The slip rings are insulted from the rotor shaft. When the current flows to the field winding through brushes and slip rings a magnetic field is produced.

The pole pieces take on the magnetic polarity (north or south) depending on the ends of the core they touch. A rotor may have 4 to 12 magnetic poles depending upon the size of the alternator. If there are 12 poles (6 north pole & 6 south pole) which are arranged in such a way that each north pole is located between two south poles and vice versa. In addition to the above mentioned parts, the rotor is fitted with a fan, which cools the alternator during operation.

- **Stator**

The stator is a stationary part of the alternator. It consists of three windings, wrapped in slots around a laminated, circular iron core, as shown in fig. each of the three windings has the same number of coils as the rotor has the pairs of north and south poles. The coils of each winding are evenly spaced in the core. The three sets of windings alternate and operlap as they pass through the core. The overlapping is needed to produce the required phase angles.

The rotor is fitted inside the stator. A small air gap is maintained between the rotor and the stator. This gap allows the rotor's magnetic field to energize all the windings of the stator at the same time and to maximise the magnetic field.

Fig. 5.14 Stator Assembly of Alternator.

- **Rectifier**

The rectifier converts the three phase alternating current generated in the stator winding into direct current. Thus, the process of conversion is referred to as rectification. The alternator generally uses six semi-conducting silicon diodes for rectification. The diode acts as a one way check valve, which allows current to pass through it in one direction and not in the other. It may be noted that they block the reverse flow of current from the battery, thus they function as cut-out relay also.

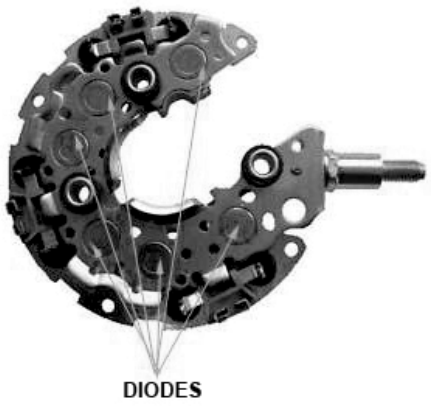


Fig. 5.15 Rectifier Assembly of Alternator

The three silicon diodes are provided on the positive side and three on the negative side, making up a set of six diodes. It may be noted that some alternators with Y-connected stator winding have additionally two neutral junction diodes i.e. eight diodes in total. The diodes are mounted on a holder (also known as heat sink). The heat sink transfers the heat into the surrounding air. Also, the cooling fan draws air into the housing to cool the diodes.

- **Slip rings and brushes**

  The current to the rotor winding is carried through the copper slip rings and carbon brushes the two brushes are held against the slip rings by springs, usually mounted in plastic brush holder that support the brushes and prevent brush sticking. Each brush is connected into the circuit by a flexible copper lead wire. The brushes ride on the slip rings and are connected through a switch to the battery. When the switch is closed , current from the battery passes through one brush, through the slip rings, and then through the field winding. After leaving the field winding, current flows through the other slip ring and brush before returning to the battery through the ground return path. The flow of electrical energy through the field winding, called field current, creates the magnetic field for the rotor.

  As these brushes carry only the field current (about 2 – 5 amps.), they have a much longer life in contrast to the carbon brushes in the DC generator, where all the current prouduced in the generator has to pass through the brushes.

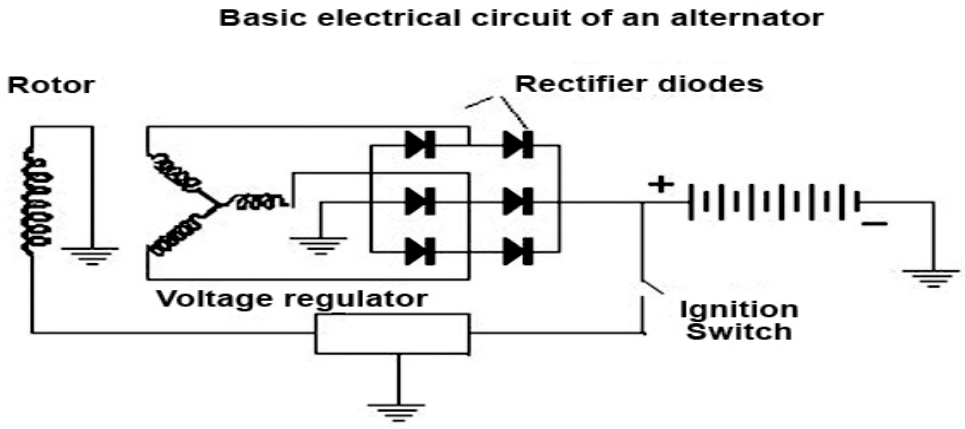


Fig. 5.16 Basic Electrical Circuit of Alternator.

❖ Advantages of Alternators over Dynamo

- For same output, the alternator is much smaller in size as compared to dynamo.
- For same current output the alternator is lighter weight.
- Alternator can produce more current output at low, engine speeds, even at idling. But dynamo can't do that.
- Alternator requires lesser maintenance
- It is more reliable
- No cut-out unit is required in alternator.
- Maximum driving speed of alternator is comparatively higher (20000 rpm) than dynamo (9000 rpm).
- Alternator requires smaller size of driving pulley as compared to dynamo.

5.5 Starting System

The starting system draws a large amount of current from the battery to power the starter motor. Thicker cables are needed to carry this current without an excessive voltage drop; the starting system has two circuits.

1. Starter circuit
2. Control circuit

Starting system mainly consists of following parts:

- Battery
- Starter switch
- Starter motor
- Starter drive
- Heavy insulted cables to starter motor
- Ignition switch

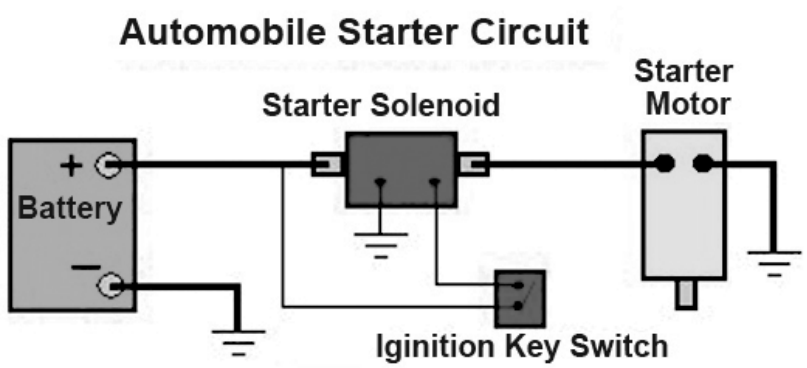


Fig. 5.17 Starting Circuit

5.5.1 Starter Motor Principle

Working of motor is based on the principle of ***Fleming's Left Hand Rule, which states that when the thumb, fore finger and middle finger of the left hand are position at right angle to each other as shown in the figure then, fore finger indicates the direction of the magnetic field, the middle finger represents the direction of the current in the conductor and the thumb indicates the direction of the force on the conductor.***

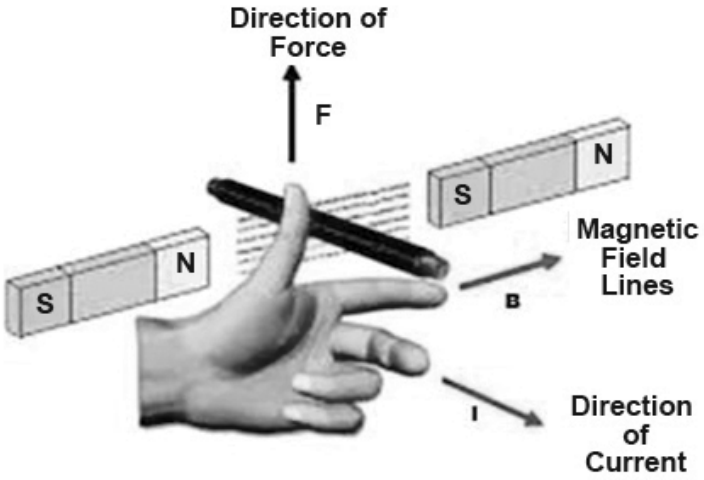


Fig. 5.18 Fleming's Left Hand Rule

When a current carrying conductor is placed in a magnetic field, a mechanical force is experienced by the conductor. The magnitude of this force (F) is directly proportional to the magnetic field strength (B) and the current (I) flowing in the conductor.

In other words, the **Force** developed in the conductor, is given by the relation,

F = B.I.L

Where **B** = Magnetic field strength in wb/m^2,

I = Current flowing in the conductor in amps, and

L = Length of the conductor in m.

Torque or turning moment is the product of radius and force:

T = F. r

Where **r** = radius

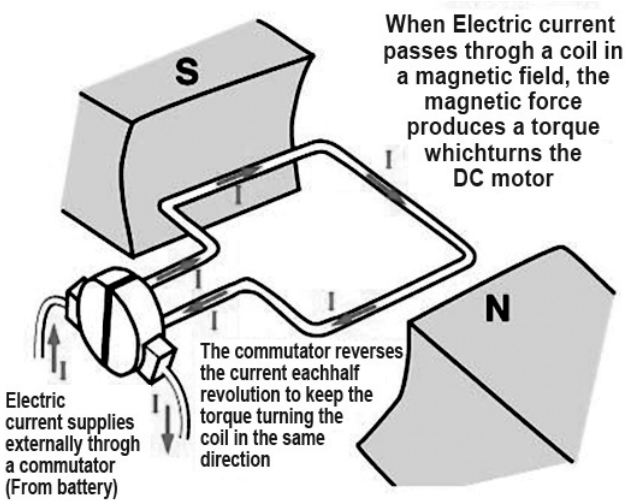


Fig. 5.19 Working of Simple Motor

The working of a simple motor is shown in the fig. 5.19.

In a simple motor the conductor is of U shape or shape as shown in the fig. 5.19. Its two ends are connected to the two halves of a split copper ring. Stationary brushes have sliding contact with the ring, which are connected to a battery to supply the current to the conductor. The conductor is placed in a magnetic field. The conductor loop and the split ring are designed in such a way so as to rotate together, the brushes remain stationary. The split ring is called the commutator. The current flows from the battery through the brushes, commutator and conductor in the direction as shown by arrows. This causes left hand part of the conductor to be pushed upward and the right hand part to be pushed downward. Thus, the conductor loop rotates in a clockwise direction. As the two sides of the loop reverse position, the direction of the current flows through the two sides also reverses. The force thus continues to rotate the loop – the motor is said to be running. To get appreciable power in an actual motor, many conductor loops rotate in a strong magnetic field. The natural magnetic field of the magnetic poles is strengthened by field winding in such a direction as to aid the magnetic field between the two poles.

5.5.2 Construction

Its construction is similar to d.c. generator (or dynamo). The starter motor consists of the following units

1. Motor unit
2. Drive unit

❖ Motor Unit

Its motor unit consists of following main parts:

- Armature
- Cylindrical housing or body or frame
- Pole shoes
- Brushes and brush – holder
- Commutator
- Field windings or field coils. End shields

Armature: Armature is the main drive of starter motor. it is a cylindrical construction and consists of iron core, armature shaft, commutator and armature windings. The windings are made of heavy copper wires and soldered to commutator. The wires are separated to each other by insulation to avoid leakage.

Housing or frame: The frame or housing of a starter motor encloses all the motor's moving parts. It supports the parts and protects them from dirt, oil and dust etc.

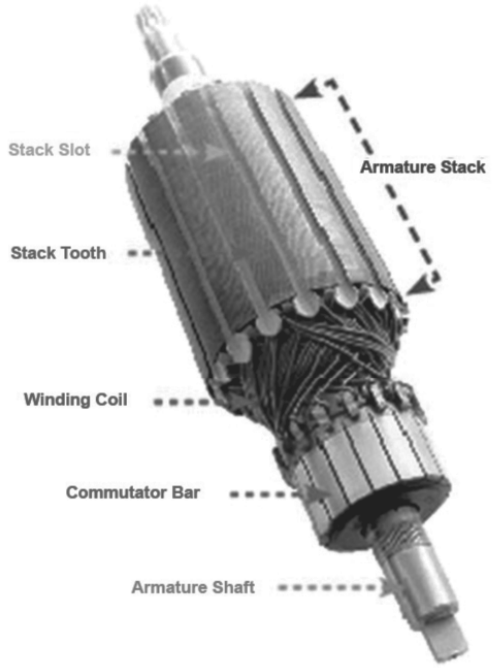


Fig. 5.20 Armature of Starter Motor.

One end of the housing holds one of the two bearings or bushings in which armature shaft turns. It also contains the brushes that conduct current to the armature. The other end of housing or frame encloses the gear that meshes with the engine fly wheel. This is called drive-end housing.

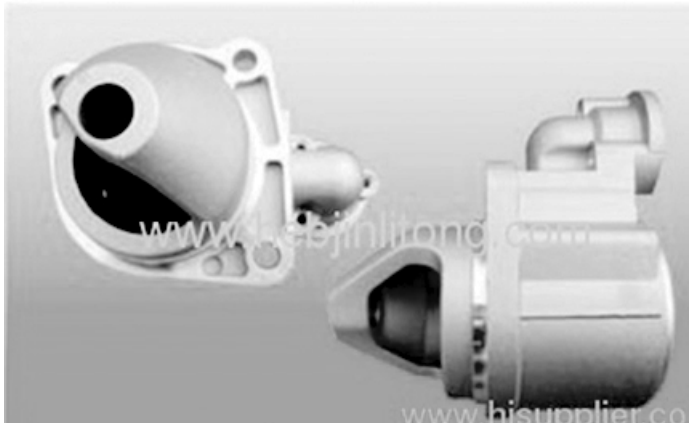


Fig. 5.21 Starter Motor Housing.

Pole shoes: The pole-shoes are made of steel and securely attached to the inner surface of housing.

They are generally 2 to 6 numbers.

Most commonly 4 numbers of pole shoes are used. The magnetic field is provided by the pole shoes and field windings. They are used to support exciting field coils.

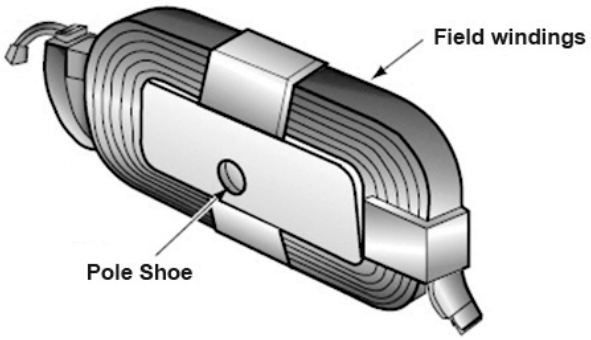


Fig. 5.22 Pole Shoe & Field Winding of Starter Motor.

Brushes: They are rectangular shaped copper blocks that conduct heavy current to the armature. They are mounted on box-shaped insulated brush holder.

Commutator: It is a cylindrical member made of highly conductive copper and made of a large number of segments insulted from each other by means of thin mica sheets. Each segment is connected to the armature conductors.

Field windings or field coils: These are made of thick copper wires in the form of coils and used to electro magnetize the poles when current is passed through them. So, the magnetic field of the starter motor is provided by field windings and pole shoes.

End shields: For small starter motor there are two end-shields are provided with bushes fitted in it to support the armature shaft.

Starter motors are available in various sizes with following salient fractures.

- Pre engaged reduction gear
- Compact and light in weight
- High power to weight ratio
- Better cold cranking capabilities
- Protection against splash-water.

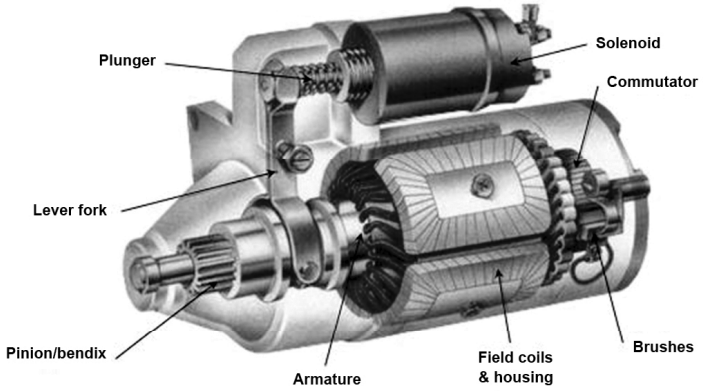


Fig. 5.23 Starter Motor Assembly Complete.

❖ Drive Unit

It is the drive mechanism of starter motor that transmits the torque developed by the motor to the engine flywheel for starting (or cranking) the engine. A pinion is fitted on the motor's armature shaft that gets meshed with the flywheel ring gear and rotates the flywheel. When the engine is started and speeds up, the drive mechanism provide automatically disengaging (or coming back) of pinion from ring gear.

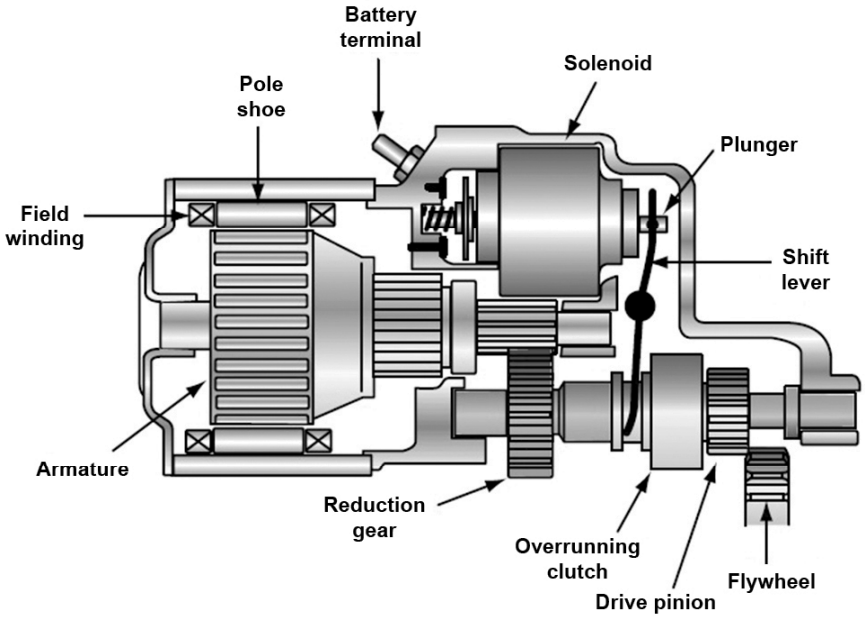


Fig. 5.24 Drive Mechanism of Starter Motor.

5.5.3 Working of Starter Motor

Starter motor armature has many coils fitted on the armature. As we have discussed in principle of starting motor that when a current carrying conductor is placed inside a strong magnetic field, the conductor experiences repulsive force. But starter motor has many conductors on its armature, so the armature is force to rotate between pole shoes with powerful torque to start engine.

When the starter switch is 'ON', current from storage battery flows to the starter motor. It sets up a strong magnetic field around the armature coils. The armature coils act as current carrying conductors. The same current from battery also flows through the field windings (or field coils) around pole shoes.

This makes pole shoes as electromagnets due to which a strong magnetic field is created between pole-shoes. So, the reaction of two magnetic fields (i.e., armature windings & field windings) tends to be distorted or bent the magnetic lines of force of field magnet. Due to distortion of magnetic field the force is exerted on the armature coil, causing the armature to rotate between pole shoes. This torque of starter motor is utilised to crank engine through drive mechanism. Torque exerted by starter motor will be proportional to the amount of current flowing in field coils and armature coils.

5.6 Different Circuit Diagrams of a Car

Circuit Diagrams of Charging System and Starting system are already shown at Fig. 5.1 and Fig. 5.17. of this chapter.

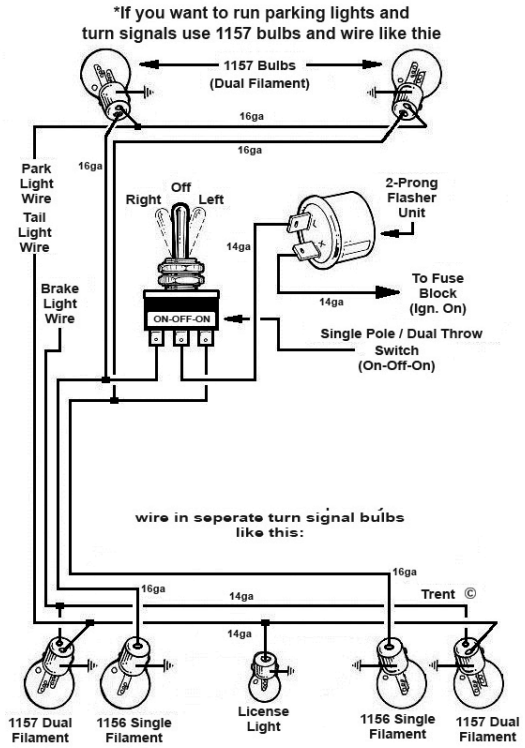


Fig. 5.25 Lighting Circuit of a Car.

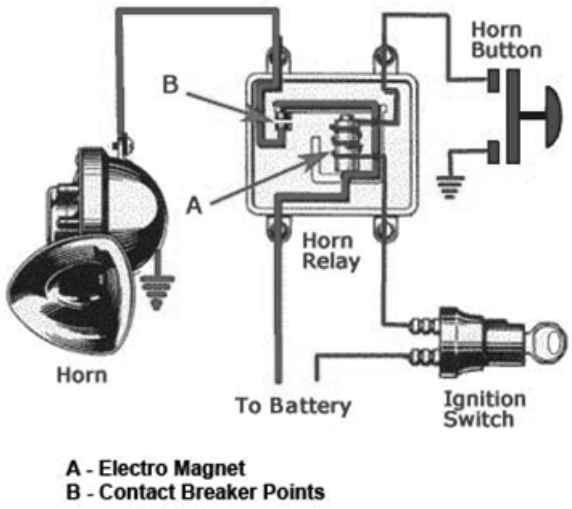


Fig. 5.26 Horn Circuit of a Car.

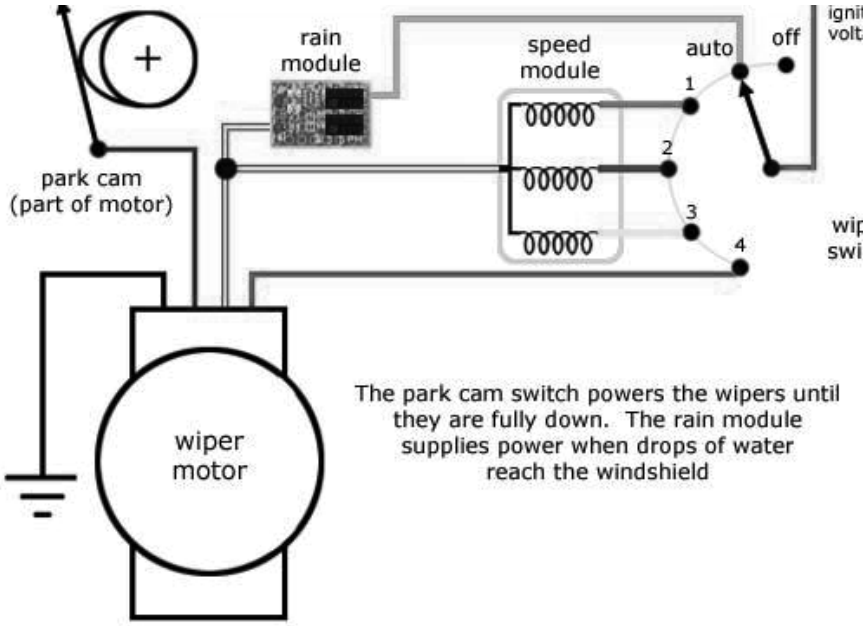


Fig. 5.27 Wind Screen Wiper Circuit of a Car.
(With rain module)

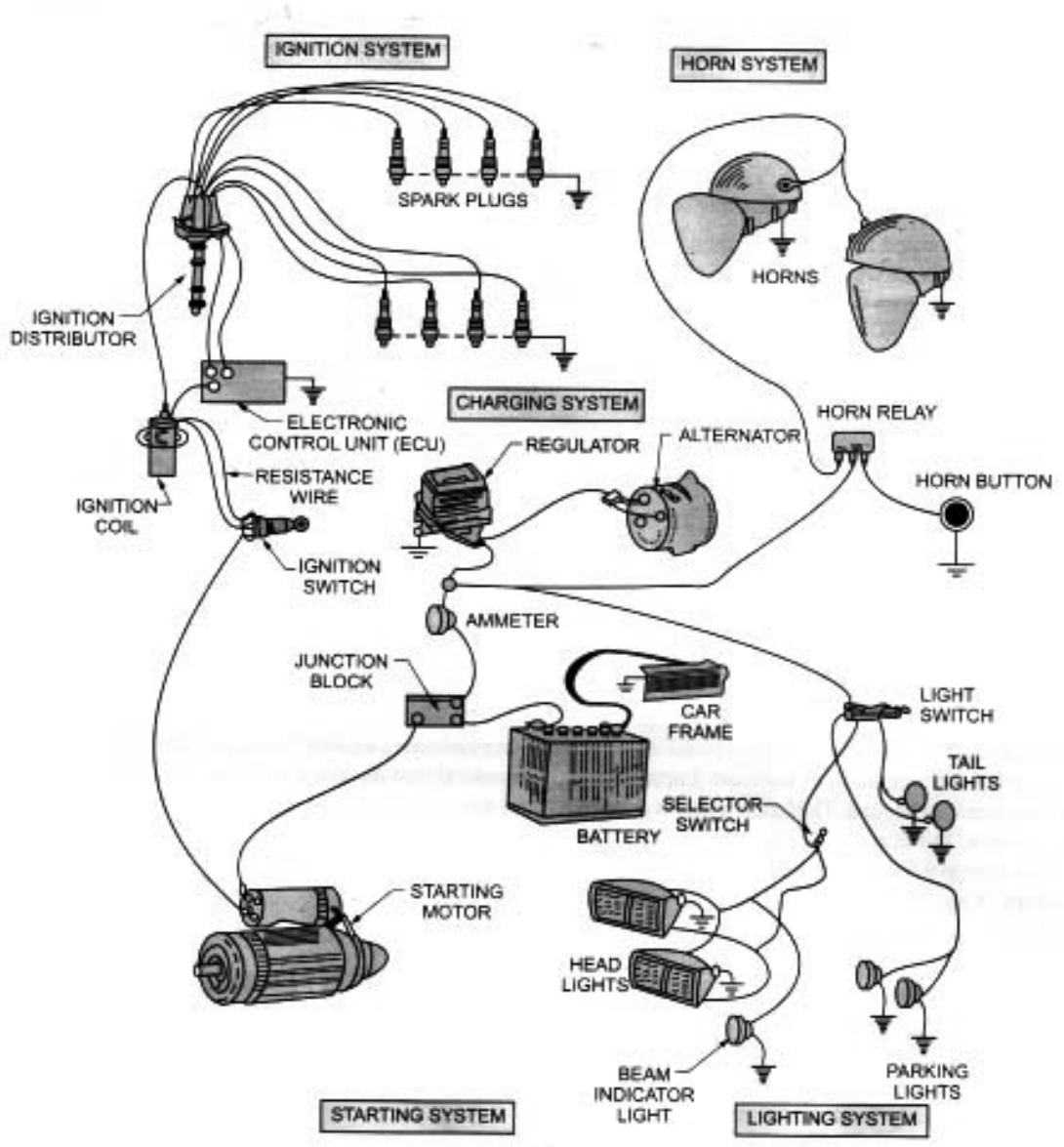


Fig. 5.28: Typical Automotive Electrical System

5.7: Engine Management System – Sensors and Actuators:

The Engine Management System (EMS) is responsible for controlling the amount of fuel being injected and for adjusting the ignition timing. Optimum functioning of the EMS assures maximum engine power, with the lowest amount of exhaust emissions and the lowest fuel consumption.

The EMS is comprised of sensors for intake air and coolant temperature, intake manifold absolute pressure (MAP) and throttle position (TPS), as well as sensors for engine speed and signals for the required injection and ignition spark events, and a sensor for information about the oxygen content in the exhaust.

Furthermore, there is an idle speed motor for adjusting and stabilizing the idle speed, or an electronic throttle body and finally a fuel pressure regulator and fuel injector(s). The supplied high-energy ignition coils are controlled by the integrated ignition module. For alternative fuel applications fuel rail pressure and temperature sensors are also utilized.

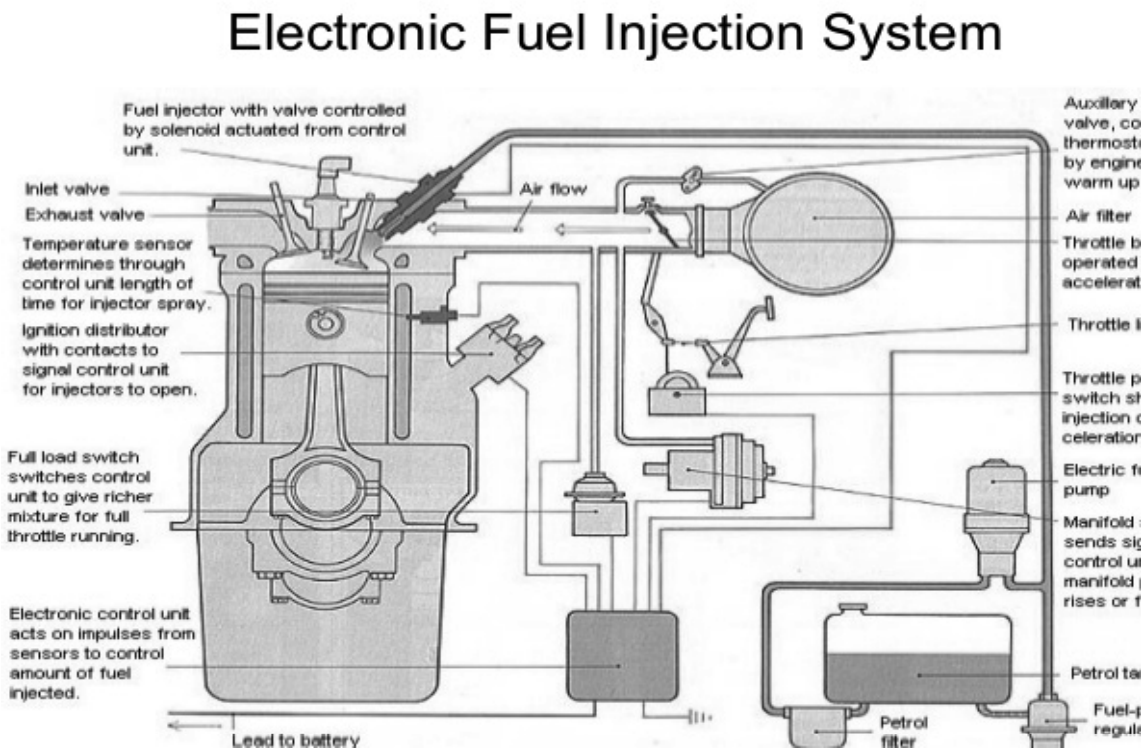


Fig. 5.29: Electronic Fuel Injection System

- **Air Induction System / Control**

  The purpose of the air induction control/system is to filter, meter and measure intake air flow into the engine.

  The air induction system consists of the air cleaner, air flow meter, throttle valve, air intake chamber, intake manifold runner, and intake valve.

When the throttle valve is opened, air flows through the air cleaner, through the air flow meter, past the throttle valve, and through a well tuned intake manifold runner to the intake valve.

Air delivered to the engine is a function of driver demand. As the throttle valve is opened further more air is allowed to enter the engine cylinders.

Toyota engines use two different methods to measure intake air volume. The L type EFI system measures air flow directly by using an air flow meter. The D type EFI system measures air flow indirectly by monitoring the pressure in the intake manifold.

- **Fuel Delivery System/Control**

The purpose of fuel delivery system/control is to inject the correct and precise amount of fuel in the intake manifold.

The fuel delivery system consists of the pipe (fuel rail), fuel injector, fuel pressure regulator, and fuel return pipe.

Fuel is delivered from the tank to the injector by means of an electric fuel pump. The pump is typically located in or near the fuel tank. Contaminants are filtered out by a high capacity in line fuel filter.

Fuel is maintained at a constant pressure by means of a fuel pressure regulator. Any fuel which is not delivered to the intake manifold by the injector is returned to the tank through a fuel return pipe.

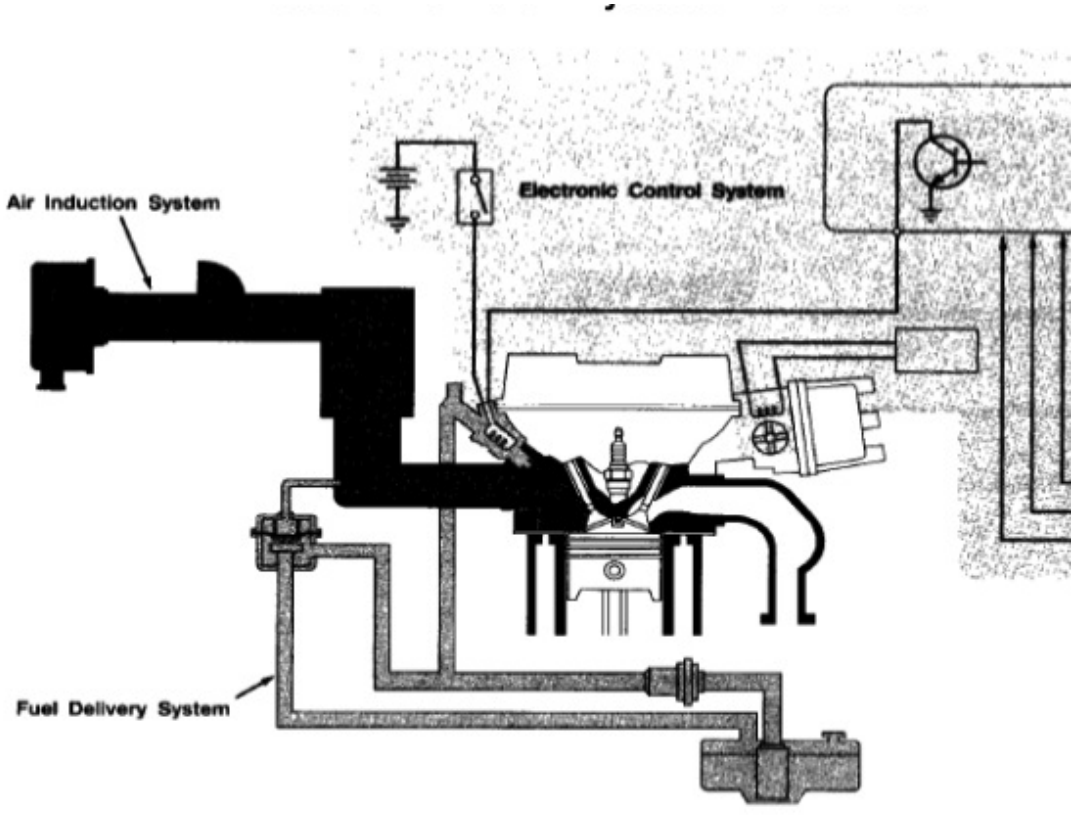


Fig. 5.30: Electronic Fuel Injection overview

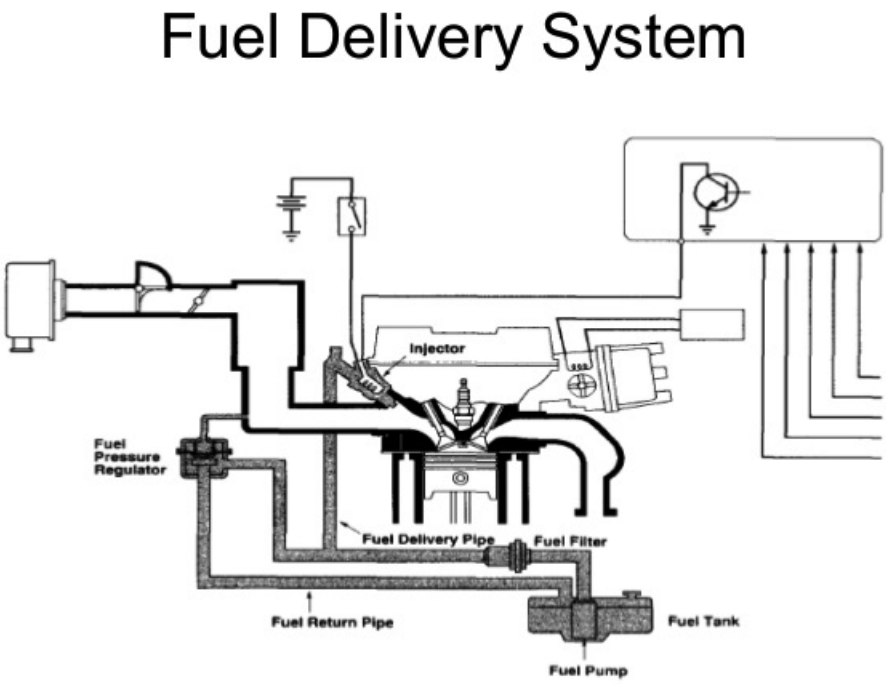


Fig. 5.31: Fuel Delivery System

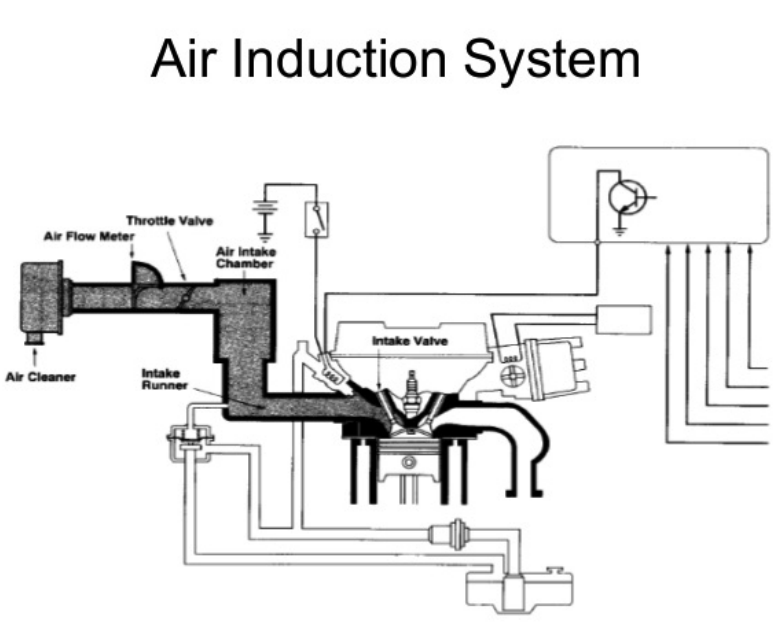


Fig. 5.32: Air Indusction System

Electronic Control System

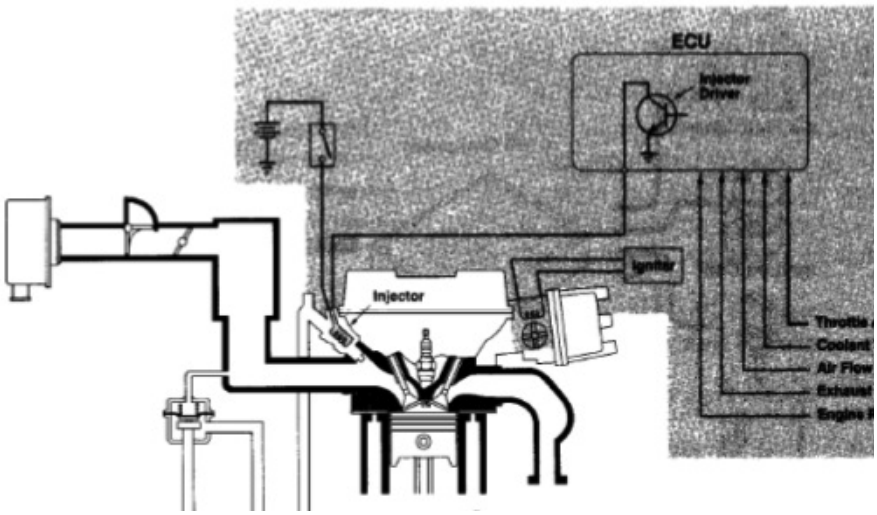


Fig. 5.33: Electronic Control System

- **Electronic Control System**

  The purpose of electronic control system is to detect air temperature, engine temperature, throttle valve opening angle, amount of air entering air induction system, etc.

  The electronic control system consists of various engine sensor, Electronic Control Unit (ECU), fuel injector assemblies, and related wiring.

  The ECU determines precisely how much fuel needs to be delivered by the injector by monitoring the engine sensors.

  The ECU turns the injectors on for a precise amount of time, referred to as injection pulse width or injection duration, to deliver the proper air/fuel ratio to the engine.

- **Electronic Control Unit**

  The Electronic control unit serves as the control center for all of the sensors on a car. The engine control unit is responsible for monitoring and controlling all the sensors on a car's engine. The ECU monitors the performance of the engine and makes adjustments according to where the problem is. The ECU also does calculations of pulse length (injector time opening) and adjustments to any change in the engine

- **Basic System Operation**

  Air enters the engine through the air induction system where it is measured by the air flow meter. As the air flows into the cylinder fuel is mixed into the air by the fuel injector.

  Fuel injectors are arranged in the intake manifold behind each intake valve. The injectors are electrical solenoids which are operated by the ECU.

  The ECU pulses the injector by switching the injector ground circuit on and off.

When the injector is turned on, it opens, spraying atomized fuel at the back side of the intake valve.

As fuel is sprayed into the intake air stream, it mixes with the incoming air and vaporizes due to the low pressures in the intake manifold. The ECU signals the injector to deliver just enough fuel to achieve an ideal air/fuel ration of 14.7:1 often referred to as stoichiometry.

The precise amount of fuel delivered to the engine is a function of ECU control.

The ECU determines the basic injection quantity based upon measured intake air volume and engine rpm.

Depending on engine operating conditions, injection quantity will vary. The ECU monitor variables such as coolant temperature, engine speed, throttle angle, and exhaust oxygen content and makes injection corrections which determine final injection quantity.

- **Sensors**
  - **Air Flow Sensor**

    Air flow sensor is a device that is used in conjunction with an oxygen sensor to accurately measure the flow of air into a fuel injection engine.
  - **Air Temperature Sensor**

    The air Temperature sensor is used to measure the temperature of the incoming air in the engines air stream.
  - **Temperature Sensor**

    Their purpose is to measure the temperatures of fluids or parts in the engine and report it to the ECU.
  - **Oxygen Sensor**

    The Oxygen sensor is a device positioned in the exhaust stream which is tasked with measuring the make-up of the exhaust whether it is running too lean or too rich.
  - **Throttle Position Sensor (TPS)**

    The purpose of the throttle position sensor/switch is to relay the position of the throttle butterfly valve to the ECU.
  - **MAP Sensor**

    The purpose of the MAP sensor or Manifold absolute pressure sensor is to provide information about the air pressure in the intake manifold to the ECU.
  - **Knock Sensor**

    The function of the knock Sensor is to produce an electrical signal that the ECU can use to determine if knock has occurred. The ECU will then provide less ignition advance until knock is removed.

    Engine knock occurs in the combustion chamber when two high-pressure waves collide. This unwanted and damaging event can be caused in different ways.Two examples are excessive load on the engine and engine overheated.

- **Engine Speed Sensor**

  The function of Engine speed sensor is to monitor engine speed, which is one of the factors used to calculate the pulse width.

- **Engine Oil Sensor**

  The function of the engine oil sensor is to produce an electrical signal that the ECU can use to determine the quality of the oil.

  The electrical capacitance value of oil varies with various oil properties; these include Viscosity anti-foaming cleaning.

  Electronic circuitry within the sensor converts the capacitance value of the oil to a voltage signal. The ECU monitors voltage signal from sensor and uses this data to determine service requirements.

- **Crankshaft Sensor**

  The crankshaft sensor is used to relay the position and speed of the crankshaft to the ECU.

- **Camshaft Sensor**

  It measures the position and speed of the camshaft to aid the ECU in engine timing.

- **Idle Air Control Valve**

  The idle air control valve controls the amount of air entering the engine while idling

l **Multi-point Fuel Injection**

Multi-point fuel injection injects fuel into the intake port just upstream of the cylinder's intake valve, rather than at a central point within an intake manifold, referred to as SPFI, or single point fuel injection.

MPFI (or just MPI) can be sequential, in which injection is timed to coincide with each cylinder's intake stroke, batched, in which fuel is injected to the cylinders in groups, without precise synchronization to any particular cylinder's intake stroke, or Simultaneous, in which fuel is injected at the same time to all the cylinders.

Multi point fuel injection or MPFI uses several injectors, normally respective to the number of engine cylinders and placed in the inlet port of each cylinder.

MPFI (or just MPI) systems can be sequential, in which injection is timed to coincide with each cylinder's before intake stroke.

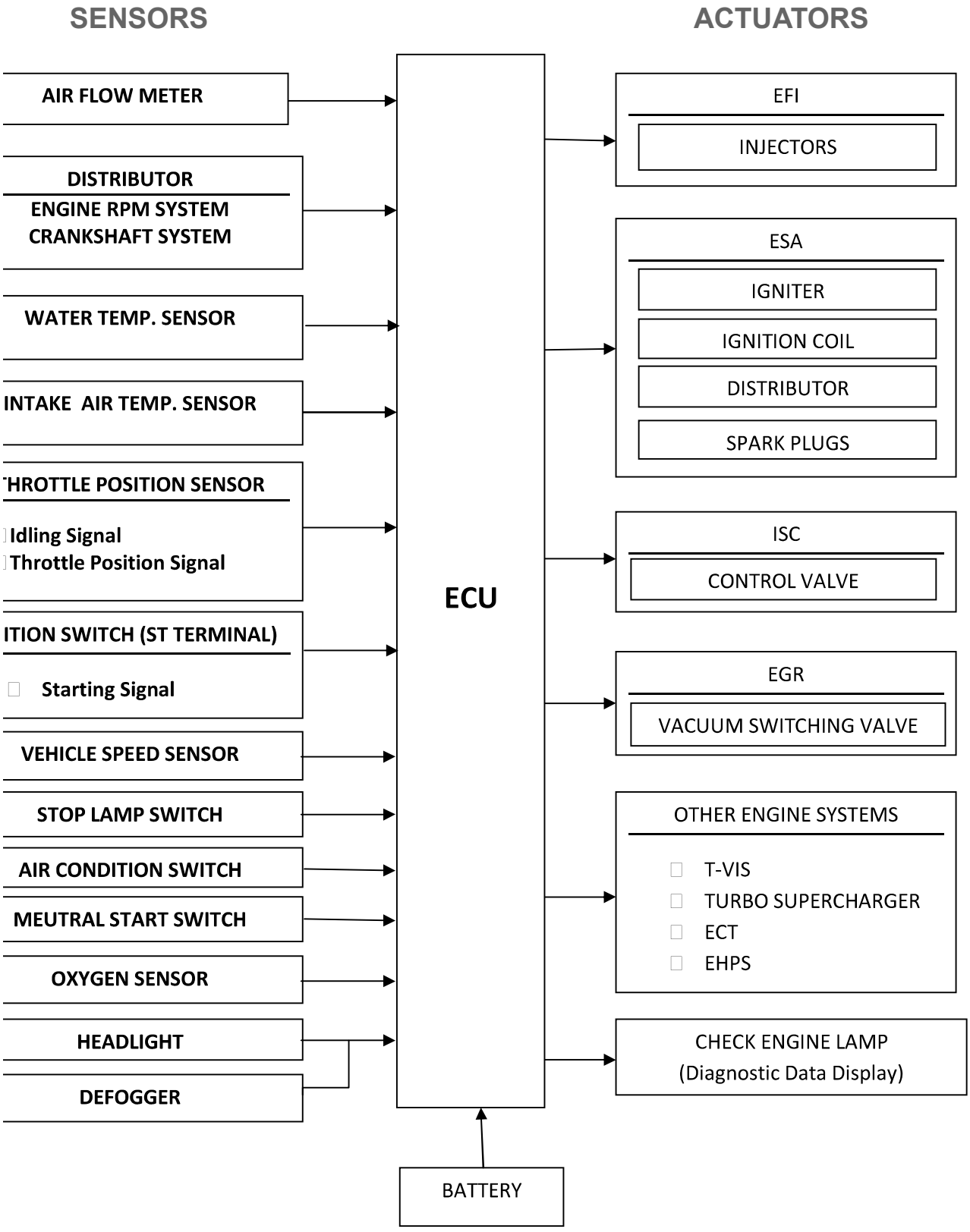
It is to be noted that fuel spaying is taking place outside of the cylinder at the correct time according to the piston position inside the cylinder.

There will be electronic control unit or ECU which will be receiving feedback from several sensors like engine speed sensor, fly wheel position sensor, vehicle speed sensor, atmospheric temperature sensor, accelerator pedal position sensor, intake airflow sensor.

This ECU will control the correct amount of fuel to be injected and the proper time at which the fuel will be injected at any speed and load condition.

This will ensure maximum power output at minimum fuel consumption.

TABLE: DIFFERENT TYPES OF SENSORS AND ACTUATORS



5.8: Trouble shooting Chart for Automotive Electrical & Electronics System

Trouble shooting Chart for Batteries

Fault	Causes	Remedies
Overcharging	a. High charging voltage	Check generator-regulator system
	b. High temperature	Reduce setting of voltage-regulator; also reduce specific gravity of electrolyte.
Use of excessive water	a. Overcharging	Check as in (1)
	b. Cracked container	Replace battery or container as required
	c. Leakage at cover seal	Replace battery or reseal as required
Run down battery	a. Defective generator or regulator	Check both
	b. Faulty wiring circuit	Check
	c. Excessive load demand	Reduce load
	d. High self-discharge	Battery may not be allowed to remain idle, recharge it periodically
	e. Old or defective battery	Recharge, re-test, replace if periodically
Cracked container	a. Battery loose in bracket	Replace battery or container; tighten in bracket properly
	b. Hold-down clamps too tight	Replace battery or container; tighten hold down clamps properly
	c. Battery frozen	Replace battery; keep it charged to avoid freezing
	d. Battery hit by flying stones	Ensure shield is in place
Bulged case	a. Hot battery	If it is from overcharge, reduce regulator voltage
	b. Hold-down clamps too tight	Tighten the clamps properly
Corroded battery bracket	a. Overfilling	Avoid overfilling; clean bracket and paint it
	b. overcharging	Adjust regulator voltage
Sulphated plates	a. undercharging	Adjust charging rate; rectify defects of generator and charging circuit if any
	b. battery left in discharged condition without attention; low electrolyte level; excessive gassing due to overcharging	Battery may be charged at low charging rate; renew plates if required

Wide variation of readings of different cells when checked with hydrometer	a. Cells with low reading may be short circuited partially; acid lost due to leakage from low-reading cells; excessive water evaporation from high reading cells	Replace plates or battery as required
Voltage readings differ on individual cells	a. Plates defective because of loss of active material due to shedding or sulphation; short-circuiting of cells; open circuit in cells	Defective cell may be opened and rectified; if battery in poor state, may be replaced
Battery cells short-circuited	a. Plates get buckled, separators charged due to over-charging, plates short circuited due to displaced active material	Rebuild or replace battery as required

Troubleshooting Chart for Generator and Alternator

Fault	Causes	Remedies
No output	a. Brushes sticking	Free; brushes and springs may be replaced as required
	b. Commutator dirty (dc)	Clean; turn down commutator and undercut mica if required
	c. Commutator burned (dc)	Clean; turn down commutator and undercut mica, if required, check setting of current regulator.
	d. Loose connections broken leads	Tighten connections; replace leads
	e. Armature earthed	Check with test lamp; repair or replace
	f. Armature open	Repair or replace
	g. Armature shorted	Test on growler; repair or replace
	h. Field earthed	Test it with test lamp; repair or replace
	i. Field open	Test with test lamp; repair or replace
	j. Field shorted	Test with ammeter; repair or replace
	k. Terminal earthed	Rectify insulation or replace terminal as required
	l. Loose/ broken drive belt	Tighten / replace belt
	m. Worn / dirty slip rings (ac)	Clean, turn or replace
	n. Brush spring broken	Replace spring
	o. Residual magnetism lost	Re-polarize
Overcharging / excessive output	a. High open circuit voltage	Reset regulator
	b. Voltage regulator shunt winding open	Locate and rectify if possible, else replace regulator
	c. Field circuit earthed	Check with test lamp, repair or replace
	d. Field circuit shorted	Test with ammeter, repair or replace

Low output / unsteady output	a. Loose drive belt	Tighten drive belt
	b. Brushes sticking	Free; replace brushes and springs as required
	c. Brush-spring tension low	Re-tension or replace
	d. Grease or oil on commutator (dc)	Clean commutator
	e. Dirty or burned commutator (dc)	Clean; turn down commutator and undercut mica
	f. Partially shorted, earthed or open in armature (dc)	Repair or replace armature as required
	g. Partially shorted, earthed or open in field	Repair or replace field as required
	h. Slip rings dirty or worn out (ac)	Clean, turn or replace as required
	i. Open or shorted rectifier (ac)	Replace
	j. Open or shorted stator winding (ac)	Locate fault and rectify or replace as required
	k. Low open circuit voltage	Reset regulator
Noisy generator	a. Mounting of generator loose	Tighten mounting
	b. Loose pulley	Tighten pulley
	c. Wornout bearings	Replace bearings
	d. Brushes not seating properly	Rectify
	e. Rectifier shorted or open (ac)	Replace
	f. Stator winding shorted or open	Rectify or replace
Warning lamp goes of but no charge to battery	a. Worn-out or burned out contacts	Replace contacts
	b. Armature of cut out stays lifted due to shock	Reset cutout top gap and other settings of regulator
	c. Open swamp resistor	Replace it
Warning lamp reappears at high speeds	a. Mica proud of segments in commutator	Under cut mica of commutator
Warning lamp does not appear when ignition switch is switched on	a. Fused bulb	Replace bulb
	b. Defective switch	Repair / replace
	c. Circuit of warning lamp	Check and rectify
Warning lamp goes dim, battery is being charged	a. High resistance in warning lamp circuit or charging cables	Check and tighten connection

Troubleshooting Chart for Cranking Motor

Fault	Causes	Remedies
No cranking of engine, no lights	a. Dead battery	Recharge or replace battery
	b. Open circuit	Clean and tighten connection; replace wiring if necessary
No cranking of engine, lights go out	a. Poor connections, most probably at battery	Clean terminals and cable clamps; also tighten clamps
No cranking of engine; lights dim slightly	a. Bendix pinion not engaging	Clean pinion and sleeve; replace damaged parts if any
	b. Excessive resistance or open circuit in cranking motor	Clean commutator; replace brushes and repair poor connections
No cranking of engine; light dim heavily	a. Trouble in engine	Check engine to find trouble
	b. Low battery	Check, recharge or replace battery as required
	c. Bendix pinion jammed	Free Bendix pinion
	d. Direct short in cranking motor, shaft bearing seized	Repair cranking motor
No cranking of engine, light remain bright	a. Open circuit in switch	Check switch connections and contacts
	b. Open circuit in cranking motor	Check connections, brushes and the commutator
	c. Open in control circuit	Check connections, relay and solenoid and switch (vacuum)
The engine cranks slowly but does not start	a. Run down battery	Check, recharge or replace battery
	b. Defective cranking motor	Check and repair cranking motor
	c. Undersized battery cables	Renew cables of adequate size
	d. Mechanical trouble in engine	Check engine
Engine cranks at normal speed but does not start	a. Defective ignition system	Perform spark test; check timing and ignition system
	b. Defective fuel system	Check fuel pump, fuel line and carburetor
	c. Air leakage in intake manifold system or carburetor	Tighten mountings, replace gasket if needed
	d. Defective engine	Check compression, valve timing, etc.
Solenoid plunger chatters	a. Solenoid hold in winding open	Replace solenoid
	b. High setting of solenoid-relay with low battery	Recharge battery; reset-relay

Armature fails to rotate or rotates slowly	a. Discharged or defective battery	Recharge battery; replace if defective
	b. Loose or oxidized battery terminals; corroded or loose connectors; defective earth connections	Clean terminals and other connections; apply petroleum jelly; tighten all connections
	c. Motor terminals or brushes earthed / short-circuited	Locate fault and rectify it
	d. Burnt commutator worn-out brushes	Clean commutator or turn down as required; replace brushes
	e. Defective solenoid switch	Replace switch or clean contacts
	f. Armature / field coils defective	Replace armature / field coils as require
	g. Excessive drop in voltage	Check and rectify starter circuit
Armature rotates but pinion fails to engage	a. Pinion sticks	Clean splines
	b. Burr on pinion or flywheel ring gear	Duburr by filing
	c. Worn-out one or both ends bushes	Replace defective bush
	d. Defective auxiliary coil	Replace auxiliary coil
	e. Mounting loose	Tighten mounting
Cranking motor continues running after release of starting switch	a. Starting switch sticks	Repair or replace switch
	b. Solenoid switch contacts stick	Check and rectify
	c. Short in wiring harness	Repair fault after locating it
	d. Pinion bush seized on shaft	Replace bush
	e. Pinion flywheel gear fouled or damaged	Clean thoroughly; deburr gear and pinion
Pinion engages but engine does not crank	a. Corroded terminals, low battery	Clean terminals; recharge battery
	b. Clutch slip	Replace clutch
	c. Defective brushes springs or wornout brushes	Replace springs or brushes as required
	d. Shorted armature	Replace armature
	e. Partially shorted field coil	Replace field coil
Pinion disengages slowly after engine has started	a. Solenoid plunger sticky	Clean and free plunger
	b. Over-running clutch sticks on shaft	Clean shaft and sleeve of clutch
	c. Defective over-running clutch	Replace clutch
	d. Weak shift lever return spring	Replace spring
	e. Defective vacuum switch	Replace switch

Troubleshooting Chart for Ignition System

Fault	Causes	Remedies
There is normal cranking of engine but it does not start	1. Primary circuit open	Check connection, coil, points and ignition switch for open circuit and rectify
	2. Primary of the ignition coil earthed	Replace coil; repair if possible
	3. Contact points not opening	Adjust points
	4. Burnt contact points	Clean or replace them as required
	5. Timing out	Check it and adjust
	6. Defective condenser	Replace it
	7. Secondary of the ignition coil open or earthed	Repair or replace ignition coil as required
	8. Leakage in high tension circuit	Check ignition coil head, distributor cap, rotor and HT (high tension) leads. Locate the fault and rectify
	9. Fouled spark plugs	Clean and adjust gap; replace if necessary
Engine running but one cylinder is missing	1. Spark plug defective	Clean or replace it
	2. Defective HT lead or distributor cap	Replace it
Engine running but missing different cylinders	1. Dirty / wornout points or parts out of adjustment	Clean, replace and adjust them as required
	2. Defective condenser	Replace it
	3. Defective spark advance mechanism	Repair or replace distributor as required
	4. HT leads defective	Replace them
	5. Defective / weak ignition coil	Replace it
	6. Corroded connections	Clean and tighten connections
	7. High-tension leakage	Check ignition coil head, distributor cap rotor and HT leads. Locate fault and rectify.
	8. Spark plugs defective	Replace / clean
Engine develops less power	1. Timing out	Check and adjust timing
Overheating of engine	1. Ignition timing rate	Check and adjust timing

Engine backfires	1. Timing out	Check and adjust timint
	2. Cross firing of ignition	Check for leakage, HT leads, distributor cap and rotor
	3. Incorrect heat range of spark plug	Replace them with correct spark plugs
Engine knocks	1. Incorrect timing	Check and adjust timing
	2. Faulty spark advance mechanism	Repair or replace distributor
	3. Contact points out of adjustment	Re-adjust them
	4. Wornout distributor bearing	Replace bearing
	5. Bent distributor shaft	Rebuild or replace it
	6. Incorrect heat range of spark plugs	Replace them with correct spark plugs
Contact points pitted	1. Incorrect capacity of condenser	Replace it with correct capacity
	2. Improperly arranged leads	Re-arrange them
Fault	**Causes**	**Remedies**
Contact points brunt	1. Condenser circuit containing excessive resistance	Tighten connections and mounting of condenser, replace condenser if required
	2. High voltage	Re-adjust voltage regulator
	3. Contact angle excessive	Reset them
	4. Spring tension weak	Adjust it or replace spring
Defective spark plugs	1. Insulator cracked	Careless handling; replace it
	2. Sooty plugs	Replace with hotter plugs
	3. White or gray plug with blistered insulator	Replace with cooler plugs

Troubleshooting Chart for Spark Plug

Fault	Causes	Remedies
Badly worn or burnt electrodes	1. Incorrect gap	Reset gap correctly
	2. Incorrect distributor contact breaker points gap	Reset gap
	3. Timing out	Re-time
	4. Hot running conditions in engine	Replace with cooler plug
External insulator broken	1. Careless handling	Install new plug
Internal insulation cracked / broken at lower end	1. Engine running hot	Install cooler plug
	2. Carelessness in adjusting gap	Adjust gap by bending the side electrode only
Upper part of external insulator blackened just above shell	1. Leakage due to gland nut being loose in case of detachable plug; washer defective	Tighten with box spanner replace washer
	2. Too hot plug used	Install cooler plug
Glassy or blistered internal insulator	1. Engine running hot	Install cooler plug
	2. Timing out	Re-time
Dry black soot on internal insulator	1. Engine running cold	Install hotter plug
	2. Distributor contact breaker points gap incorrect	Reset gap
Oily deposits on internal insulator	1. Engine running cold	Install hotter plug
	2. Timing out	Re-time
	3. Distributor contact breaker points gap incorrect	Reset gap
Oily plug	1. Timing out	Re-time
	2. Distributor contact breaker points gap incorrect	Reset gap

Troubleshooting Chart for Lighting System

Fault	Causes	Remedies
A. **Lighting system**		
Lamps do not give sufficient illumination	1. Battery discharged / defective	Charge or replace battery as required
	2. Bulbs out-of-focus	Focus the bulbs
	3. Reflector dirty / bulbs discoloured due to long use	Clean reflectors; replace bulbs
	4. Improperly earthed reflector, lamp body or mounting	Check earthing connections and rectify
Lamps do light when switched on but they gradually dim out	1. Discharged / defective battery	Recharge or replace battery as required
Brightness varies with vehicle speed	1. Discharged battery	Recharge it
	2. Excessive resistance in circuit	Tighten connections; replace defective cables
Lights flicker	1. Loose connections	Locate faulty connections and tighten them
Lights fail	1. Blown fuse	Check the circuit and replace fuse
B. **Direction Indicator**		
Arm fails to rise in case of arm type indicator	1. Arm jammed in recess or case	Rock arm in case and apply pressure at top of arm
	2. Mechanism binding due to lack of lubrication	Lubricate pivots and linkage with thin oil
	3. Faulty switch	Check and rectify or replace as required
	4. Improperly earthed indicator casing	Rectify connection
	5. Defective solenoid	Rectify connection
Arm rises but bulb does not light	1. Bulb incorrectly **positioned** in carrier	Rectify
	2. Bulb carrier contact with arm or clip not good	Clean and rectify
	3. Wire to bulb broken or disconnected	Rectify
	4. Switch contacts at inner end of arm dirty	Clean and rectify
No current passing in case of flashing type indicators	1. Wire disconnected or cracked in feed or earth circuit	Rectify or replace
	2. Fuse blown	Replace
	3. Contacts of switch dirty	Clean them

Troubleshooting Chart for Indicating and Warning Devices

Fault	Causes	Remedies
	A. **Fuel Gauge**	
Gauge needle remains at "Empty"	1. Wire disconnected from ignition switch to gauge or gauge to tank unit	Locate fault and rectiry
	2. Tank unit not earthed	Earth it
	3. Float punctured	Replace it
	4. Float arm sticking	Find cause and rectify
	5. Defective gauge	Replace it
Gauge needle remains at "Full"	1. Casing of gauge not earthed	Earth it properly
	2. Wire earthed between gauge and tank unit	Rectify
	3. Tank unit terminal earthed	Insulate it
	4. Float arm sticking	Find the cause and rectify
	5. Defective gauge	Replace
	B. **Oil Pressure Gauge**	
1. Bourdon Tube type:		
Incorrect gauge readings	1. Bourdon tube punctured; faulty soldering	Replace tube; rectify soldering
	2. Bourdon tube strained	Replace
	3. Oil gauge pipe line choked	Clean or replace it as required
	4. Defective gauge	Replace
2. Electric type Gauge: in this case the trouble-shooting chart is similar to that of the fuel gauge discussed above. Here, the tank unit is to be read as engine unit, empty as low pressure and full as high pressure. Further, the engine unit will consist of oil pressure operated diaphragm.		
	C. **Oil Pressure Warning Light**	
Light continues to glow when oil pressure is adequate	1. Defective pressure switch	Replace
	2. Wire earthed between pressure switch and light	Rectify
Light does not glow when ignition switch is switched on	1. Defective pressure	Replace
	2. Wire disconnected between ignition switch and warning light or between light and pressure	Locate the spot and rectify

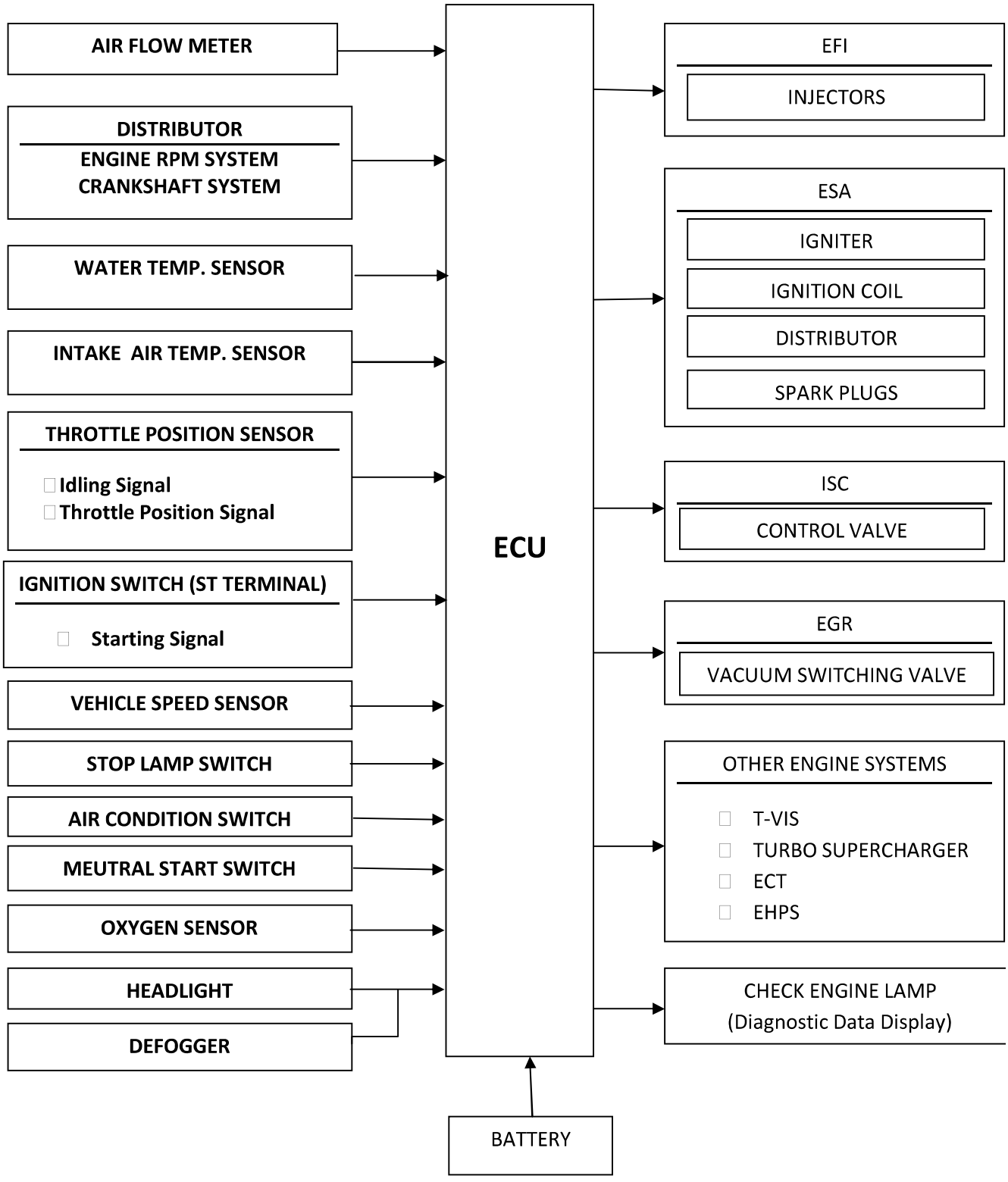
D. **Speedometers**		
Needle remains at zero	1. Incorrectly engaged shaft with spindle of speedometer	Rectify
	2. Worn or sheared driving key at the gear-box end of the shaft	Replace
	3. Driving gear stripped	Replace
	4. Worn mating surfaces of shaft and spindle	Replace
	5. Speedometer cable broken	Replace
	6. Undue friction between casing and speedometer cable	Lubricate
	7. Speedometer defective	Rectify or replace
Readings wavering and erratic	1. Sharp bends in cable casing	Replace
	2. Speedometer cable worr or stretched	Replace
	3. Defective speedometer	Rectify or replace
Gives steady but inaccurate readings	1. Defective speedometer	Rectify or replace
	2. Wrong size tyres fitted on rear wheels	Replace with correct size
	3. Rear axle ratio altered from standard	Recalibrate speedometer

Troubleshooting Chart for Miscellaneous Electrical Equipment

Fault	Causes	Remedies
A. **Windshield Wipers**		
1. Defective wiper having motor with wound armature		
No current passing	1. Wire disconnected or broken in feed or earth return circuit	Rectify
	2. Blown fuse	Replace
	3. Dirty switch contacts	Clean them with fine emery
	4. Loose / broken connection in motor	Tighten / replace as required
to A field current taken	1. Sticky or worn brushes	Rectify or replace them
	2. Oil, grease or carbon on commutator	Clean it
	3. Open in armature circuit	Check and rectify or replace as required

Motor overheats	1. Dirty commutator	Clean
	2. Binding in armature bearings	Lubricate or replace as required
	3. Short circuited brush gear	Rectify
	4. Wiper spindle binding	Lubricate
	5. Defective gears / linkage	Replace
2. Defective wiper having induction type motor		
When starting knob is operated, no current taken and no impulses felt	1. Dirty switch contacts; incorrectly adjusted contacts	Clean them; adjust them
	2. Wire disconnected or broken in feed or earth circuit	Connect or replace it
	3. Blown fuse	Replace
	4. CB contacts not closing / faces dirty	Rectify, clean them
	5. Open in field winding	Check and rectify or replace as required
	6. Loose / broken connections in motor	Tighten / replace them
Motor runs sluggishly	1. CB gap not correct	Adjust it
	2. Bindings in spindle or gear	Lubricate
	3. Excessive blade pressure	Rectify / reduce the pressure
Rotor magnetically locked between pole pieces	1. Incorrect contact gap	Adjust it
	2. Incorrectly set fibre cam	Reset it
3. Defective vacuum-operated type wiper	1. Air leaks past pistons or paddle	Lubricate or replace
	2. Sticking throw-over valve in wiper, stretched valve spring or bent	Replace defective item
	3. Spindle bent / binding	Lubricate / replace
	4. Excessive blade pressure	Rectify / reduce pressure
4. Mechanically operated wiper fails to operate	1. Faulty worm wheel or worm gear driving spindle	Replace whichever is defective
	2. Spindle sheared or loose in worm	Replace
	3. Drive able broken	Replace
	4. Worn dog clutch / weak spring	Replace
	5. Incorrectly adjusted operating control	Adjust it
	6. Camshaft gear or driven gear faulty	Replace

Fault	Causes	Remedies
	B. **Electric Horns**	
Horn does not sound	1. Defective switch	Replace
	2. Wire broken in steering column	Rectify
	3. Incorrectly adjusted / defective relay	Adjust / replace relay as required
	4. Contact points in horn or relay burnt	Replace
	5. Incorrectly adjusted or defective horn	Adjust or replace horn as required
Horn sounds continuously	1. Defective switch	Replace
	2. Switch wire short circuited	Check; rectify or replace
	3. Incorrectly adjusted relay or defective relay	Adjust or replace relay as required
Horn gives incorrect note	1. Too high or too low generator voltage	Check and reset the output of generator
	2. Excessive drop of voltage in circuit	Locate the fault and rectify
	3. Loose parts in horn	Rectify them
	4. Incorrectly adjusted horn	Adjust the gaps as specified
	5. Matched horns not tuned to chord	Adjust
	6. Defective horn	Replace


AIR FLOW METER
DISTRIBUTOR
ENGINE RPM SYSTEM
CRANKSHAFT SYSTEM
WATER TEMP. SENSOR
INTAKE AIR TEMP. SENSOR
THROTTLE POSITION SENSOR
Idling Signal
Throttle Position Signal
IGNITION SWITCH (ST TERMINAL)
Starting Signal
VEHICLE SPEED SENSOR
STOP LAMP SWITCH
AIR CONDITION SWITCH
MEUTRAL START SWITCH
OXYGEN SENSOR
HEADLIGHT
DEFOGGER
ECU
BATTERY
EFI
INJECTORS
ESA
IGNITER
IGNITION COIL
DISTRIBUTOR
SPARK PLUGS
ISC
CONTROL VALVE
EGR
VACUUM SWITCHING VALVE
OTHER ENGINE SYSTEMS
T-VIS
TURBO SUPERCHARGER
ECT
EHPS
CHECK ENGINE LAMP
(Diagnostic Data Display)

QUESTIONS

Very Short Answer Type Questions

1. If the rotating coil is connected to the external circuit through brushes and slip rings instead of the commutator, the current generated will be _____ in character.
2. The voltage induced in the coil of D.C. generator will follow _____ wave.
3. Modern automobile generators are the two-pole, two-brush, _____ wound type.
4. In modern automobile generator which type of following wound is used?
   a. Series wound
   b. Shunt wound
   c. Compound wound
5. The speed of the generator at which its output voltage just rises above voltage of the battery being charged is called _____ speed.
6. The principle on which the regulator works is called _____ principle.
7. A rotor may have ____ ____ magnetic poles depending upon the size of the alternator.
8. In alternator rectifiers are fitted on a plate called _____ _____.

Short Answer Type Questions

1. Name different components fitted in the charging system.
2. On what are the factors the amount of current induced in a conductor depends upon?
3. Write the function of cut-out.
4. Write the function of current regulator.
5. Write the function of voltage regulator.
6. What is the principle on which regulator works? And write the principle.
7. Write the function of rectifier in alternator.
8. Name different components of the starting system.

Short Answer Type Questions

1. Draw the charging circuit of a car and label its different component.
2. Write the principle on which generator works.
3. Explain the function of commutator.
4. Write how voltage fluctuation in D.C. generator is eliminated?

5. With circuit diagram explain the operation of cut-out.
6. Draw the starting circuit of a car and label its different components.
7. Write the principle on which starter motor works.

Long Answer Type Questions

1. Explain the principle of D.C. generator (dynamo) and its working.
2. Explain with circuit diagram different type of generator field windings.
3. Briefly explain the construction of automobile dynamo.
4. Which circuit diagrams explain the operation of voltage and current regulator?
5. Write the working principle of alternator (A.C. generator).
6. Explain the construction of alternator.
7. Write the advantages of alternator over dynamo.
8. Draw the rectifier circuit and label its different components.
9. Explain with neat sketch the operation of simple motor.
10. Explain the construction of alternator fitted in automobile.
11. Explain with neat sketch the drive unit of starter motor.
12. Draw the lighting circuit of any Indian car.
13. Draw the horn circuit of a car.
14. Draw the wind screen wiper circuit of a car.

UNIT – 6

Session – 1

Motor Vehicle Act and Rules

Learning Outcome

Session 1 : Motor Vehicle Act and Rules				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Transport Authority.	Students should be able to understand: 1. Different types of license and eligibility criterion, documents requirement for obtaining those licenses and their renewal. 2. Registration procedure of a vehicle and documents required for registration. 3. Types of insurance policies and settlement procedure. 4. Documents required for transfer of ownership and fitness of vehicle.	Explain: 1. Different types of license and eligibility criterion, documents requirement for obtaining those licenses and their renewal. 2. Registration procedure of a vehicle and documents required for registration. 3. Types of insurance policies and settlement procedure. 4. Documents required for transfer of ownership and fitness of vehicle.	Demonstrate different types of license from, different documents and different types of insurances.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Transport Authority to observe the procedure of making license and registration.

Session 2 : Motor Vehicle Act and Rules (Indian Traffic Rules & Signs)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Traffic Police Department or Transport Authority.	Students should be able to understand: 1. Different types of road safety signs. 2. Different Hand Signals used by the drivers and traffic personal.	Explain: 1. Different types of road safety signs. 2. Different Hand Signals used by the drivers and traffic personal.	Demonstrate or draw: 1. Different types of road safety signs. 2. Different Hand Signals used by the drivers and traffic personal.	Interactive Lecture: 1. Chalk & talk method. 2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Transport Authority office and traffic police HQ to acquire the knowledge.

Session 3 : Motor Vehicle Act and Rules (Emission and its Control)				
Location	**Learning Outcome**	**Knowledge Evaluation**	**Performance Evaluation**	**Teaching and Training Method**
Classroom / Traffic Police Department or Transport Authority.	Students should be able to understand: 1. What is emission.	Explain: 1. What is emission.	Demonstrate: 1. Different emission control components used in automobile.	Interactive Lecture: 1. Chalk & talk method.

	2. Different sources of emission. 3. Different types of emission and their control.	2. Different sources of emission. 3. Different types of emission and their control.		2. PPT method - Using e-classroom (having interactive board & projector). **Activity:** Visit nearby Pollution checking center and observe how to measure the pollutants of at least five vehicles of each type.

Objectives

After attending this session you should be able to:-

- *Explain types of licence, Eligibility for obtaining it.*
- *Documents required for obtaining different types of driving licence and its renewal.*
- *Understand registration procedure of a vehicle and documents required for registration.*
- *Explain types of insurance policies and settlement procedure.*
- *Explain documents required for transfer of ownership and fitness of vehicle.*

6.1.1 Provision regarding Issue of Driving Licence

- **Driving licence:** Driving licence is the permission granted by Govt. Authorities to drive the motor vehicle in public place
- **Necessity for driving licence:** No person shall drive a motor vehicle in any public place unless he holds an effective driving licence issued to him authorising him to drive the vehicle; and no person shall so drive a transport vehicle unless his driving licence specifically entitles him so to do.

The driving licence are of two types:

- **Learner Licence:** This is a temporary licence valid up to 6 month only. It is issued to learn driving of Motor Vehicles.
- **Permanent Licence:** One become eligible for permanent licence after expiry of one month from the date of issuing the learner licence.

Eligibility for obtaining a licence:-

- A person should have completed 16 years to obtain license for 2 wheelers without gear.
- A person should have completed 18 years age to obtain license for 2 wheelers with gear, Motor-car, Tractor and other non-transport vehicles.
- For transport vehicles, a person should have completed 20 years of age. In addition he should be passed standard 8th and should have experience of 1 year driving a light motor vehicle.

❖ Documents required for learner licence

The documents required along with the learner application form are as follows:-

1) Form No. 1, 2, 3
2) Three 3 copies of applicant recent passport size photograph
3) Proof of residence
4) Proof of Age

5) Proof of citizenship
6) In the case of an application for transport vehicle, the driving license held by the applicant.
7) Appropriate Fee has specified in rule 32.

❖ Documents required for permanent licence

The person having a valid learner licence can apply for permanent licence after 30 days and within 180 days from the date of issuance of learner licence.

An application for a driving license shall be made in form no.4 and shall be accompanied by :-

1) An effective learner's license to drive the vehicle of the type to which application relates
2) Appropriate fee as specified for the test of competence to drive and issue of license.
3) Nationality Proof.
4) Proof of citizenship. (Attested photocopies)
5) One recent passport size photograph
6) A driving certificate in Form No. 5 & 14 issued by the school or establishment from where the applicant received instruction.
7) The vehicles for test which category you are applying the licence.

Your original licence in case of endorsements of categories.

❖ Documents required for renewal of driving licence

- **For Private Licence:**
  1) Application in Form No.9.
  2) Fees and Penalties as Applicable.
  3) 2 copies of your recent passport size photograph.
  4) Original driving licence held.
  5) Attested Copy of valid Proof of age and residence.
  6) form No.1 self declaration of physical fitness
- **For Commercial Licence:**
  1) The above documents as required in Private Licence.
  2) Medical Certificate in form No.1-A (In case of Commercial category).
  3) Driver refreshing Training certificate in case of HMV.
  4) In case of Private licence the record is not verified if the particular seems to be clear on the licence. However for commercial licence the particulars are verified from the issuing authority. The renewal of licence in case of private licence is done on the same day but for commercial licence the renewal is made after verification of the particulars.

❖ Documents required to get a duplicate licence

1) Application in Form LLD.
2) FIR/NCR of the lost licence
3) Challan clearance report from Traffic Police (in case of Commercial licence renewal).
4) Fee amount, Form No 1.Self Declaration of Physical Fitness.
5) Attested Copy of valid address Proof

For duplicate licence you have to approach the issuing authority and the particulars will be verified from their records. The validity of duplicate licence will be the same of your previous licence. The original issuing authority will issue your duplicate licence. If your licence is lost and expired by more than 6 months your case requires permission from Head Quarter of Transport Department.

The following documents can be used as proofs:-

1. Residence proof:

1) Voter Identity Card
2) Life Insurance Policy
3) Passport
4) Pay slip issued any office of the central government or a state government or local body.

The following documents are also accepted along with an affidavit sworn before a notary public or any competent magistrate

1) Water Bill
2) Electricity Bill
3) Telephone Bill
4) Pay slip accompanied by a PF Receipt (In case of private sector employees)
5) Property Ownership like, Registry, Power of Attorney etc.
6) Post office or bank Passbook indicating residential address
7) House tax receipt
8) Certificate from employer in case of Government Servant.
9) Ration Card
10) Marriage certificate issued by District Administration
11) Income Tax Returns
12) Residence Certificate issued by District Administration

❖ Documents valid for proof of age

1) School certificate
2) Passport

3) Birth Certificate
4) Certificate issued by a registered medical practitioner not below the rank of a Civil Surgeon, as to the age of the applicant
5) Affidavit sworn by the applicant before an Executive Magistrate and or a First Class Magistrate as a evidence of age.
6) PAN Card
7) CGHS Card

❖ **Documents valid for proof of citizenship**

1) Proof of Birth in India from municipality or registrar of birth & death.
2) School Leaving Certificate/Secondary School Certificate Showing Nationality/Place of birth
3) Passport Showing place of birth/citizenship/nationality
4) Certificate of citizenship/nationality issued by magistrate or any other administrative officer
5) Residency permit/domicile certificate issued by state government.
6) Grant of patta/lease of property by the central/state government.
7) Refugee Registration card pertaining for the period of 1947-1950
8) Certificate of SC/ST/OBC.

6.1.2 Registration of Vehicle

The vehicle can be driven or allowed to be driven in public place only after registration by registering authority as under the provision of section 39 of motor vehicle Act 1988.

Procedure of registration:

1. **Registration by transport department:** In this the applicant has to get his vehicle registered by the transport department after getting the vehicle inspected physically by the department and by paying registration charges, road tax etc.
2. **Registration by dealers:** Transport Department has authorized dealers to register the vehicles and to deliver the registration certificate as well, to the registered owner at their end for the benefit of public and to avoid the hassles in registration procedure

The registration procedure includes the vehicle to be inspected physically by Inspecting Authority at zonal office for its particulars and followed by registration. The documents required to apply the registration are as follows :

1) Form 20duly filled up.
2) Form 21 (Sale certificate) issued by the vehicle dealer
3) Form 22 (Road worthiness certificate) issued by the which manufacturer

4) Attested copy of valid vehicle insurance policy/cover note
5) Attested copy of address proof at which vehicle is to be registered.
6) Form 34 duly signed by owner and the financer
7) One time road tax as applicable
8) Prescribed fee for registration
9) PAN Card or Form 60 & 61 (as applicable)
10) Parking fees.
11) Dealer invoice along with manufacturer invoice.

The following documents are required for change of address in Registration Certificate.

1) Form No. 33
2) Original Registration Certificate.
3) Attested copy of valid insurance.
4) Attested copy of address proof of the registered owner.
5) Attested copy of valid pollution under control certificate.
6) Prescribed fee.
7) Attested copy of PAN Card or Form 60 & 61(as applicable)
8) Regarding the change of address in Registration Certificate, where the hypothecation is endorsed in the Registration Certificate, No Objection Certificate from the financer is needed to get the address changed in the Registration Certificate.

The change of address should be applied within 14 days from the date of effect, after that penalty is applicable.

If a registered owner of a vehicle brings the vehicle to some state, which is already registered in some other state after obtaining a N.O.C from the concerned state can apply for re-registration in that state, the documents required are as under:

1) Other state registration certificate in original.
2) Form 20
3) Form 27
4) Form 28(NOC in duplicate)
5) Attested copy of address proof.
6) Attested copy of valid insurance.
7) Attested copy of pollution under control certificate.
8) Challan clearance from traffic police or enforcement wing of transport department. On case of commercial vehicle only.
9) Fitness certificate issued by the board of inspection.
10) Road tax (as applicable)

11) Prescribed fee for registration.
12) PAN Card or Form 60 & 61(as applicable)
13) Parking fees
14) Certificate manufactured regarding emission norms

Note: *Registration of such vehicle is subject to clearance from National Crime Record Bureau.*

6.1.3 Insurance

This is the class of Insurance through which a majority of the people recognize general Insurance and that too because it is compulsory for all motorized vehicles to have an Insurance policy against third party liability before they can come on road. Motor insurance gives protection to the vehicle owner against Damages to his/her vehicle and Pays for any Third Party Liability determined as per law against the owner of the vehicle. Third Party Insurance is a statutory requirement. The owner of the vehicle is legally liable for any injury or damage to third party life or property caused by or arising out of the use of the vehicle in a public place. Driving a motor vehicle without insurance in a public place is a punishable offence in terms of the Motor Vehicles Act, 1988. To a lesser degree vehicle insurance may additionally offer financial protection against theft of the vehicle and possibly damage to the vehicle, sustained from things other than traffic collisions.

Types of Motor Insurance policies:

Broadly there are two types of insurances policies that offer motor insurance cover:

a) Liability Only Policy (Statutory requirement) (Form A)
b) Package Policy (Liability Only Policy + Damage to owner's Vehicle (Form B)

If you take only a Liability Only Policy, damage to your vehicle will not be covered. Hence, it would be prudent to take a Package Policy which would give a wider cover, including cover for your vehicle.

For purpose of insurance, motor vehicles are classified into three broad categories:

a) Private cars
b) Motor cycles and motor scooters
c) Commercial vehicles

6.1.4 Claims

On receipt of notice of loss, the policy records are checked & the loss is entered in the Claims Register and a claim form is issued to the insured for completion and return. The insured is required to submit a detailed estimate of repairs from any repairer of his choice. Generally, these repairs are acceptable to the insurers but they at times ask the insured to obtain repair estimate from another repairer, if they have reason to believe that the competence, moral hazard or business integrity of the repairer first chosen is not satisfactory.

Assessment

Independent automobile surveyors with engineering background are assigned the task of assessing the cause and extent of loss. They are supplied with a copy of the policy, the claim form and the repairer's estimate. They inspect the damaged vehicle, discuss the cost of repair or replacement with the repairer, negotiate as per the indemnity, and submit their survey report. In respect of minor damage claims, independent surveyors are not always appointed. The insurer's own officials or their own automobile engineers inspect the vehicle and submit a report.

Settlement

The survey report is examined and settlement is effected in accordance with the recommendations contained therein. The usual practice is to authorise the repairs directly with the repairer to whom a letter is issued to that effect. In this letter the repairers are also instructed to collect direct from the insured the amount of the excess, depreciation, salvage, etc.If applicable to the claim, before delivering the repaired vehicle to him. The repairers are also instructed to keep aside the salvage of damaged parts, if there are any, for being collected by the salvage buyer nominated by the Insurers. Or else, if the repairers are willing to retain the salvage, its value, as indicated by the surveyor, is deducted from the claim bill. On receipt of their final bill of repairs after completion of repairs and a satisfaction note or voucher from the insured that the vehicle has been repaired to his satisfaction, the payment to the repairer is effected. Sometimes, the repairer is paid directly by the insured in which case the latter is reimbursed on submission of a receipted bill from the repairers. In either case, discharge voucher or receipt is obtained. The Claims Register and the policy and renewal records are marked that the claim is paid indicating the amount of claim and the amount of salvage, if any.

Claims Documents

Apart from claim form and Survey report the other documents required for processing the claim are:

1) Driving Licence
2) Registration Certificate Book
3) Fitness Certificate (Commercial Vehicles)
4) Permit (Commercial Vehicles)
5) Police Report (Taxis, commercial Vehicle need F.I.R./ spot survey if loss is heavy or T.P. loss occurs)
6) Final Bill from repairers
7) Satisfaction Note from the insured
8) Receipted bill from the repairer, if paid by insured.
9) Discharge voucher (full and final payment)

Total Loss Claims

Whenever a surveyor finds that a vehicle is either beyond repairs or the repairs are not an economic proposition, he negotiates with the insured to assess the loss on a Total Loss basis - for a reasonable sum representing the market value of the vehicle immediately prior to the loss. If the market value is more than the insured value, the settlement will be brought about for the insured value. The Insured will be paid in cash and the Insurers will take over the salvage of the damaged vehicle which will thereafter be disposed off for their own benefit calling tenders through advertisements in news papers. However, before the actual payment is made to the Insured, the Insurer will collect from him the Registration and Taxation books, ignition keys and blank TO. and T.T.0. forms duly signed by the insured, so that the salvage is usually not encouraged, unless insured desires, so as to avoid the hassle of salvage disposal.

6.1.5 Transfer of Ownership

The transfer of ownership of a vehicle is to be applied in the concerned zonal office where vehicle is already registered and following are the documents to be submitted:-

1) Registration certificate in original
2) Form no 29
3) Form no 30
4) Attested copy of valid insurance certificate
5) Attested copy of address proof of purchaser
6) Attested copy of valid Pollution Under Control Certificate
7) Prescribed fee along with penalty if the transfer of ownership not applied within 14 days from the date of purchase.
8) Attested copy of PAN Card or Form 60 & 61(as applicable)

Application should be submitted within 14 days otherwise penalty will be charged

For commercial vehicles in addition to above

1) Permit surrenders slip for S.T.A.
2) Challan clearance from Traffic Police & Enforcement branch of the Transport Deptt. are required.
3) Tax clearance report from Accounts.
4) Copy of Valid Fitness certificate.

Transfer of ownership in case of death of the registered owner:

In such case the application is to be made by the first legal heirs/the person succeeding to the possession of the vehicle with following documents.

1) Registration certificate in original

2) Form No. 30 & 31 in duplicate with endorsement of the financier if the vehicle is held on hire purchase agreement along with NOC from financier.
3) Original copy of death certificate of the registered owner.
4) Succession/Survival member Certificate issued by SDM.
5) Affidavit by the applicant to this effect and from the other legal heirs relinquishing their right in favour of the applicant.
6) Valid insurance certificate.
7) Address proof of Applicant.
8) Copy of valid PUC.
9) Copy of PAN Card or Form 60 & 61(as applicable)
10) Verification of vehicle on form no. 20

Application should be submitted within 30 days of death to the zonal office otherwise penalty will be charged.

For Commercial Vehicle in addition to above

1) Permit surrender slip issued by STA branch.
2) Challan clearance from Traffic and enforcement branch.
3) Tax clearance report from Accounts branch.
4) Valid Fitness Certificate

6.1.6 Fitness Certificate

Under the provision of Motor Vehicle Act, the registrations of vehicle are treated as valid only if the vehicle have valid certificate of fitness. The duplicate fitness is issued in case of loss, theft or mutilation. The duplicate fitness is issued after verifying the records of previous fitness. In case of Private Vehicles the fitness certificates is valid for 15 years and thereafter for every 5 years. In case of Commercial vehicles the fitness certificates is issued for new vehicle for 2 years and subsequently renewed for one year.

Documents are required for fitness of new vehicle:

1) Application From 20
2) Sales certification Form 21
3) Valid insurance Certificate
4) LOI from S.T.A. (for commercial passenger vehicles)
5) Temporary registration if any
6) Road worthy Certificate in form 22 from the manufacturers for road worthiness and pollution under control
7) Prescribed Fees

Documents required for renewal fitness of Commercial vehicle:

1) Registration certificate
2) Old C.O.F.
3) Road tax clearance from account branch up to date
4) Prescribed Fees
5) In case of fitness certificate expires penalty is charged.
6) Challan clearance from Transport Deptt.
7) Address proof of the owner
8) Valid Permit
9) For CNG vehicles Third Party Inspection Report for Compliance of CNG Safety Norm

QUESTIONS

Very Short Answer Type Questions

1. Name two type of driving licence.
2. Temporary licence is valid for.....months
3. For transport vehicles licence, a person should have completed .....years of age. In addition he should be passed..... standard.
4. Liability Only Policy requires.....Form
5. Emission includes:-

   a) NOx b) SOx
   c) Hydrocarbons d) All of the above

6. For a private new vehicle the initial fitness certificate is valid for

   a) 20 years b) 15 years
   c) 10 years d) 5 years

7. For a commercial new vehicle the initial fitness certificate is valid for

   a) 15 years b) 10 years
   c) 5 years d) 2 years

Short Answer Type Questions

1. What is the necessity of a driving licence?
2. Write the eligibility for obtaining a driving licence.
3. What do you mean by fitness certificate of a vehicle?

Short Answer Type Questions

1. What are the types of driving licence?
2. Explain the two types of registration procedure.
3. Enlist the document required for applying a registration.
4. What are the documents required for the transfer of ownership in case of death of the registered owner?
5. Explain the types of motor insurance policies
6. What is the fitness certificate?
7. Enlist the documents required for vehicle fitness certificate.

Long Answer Type Questions

1. What is the use of driving licence and what are the documents required for a Lerner licence?
2. What are the documents required for the renewal and issue of a duplicate driving licence?
3. How the insurance claims are carried out and what are the documents required for it?
4. Explain the procedure of claims settlement and what are the documents required for it?

UNIT – 6

Session – 2

Motor Vehicle Act and Rules (Indian Traffic Rules & Signs)

Objectives

After attending this session you should be able to:-

- *Understand and explain the different types of road safety signs.*
- *Understand different hand signals used by the drivers and traffic personnel.*

6.2.1 Indian Traffic Rules & Signs

At the beginning when the number of vehicle was very low on the roads of our country there were no serious needs for traffic rules and regulations. But as and when mass production of vehicles begun and the roads flooded with different kind and class of vehicles the Government felt the need for a system to control the vehicular traffic. In the year 1914 the first legislation as “Indian Motor Vehicle Act 1914” was passed in our country to regulate the motor vehicles and as well as other road users. Since then the traffic pressure on the roads of our country multiply several times and at the same time to control the unprecedented growth in the number of motor vehicles, the first Motor Vehicle Act 1914 which was in later years known as “The motor Vehicle Act 1988” was amended and revised several times by the Government of India. Traffic rules and regulations are devised to assure the smooth flowing of motor vehicles in the road. These have been prepared for the benefit of the people and the idea or preparing these rules are not that they should be understood by the drivers but it should also be understood by the other people. It is essential to follow all the rules and regulations. Traffic signs are silent speakers on the road. Be it the person behind the wheel or a pedestrian having a sound knowledge about road safety is necessary for all before hitting the roads The proper knowledge of these rules can reduce the number of accident and thus can establish a healthy and organised traffic system in our country.

Traffic signs give information about the road condition, instruction to be followed at the junctions, guide drivers and ensure proper functioning of road traffic. Being unaware of road signs can lead to loss of life and property

Types of road safety signs:

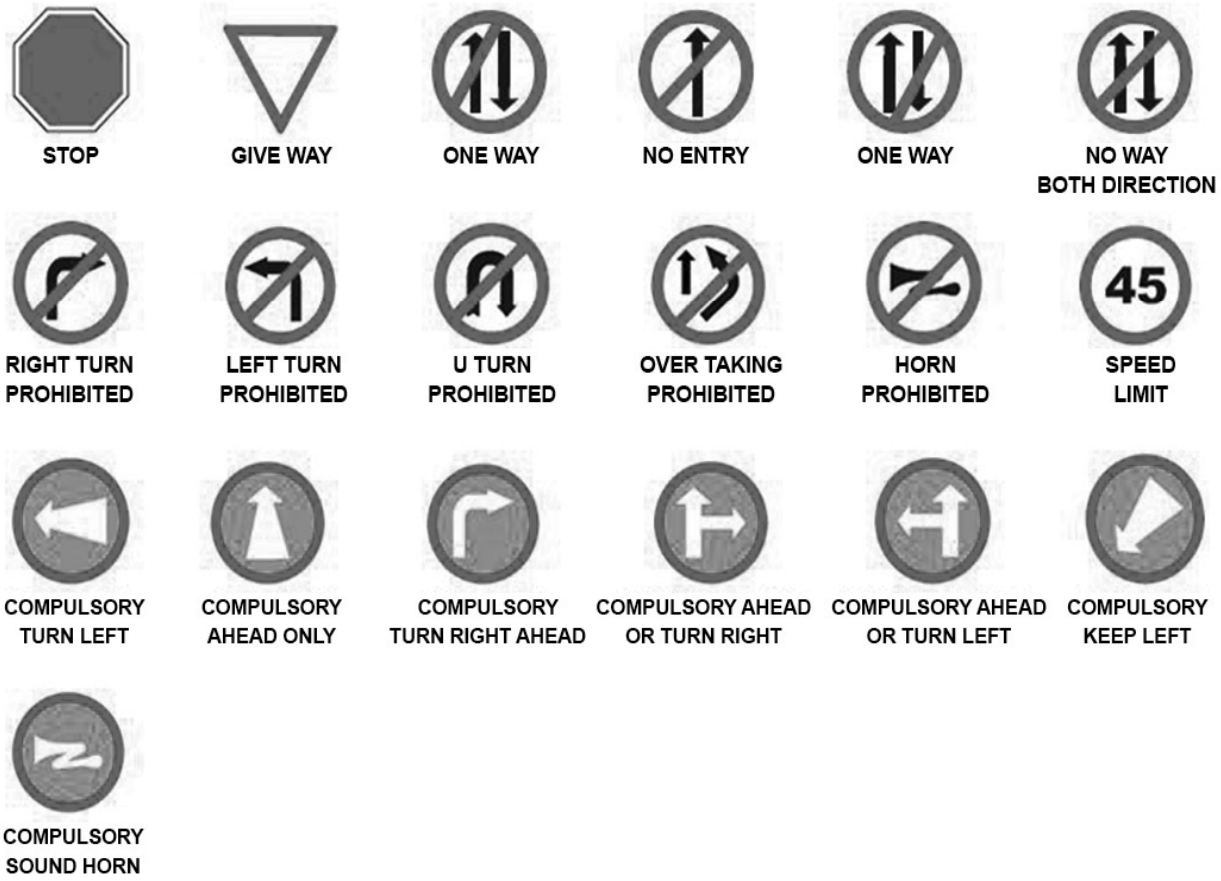
Road safety signs are of three types

1. Mandatory signs

2. Cautionary signs
3. Information signs

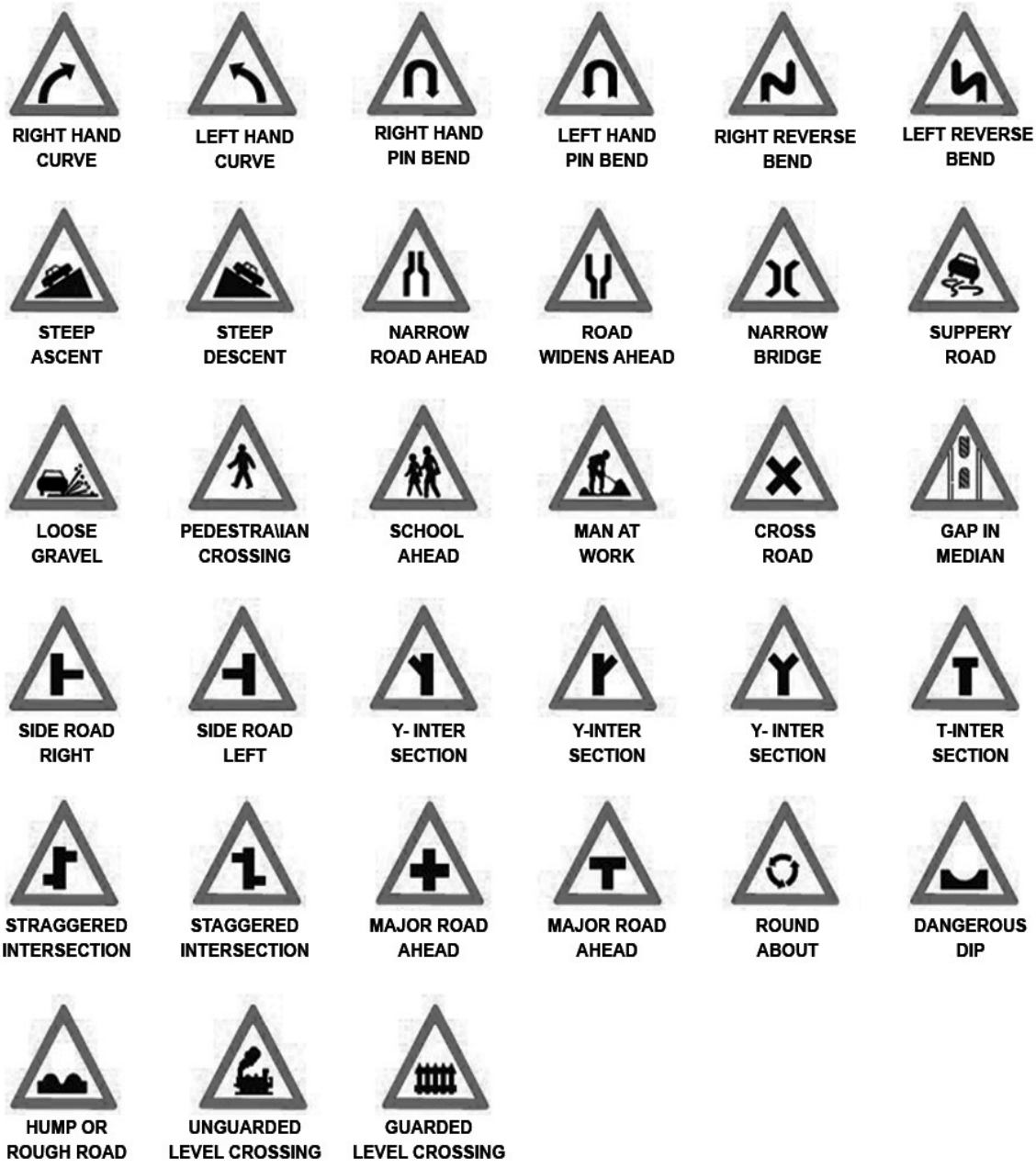
1. Mandatory Signs

These signs are used to inform road users of certain laws and regulations to provide safety and free flow of traffic. These include all signs which give notice of special obligation, prohibition or restrictions with which the road user must comply. The violation of these signs is a legal offence. Some of the signs, which fall under this category, are provided as follows.



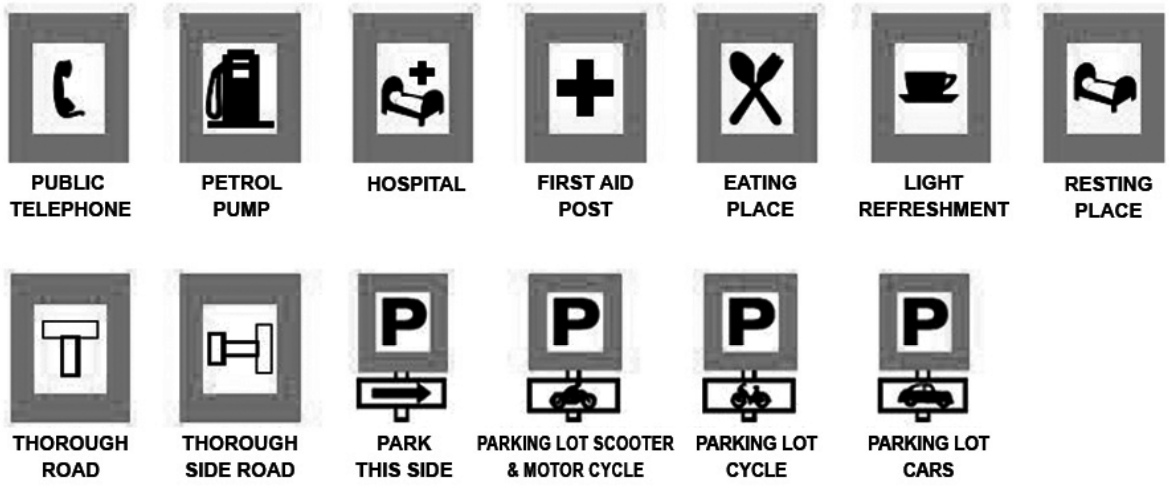
2. Cautionary Signs

These signs are used to warn the road users of the existence of certain hazardous condition either on or adjacent to the roadway, so that the motorists are cautious and take the desired action. Some of the signs, which fall under this category, are provided as follows.



3. Informatory Signs

These signs are used to guide road users along routes, inform them about destination and distance, identify points of geographical and historical interest and provide other information that will make the road travel easier, safe and pleasant. Some of the signs, which fall under this category, are provided as follows.



6.2.2 Hand Signals used by the Drivers

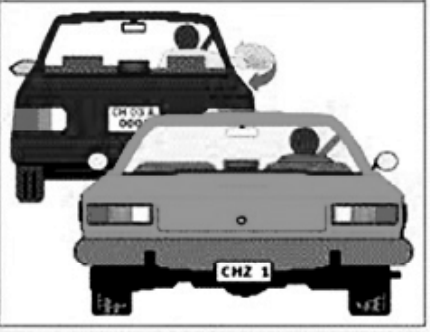
With modern road vehicles having the advantage of electronic light signals, the use of driving hand signals is for the majority of time unnecessary. Part of the training process for driving instructors involves driving hand signals, which they convey to their learner drivers.

However, hand signals are so infrequently used or needed in real life driving that many driving instructors do in fact not even cover this part of the training process for their learner drivers. There are certain situations where knowing the appropriate driving hand signals may become helpful and in certain circumstances essential. Detailed are driving hand signals with diagrams and reasons why you need them.

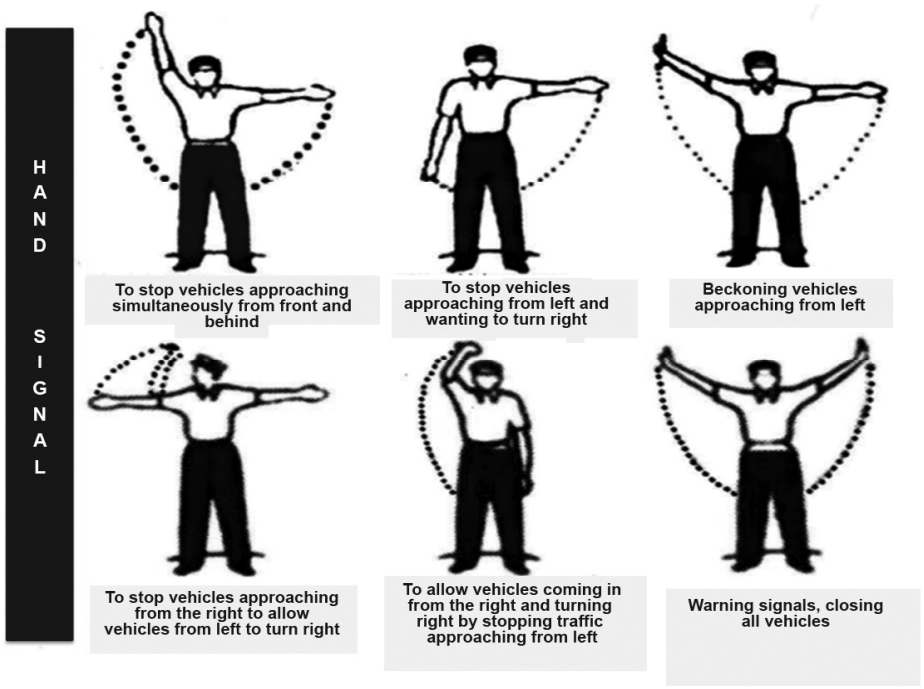
Case1:- The most essential reason for the use of hand signals is if your vehicle has electronic signalling failure, or more commonly if an indicator bulb fails. It's unlikely that with modern reliable technology that the electronics or wiring that control external lights will fail on a vehicle, but it can happen. Likewise if an indicator bulb fails, especially a rear indicator, a hand signal is essential because if you are making a left or right turn, the driver behind will not know this if you are unable to signal. If the road ahead is clear, this may lead to confusion for the driver if they see only your brake lights. This may provoke them to overtake you which is especially dangerous if you intend on turning right.

Case2:- Other situations can be for example at a pedestrian crossing. If for instance you are approaching a pedestrian crossing where your side of the road is congested with traffic, but the opposite side is free of traffic, it could be difficult for drivers t see a pedestrian making the cross starting from your side of the road. Especially at a Zebra crossing, the use of the slowing down hand signal can be of benefit to other motorists who may not see a pedestrian or small child.

6.2.3 The Driving Hand Signals used by the Driver

I intend to move in to the left or turn left	
I intend to move out to the right or changing the lane or turn right	
I intend to stop	
I intend to slow down	
Indicating the car following you to overtake	

6.2.4 Hand Signals used by the Traffic Personnel



6.2.5 Traffic Police Hand Signals (Manual)

To start vehicles coming from right

To change sign

To start one sided vehicles

To start vehicles on T-Point

To give VIP health

To manage vehicles on T-Point

To start one sided vehicles

To stop vehicles coming from front

To stop vehicles approaching from behind

To stop vehicles approaching simultaneously from front and behind

To stop vehicles approaching simultaneously from right and left

To start vehicle approaching from left

QUESTIONS

Very Short Answer Type Questions

1. Which one of the following is they type of **type safety sign?**

   a) Mandatory signs b) Cautionary signs

   c) Information signs d) All of the above

2. The violation of which of the following road safety signs is a legal offence?

   a) Mandatory signs b) Cautionary signs

   c) Information signs d) All of the above

3. Which of the following road signsare used to guide road users along routes to make the road travel easier, safe and pleasant?

   a) Mandatory signs b) Cautionary signs

   c) Information signs d) All of the above

Short Answer Type Questions

1. What is the use of traffic signs ?
2. What is the use of hand signals used by the drivers ?

Short Answer Type Questions

1. Explain the hand signals used by the drivers while driving a vehicle.

Long Answer Type Questions

1. Explain the type of road safety signs with examples.
2. Explain the hand signals used by the traffic police.

UNIT – 6

Session – 3

Motor Vehicle Act and Rules (Emission and its Control)

Objectives

After attending this session you should be able to:-

- *Understand what is emission?*
- *Explain various sources of emission.*
- *Explain various types of emission and their control.*

6.3.1 Emission

Emissions are any kind of substance released into the air from natural or human sources — flows of gases, liquid droplets or solid particles. Not all emissions become air pollutants, but many do, causing significant health and environmental problems. The amount of air pollutants in an area depends on the number and size of emission sources, along with the weather and lay of the land (topography)

6.3.2 Sources of Emission

Point Sources

Point sources are stationary industrial facilities such as pulp and paper mills and factories that burn fossil fuels. They operate under ministry authorization (a regulation, permit, approval, or code of conduct), or under an air-discharge permit issued by Metro Vancouver.

Area Sources

Area sources are stationary sources that are not normally required to obtain a discharge permit from the ministry. They include prescribed burning, residential wood use, light industry, and other residential, commercial and institutional sources. Emissions from most of these area sources individually are small compared to point sources, but can be significant when considered collectively.

Mobile Sources

Mobile sources include motor vehicles mainly involved in the transportation of people and goods (e.g., passenger cars, trucks and motorcycles), aircraft, marine vessels, trains, off-road vehicles, and small off-road engines (e.g., agricultural, lawn/garden, construction and recreational equipment).

Natural Sources

Natural sources of emissions occur in nature without the influence of human beings, such as wildfires, plants, wildlife and marine aerosol.

6.3.3 Types of Emission

Emissions of many air pollutants have been shown to have variety of negative effects on public health and the natural environment. Emissions that are principal pollutants of concern include:

- **Hydrocarbons -** A class of burned or partially burned fuel, hydrocarbons are toxins. Hydrocarbons are a major contributor to smog, which can be a major problem in urban areas. Prolonged exposure to hydrocarbons contributes to asthma, liver disease, lung disease, and cancer. Regulations governing hydrocarbons vary according to type of engine and jurisdiction; in some cases, “non-methane hydrocarbons” are regulated, while in other cases, “total hydrocarbons” are regulated. Methane is not directly toxic, but is more difficult to break down in a catalytic converter, so in effect a “non-methane hydrocarbon” regulation can be considered easier to meet. Since methane is a greenhouse gas, interest is rising in how to eliminate emissions of it.
- **Carbon monoxide (CO) -** A product of incomplete combustion, carbon monoxide reduces the blood’s ability to carry oxygen; overexposure (carbon monoxide poisoning) may be fatal. Carbon Monoxide poisoning is a killer in high concentrations.
- **NOx -** Generated when nitrogen in the air reacts with oxygen at the high temperature and pressure inside the engine. NOx is a precursor to smog and acid rain. NOx is the sum of NO and NO2. NO2 is extremely reactive. NOx production is increased when an engine runs at its most efficient (i.e. hottest) part of the cycle.
- **Particulate matter –** Soot or smoke made up of particles in the micrometre size range. Particulate matter causes negative health effects, including but not limited to respiratory disease and cancer.
- **Sulfur oxide (SOx) -** A general term for oxides of sulfur, which are emitted from motor vehicles burning fuel containing sulfur. Reducing the level of fuel sulfur reduces the level of Sulfur oxide emitted from the tailpipe.
- **Volatile organic compounds (VOCs) -** Organic compounds which typically have a boiling point less than or equal to 250° C, e.g. chlorofluorocarbons (CFCs) and formaldehyde. Volatile organic compounds are a subsection of Hydrocarbons that are mentioned separately because of their dangers to public health.

6.3.4 Emission Control

To reduce the level of pollutant substances in the exhaust, the advanced technologies or control techniques such as **fuel injection, catalytic converter, thermal after burning, exhaust gas recirculation, evaporative emission contro**l have been developed and adopted.

However, exhaust emission problems are not easy to solve. For example, as the CO content is

reduced, the proportion of equally toxic oxides of nitrogen tends to rise.

The air pollution due to internal combustion engines can be reduced in the following ways.

i. Modification of internal combustion engines to reduce the amount of pollutants formed during fuel combustion.

ii. Development of substitute fuels for petroleum based fuels which will yield low concentration of pollutants during combustion.

iii. Addition of emission control devices to remove or to decompose pollutants into harmless gases.

Each car now has the following major systems for controlling pollutants.

❖ Positive Crankcase Ventilation (PCV)

This is a system that sends fresh air through the crankcase to sweep out blow by and fuel vapours. The air then enters the engine where the pollutants from the crankcase have another chance to burn.

During normal engine operation, some combustion gases leak past the piston rings (blow by) and tend to pressurize the crankcase. In addition traces of water appear, and some unburned fuel may reach the crankcase. Without ventilation, all these would have a deteriorating effect on the engine oil and also on mechanical parts. Earlier ventilation systems merely vented the crankcase to the atmosphere, but this contributed to air pollution. Closed crankcase ventilation systems were therefore developed. This type of system is referred to as closed crankcase ventilation or positive crankcase ventilation (PCV). Clean air is drawn in through the filter in the air cleaner, where it mixes with the blow by gases in the crankcase. The gases are then drawn from the crankcase through a flow control valve (PCV valve) into the intake manifold and then to the combustion chambers, where they are burned.

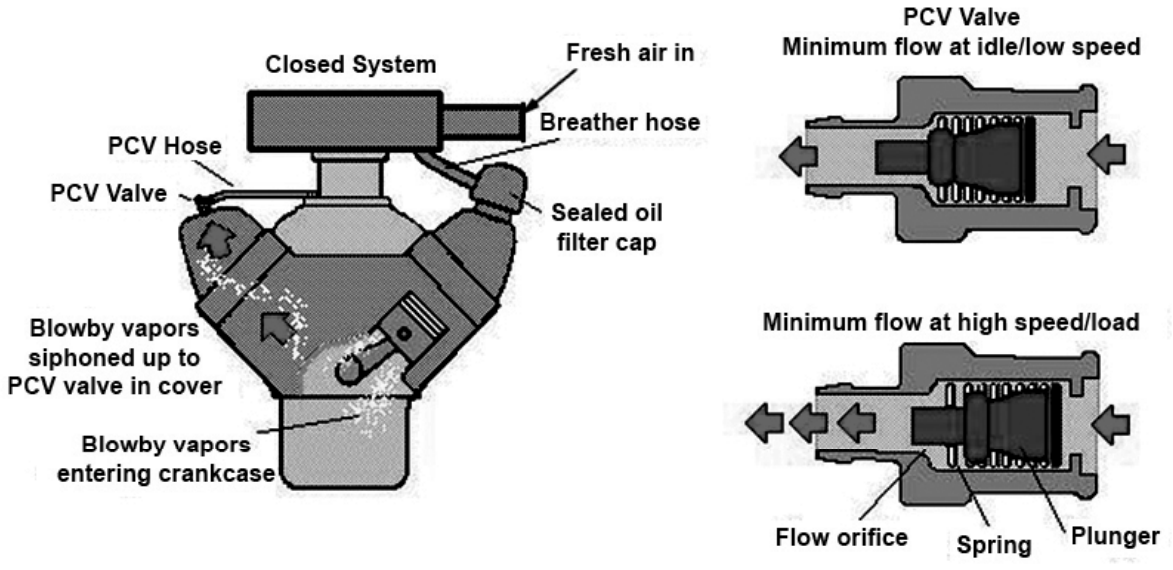


Fig. 6.3.1 Positive Crankcase Ventilation (PCV) System.

❖ Evaporative Emission Control

This is a system that captures any fuel vapours coming from the fuel tank and float bowl. It prevents the vapours from escaping into the atmosphere.

Harmful hydrocarbon (HC) gas is generated in the fuel tank, and must not be discharged into the atmosphere. In some engines, such fuel vapour is stored temporarily in a container when the engine is off and is sent to the combustion chamber to be burned when the engine we turned on again.

The charcoal canister is one such fuel vapour container. It is filled with activated charcoal and charcoal. When the engine is turned on, the gas is sent through the intake manifold to the combustion chamber where it is burned and becomes a harmless exhaust gas.

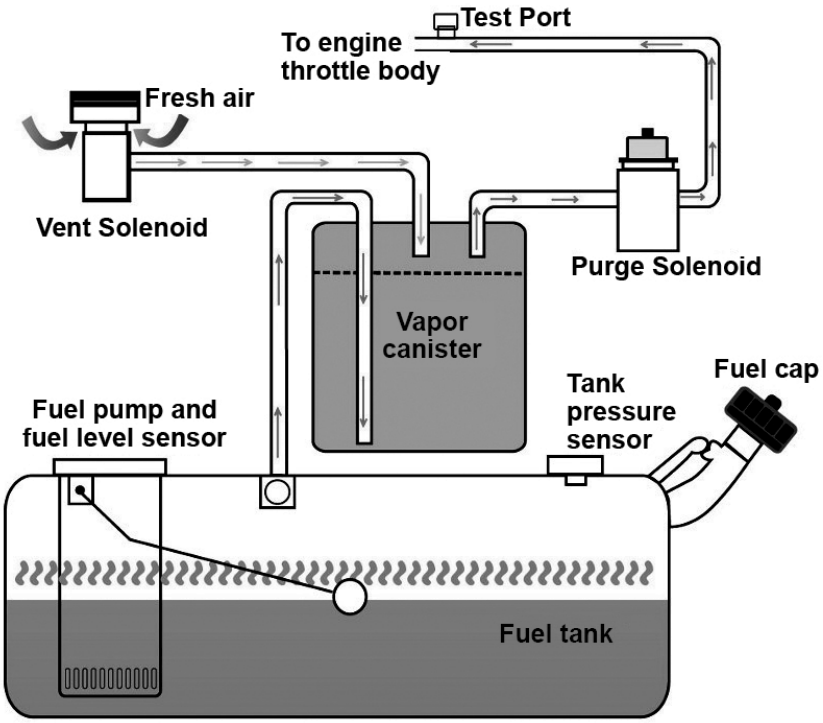


Fig. 6.3.2 Evaporative Emission Control

❖ Exhaust Emission Control

Exhaust emissions can be reduced by following three methods:

i. ***Modification in engine design.*** Minor modification in automobile engine can considerably reduce the CO emissions. Using specially designed carburettors can also maintain low pollution level.

ii. ***Improving fuel quality or using alternative fuels.*** Improving fuel quality can helps to reduce exhaust emission very effective. Using fuel having low head content can reduce emission of lead particulates. Using higher air-fuel ratio can also reduce emission of CO and HC, but it will increase the NOX emission.

Some fuel additives can also be used for improving combustion performance and reducing emission of pollutants. However using alternative fuels like CNG is the best option to reduce pollution. CNG does not contain any harmful substance like nitrogen, lead and sulphur, thus there are no NOX and SOX emission. Further CNG burns completely and does not produce CO and any odour nuisance.

iii. **Treatment of Exhaust gases.** This includes variety of systems such as catalytic converters, air injection system, exhaust gas re-circulation, etc. These works together to reduce the pollutants in the exhaust gas emitted from the tailpipe.

- Air injection (AI) & Air suction (AS) system
- Catalytic Converter: Catalytic converters provide another way to treat the exhaust gas. These devices located in the exhaust system, convert harmful gases into harmless gases. Inside the catalytic converter, the exhaust gases Passover a catalyst. A catalyst is a material that promotes a chemical reaction without being affected by the reaction. In effect, the catalyst encourages chemicals to react with each other.

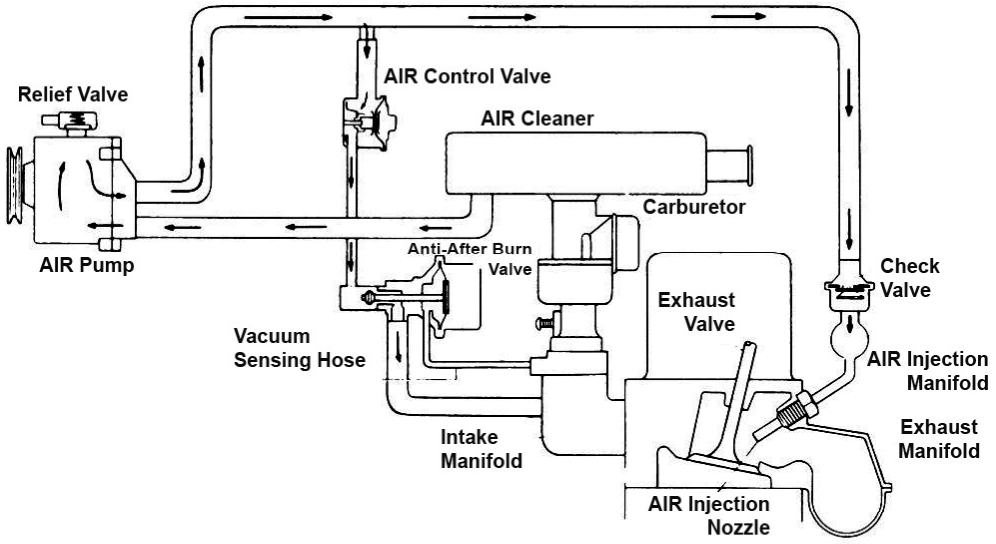


Fig. 6.3.3 Air injection (AI) & Air suction (AS) system

Converter systems with both oxidation and reduction catalysts are called 2 stage or 3-way catalytic converter systems. The three way catalytic converter is the most ideal type of catalytic converter since it can convert not only CO and HC, but also NO_x into non-polluting substances.

Some of the newest converters have even started to use gold mixed with the more traditional catalysts. Gold is cheaper than the other materials and could increase oxidation, the chemical reaction that reduces pollutants, by up to 40 percent.

The oxidizing converter handles HC and CO, using platinum or palladium as the catalysts. The air helps the oxidizing catalyst convert the HC and CO into carbon dioxide and water. The reducing converter handles NO_x using metal rhodium. It splits oxygen from the nitrogen. The NO_x becomes harmless nitrogen (N_2) and Oxygen (O_2)

❖ Trees Plantation

Trees are found to be very helpful in reducing air pollution caused due to automobile. They can absorb most of the CO2 and CO emitted from automobiles.

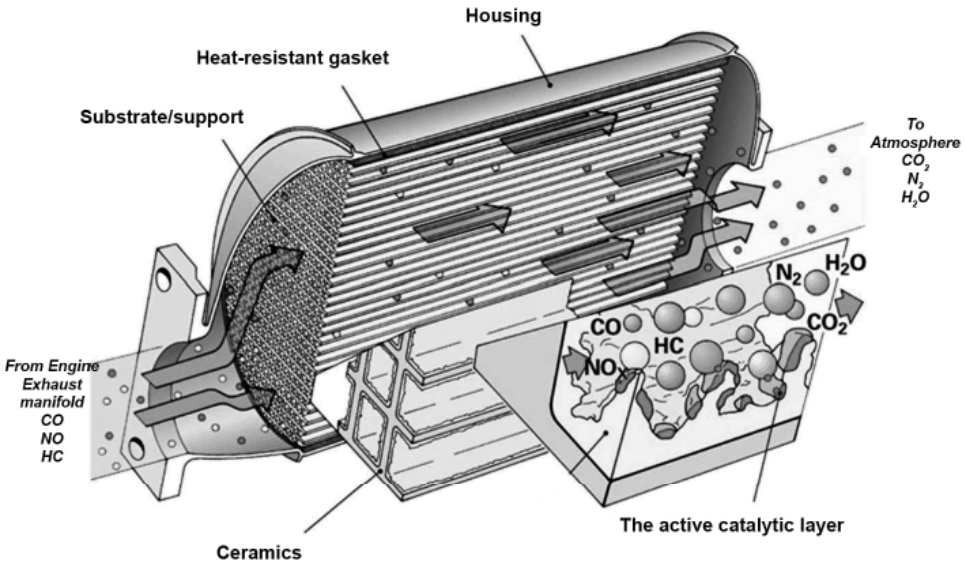


Fig. 6.3.4 Sectional view of Catalytic Converter

❖ Pollution Control by Preventive Maintenance

It is necessary to check the carbon monoxide label in the exhaust. If the vehicles are not maintain properly in due time the CO% may increase in the exhaust. So the preventive maintenance should be carried out in due time.

6.3.5 Emission Norms in India

The Indian Automobile Industry has developed emission norms as Bhart-I, Bhart-II etc. based on Euro-norms. The norms of emission and year of implementation for petrol and diesel vehicles are given in the following tables.

Table 1: Indian Emission Standards (4-Wheel Vehicles)

Standard	Reference	YEAR	Region
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR*, Mumbai, Kolkata, Chennai
		2003.04	NCR*, 13 Cities†
		2005.04	Nationwide
Bharat Stage III	Euro 3	2005.04	NCR*, 13 Cities†

Bharat Stage III	Euro 3	2005.04	NCR*, 13 Cities†
		2010.04	Nationwide
Bharat Stage IV	Euro 4	2010.04	NCR*, 13 Cities†
Bharat Stage V	Euro 5	(to be skipped)	
Bharat Stage VI	Euro 6	2020.04 (proposed)	Entire country
* National Capital Region (Delhi) † Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Sholapur, Jamshedpur and Agra			

The above standards apply to all new 4-wheel vehicles sold and registered in the respective regions. In addition, the National Auto Fuel Policy introduces certain emission requirements for interstate buses with routes originating or terminating in Delhi or the other 10 cities.

Progress of emission standards for 2-and 3-wheelers:

Table 2: Indian Emission Standards (2 and 3 wheelers)

Standard	Reference	Date
Bharat Stage II	Euro 2	1 April 2005
Bharat Stage III	Euro 3	1 April 2010
Bharat Stage IV	Euro 4	1 April 2012
Bharat Stage VI	Euro 6	April 2020 (proposed)

In order to comply with the BSIV norms, 2- and 3-wheeler manufacturers will have to fit an evaporative emission control unit, which should lower the amount of fuel that is evaporated when the motorcycle is parked.

Table 3: Emission Standards for Diesel Truck and Bus Engines, g/kWh

Year	Reference	Test	CO	HC	NO_x	PM
1992	–	ECE R49	17.3–32.6	2.7–3.7	–	–
1996	–	ECE R49	11.20	2.40	14.4	–
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36*
2005†	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010†	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010‡	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03
* 0.612 for engines below 85 kW † earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1						

- **Light-duty diesel vehicles**

Table 4: Emission Standards for Light-Duty Diesel Vehicles, g/km

Year	Reference	CO	HC	HC+NO_x	NO_x	PM
1992	–	17.3–32.6	2.7–3.7	–	–	–
1996	–	5.0–9.0	–	2.0–4.0	–	–
2000	Euro 1	2.72– 6.90	–	0.97– 1.70	0.14– 0.25	–
2005†	Euro 2	1.0–1.5	–	0.7–1.2	0.08–0.17	–
2010†	Euro 3	0.64 0.80 0.95	– –	0.56 0.72 0.86	0.50 0.65 0.78	0.05 0.07 0.10
2010‡	Euro 4	0.50 0.63 0.74	–	0.30 0.39 0.46	0.25 0.33 0.39	0.025 0.04 0.06
† earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1						

Table 5: Emission Standards for Light-Duty Diesel Engines, g/kWh

Year	Reference	CO	HC	NOx	PM
1992	–	14.0	3.5	18.0	–
1996	–	11.20	2.40	14.4	–
2000	Euro I	4.5	1.1	8.0	0.36*
2005†	Euro II	4.0	1.1	7.0	0.15
* 0.612 for engines below 85 kW † earlier introduction in selected regions, see Table 1					

- **Light-duty petrol vehicles**

4-wheel vehicles

Table 6: Emission Standards for Petrol Vehicles (GVW ≤ 3,500 kg), g/kmt

Year	Reference	CO	HC	HC+NO_x	NO_x
1991	–	14.3–27.1	2.0–2.9	–	
1996	–	8.68–12.4	–	3.00–4.36	
1998* 2000	– Euro 1	4.34–6.20 2.72–6.90	– –	1.50–2.18 0.97–1.70	
2005†	Euro 2	2.2–5.0	–	0.5–0.7	

2010†	Euro 3	2.3 4.17 5.22	0.20 0.25 0.29	–	0.15 0.18 0.21
2010‡	Euro 4	1.0 1.81 2.27	0.1 0.13 0.16	–	0.08 0.10 0.11
* for catalytic converter fitted vehicles † earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1					

- **3- and 2-wheel vehicles**

  Emission standards for 3- and 2-wheel petrol vehicles are listed in the following tables.

Table 7: Emission Standards for 3-Wheel Petrol Vehicles, g/km

Year	CO	HC	HC+NOx
1991	12–30	8–12	–
1996	6.75	–	5.40
2000	4.00	–	2.00
2005 (BS II)	2.25	–	2.00
2010.04 (BS III)	1.25	–	1.25

Table 8: Emission Standards for 2-Wheel Petrol Vehicles, g/km

Year	CO	HC	HC+NOx
1991	12–30	8–12	–
1996	5.50	–	3.60
2000	2.00	–	2.00
2005 (BS II)	1.5	–	1.5
Apr.2010 (BS III)	1.0	–	1.0

Table 9: Emission Standards for 2- And 3-Wheel Diesel Vehicles, g/km

Year	CO	HC+NOx	PM
Apr.2005	1.00	0.85	0.10
Apr.2010	0.50	0.50	0.05

Overview of the emission norms in India

- 1991 – Idle CO Limits for Petrol Vehicles and Free Acceleration Smoke for Diesel Vehicles, Mass Emission Norms for Petrol Vehicles.
- 1992 – Mass Emission Norms for Diesel Vehicles.
- 1996 – Revision of Mass Emission Norms for Petrol and Diesel Vehicles, mandatory fitment of Catalytic Converter for Cars in Metros on Unleaded Petrol.
- 1998 – Cold Start Norms Introduced.
- 2000 – India 2000 (Equivalent to Euro I) Norms, Modified IDC (Indian Driving Cycle), Bharat Stage II Norms for Delhi.
- 2001 – Bharat Stage II (Equivalent to Euro II) Norms for All Metros, Emission Norms for CNG & LPG Vehicles.
- 2003 – Bharat Stage II (Equivalent to Euro II) Norms for 13 major cities.
- 2005 – From 1 April Bharat Stage III (Equivalent to Euro III) Norms for 13 major cities.
- 2010 – Bharat Stage III Emission Norms for 2-wheelers, 3-wheelers and 4-wheelers for entire country whereas Bharat Stage – IV (Equivalent to Euro IV) for 13 major cities for only 4-wheelers. Bharat Stage IV also has norms on OBD (similar to Euro III but diluted)
- 2020 – Proposed date for country to adopt Bharat Stage VI norms for cars, skipping Bharat Stage V

QUESTIONS

Very Short Answer Type Questions

1. Emission includes:-

   a) NOx b) SOx

   c) Hydrocarbons d) All of the above

2. _____ reduces the blood's ability to carry oxygen.

   a) Sulphur oxides (SOx) b) Carbon monoxide (CO)

   c) Nitrogen oxides (NOx). d) Hydrocarbons

Short Answer Type Questions

1. What is emission?
2. What do you mean by point sources of emission?
3. What do you mean by area sources of emission?
4. What do you mean by mobile sources of emission?

5. What do you mean by natural sources of emission?
6. What are the advanced technologies or control techniques developed and adopted to control the vehicular pollution?
7. How the pollution is controlled by plantation of trees?
8. How the pollution is controlled by the preventive maintenance of a vehicle?

Short Answer Type Questions

1. Explain any two sources of emission.
2. Explain any two air pollutants.
3. How air pollutants effect the human health?
4. What are the ways to reduce the internal combustion (I.C.) engines pollutions?

Long Answer Type Questions

1. What is emission? Explain the various sources of emission.
2. Explain various types of emission.
3. How the emission in the atmospheric air can be controlled?
4. Explain with diagram the positive crankcase ventilation system of I.C. engine.
5. Explain with diagram the evaporative pollution control of automobile engine.
6. With neat sketch explain the working of catalytic converter used in automobile.

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