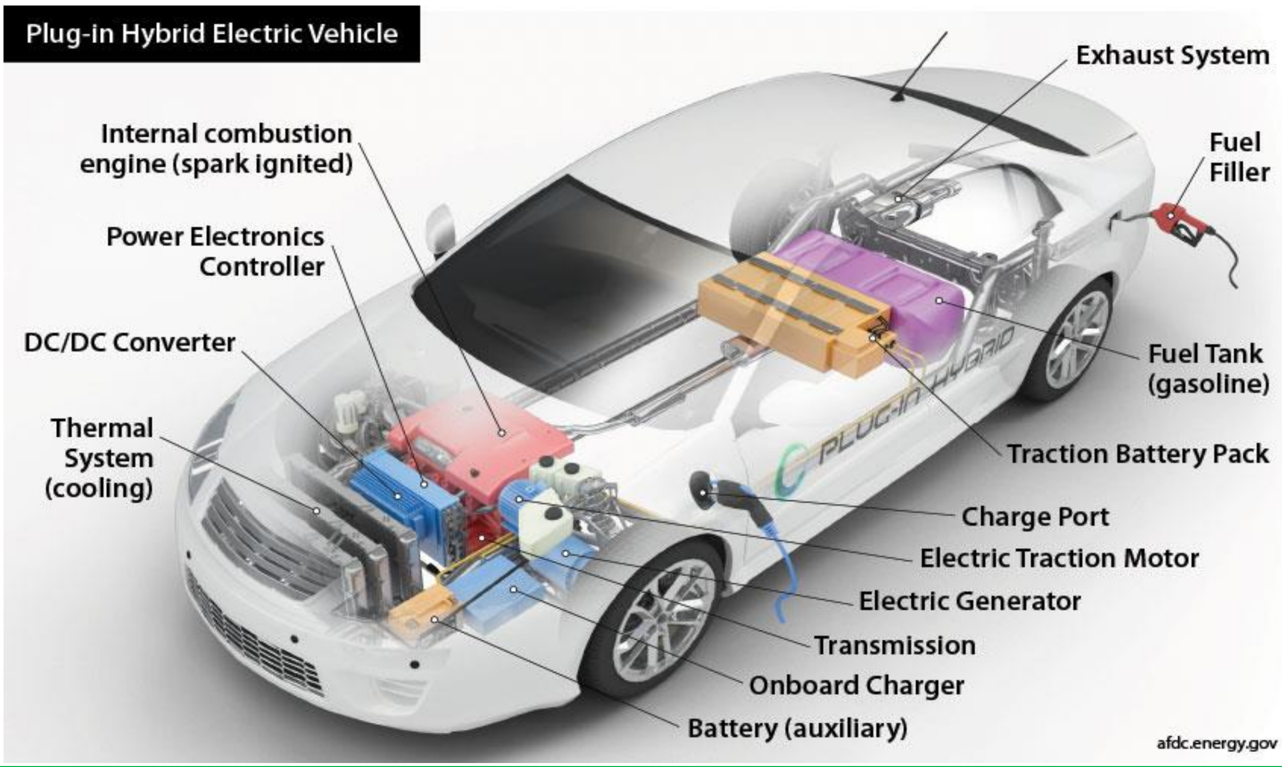
DEPARTMENT OF AUTOMOBILE ENGINEERING

SUBJECT : AUTOMOBILE ELECTRICITY

5th SEMESTER AUTOMOBILE ENGG.



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CH-1
BATTERIES

Types of Batteries

A battery is a collection of one or more cells that go under chemical reactions to create the flow of electrons within a circuit. There is lot of research and advancement going on in battery technology, and as a result, breakthrough technologies are being experienced and used around the world currently. Batteries came into play due to the need to store generated electrical energy. As much as a good amount of energy was being generated, it was important to store the energy so it can be used when generation is down or when there is a need to power standalone devices which cannot be kept tethered to the supply from the mains. Here it should be noted that only DC can be stored in the batteries, AC current can't be stored.

Battery cells are usually made up of three main components;

1. The Anode (Negative Electrode)
2. The Cathode (Positive Electrode)
3. The electrolytes

The anode is a negative electrode that produces electrons to the external circuit to which the battery is connected. When batteries are connected, an electron build-up is initiated at the anode which causes a potential difference between the two electrodes. The electrons naturally then try to redistribute themselves, this is prevented by the electrolyte, so when an electrical circuit is connected, it provides a clear path for the electrons to move from the anode to the cathode thereby powering the circuit to which it is connected. By changing the arrangement and material used to build the Anode, Cathode and Electrolyte we can achieve many different types of battery chemistries enabling us to design different types of battery cells. In this article lets understand the **different types of batteries and their uses**, so let's get started.

Types of Batteries

Batteries generally can be classified into different categories and types, ranging from chemical composition, size, form factor and use cases, but under all of these are two major battery types;

1. Primary Batteries
2. Secondary Batteries

Let's take a deeper look to understand the major differences between a **Primacy cell and Secondary Cell.**

1. Primary Batteries

Primary batteries are batteries that **cannot be recharged** once depleted. Primary batteries are made of electrochemical cells whose electrochemical reaction cannot be reversed.

Primary batteries exist in different forms **ranging from coin cells to AA batteries**. They are commonly used in standalone applications where charging is impractical or impossible. A good example of which is in military grade devices and battery powered equipment. It will be impractical to use rechargeable batteries as recharging a battery will be the last thing in the mind of the soldiers. Primary batteries always have high specific energy and the systems in which they are used are always designed to consume low amount of power to enable the battery last as long as possible.

Primary Batteries

Some other **examples of devices using primary batteries include**; Pace makers, Animal trackers, Wrist watches, remote controls and children toys to mention a few.

The most popular type of primary batteries are **alkaline batteries**. They have a high specific energy and are environmentally friendly, cost-effective and do not leak even when fully discharged. They can be stored for several years, have a good safety record and can be carried on an aircraft without being subject to UN Transport and other regulations. The only downside to alkaline batteries is the low load current, which limits its use to devices with low current requirements like remote controls, flashlights and portable entertainment devices.

2. Secondary Batteries

Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction. Also referred to as **rechargeable batteries**, secondary cells unlike primary cells can be recharged after the energy on the battery has been used up.

They are typically used in high drain applications and other scenarios where it will be either too expensive or impracticable to use single charge batteries. Small capacity secondary batteries are used to power portable electronic devices like **mobile phones**, and other gadgets and appliances while heavy-duty batteries are used in powering diverse **electric vehicles** and other high drain applications like load levelling in electricity generation. They are also used as standalone power sources alongside **Inverters to supply electricity**. Although the initial cost of acquiring rechargeable batteries is always a whole lot higher than that of primary batteries but they are the most cost-effective over the long-term.

Secondary batteries can be further classified into several other types based on their chemistry**.** This is very important because the chemistry determines some of the attributes of the battery including its specific energy, cycle life, shelf life, and price to mention a few.

The following are the **different types of rechargeable batteries** that are commonly used.

1. Lithium-ion(Li-ion)
2. Nickel Cadmium(Ni-Cd)
3. Nickel-Metal Hydride(Ni-MH)
4. Lead-Acid

1. Nickel-Cadmium Batteries

The nickel–cadmium battery (NiCd battery or NiCad battery) is a type of rechargeable battery which is developed using nickel oxide hydroxide and metallic cadmium as electrodes. Ni-Cd batteries excel at maintaining voltage and holding charge when not in use. However, NI-Cd batteries easily fall a victim of the dreaded "memory" effect when a partially charged battery is recharged, lowering the future capacity of the battery.

Nickel – Cadmium battery

In comparison with other types of rechargeable cells, Ni-Cd batteries offer good life cycle and performance at low temperatures with a fair capacity but their most significant advantage will be their ability to deliver their full rated capacity at high discharge rates. They are available in different sizes including the sizes used for alkaline batteries, AAA to D. Ni-Cd cells are used individual or assembled in packs of two or more cells. The small packs are used in portable devices, electronics and toys while the bigger ones find application in aircraft starting batteries, Electric vehicles and standby power supply.

Some of the properties of Nickel-Cadmium batteries are listed below.

- Specific Energy: 40-60W-h/kg
- Energy Density: 50-150 W-h/L
- Specific Power: 150W/kg
- Charge/discharge efficiency: 70-90%
- Self-discharge rate: 10%/month
- Cycle durability/life: 2000cycles

2. Nickel-Metal Hydride Batteries

Nickel metal hydride (Ni-MH) is another type of chemical configuration used for rechargeable batteries. The chemical reaction at the positive electrode of batteries is similar to that of the nickel–cadmium cell (NiCd), with both battery type using the same nickel oxide hydroxide (NiOOH). However, the negative electrodes in Nickel-Metal Hydride use a hydrogen-absorbing alloy instead of cadmium which is used in NiCd batteries

. Ni-MH Battery

NiMH batteries find application in high drain devices because of their high capacity and energy density. A NiMH battery can possess two to three times the capacity of a NiCd battery of the same size, and its energy density can approach that of a lithium-ion battery. Unlike the NiCd chemistry, batteries based on the **NiMH chemistry are not susceptible to the "memory"** effect that NiCads experience.

Below are some of the properties of batteries based on the Nickel-metal hydride chemistry;

- Specific Energy: 60-120h/kg
- Energy Density: 140-300 Wh/L
- Specific Power: 250-1000 W/kg
- Charge/discharge efficiency: 66% - 92%
- Self-discharge rate: 1.3-2.9%/month at 20ºC
- Cycle Durability/life: 180 -2000

3. Lithium-ion Batteries

Lithium-ion batteries are one of the most popular types of rechargeable batteries. There are many **different types of Lithium batteries**, but among all the lithium-ion batteries are the most commonly used. You can find these lithium batteries being used in different forms popularly among electric vehicles and other portable gadgets. If you are curious to know more about batteries used in Electric vehicles, you can check out this article on Electric Vehicle Batteries. They are found in different portable appliances including mobile phones, smart devices and several other battery appliances used at home. They also find applications in aerospace and military applications due to their lightweight nature.

Lithium-Ion Battery

Lithium-ion batteries are a type of rechargeable battery in which lithium ions from the negative electrode migrate to the positive electrode during discharge and migrate back to the negative electrode when the battery is being charged. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in non-rechargeable lithium batteries.

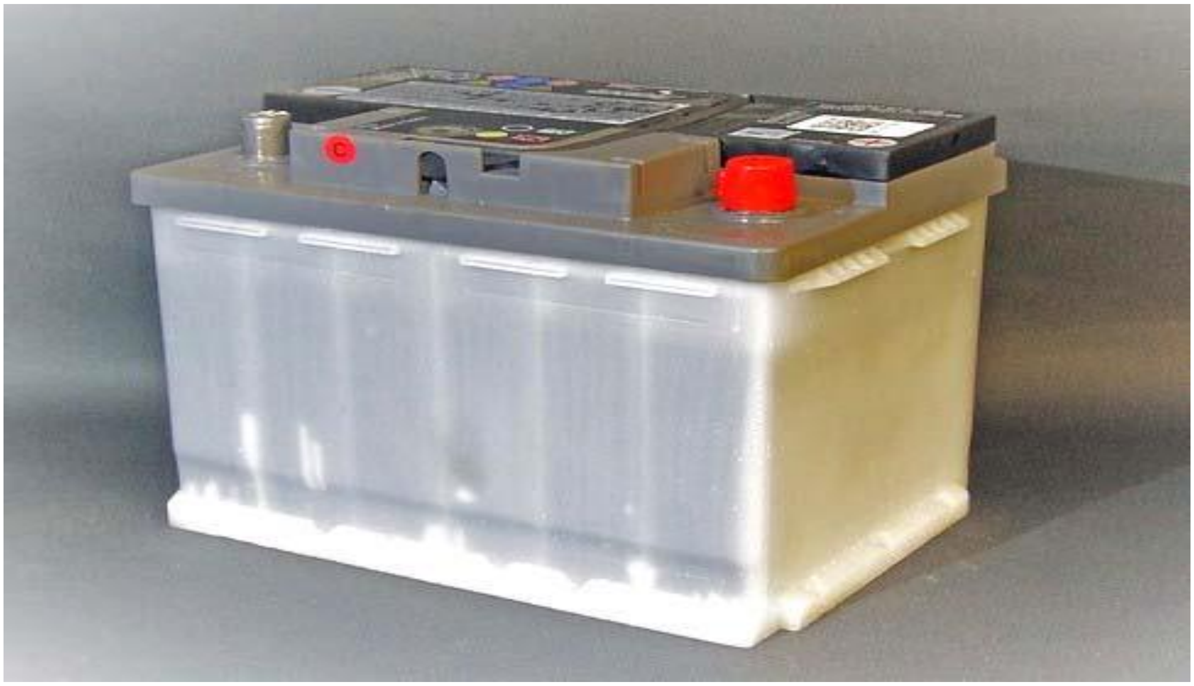
Lithium-ion batteries generally possess high energy density, little or no memory effect and low self-discharge compared to other battery types. Their chemistry alongside performance and cost vary across different use cases, for example, Li-ion batteries used in handheld electronic devices are usually based on lithium cobalt oxide ($LiCoO_2$) which provides high energy density and low safety risks when damaged while Li-ion batteries based on Lithium iron phosphate which offer a lower energy density are safer due to a reduced likelihood of unfortunate events happening are widely used in powering electric tools and medical equipment. Lithium-ion batteries offer the best performance to weight ratio with the lithium sulphur battery offering the highest ratio.

Some of the attributes of lithium-ion batteries are listed below;

- Specific Energy: 100: 265W-h/kg
- Energy Density: 250: 693 W-h/L
- Specific Power: 250: 340 W/kg
- Charge/discharge percentage: 80-90%
- Cycle Durability: 400: 1200 cycles
- Nominal cell voltage: NMC 3.6/3.85V

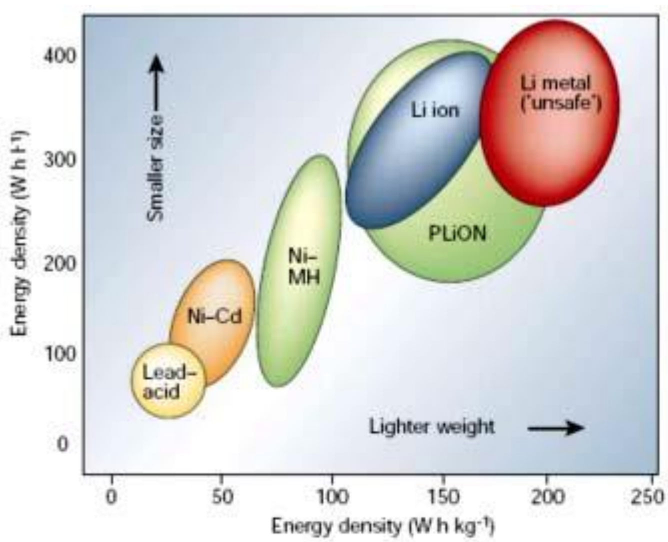
4. Lead-Acid Batteries

Lead-acid batteries are a low-cost reliable power workhorse used in heavy-duty applications. They are usually very large and because of their weight, they're always used in non-portable applications such as solar-panel energy storage, vehicle ignition and lights, backup power and load levelling in power generation/distribution. The lead-acid is the oldest type of rechargeable battery and still very relevant and important into today's world. Lead-acid batteries have very low energy to volume and energy to weight ratios but it has a relatively large power to weight ratio and as a result, can supply huge surge currents when needed. These attributes alongside its low cost make these batteries attractive for use in several high current applications like powering automobile starter motors and for storage in backup power supplies. You can also check out the article on Lead Acid Battery working if you want to know more about the different types of Lead-acid batteries, its construction and applications.



Lead Acid Batteries

Each of these batteries has its area of best fit and the image below is to help choose between them.



Selecting the right battery for your application

One of the main problems hindering technology revolutions like IoT is power, battery life affects the successful deployment of devices that require long battery life and even though several power management techniques are being adopted to make the battery last longer, a compatible battery must still be selected to achieve the desired outcome.

Below are some factors to consider when selecting the right type of battery for your project.

1. **Energy Density:** The energy density is the total amount of energy that can be stored per unit mass or volume. This determines how long your device stays on before it needs a recharge.

2. Power Density: Maximum rate of energy discharge per unit mass or volume. Low power: laptop, i-pod. High power: power tools.

3. Safety: It is important to consider the temperature at which the device you are building will work. At high temperatures, certain battery components will breakdown and can undergo exothermic reactions. High temperatures generally reduces the performance of most batteries.

4. Life cycle durability: The stability of energy density and power density of a battery with repeated cycling (charging and discharging) is needed for the long battery life required by most applications.

5. Cost: Cost is an important part of any engineering decisions you will be making. It is important that the cost of your battery choice is commensurate with its performance and will not increase the overall cost of the project abnormally.

Lead Acid Battery: Working, Construction and Charging/Discharging

Almost every portable and handheld device consist a battery. The battery is a storage device where energy is stored to provide the power whenever needed. There are different types of batteries available in this modern electronics world, among them Lead Acid battery is commonly used for high power supply. Usually Lead Acid batteries are bigger in size with hard and heavy construction, they can store high amount of energy and generally used in automobiles and inverters.

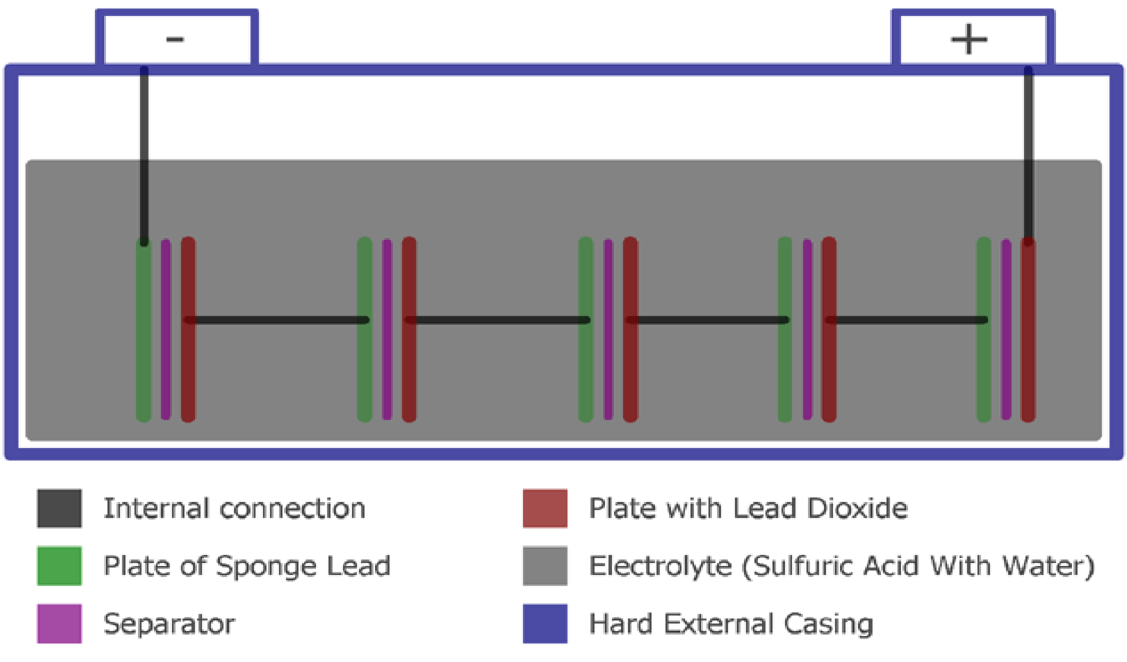
Even after getting competition with Li-ion batteries, Lead acid batteries demand is increasing day by day, because they are cheaper and easy-to-handle in comparison with Li-ion batteries. As per some market research India Lead Acid Battery Market is projected to grow at CAGR of over 9% during 2018-24. So, it has huge market demand in Automation, Automotive, and Consumer Electronics. Altough most of the Electric vehicle comes with Lithion-ion batteries, but still there are many electric two wheeler which use Lead Acid battries to power the vehicle.In previous tutorial we learned about Lithium-ion batteries, here we will understand the Working, construction and applications of Lead Acid Batteries. We will also learn about charging/discharging ratings, requirements and safety of Lead Acid Batteries.

Construction of Lead Acid Battery

What is a Lead Acid Battery? If we break the name Lead Acid battery we will get Lead, Acid, and Battery. Lead is a chemical element (symbol is Pb and the atomic number is 82). It is a soft and malleable element. We know what Acid is; it can donate a proton or accept an electron pair when it is reacting. So, a battery, which consists of Lead and anhydrous plumbic acid (sometimes wrongly called as lead peroxide), is called as Lead Acid Battery.

Now, what is the internal construction?

A Lead Acid Battery consists of the following things, we can see it in the below image:



A Lead Acid Battery consists of Plates, Separator, and Electrolyte, Hard Plastic with a hard rubber case.

In the batteries, the plates are of two types, positive and negative. The positive one consists of Lead dioxide and negative one consists of Sponge Lead. These two plates are separated using a separator which is an insulating material. This total construction is kept in a hard plastic case with an electrolyte. The electrolyte is water and sulfuric acid.

The hard plastic case is one cell. A single cell store typically 2.1V. Due to this reason, A 12V lead acid battery consists of 6 cells and provide 6 x 2.1V/Cell = 12.6V typically.

Now, what is the charge storage capacity?

It is highly dependable on the active material (Electrolyte quantity) and the plate's size. You may have seen that lithium battery storage capacity is described in mAh or milliamp-hour rating, but in the case of Lead Acid battery, it is Amp hour. We will describe this in later section.

Working of Lead Acid Battery

Working of the Lead Acid battery is all about chemistry and it is very interesting to know about it. There are huge chemical process is involved in Lead Acid battery's charging and discharging condition. The diluted sulfuric acid H_2SO_4 molecules break into two parts when the acid dissolves. It will create positive ions 2H+ and negative ions SO_4-. As we told before, two electrodes are connected as plates, Anode and Cathode. Anode catches the negative ions and cathode attracts the positive ions. This bonding in Anode and SO_4- and Cathode with 2H+ interchange electrons and which is further react with the H2O or with the water (Diluted sulfuric acid, Sulfuric Acid + Water).

The battery has two states of chemical reaction, Charging and Discharging.

Lead Acid Battery Charging

As we know, to charge a battery, we need to provide a voltage greater than the terminal voltage. So to charge a 12.6V battery, 13V can be applied.

But what actually happen when we charge a Lead Acid Battery?

Well, the same chemical reactions which we described before. Specifically, when the battery is connected with the charger, the sulfuric acid molecules break into two ions, positive ions 2H+ and negative ions SO_4-. The hydrogen exchange electrons with the cathode and become hydrogen, this hydrogen reacts with the $PbSO_4$ in cathode and form Sulfuric Acid (H_2SO_4) and Lead (Pb). On the other hand, SO_4- exchange electrons with anode and become radical SO_4. This SO_4 reacts with $PbSO_4$ of anode and create the lead peroxide PbO_2 and sulfuric acid (H_2SO_4). The energy gets stored by increasing the gravity of sulfuric acid and increasing the cell potential voltage.

As explained above, following chemical reactions takes place at Anode and Cathode during the charging process.

At cathode

$$PbSO_4 + 2e^- \Rightarrow Pb + SO_4^{2-}$$

At anode

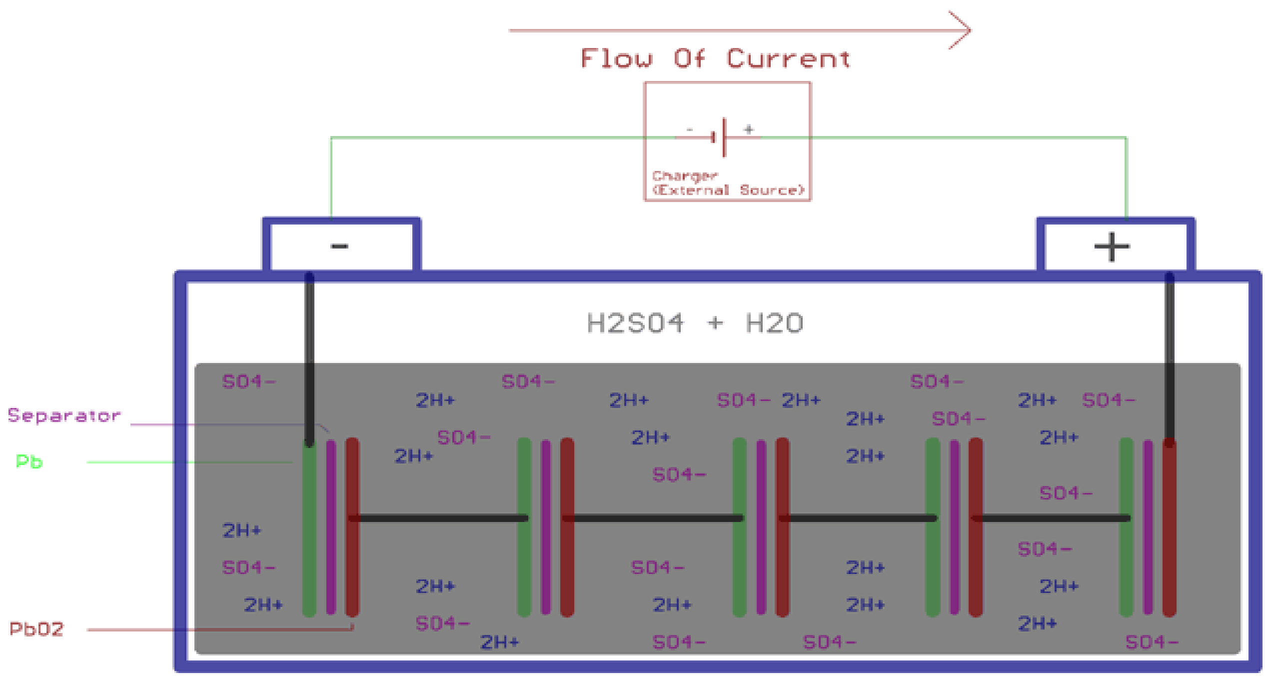
$$PbSO_4 + 2H_2O \Rightarrow PbO_2 + SO_4^{2-} + 4H^- + 2e^-$$

Combining above two equation, the overall chemical reaction will be

$$2PbSO_4 + 2H_2O \Rightarrow PbO_2 + Pb + 2H_2SO_4$$

There are various methods applicable for charging the lead-acid battery. Each method can be used for specific lead-acid battery for specific applications. Some application uses constant voltage charging method, some application uses a constant current method, whereas tickle charging also useful in some cases. Normally battery manufacturer provides the proper method of charging the specific lead-acid batteries. Constant current charging is not typically used in Lead Acid Battery charging.

Most common charging method used in lead acid battery is constant voltage charging method which is an effective process in terms of charging time. In full charge cycle the charge voltage remains constant and the current gradually decreased with the increase of battery charge level.



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Lead Acid Battery Discharging

Discharging of a lead acid battery is again involved with chemical reactions. The sulfuric acid is in the diluted form with typically 3:1 ratio with water and sulfuric acid. When the loads are connected across the plates, the sulfuric acid again breaks into positive ions 2H+ and negative ions SO_4. The hydrogen ions react with the PbO_2 and make PbO and water H_2O. PbO start reacting with the H_2SO_4 and creates $PbSO_4$ and H_2O.

On the other side SO_4- ions exchange electrons from Pb, creating radical SO_4 which further creates $PbSO_4$ reacting with the Pb.

As explained above, following chemical reactions takes place at Anode and Cathode during the discharging process. These reaction are exactly opposite of charging reactions:

At cathode

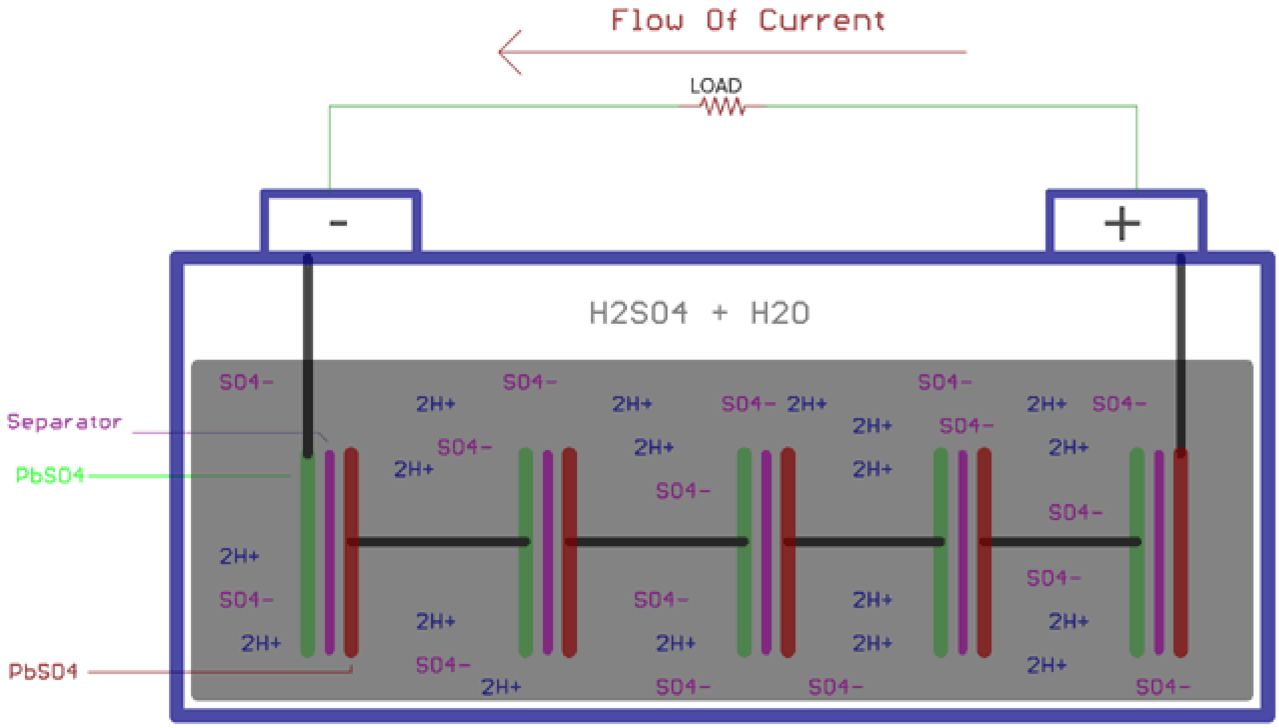
$$Pb + SO_4^{2-} => PbSO_4 + 2e^-$$

At anode:

$$PbO_2 + SO_4^{2-} + 4H^- + 2e^- => PbSO_4 + 2H_2O$$

Combining above two equation, the overall chemical reaction will be

$$PbO_2 + Pb + 2H_2SO_4 => 2PbSO_4 + 2H_2O$$



Due to the electron exchange across anode and cathode, electron balance across the plates is affected. The electrons then flow through the load and the battery gets discharged.

During this discharge, the diluted sulfuric acid gravity decrease. Also, at the same time, the potential difference of the cell decrease.

<u>Risk Factor and Electrical Ratings</u>

The Lead Acid battery is harmful if not maintained safely. As the battery generates Hydrogen gas during the chemical process, it is highly dangerous if not used in the ventilated area. Also, inaccurate charging severely damages the battery.

What are the standard ratings of Lead Acid battery?

Every lead-acid battery is provided with datasheet for standard charge current and discharges current. Typically a 12V lead-acid battery which is applicable for the automotive application could be ranged from 100Ah to 350Ah. This rating is defined as the discharge rating with an 8 hour timing period.

For example, a 160Ah battery could provide 20A of supply current to the load for 8 hours of the span. We can draw more current but it is not advisable to do so. By drawing more current than the maximum discharge current in respect of 8 hours will damage the battery efficiency and the battery internal resistance could also be changed, which further increases the battery temperature.

On the other hand, during the charging phase, we should be careful about the charger polarity, it should be properly connected with the battery polarity. Reverse polarity is dangerous for the lead-acid battery charging. The readymade charger comes with a charging voltage and charging current meter with a control option. We should provide greater voltage than the battery voltage to charge the battery. Maximum charge current should be the same as the maximum supply current at 8 hours discharging rates. If we take the same 12V 160Ah example, then the maximum supply current is 20A, so the maximum safe charging current is the 20A.

We should not increase or provide large charging current as this will result in heat and increased gas generation.

Lead-acid battery maintenance rules

1. Watering is the most neglected maintenance feature of flooded lead-acid batteries. As overcharging decreases water, we need to check it frequently. Less water creates oxidation in plates and decreases the lifespan of the battery. Add distilled or ionized water when needed.
2. Check for the vents, they need to be perfected with rubber caps, often the rubber caps sticks with the holes too tightly.
3. Recharge lead-acid batteries after each use. A long period without recharging provides sulfating in the plates.
4. Do not freeze the battery or charge it more than 49-degree centigrade. In cold ambient batteries need to be fully charged as fully charge batteries safer than the empty batteries in respect of freezing.
5. Do not deep discharge the battery less than 1.7V per cell.
6. To store a lead acid battery, it needs to be completely charged then the electrolyte needs to be drained. Then the battery will become dry and can be stored for a long time period.

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CH-2

STARTING SYSTEM

The starting system:

The starting system includes the battery, starter motor, solenoid, ignition switch and in some cases, a starter relay. An inhibitor or a neutral safety switch is included in the starting system circuit to prevent the vehicle from being started while in gear.

When the ignition key is turned to the **start** position, current flows and energizes the starter's solenoid coil. The energized coil becomes an electromagnet which pulls the plunger into the coil. The plunger closes a set of contacts which allow high current to reach the starter motor.

The charging system:

The charging system consists of an alternator (generator), drive belt, battery, voltage regulator and the associated wiring. The charging system, like the starting system is a series circuit with the battery wired in parallel. After the engine is started and running, the alternator takes over as the source of power and the battery then becomes part of the load on the charging system.

The alternator, which is driven by the belt, consists of a rotating coil of laminated wire called the rotor. Surrounding the rotor are more coils of laminated wire that remain stationary (called stator) just inside the alternator case. When current is passed through the rotor via the slip rings and brushes, the rotor becomes a rotating magnet having a magnetic field. When a magnetic field passes through a conductor (the stator), alternating current (A/C) is generated

This A/C current is rectified, turned into direct current (D/C), by the diodes located within the alternator.

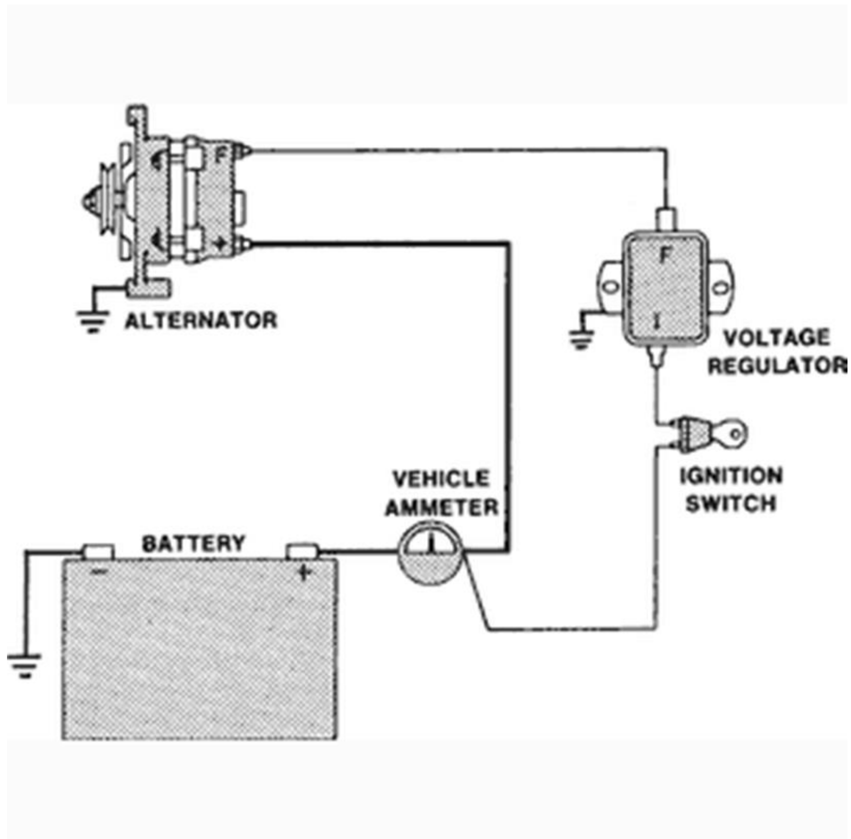


Fig 2.1: Common Charging system schematic diagram.

1. Condition at starting:

The starting torque should be very high and the speed should be very low while starting the starter motor of a automobile.

2. Behavior of starter during starting.

The starter motor is a dc series motor which has the high starting torque characteristics.

3(a) DC machines:

D.C. machines are electro mechanical energy converters which work from a d.c. source and generate mechanical power (called as motor) or convert mechanical power into a d.c. power(called as generator).

DC Motor:

A motor is an electrical machine which converts electrical energy into mechanical energy.

Principle of DC Motor:

Whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. The direction of this force is given by Fleming's left hand rule and it's magnitude is given by F = BIL. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.

Fleming's left hand rule:

Stretch the fore finger, middle finger and thumb of left hand to be perpendicular to each other, the direction of magnetic field is represented by the fore finger, direction of the current is represented by middle finger then the thumb represents the direction of the force experienced by the current carrying conductor.

Types Of DC Motors:

DC motors are usually classified of the basis of their excitation configuration, as given below.

- Separately excited (field winding is fed by external source)
- Self excited -

- Series wound (The field winding is connected in series with armature winding)
- Shunt wound (The field winding is connected in parallel with armature wdg)
- Compound wound -
    - Long shunt
    - Short shunt

The Classification chart of DC machine is given in fig.2.2

DC Machine

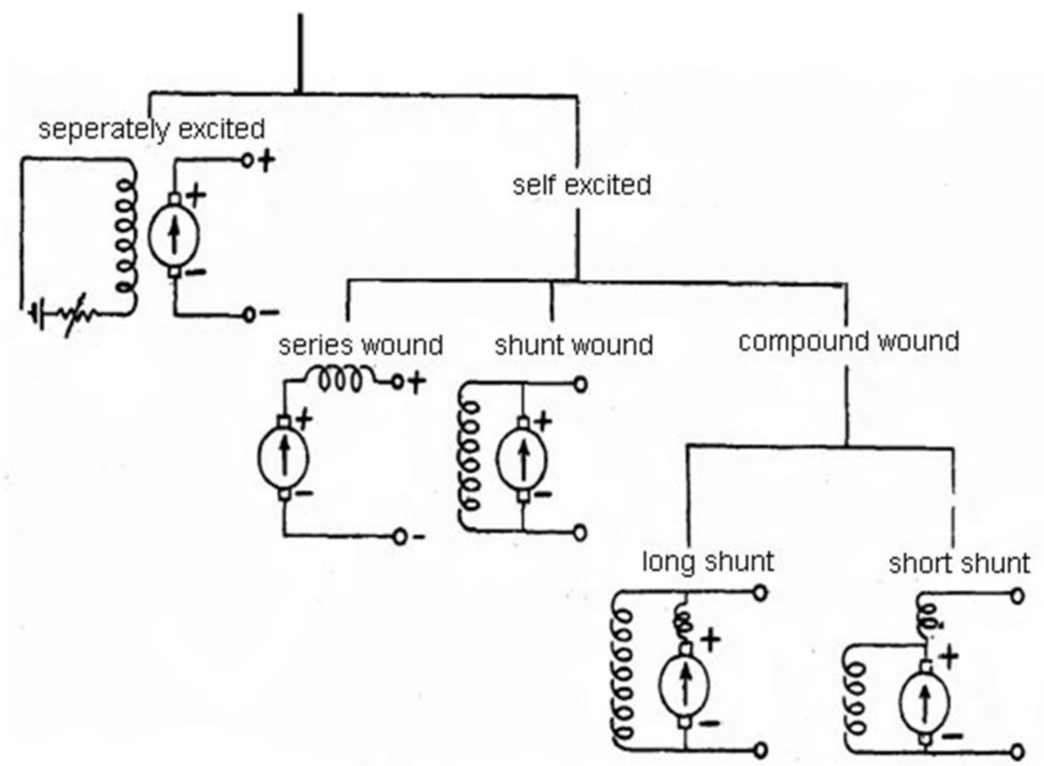


Fig 2.2 Dc machine classifications

DC Generator:

A dc generator is an electrical machine which converts mechanical energy into direct current electricity. This energy conversion is based on the principle of production of dynamically induced emf.

Construction Of A DC Machine:

A DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Hence a DC generator/DC motor can be termed as a **DC machine**. The basic constructional details are valid for both of them.

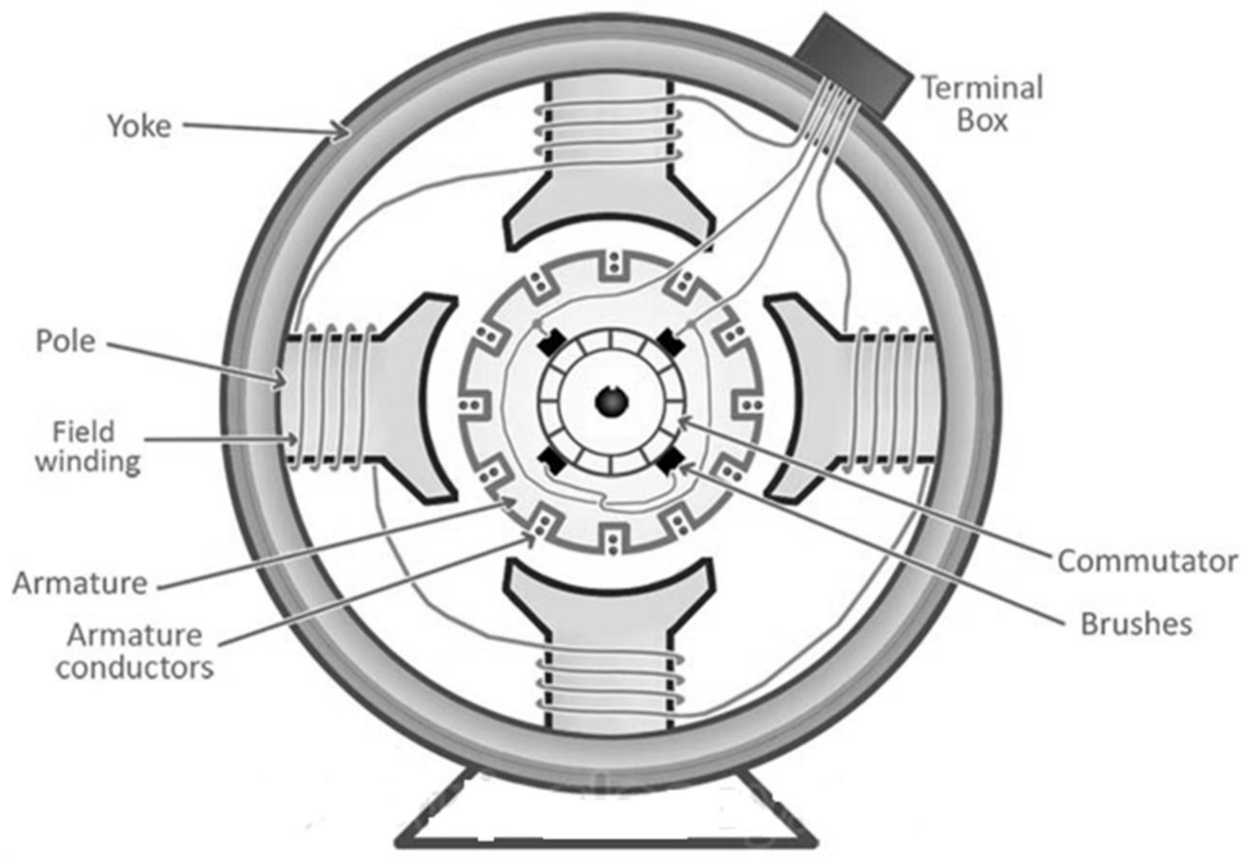


Fig.2.3 Construction of a simple 4-pole DC machine.

The above figure shows the constructional details of a simple 4-pole DC machine. A dc machine(motor/generator) consists of two basic parts named as stator and rotor.

The basic constructional parts of a DC machine are briefed below.

1. **Poles and pole shoes:** Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.
2. **Field winding:** They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.

Fig 2.4 Armature core and winding coil (rotor)

3. **Armature core:** Armature core is the rotor of the machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.
4. **Armature winding:** It is usually a former wound copper coil which rests in armature slots.

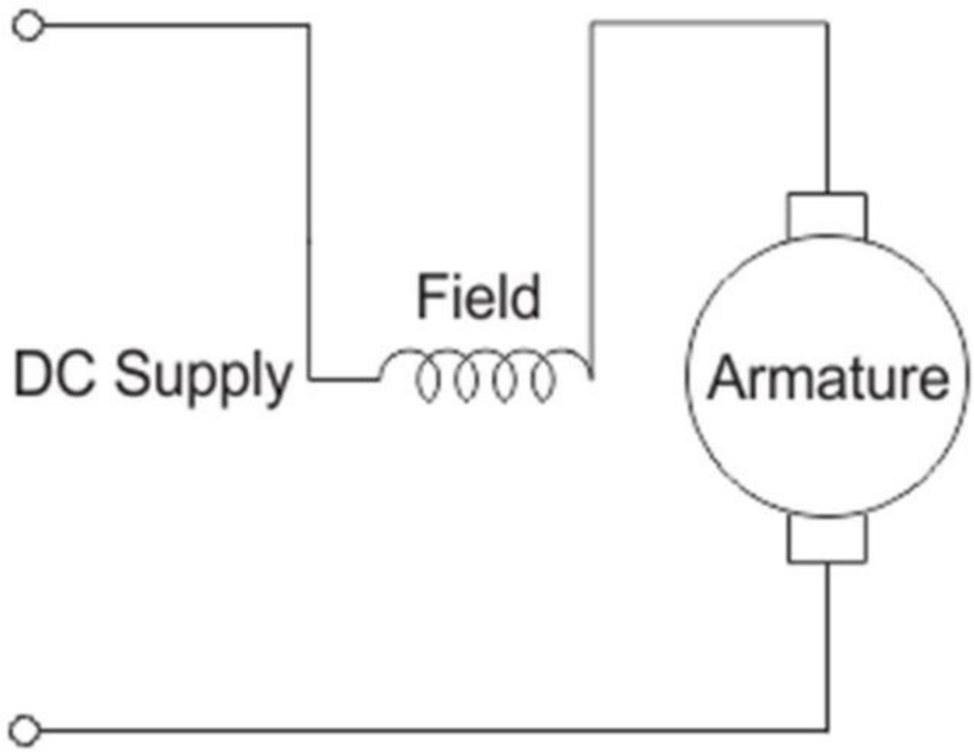
   The armature conductors are insulated from each other and also from the armature core. Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.

5. **Commutator and brushes:** Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors. A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

Commutator consists of radial copper bars separated by an insulating material, usually mica. The number of coils in the armature, the number of poles, and the type of winding determine the number of commutator bars

3(b).Series motor and its characteristics:

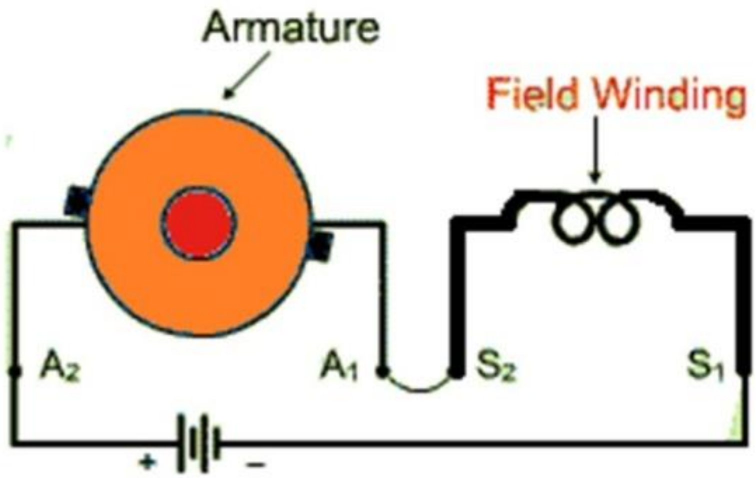
This motor has field coil connected in series to the armature winding.



Series Excited DC Motor

For this reason relatively higher current flows through the field coils, it is designed accordingly as mentioned below.

1. The field coils of DC series motor are wound with relatively fewer turns as the current through the field is its armature current and hence for required mmf less numbers of turns are required.
2.



Field winding with thicker diameter & fewer turns.

3. The wire is heavier, as the diameter is considerable increased to provide minimum electrical resistance to the flow of full armature current.
4. In spite of the above mentioned differences, about having fewer coil turns the running of this DC motor remains unaffected, as the current through the field is reasonably high to produce a field strong enough for generating the required amount of torque.

Torque Vs. Armature Current (T_a-I_a):

This characteristic is also known as **electrical characteristic**. We know that torque is directly proportional to the product of armature current and field flux, $T_a \propto \phi . I_a$.

In DC series motors, field winding is connected in series with the armature, i.e. $I_a = I_f$. Therefore, before magnetic saturation of the field, flux ϕ is directly proportional to Ia. Hence, before magnetic saturation Ta α Ia^2. Therefore, the Ta-Ia curve is parabola for smaller values of Ia.

After magnetic saturation of the field poles, flux ϕ is independent of armature current Ia. Therefore, the torque varies proportionally to Ia only, T ∝ Ia.Therefore, after magnetic saturation, Ta-Ia curve becomes a straight line.
The shaft torque (Tsh) is less than armature torque (Ta) due to stray losses. Hence, the curve Tsh vs Ia lies slightly lower.
I n DC series motors, (prior to magnetic saturation) torque increases as the square of armature current, these motors are used where high starting torque is required.

Speed Vs. Armature Current (N-Ia)

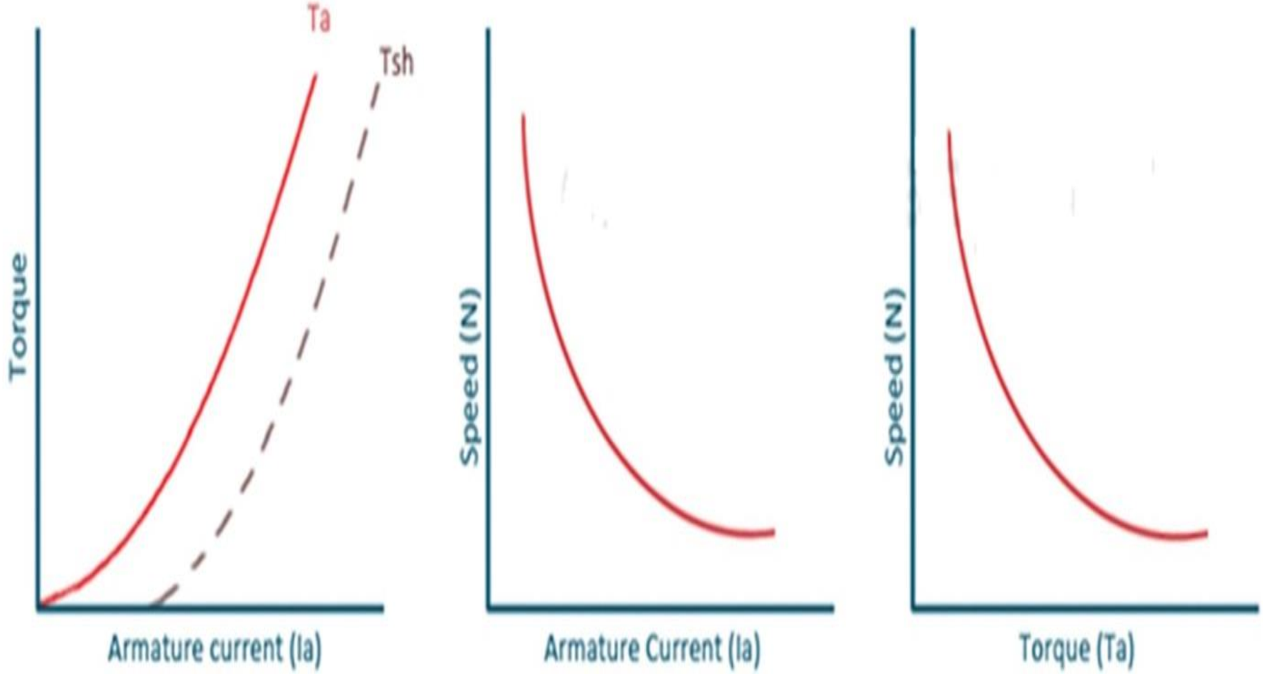
As per the relation, $N \propto E_b/\phi$

For small load current (and hence for small armature current) change in back emf Eb is small and it may be neglected. Hence, for small currents speed is inversely proportional to ϕ. As we know, flux is directly proportional to Ia, speed is inversely proportional to Ia. Therefore, when armature current is very small the speed becomes dangerously high. Hence a series motor should never be started at no load.

But, at heavy loads, armature current Ia is large and hence the speed is low which results in decreased back emf Eb. Due to decreased Eb, more armature current is allowed.

Speed Vs. Torque (N-Ta)

This characteristic is also called as **mechanical characteristic**. From the below two **characteristics of DC series motor**, it can be found that when speed is high, torque is low and vice versa.



Ref: http://what-when-how.com/automobile/starter-motor-construction-automobile/

4. Principle & construction of starter motor.

The starter motor or Self Starter or Self Motor is used to crank the engine for starting. It utilizes the electrical energy stored in the battery and converts into mechanical energy. It is a powerful electric motor with a small gear type arrangement (pinion) attached to the end. When it gets activated, the gear is meshed with a larger gear (ring) that is attached to the engine. The starter motor then spins the engine over so that the piston can absorb in a fuel/ air mixture, which is then ignited to start the engine. When the engine starts to spin faster than starter, a device called an overrunning clutch (Bendix drive) automatically disengages the starter gear from the engine gear.

Working of different starter drive units:

There are four different main types of starter drives generally in use. They are given below.

1. The inertia drive (shock drive)
2. The pre–engaged drive
3. The single stage sliding gear drive and
4. The sliding armature drive.

STARTER TYPES ARE THREE "with light vehicles only." there are some other starter motors but for the heavy duties like bulldozer.

1. INERTIA.
2. PRE-ENGAGED.
3. GEAR REDUCTION.

1) INERTIA

Magnetic-torque Production

When the current flows through the yoke field windings, it converts the yoke into an electromagnet due to which a magnetic field or flux is created between the pole-pieces (Fig. 15.15). Similarly, due to the flow of current through the armature loop, concentric rings of magnetic flux are established around the two half-conductor cores. This magnetic flux flows anticlockwise around the left-hand conductor and clockwise around the right-hand conductor. It can be seen from the figure that the magnetic lines of force between the yoke poles and those for the armature conductors travel in the same direction, and the two sets of lines merge and strengthen each other. This is indicated below the left-hand conductor and above the right-hand conductor. Conversely, where the yoke and armature magnetic fields travel in opposite directions, they neutralise each other. Hence, the field strength above the left-hand conductor and below the right-hand conductor is very weak. The difference in the magnetic field strengths above and below each conductor gives rise to a net upward force, exerted on the left-hand conductor and a net downward force, on the right-hand conductor so that a clockwise-rotating torque is applied to the armature loop.

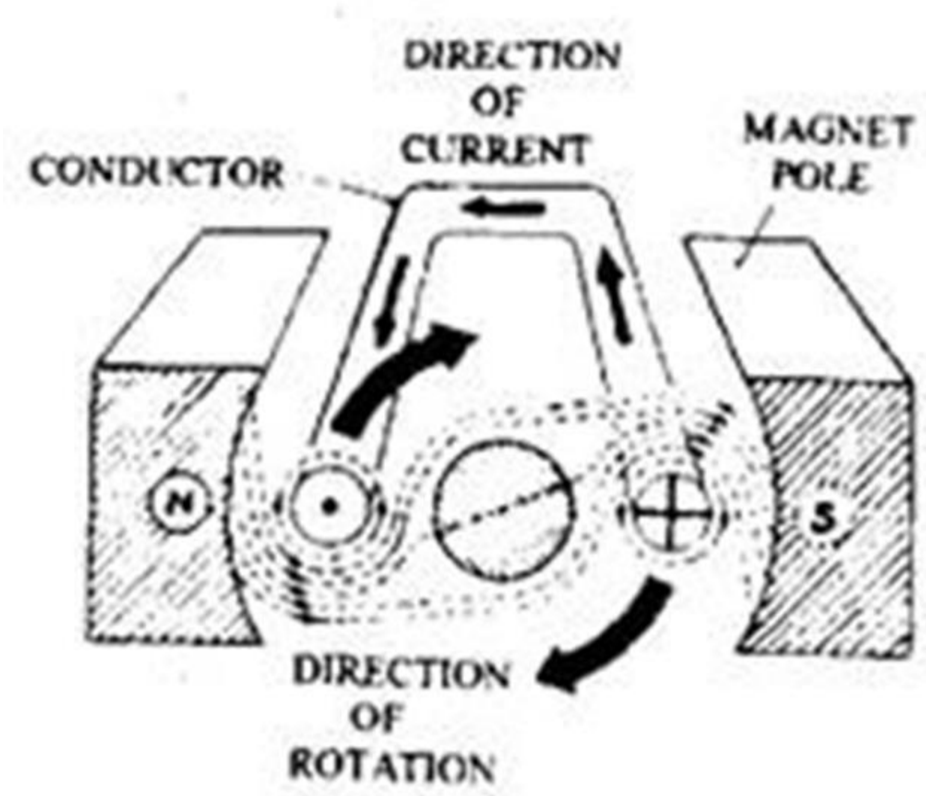


Fig. 15.15. Production of a magnetic torque.

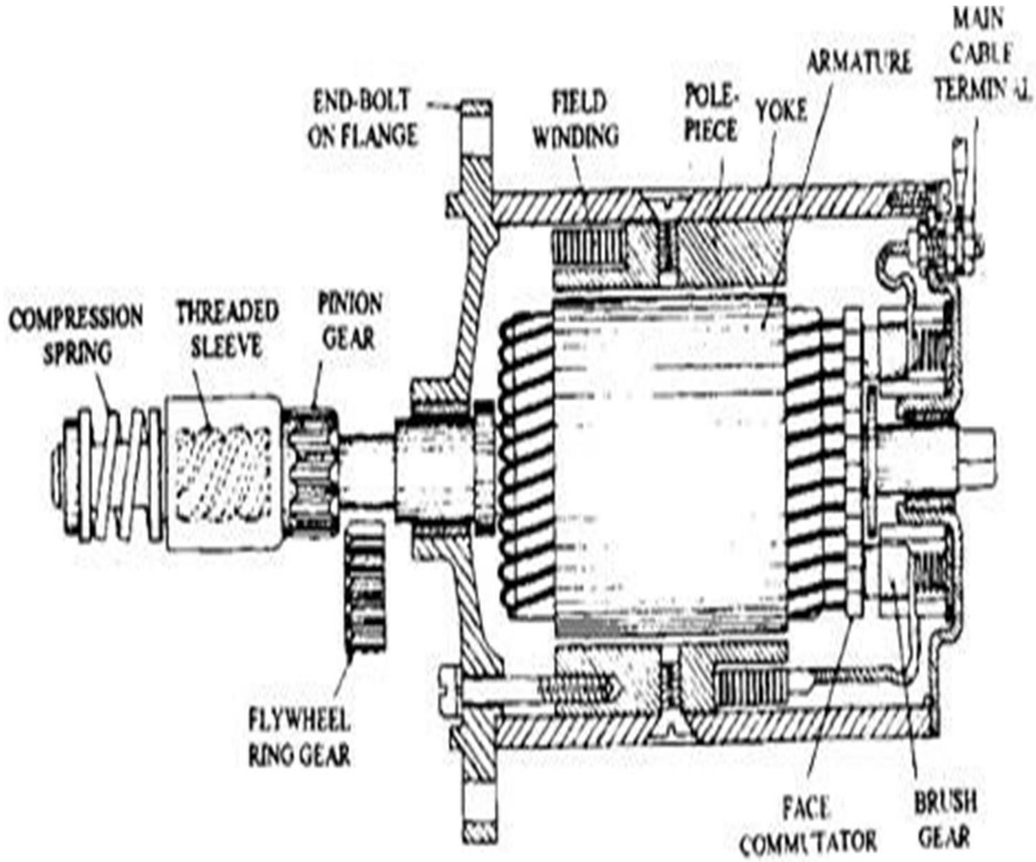
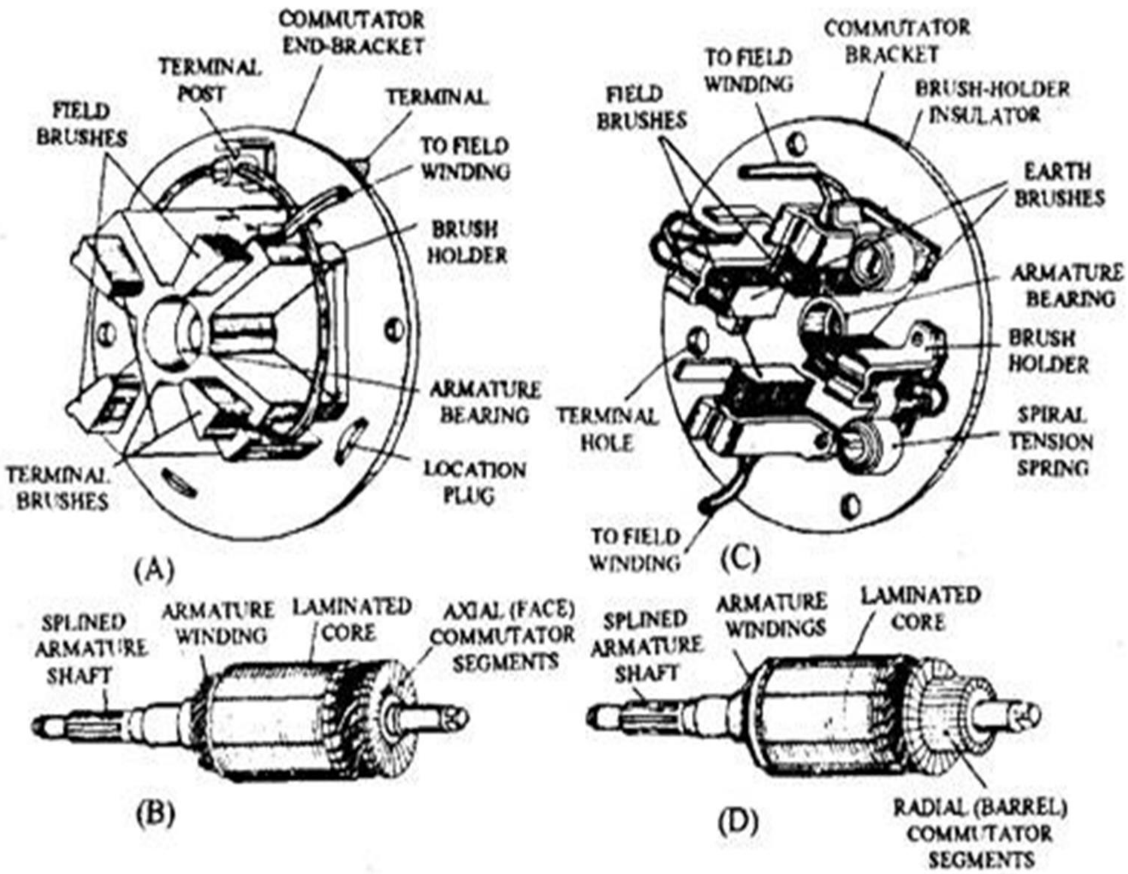


Fig. 15.16. Inertia starter motor.

Commutation

When battery supplies power to the armature loop, the magnetic-field interaction rotates the loop causing the two half-conductors to change places with each other. Also this alters the direction of the current flowing in the conductor relative to the North and South Poles of the yoke. As a result the loop reverses its direction of rotation and turns backward.

To have the continuous rotation of armature loop in only one direction, the direction of current flowing in each half-loop is required to be reversed every half-revolution, called commutation. This is achieved by connecting the armature-loop ends to a split-ring (Fig. 15.14). As a result each half-ring segment comes in contact with a different brush during every half revolution of the armature, so that the direction of the current flow within the armature loop repeatedly reverses.



Permanent-magnet Starter Motor

Permanent magnet starters were introduced on the vehicles in the late 1980s. Less weight and small size are the two advantages of these motors, compared to conventional types. This causes the permanent magnet starter to be more popular as less space is available for engine electrical in modern cars. The reduction in weight also contributes towards reduction in fuel consumption.
The standard permanent magnet starters produced are suitable for spark ignition engines up to about 2L capacity and are rated in the capacity of 1 kW or less. Some examples are the Bosch DM range (Fig. 15.23) and the Lucas Models M78R / M80R (Fig. 15.24)

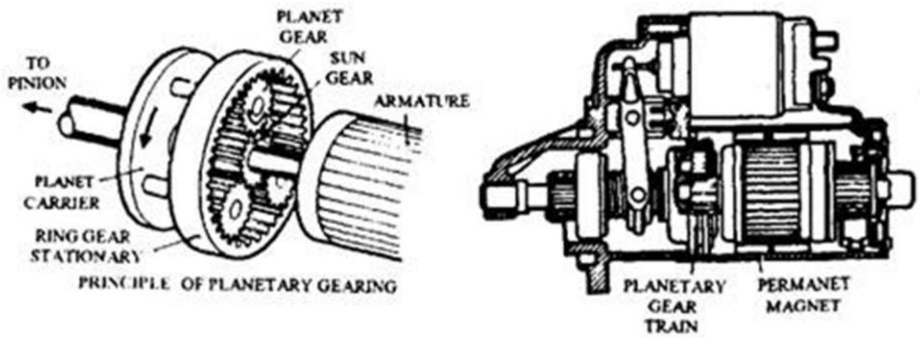


Fig. 15.23. Bosch permanent magnet starter.

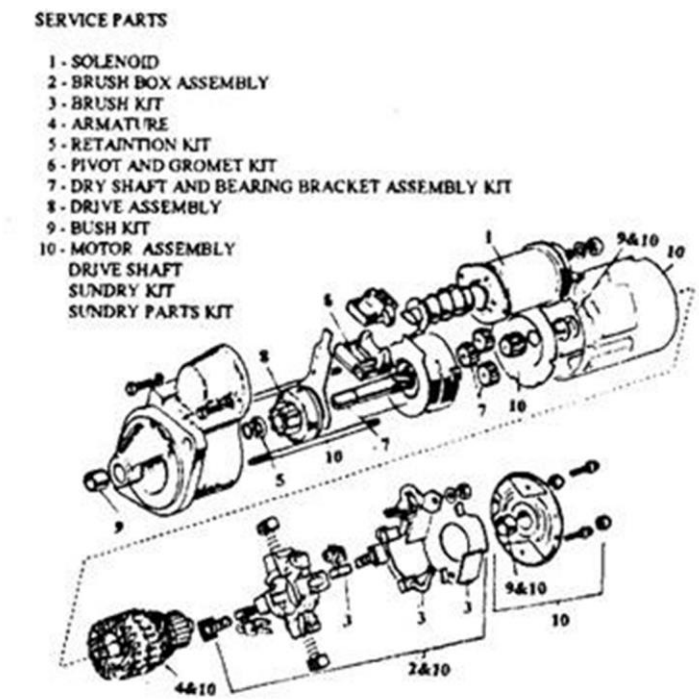


Fig. 15.24. Lucas M78R I M80R starter.

The principle of operation is almost similar to the conventional pre-engaged starter motor, in which the field windings and pole shoes are replaced with high quality permanent magnets. This provides a reduction in weight up to 15 percent. The diameter of the yoke can also be reduced by a similar value. Permanent magnets provide constant excitation due to which the speed and torque characteristic is expected to be constant. However, due to the fall in battery voltage under load and the low resistance of the armature windings, the characteristic is comparable to that of series wound motors. Sometimes flux concentrating pieces or inter-poles are installed between the main magnets (Fig. 15.25). The warping effect of the magnetic field causes the characteristic curve to be very similar to that of the series motor.

Considerable improvement in the construction of the brushes has taken place. A copper and graphite mix is used to make the brushes in two parts, so that higher copper content is in the power zone and higher graphite content is in the commutation zone. This provides an increase in the service life and a reduction in voltage drop, giving higher starter power output.

Permanent magnet motors for a higher power application, have been developed with intermediate transmission of generally epicyclic type (Fig. 15.26). These enable the armatures to rotate at a higher and more efficient speed while delivering the torque, due to the gear reduction. Permanent magnet starters with intermediate transmission are available with power outputs of about 1.7 kW, suitable for spark ignition engines up to about 5 L or compression ignition engines up to about 1.6 L. The principle of operations of this type of permanent magnet motor is again similar to the conventional pre-engaged starter, but can provide a weight saving of up to 40 percent.

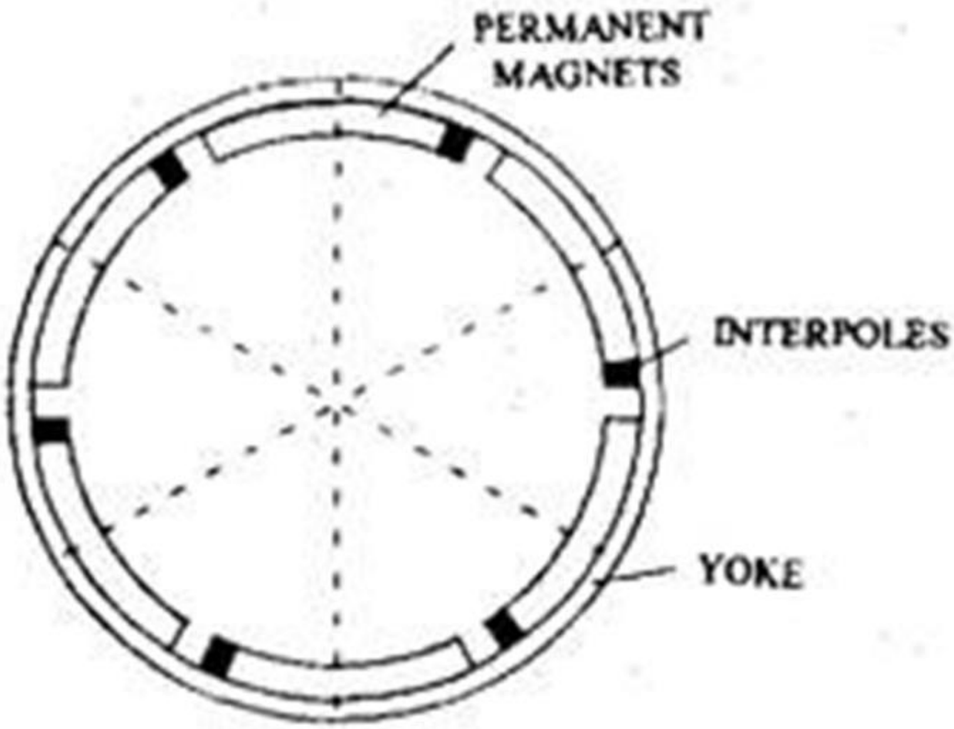


Fig. 15.25. Permanent magnet fields with inter-poles.

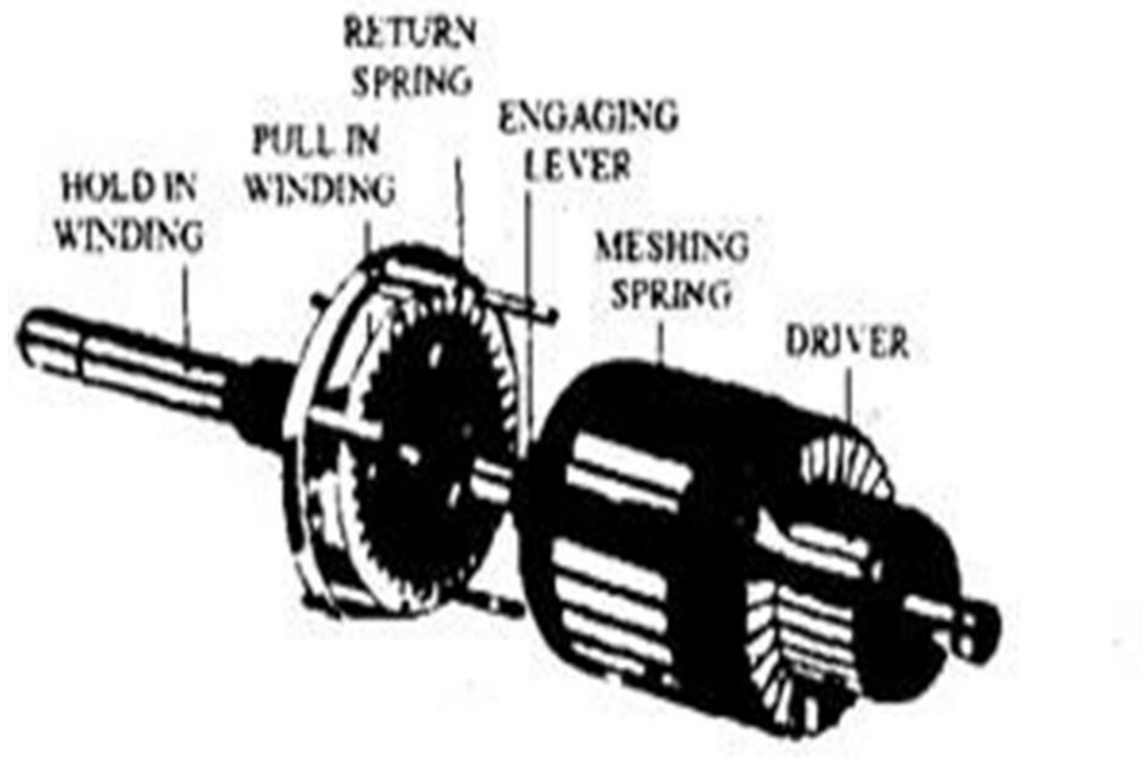


Fig. 15.26. Starter motor intermediate transmission. In the epicyclic type intermediate transmission, the sun gear is on the armature shaft and the pinion is driven by the planet carrier. The ring gear or annulus remains stationary acting as an intermediate bearing. This arrangement of gears provides a reduction ratio of about 5:1, which can be calculated by the simple formula;
Reduction Ratio = (A + S)/S

where, A = number of teeth on the annulus
S – number of teeth on the sun gear.

3) GEAR REDUCTION

Construction

This type of starter motor contains a magnetic switch, A compact high-speed motor, Several reduction gears, A pinion gear, A starter clutch etc. The extra gears reduce the motor speed by a factor of one to three or four and transmit it to the pinion gear. The plunger of the magnetic switch directly pushes the pinion gear, Which is located on the same axis, Causing it to mesh with the ring gear. This type of starter motor generates much greater torque, In proportion to size and weight, Than the conventional type.

When the ignition switch has been turned to the START position, Terminal 50 passes electrical current from the battery to the hold-in and pull-in coils. From the pull-in coil, The current then flows to the field coils and armature coils via Terminal C. The motor rotates at a lower speed at this point, Since the energized pull-in coil causes a voltage drop which limits the supply of current to the motor components (The field coils and the armature). The hold-in and pull-in coils, At the same time, Set up a magnetic field which pushes the plunger to the left against the return springs. The pinion gear therefore shifts to the left until it engages with the ring gear. The low motor speed at this stage means that both gears mesh smoothly. The screw splines also help the pinion and ring gears to engage more smoothly.

Pinion And Ring Gears Engaged

When the magnetic switch and the screw splines have pushed the pinion gear to the position where it meshes completely with the ring gear, The contact plate attached to the plunger turns the main switch on by short-circuiting the connection between terminals 30 and C. The resulting connection allows the larger electrical current to pass through the starter motor, Which causes the motor to rotate with a greater torque. The screw splines help the pinion gear mesh more securely with the ring gear. At the same time, The voltage levels at both ends of the pull-in coil become equal so that no current flows through this coil. The plunger is therefore held in position by the magnetic force exerted by the hold-in coil.

Ignition Switch In ON Position

Turning the ignition switch back to the ON position from START cuts off the voltage being applied to terminal 50. The main switch remains closed, However, Some current flows from Terminal C to the hold-in coil via the pull-in coil. Since current flows through the hold-in coil in the same direction as when the ignition switch is in the START position, It generates a magnetic force which pulls the plunger. In the pull-in coil on the other hand, Current flows in the opposite direction, Generating a magnetic force which attempts to return the plunger to its original position. The magnetic fields set up by these two coils cancel each other out, So the plunger is pulled backward by the return springs. Therefore, The heavy current which has been supplied to the motor is cut off and the plunger disengages the pinion and ring gears at about the same time. The armature used in the reduction type starter motor has less inertia than the one in the conventional type, So friction soon brings it to a stop. This type of starter motor therefore does not require the brake mechanism used in the conventional type starter motor.

Care and maintenance of starter motor.

The most important component of a starting system is the battery, and until this is in sound condition, the speed of starter motor remains low and possibly with a limited duration of cranking. However, a battery may be faulty due to other factors like, a defective charging system, a short to earth in another system, or overload of the battery due to driving or seasonal conditions. Indications from warning instruments and observation of the engine's starting performance, enable the driver to identify the initial conditions that may lead a major fault. A battery supplies a very large current to the starting motor, and hence a drop in the battery p.d. takes place. When this drop is very high, the ignition system does not receive sufficient power to provide suitable spark at the plugs, although the starting motor is still functioning at a low speed. This condition is confirmed when an engine fails to start with the motor, but starts easily by "bump starting" (rolling the vehicle in top gear and suddenly releasing the clutch). Normally this problem is attributed to a battery fault, but on many modern engines the problem is resolved by installing cold-start ballast resistor in the ignition supply lead. In addition to the resistor lead, a separate lead is used between a terminal on the starter solenoid and the ignition coil so that the resistor is bypassed when the starter is operated.

Maintenance.

Routine maintenance work should be attended to the battery, especially the terminals. All terminals and connectors in the starter circuit should be maintained clean and secure.

Fault Diagnosis.

If the probable defects of each component of the system are considered, along with the possible symptoms indicated by each defect, then it is possible for the electrician to find a likely cause of a particular fault. The main problems, and the possible faults, faced by various components of the starting system, are presented below.

between the engine and frame.

Solenoid : **Dirty contacts or faulty connection between windings and terminals.**
Starter switch : High resistance at contacts or broken cables.
Motor **Poor bedding of brushes or dirty commutator.**

Pinion : **Not meshing or jammed due to a worm flywheel ring gear.**

Ref: http://what-when-how.com/automobile/starter-motor-maintenance-and-fault-diagnosis-automobile

6. Starter Switches.

There are two types, one is manually operated starter switch and the other is solenoidal starter switch

7. Generation of direct current.

Direct current (**DC**):

It is the unidirectional flow of electric charge(current) which is generated by sources like dynamo or dc generators, batteries, power supplies, thermocouples, solar cells etc.

Alternating current (AC):

It is the bidirectional flow of current and is generated by sources called ac generator or alternator

8(a) Types of DC Generator:

DC generators can be classified in two main categories, viz; (i) Separately excited and (ii) Self-excited.

(i) **Separately excited**: In this type, field coils are energized from an independent external DC source.

(ii) **Selfexcited**: In this type, field coils are energized from the current produced by the generator itself. Initial emf generation is due to residual magnetism in field poles. The generated emf causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing emf generation. Self excited dc generators can further be divided into three types -

(a) Series wound - field winding in series with armature winding

(b) Shunt wound - field winding in parallel with armature winding

(c) Compound wound - combination of series and shunt winding

9. Armature reaction.

In a DC machine(motor/generator), the main field is produced by field coils. In both the generating and motoring modes, the armature carries current and a magnetic field is established, which is called the armature flux. The effect or reaction of armature flux on the main field is called the **armature reaction**.

In the fig.X below shows the main field flux being distorted by the armature flux.

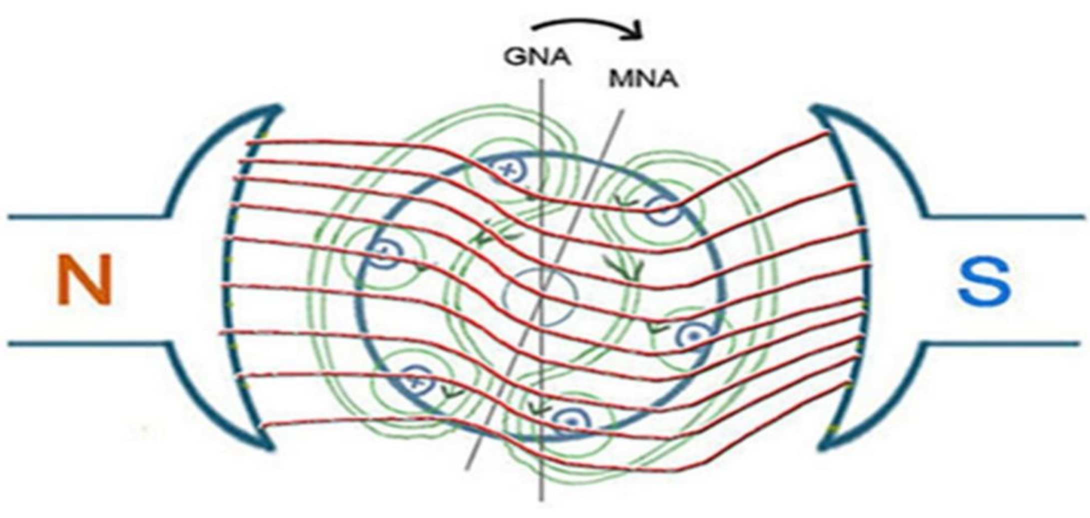


Fig.XX Shows armature reaction.

Third brush regulation.

Third-brush regulation is simpler in operation andcheap to manufacture than

other methods of control. However it can be used for some special and limited applications. Generators with this type of control have an additional brush called the third brush which is located between the two main brushes.

Construction:

The arrangement of a typical two-pole, third brush type of generator is shown in figure

xx. One end of the shunt field winding is connected to the third brush, the other end is grounded.

Only a part of the total voltage generated is supplied to the field by the third brush.

Working:

(I) When the generator is running at a low speed and little or no current is flowing in the armature winding, the magnetic field produced by the field winding is approximately straight through the armature from one pole piece to the other (fig. 148 (1)). The voltage generated by each armature coil is then practically uniform during the time the coil is under the pole pieces.

(2) As the generator speed and charging current increase, the arma-ture winding acts like a solenoid coil to produce a cross magnetic field. The magnetic whirl around the armature winding distorts the magnetic field produced by the shunt field winding, so that the magnetism is not equally distributed under the pole pieces (fig. 148 (2)). With this distor-tion of the magnetic field, the armature coils no longer generate a uniform voltage while passing under the different parts of the pole. Although the voltage across the main brushes remains nearly the same, a greater proportion of this voltage is generated by the coils between the positive brush and the third brush than was generated between them when little current was flowing through the armature winding. This is due to the distortion of the magnetic field which crowds more magnetic lines of force between the positive and. third brush.

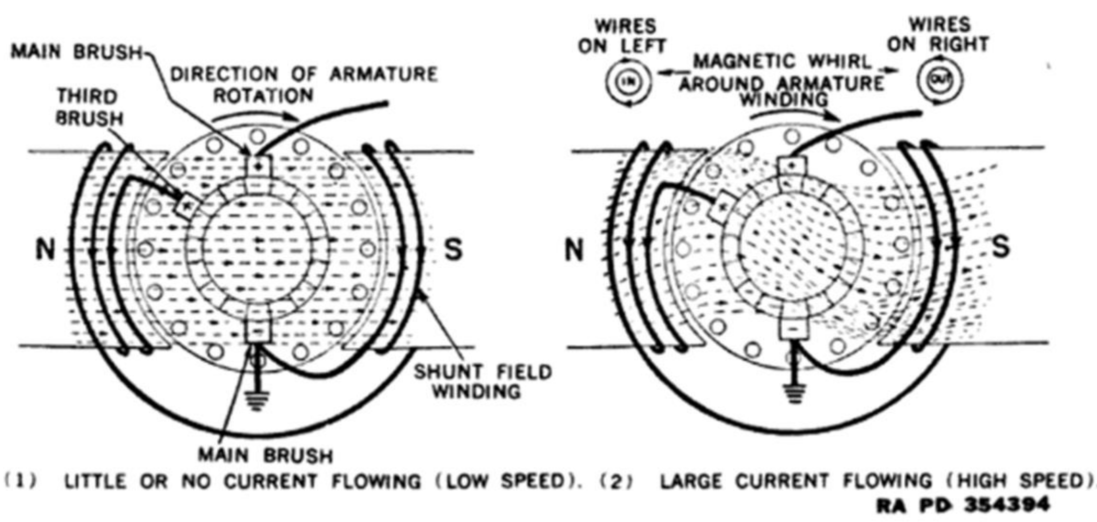
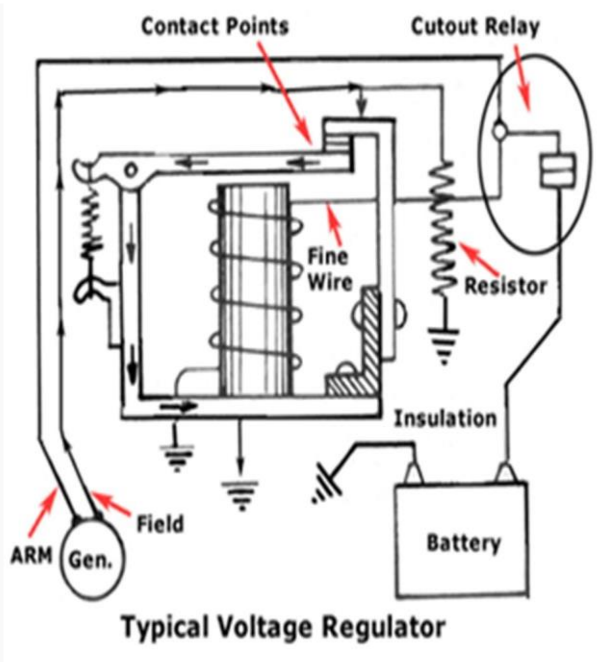


Figure 148. Third Brush Generator Regulation.

(3) The coils which connect the commutator between the negative and third brushes are in the region of the weakened field and generate a lower proportion of the voltage. The result is a dropping off of the voltage between the negative and third brushes, which is applied to the shunt field winding, thereby weakening the field strength. As the field strength decreases with increased generator current, the result will be an automatic regulation of the current output.

Voltage Regulators

In the function of generators, there is no means of internally controlling the output of one. In other words, the faster it spins the more voltage goes into the car's electrical system. If this weren't controlled the generator would damage the battery and burn out the car's lights. Also, if the generator weren't cut out from the car's circuitry when not running, the battery would discharge through its case.

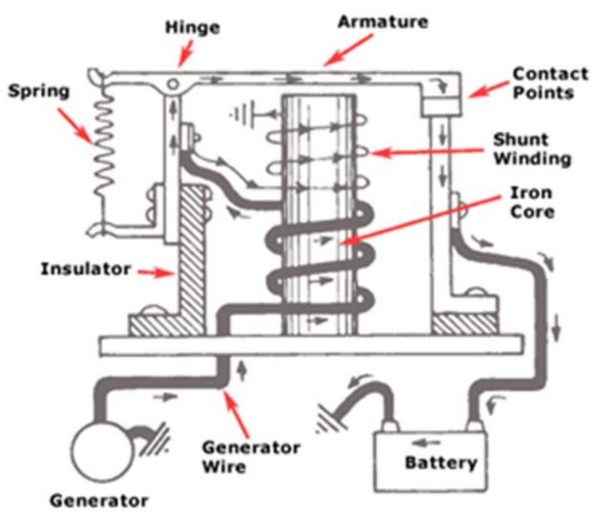


That's where the REGULATOR (commonly called the Voltage Regulator, but that's only one component of the system) comes in. Regulators have seen many design improvements over the decades, but the most commonly used electro-mechanical regulator is the three-control units in one box type. Let's look at how these things work...

Cutout Relay

Sometimes called the circuit breaker, this device is a magnetic "make-and-break" switch. It connects the generator to the battery (and therefore the rest of the car) circuit when the generator's voltage builds up to the desired value. It disconnects the generator when it slows down or stops.

The relay has an iron core that is magnetized to pull down a hinged armature. When the armature is pulled down a set of contact points closes and the circuit is completed. When the magnetic field is broken (like when the generator slows down or stops) a spring pulls the armature up, breaking the contact points.



A Schematic of the cutout relay. Trace the flow of current through its components.

An obvious failure mode is the contact points. As they open and close, a slight spark is generated, eventually eroding the material on the points until they either "weld" themselves together or become so high in resistance that they won't conduct current when closed. In the first case the battery would discharge through the generator overnight and in the second there would be no charging to the system.

Voltage Regulator

Another iron core-operated set of contact points is utilized to regulate maximum and minimum voltage at all times. This circuit also has a shunt circuit (a shunt re-directs electrical flow) going to ground through a resistor and placed just ahead (electrically) of the points. When the points are closed the field circuit takes the "easy" route to ground but when the points are open the field circuit must pass through the resistor to get to ground.

The field coil on the generator is connected to one of the voltage regulator contact points. The other point leads directly to ground.

When the generator is operating (battery low or a number of devices running) its voltage may stay below that for which the control is set. Since the flow of current will be too weak to pull the armature down the generator field will go to ground through the points. However, if the system is fully charged the generator voltage will increase until it reaches the maximum limit and current flow through the shunt coil will be high enough to pull the armature down and separate the points.

This cycle is repeated over and over in real time. The points open and close about 50 to 200 times per second, maintaining a constant voltage in the system.

Current Regulator

Even though the generator's voltage is controlled it is possible for its current to run too high. This would overheat the generator, so a current regulator is incorporated to prevent premature failure.

Similar in appearance to the voltage regulator's iron core, the current regulator's core is wound with a few turns of heavy wire and connected in series with the generator's armature.

In operation, current flow increases to the predetermined setting of the unit. At this time, current flow through the heavy wire windings will cause the core to draw the armature down, opening

the current regulator points. In order to complete the circuit the field circuit must pass through a

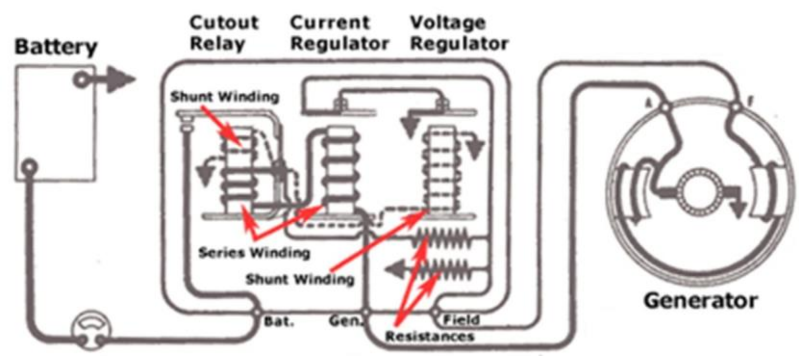


Diagram of a typical three-unit regulator. Trace all circuits a few times and you will understand how it functions.

resistor. This lowers current output, points close, output increases, points open, output down, points close, and so on. The points, therefore, vibrate open and closed much as the voltage regulator's points do, many times every second.

CH-3

GENERATING SYSTEM

DC Machines

Construction, working of DC Generator, EMF Equation, types and characteristics of DC generators, Principle of DC motor, Torque Equation of Motor, types of DC Motors, Torque speed characteristic and speed control of DC motor, (Theoretical Concepts only)

DC machines

1. DC Generator

Fig. 4.1

2. DC Motor

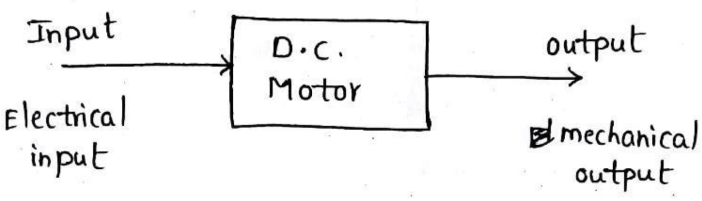


Fig. 4.2

DC Generator

Generator Principle:

A set conductors being rotated in a steady magnetic field an E.M.F(Electro motive force)is induced in a set of conductors, which will cause a current to flow if the conductor circuit is closed, According to Faradays law's(First law) of electromagnetic induction.

Therefore, the essential components of a generator are:

(a) A steady magnetic field
(b) Conductor or a group of conductors
(c) motion of conductor w.r.t. magnetic field.

An electric generator is a machine that converts mechanical energy into electricalenergy.

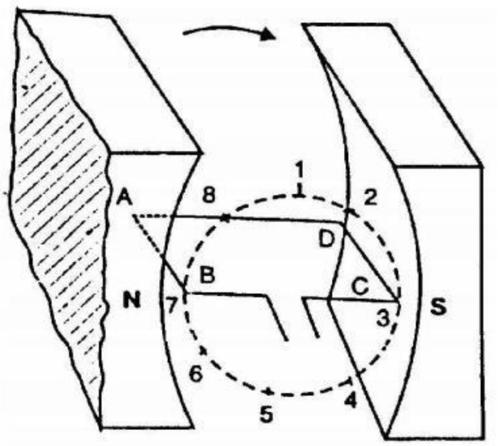
Simple Loop D.C. Generator or Working of D.C Generator:

Consider a single turn loop ABCD rotating clockwise in a uniform magnetic field with a constant speed as shown in Fig.(4.3). As the loop rotates, the flux linking the coil sides AB and CD changes continuously. Hence the e.m.f. induced in these coil sides.

Explanation:

(i) When the loop is in position no. 1 [See Fig. 4.3], the generated e.m.f. is zero because the coil sides (AB and CD) are cutting no flux but are moving parallel to it.

(ii) When the loop is in position no. 2, the coil sides are moving at an angle to the flux and, therefore, a low e.m.f. is generated as indicated by point 2 in Fig. (4.4).



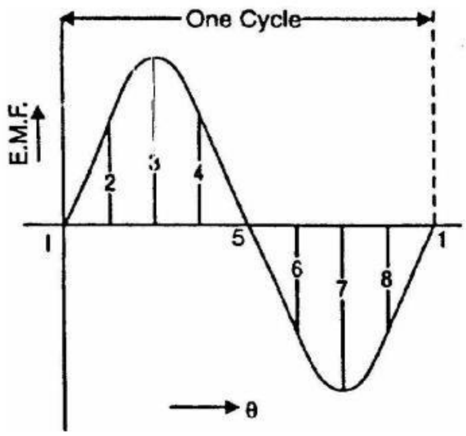


Fig 4.3 **Fig 4.4**

(iii) When the loop is in position no. 3, the coil sides (AB and CD) are at right angle to the flux and are, therefore, cutting the flux at a maximum rate, the generated e.m.f. is maximum as indicated by point 3 in Fig. (4.4).

(iv) When the loop is in position 4, the generated e.m.f. is less because the coil sides are cutting the flux at an angle and, therefore, a low e.m.f. is generated as indicated by point 4 in Fig. (4.4).

(v) When the loop is in position 5, the generated e.m.f. is zero because the coil sides (AB and CD) are cutting no flux but are moving parallel to it.

(vi) When the loop is in position 6, the coil sides move under a pole of opposite polarity and hence the direction of generated e.m.f. is reversed. The coil sides are moving at an angle to the flux and, therefore, a low e.m.f. is generated as indicated by point 6 in Fig. (4.4).

(vii) When the loop is in position no. 7, the coil sides (AB and CD) are at right angle to the flux and are, therefore, cutting the flux at a maximum rate, the generated e.m.f. is maximum as indicated by point 7 in Fig. (4.4).

(viii) When the loop is in position 8, the generated e.m.f. is less because the coil sides are cutting the flux at an angle and, therefore, a low e.m.f. is generated as indicated by point 8 in Fig. (4.4).

Induced E.M.F $E_g \propto \Phi$ (Magnetic flux)

$E_g \propto N$ (Speed of the armature)

$E_g \propto Z$ (Number of conductors)

Construction of D.C Machine or D.C. Generator or D.C. Motor

A DC Machine is a Electro-Mechanical Energy Conversion Device, which can be operated as a DC generator or DC motor. The d.c. generators and d.c. motors have the same general construction. Any d.c. generator can be run as a d.c. motor and vice-versa

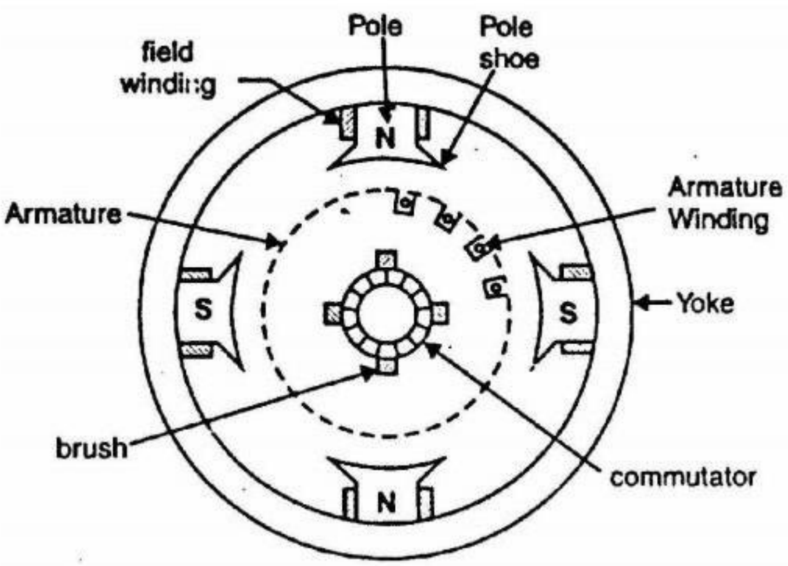


Fig 4.5

All d.c. machines have five principal components viz.,

(i) Yoke

(ii) Field system

(iii) Armature core

(iv) Armature winding

(v) Commutator

(vi) Brushes

(i) Yoke

It is a stationary part.

- The outer frame of a dc machine is called as yoke.
- It is made up of cast **iron** or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.
- Poles are joined to the yoke with the help of bolts or welding.

(ii) Field system

It is a stationary part.

a) Field Poles b) Field winding c) Pole shoe

- The function of the field system is to produce uniform magnetic field.
- It consists of a number of salient poles (of course, even number) bolted to the inside of circular frame (generally called yoke).
- Field coils are mounted on the poles and carry the d.c. exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity. The m.m.f. developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame (See Fig. 4.6).
- Practical d.c. machines have air gaps ranging from 0.5 mm to 1.5 mm.

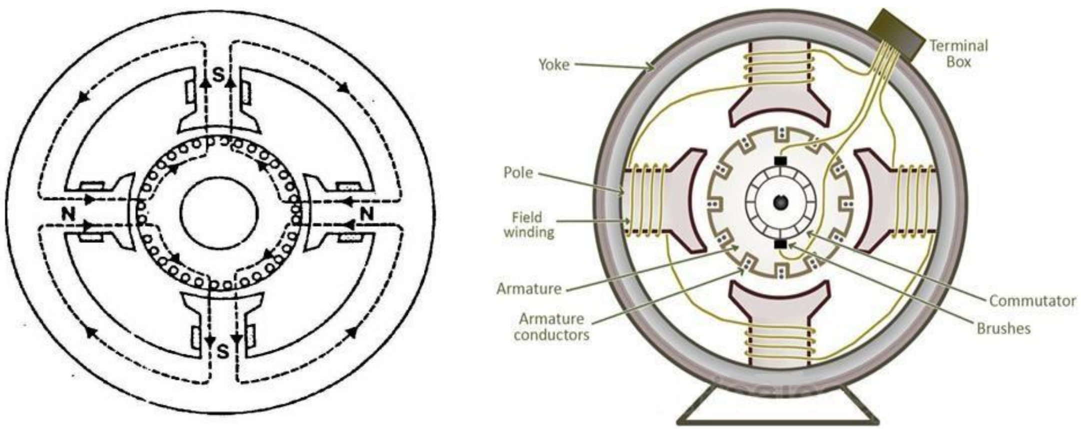


Fig 4.6

(iii) Armature core

It is a rotating part.

- The armature core is keyed to the machine shaft and rotates between the fieldpoles.
- Conductors are placed on armature slots.
- It consists of slotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in Fig (4.7).

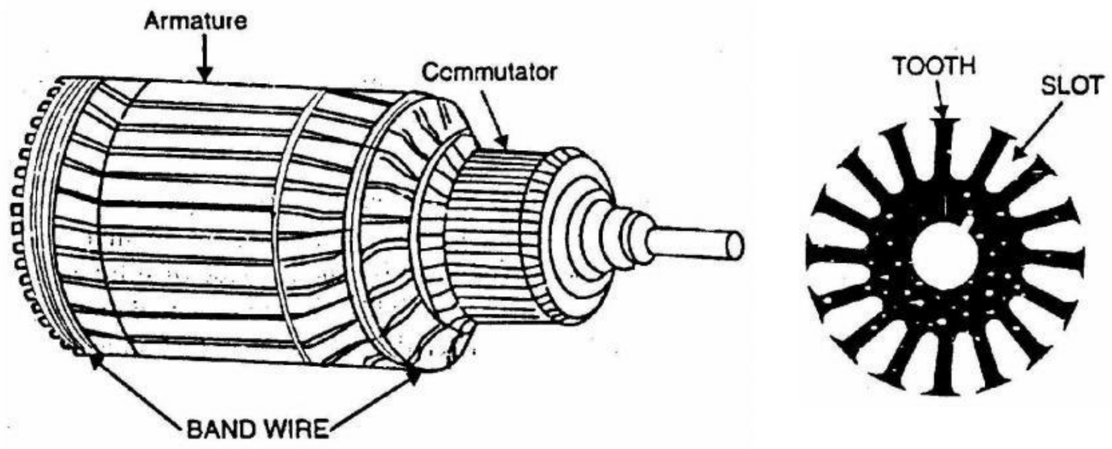


Fig 4.7

(iv) Armature winding

It is a rotating part.

- The slots of the armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding.
- This is the winding in which "working" e.m.f. is induced.
- The armature conductors are connected in series-parallel; the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.
- there are two types of armature winding in a d.c. machine viz.,
  (a) Lap winding
  (b) Wave winding.

(v) Commutator

It is a rotating part.

Which converts AC to DC and DC to AC

- A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.
- The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine (See Fig 4.8).
- The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding.

- Great care is taken in building the commutator because any eccentricity will cause the brushes to bounce, producing unacceptable sparking. The sparks may bum the brushes and overheat and carbonise the commutator.

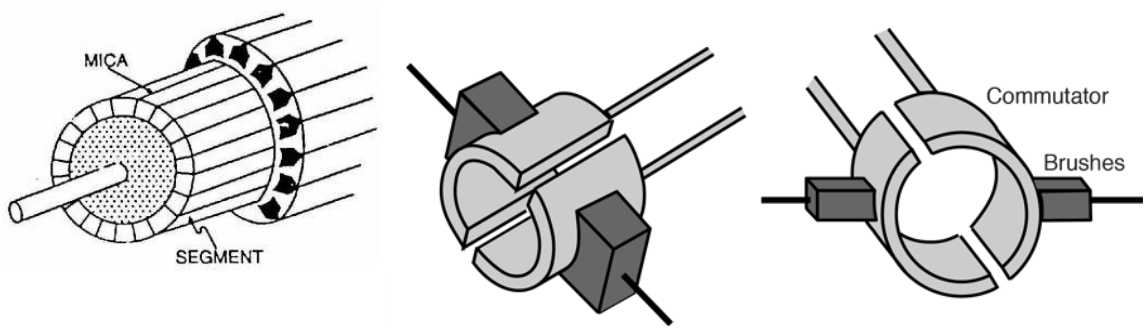


Fig 4.8

(vi) Brushes

It is a stationary part.

- The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit.
- The brushes are made of carbon and rest on the commutator.
- The brush pressure is adjusted by means of adjustable springs (See Fig. 4.9).
- If the brush pressure is very large, the friction produces heating of the commutator and the brushes. On the other hand, if it is too weak, the imperfect contact with the commutator may produce sparking.

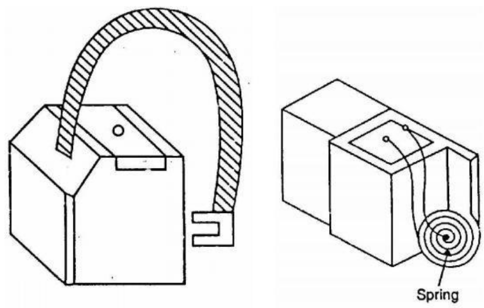


Fig 4.9

E.M.F. Equation of a D.C. Generator

Derive an expression for the e.m.f. generated in a d.c. generator. Let

Φ = flux/pole in Wb

Z = total number of armature conductors P

= number of poles

N = speed of armature in r.p.m.

A = number of parallel paths A = 2 ... for wave winding

= P ... for lap winding

Eg = e.m.f. of the generator = e.m.f./parallel path

Flux cut by one conductor in one revolution of the armature,

$$d\Phi = P\Phi \text{ webers}$$

Time taken to complete one revolution,

$$dt = 60/N \text{ second}$$

e.m.f generated/conductor = $\frac{d\Phi}{dt} = \frac{P\Phi}{60/N} = \frac{P\Phi N}{60}$ Volts

e.m.f. of generator,

Eg = e.m.f. per parallel path

= (e.m.f generated/conductor) X No. of conductors in series per parallel path

$$= \frac{P\Phi N}{60} \times \frac{Z}{A}$$

$$Eg = \frac{\Phi Z N}{60} \times \frac{P}{A}$$

where A = 2 for-wave winding

= P ... for lap winding

NOTE: Induced E.M.F Eg α Φ (Magnetic flux)

Eg α N (Speed of the armature)

Eg α Z (Number of conductors)

Types of D.C. Generators

Generators are generally classified according to their methods of field excitation.

D.C. generators are divided into the following two classes:
(1) Separately excited d.c. generators
(2) Self-excited d.c. generators

(a) Series generator;
(b) Shunt generator;
(c) Compound generator

(i) Short shunt compound generator
(ii) Long shunt compound generator

(1) Separately Excited D.C. Generators

A d.c. generator whose field magnet winding is supplied from an independent external d.c. source (e.g., a battery etc.) is called a separately excited generator.

The voltage output depends upon the speed of rotation of armature and the field current. The greater the speed and field current, greater is the generated e.m.f.

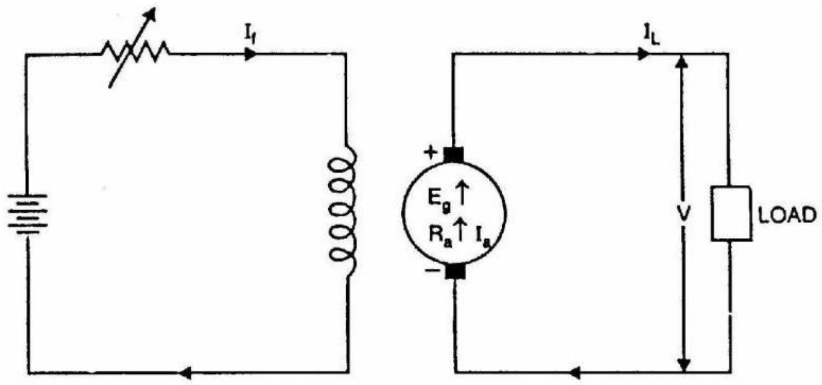


Fig 4.10

Apply KVL to right side circuit in fig 4.10

e.m.f. of the generator $E_g = V_L + I_aR_a$

Armature current, $I_a = I_L$

Electric power developed $P_d = E_gI_a$
Power delivered to load $P_L = V_LI_a$

(2)Self-Excited D.C. Generators

A D.C. generator whose field magnet winding is supplied current from the output of the generator itself is called a self-excited generator.

There are three types of self-excited generators depending upon the manner in which the field winding is connected to the armature, namely;
(a) Shunt generator
(b) Series generator
(c) Compound generator

i) Short shunt compound generator
(ii) Long shunt compound generator

(a) Shunt generator

In a shunt generator, the field winding is connected in parallel with the armature winding so that terminal voltage of the generator is applied across it.

The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load.

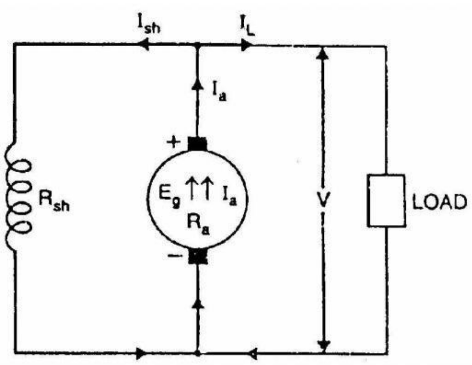


Fig 4.11

Apply KVL to the circuit shown in fig 4.11

e.m.f. of the generator $E_g = V_L + I_a R_a$
According to KCL, Armature current, $I_a = I_L + I_{sh}$
Shunt field current, $I_{sh} = V/R_{sh}$

Electric power developed $P_d = E_g I_a$
Power delivered to load $P_L = V_L I_L$
R_{sh}—Shunt field resistance

Shunt field winding have more number of turns and thin wire

(b) Series generator

In a series wound generator, the field winding is connected in series with armature winding so that whole armature current flows through the field winding as well as the load.

Since the field winding carries the whole of load current, it has a few turns of thick wire having low resistance.

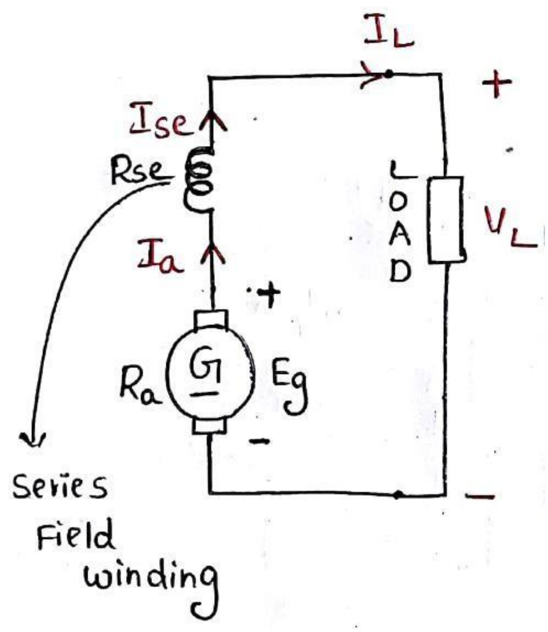


Fig 4.12

Apply KVL to the circuit shown in fig 4.12

e.m.f. of the generator $E_g = V_L + I_a (R_a + R_{se})$

Armature current, $I_a = I_{se} = I_L$
Electric power developed $P_d = E_g I_a$
Power delivered to load $P_L = V_L I_L$
R_{se}—Series field resistance

Series field winding have more less of turns and thick wire

Applications: Boosters

(c) Compound generator

In a compound-wound generator, there are two sets of field windings on each pole— one is in series and the other in parallel with the armature.

(i) Short shunt compound generator

In which only shunt field winding is in parallel with the armature winding.

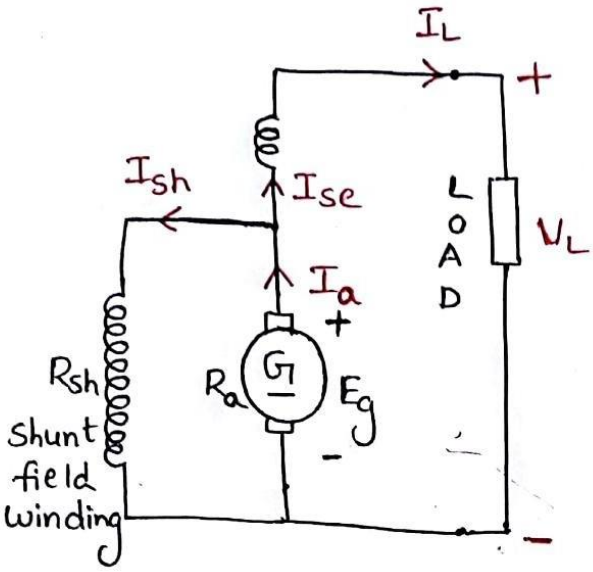


Fig 4.13

Apply KVL to the circuit shown in Fig 4.13

e.m.f. of the generator $E_g = V_L + I_a R_a + I_{se} R_{se}$

Series field current, $I_{se} = I_L$ Apply KCL to the circuit Armature Current $I_a = I_{se} + I_{sh}$ Apply KVL to the circuit

$$-V + I_{se}R_{se} + I_{sh}R_{sh} = 0$$

Shunt field current, Ish= □□+□□□□□□

□□h

Power developed in armature = $E_g I_a$
Power delivered to load = $V_L I_L$

(ii) Long shunt compound generator

In which shunt field winding is in parallel with both series field and armature Winding.

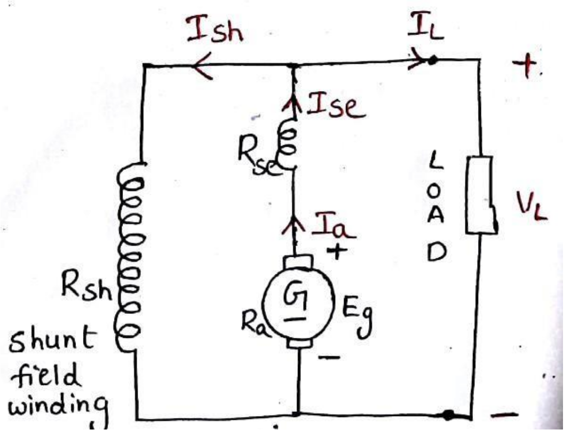


Fig 4.14

Series field current, $I_{se} = I_a = I_L + I_{sh}$
Shunt field current, $I_{sh} = V/R_{sh}$ Apply
KVL to the circuit in Fig 4.14

e.m.f. of the generator $E_g = V + I_a\ (R_a + R_{se})$

Power developed in armature = $E_g I_a$
Power delivered to load = $V_L\ I_L$

Characteristics of DC generators

Important characteristics of a d.c. generator:

1. Open Circuit Characteristic (O.C.C.) (Eg versus If)
2. Internal or Total characteristic (Eg versus Ia)
3. External characteristic (VL versus IL)

Characteristics of a Separately Excited D.C. Generator

1. Open Circuit Characteristic

The field winding of the d.c. generator (series or shunt) is disconnected from the machine and is separately excited from an external d.c. source as shown in Fig. 4.15.

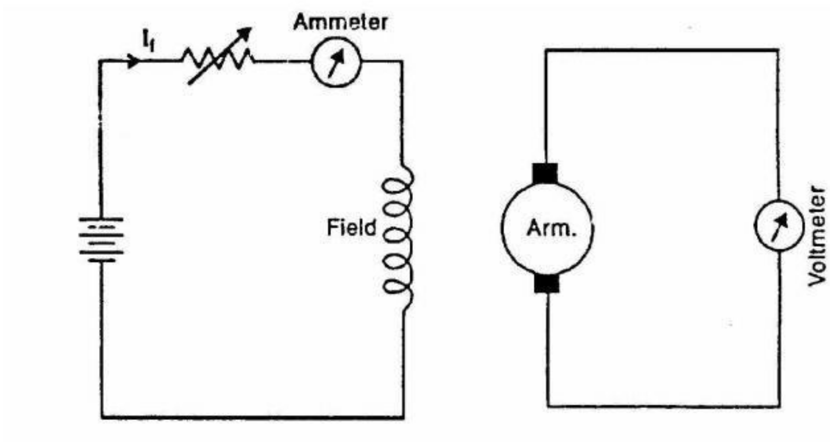
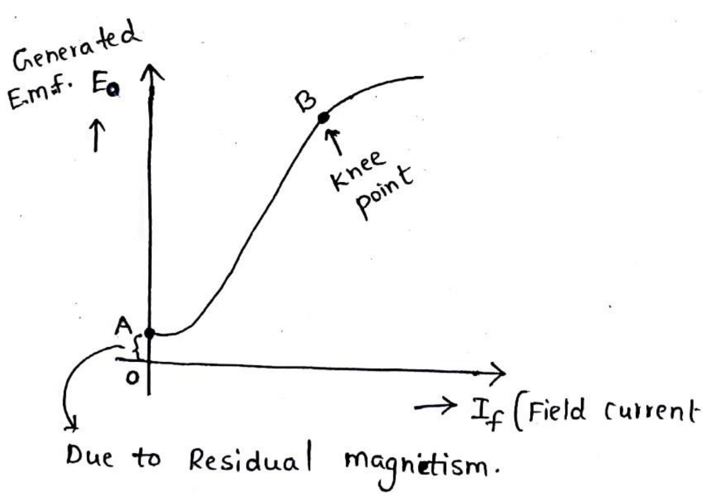


Fig 4.15

The generator is run at fixed speed. The field current (If) is increased from zero in steps and the corresponding values of generated e.m.f (E0) read off on a voltmeter connected across the armature terminals. On plotting the relation between E0 and If, we get the open circuit characteristic as shown in Fig. 4.16.



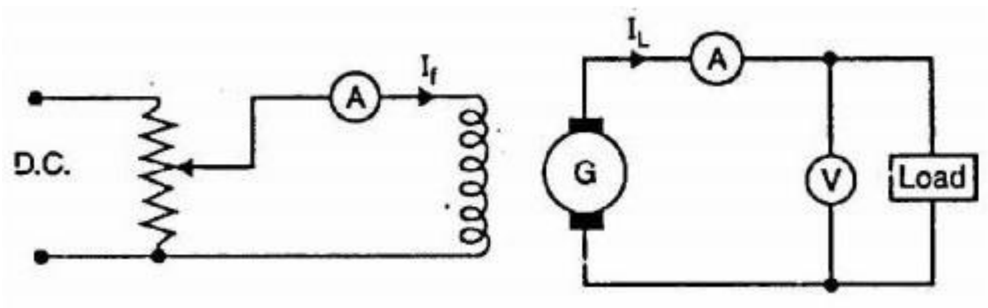
Knee point: The point at which saturation starts.

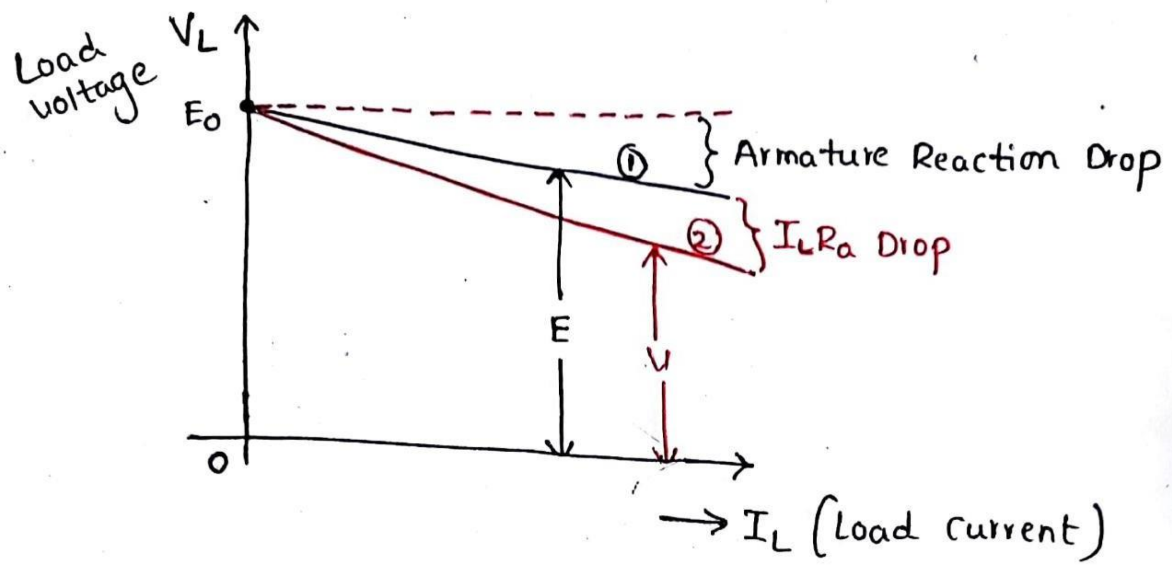
2. Internal and External Characteristics

The external characteristic of a separately excited generator is the curve between the terminal voltage (V_L) and the load current I_L in Fig 4.17(Curve 2).

As the load current increases, the terminal voltage falls due to two reasons:
(a) The armature reaction

(b) There is voltage drop across armature resistance (= I_LR_a = I_aR_a).





Curve 1-- Internal characteristics Curve 2-- External characteristics **Fig 4.17**

The internal characteristic can be determined from external characteristic by adding I_LR_a drop to the external characteristic.

CH-4

ALTERNATOR

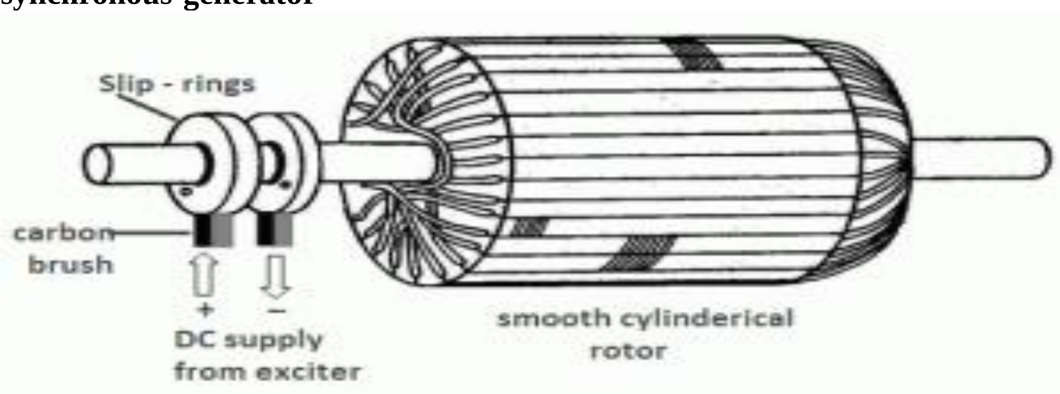
What is Synchronous Generator /ALTERNATOR: Construction, Working & Its Applications

In the previous article, we have discussed the DC generator which works on Faraday’s law of electromagnetic induction. Similarly, the asynchronous motor also works on the same principle but the only difference is, this generator gives a 3-phase AC output voltage from stator windings whereas the DC generator gives the output like a DC or a single DC. The first synchronous generator was used in the year 1870 when the arc lamp was invented by P.N. Jablochkov which is named the Jablochkov candle.

What is Synchronous Generator/ALTERNATOR?

Definition: A synchronous machine that works like a generator is known as a synchronous generator and also called an alternator. The main function of this generator is to generate commercial frequency current frequently by converting the mechanical energy from the main mover to an AC electrical energy at a specific frequency & voltage. These generators are used in the power industry in thermal power, hydropower, and generation of power in nuclear & diesel.

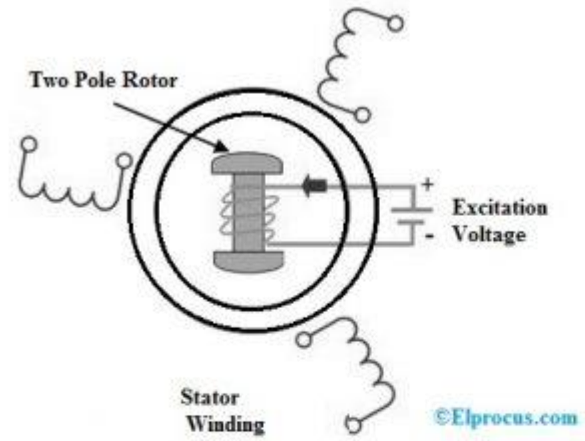
synchronous-generator



These generators are applicable for changeable speed wind turbine applications because of less revolving synchronous speeds. At a grid frequency, they generate the voltage and they don’t require a pitch control machine. This machine will increase the turbine cost and makes pressure on the generator as well as the turbine. The operation of these generators in changeable speed will produce variable frequency power as well as variable voltage.

Construction

The **construction of a synchronous generator** is shown below. The main parts of this motor mainly include a stator as well as a rotor. But in most of these generators, field exciters revolve and the armature coil will be immobile.



synchronous-generator-construction

a). Stator

Not like in the DC machine, the stator of this generator is not used to serve lane for magnetic flux. As an alternative, the stator is utilized to hold armature winding. The stator core can be designed with a magnetic iron otherwise steel alloys lamination to reduce the eddy current losses

- In synchronous generator, armature winding is stationary because of simple immobile armature winding insulation at high voltages, which may be high like 30 kV or above.
- The output of high voltage is directly received from the motionless armature whereas, for a rotating armature, there is a huge brush contact drop at high voltages, and also the flashing at the surface of the brush will occur.
- Field exciter winding can be arranged within a rotor as well as the low DC voltage is transmitted securely.
- The armature winding can be braced well, so as to prevent deformation caused by the high centrifugal force.

b). Rotor

In the synchronous generator, there are two kinds of rotors used namely Salient type and cylindrical type.

- Salient pole rotor can be used in alternators with low & medium speed. In type, it includes a large number of salient poles attached to a magnetic wheel. These are covered to reduce the eddy current losses. These rotors have large diameters and short wavelengths.
- Cylindrical rotors are mainly used in high-speed alternators like turbo-alternators. This rotor includes a flat as well as a solid steel cylinder with slots and an external periphery. These slots consist of field windings.

Working Principle

The **synchronous generator working principle** is the same as a DC generator. It uses Faraday's law of electromagnetic induction. This law states that when the flow of current is induced within the conductor in a magnetic field then there will be a relative motion among the conductor as well as the magnetic field.

In synchronous generator, the magnetic field is immobile & conductors will rotate. However, in practical construction, armature conductors are motionless & field magnets will rotate between them.

The rotor in the synchronous generator can be fixed mechanically toward the shaft to turn at synchronous speed (Ns) under some mechanical force which consequences in magnetic flux cutting in the stationary armature conductors of the stator. Due to this direct flux cutting result, an induced e.m.f and flow of current will be there in armature conductors. For each winding, there will be a current flow in the first half cycle after that in the second half cycle with a specific time lag of 120°.

E.M.F Equation of Synchronous Generator

The e.m.f equation of this generator is shown below.

Eph = 4.44 KcKdΦfTph Volts

Where,

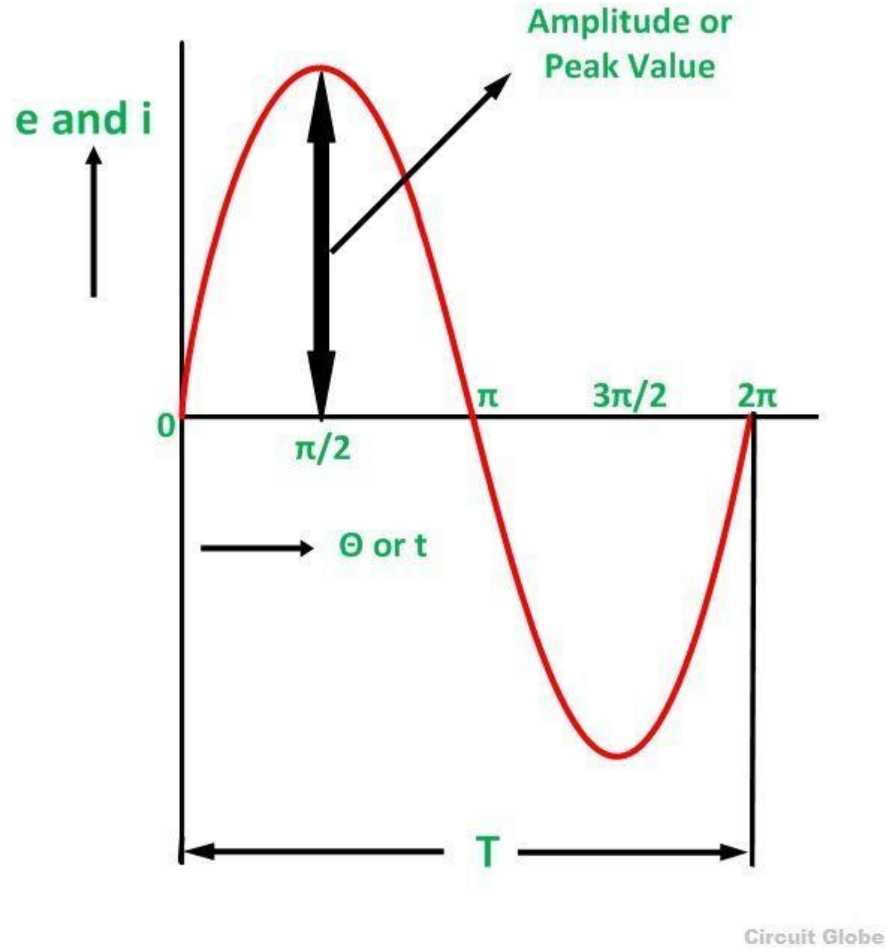
'P' is poles
'ϕ' is Flux for each pole in Webers
'N' is the speed in rpm (revolution per minute)
'f' is the frequency in Hz
'Tph' is the number of turns connected in series per phase
'Kc' is the span factor of the coil
'Kd' is the distribution factor of the coil

Peak Value, Average Value and RMS Value

Peak Value

Definition: The maximum value attained by an alternating quantity during one cycle is called its P**eak value**. It is also known as the maximum value or amplitude or crest value. The sinusoidal alternating quantity obtains its peak value at 90 degrees as shown in the figure below.

The peak values of alternating voltage and current is represented by E_m and I_m respectively.



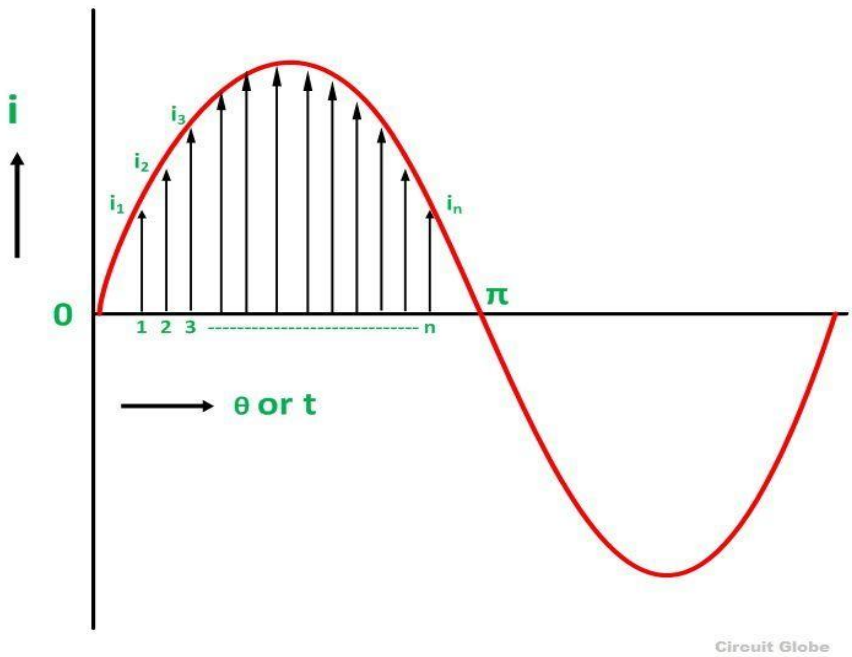
Average Value

Definition: The average of all the instantaneous values of an alternating voltage and currents over one complete cycle is called **Average Value.**

If we consider symmetrical waves like sinusoidal current or voltage waveform, the positive half cycle will be exactly equal to the negative half cycle. Therefore, the average value over a complete cycle will be **zero**.

The work is done by both, positive and negative cycle and hence the average value is determined without considering the signs.

So, the only positive half cycle is considered to determine the average value of alternating quantities of sinusoidal waves. Let us take an example to understand it.



Divide the positive half cycle into (*n*) number of equal parts as shown in the above figure

Let i_1, i_2, i_3…….. i_n be the mid ordinates

The Average value of current I_{av} = mean of the mid ordinates

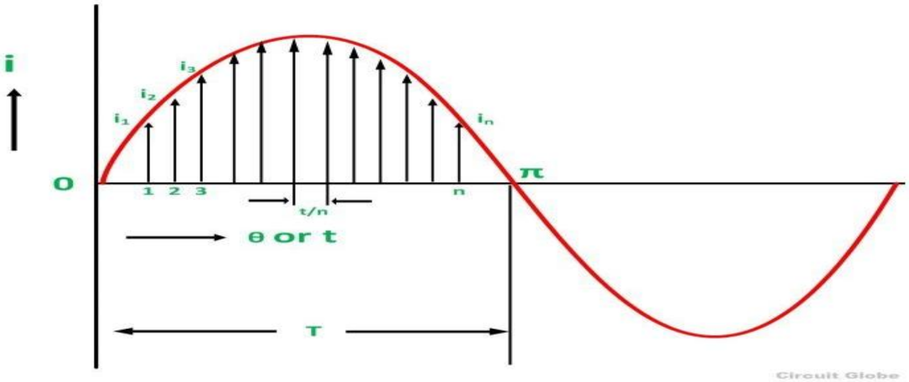
$$I_{av} = \frac{i_1 + i_2 + i_3 + \dots\dots\dots + i_n}{n} = \frac{\text{Area of alternation}}{\text{Base}}$$

R.M.S Value

Definition: That steady current which, when flows through a resistor of known resistance for a given period of time than as a result the same quantity of heat is produced by the alternating current when flows through the same resistor for the same period of time is called **R.M.S** or effective value of the alternating current.

In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values.

Let I be the alternating current flowing through a resistor R for time t seconds, which produces the same amount of heat as produced by the direct current (I_{eff}). The base of one alteration is divided into n equal parts so that each interval is of t/n seconds as shown in the figure below.



Let i_1, i_2, i_3,……….in be the mid ordinates

Then the heat produced in

$$\text{First interval} = \frac{i_1^2 Rt}{Jn} \quad \text{calories}$$

$$\text{Second interval} = \frac{i_2^2 Rt}{Jn} \quad \text{calories}$$

$$\text{Third interval} = \frac{i_3^2 Rt}{Jn} \quad \text{calories}$$

$$n^{th} \text{ interval} = \frac{i_n^2 Rt}{Jn} \quad \text{calories}$$

$$\text{Total heat produced} = \frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + i_3^2 + \ldots \ldots + i_n^2}{n}\right) \quad \text{calories} \ldots \ldots \ldots (1)$$

Since Ieff is considered as the effective value of this current, then the total heat produced by this current will be

$$\frac{I_{eff}^2 Rt}{J} \quad \text{calories} \ldots \ldots \ldots (2)$$

Now, equating equation (1) and (2) we will get

$$\frac{I_{eff}^2 Rt}{J} = \frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + i_3^2 + \ldots\ldots + i_n^2}{n}\right) \quad \text{or}$$

$$I_{eff} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \ldots\ldots.. + i_n^2}{n}}$$

$$I_{eff} = \sqrt{\text{mean of squares of instantaneous values}}$$

I_{eff} = square root of mean of squares of instantaneous values = R.M.S value

Root Mean Square is the actual value of an alternating quantity which tells us an energy transfer capability of an AC source.

The ammeter records the RMS value of alternating current and voltmeter record's the root mean square (R.M.S) value of alternating voltage. The domestic single-phase AC supply is 230 V, 50 hertz, where 230 V is the R.M.S value of alternating voltage.

The values of voltage and the current system in a DC circuit is constant, so there is no issue in evaluating their magnitudes, but in an AC system, the alternating voltage and current vary from time to time and hence it is necessary to evaluate their magnitudes.

The following three ways (peak value, Average value and R.M.S value) given above are adopted to express the magnitude of the voltage and current.

CHAPTER - 5 : IGNITION SYSTEMS

Ignition System:

The ignition system is a system used to generate a very high voltage from the car battery and to send it to each sparkplug in turn thereby igniting the fuel-air mixture in the combustion chamber of the engine.

Types of Ignition System:

1. Battery coil ignition systems
2. Magneto ignition systems
3. Electronic ignition system

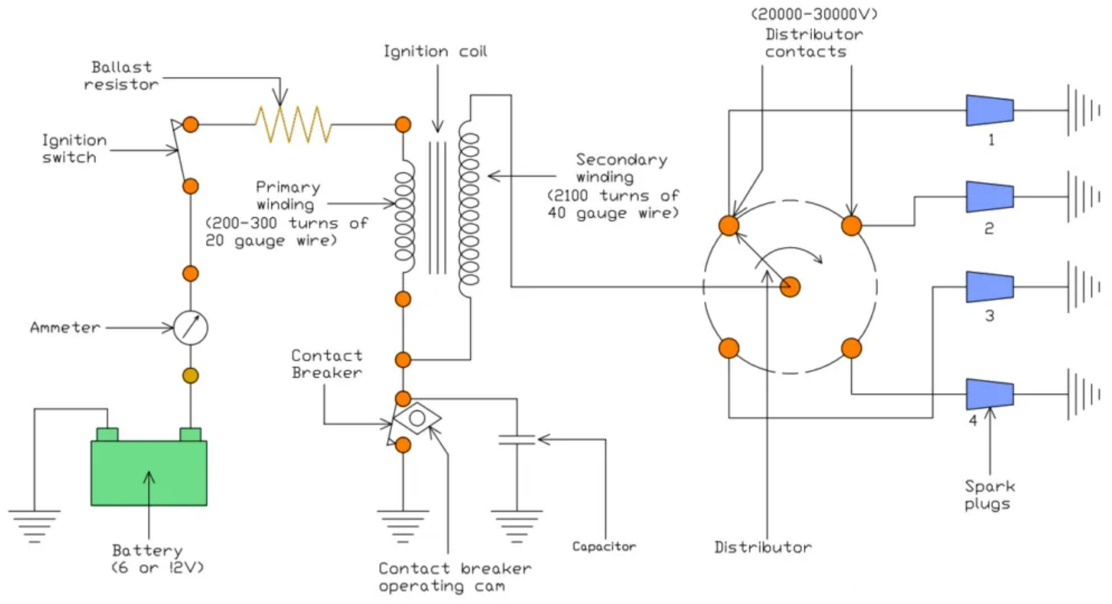
Battery Ignition System:

A battery Ignition System is used in an automobile to produce a spark in the spark plug with the help of a Battery. It is generally used in the 4-wheeler vehicle but nowadays it is also used in two-wheeler vehicles where a 6-volt or 12-volt battery supplies the current to the ignition coil.

Parts of Battery Ignition System:

The main components of Battery Ignition system are listed below:

1. Ignition switch
2. Battery
3. Ignition coil
4. Ballast resistor
5. Contact breaker
6. Distributor
7. Capacitor
8. Spark Plug



(Diagram of Battery Ignition System)

1 Ignition Switch:

It is used for ON or OFF the engine. One end of the switch is connected with the Primary Winding of Ignition Coil via Ballast Resistor, and another end is connected with the Battery.

Basically when the key is put inside it and turned the switch in ON position then the circuit is completed (Close Circuit), and when moved towards the OFF position than its work as an open circuit. Nowadays, this switch is replaced by the Push Button, and this system is called a keyless system.

2 Battery:

The battery is provided for supply the initial current to the ignition system more specifically ignition coil. Generally, the voltage of the battery is 6V or 12V or 24 V. In an automobile there are two types of Battery use widely, one is lead-acid battery and another one is the alkaline battery. Although there are Zinc Acid Battery and Lithium-Ion Battery is used in modern vehicles.

3 Ignition coil:

It is the main junction or you can say the main part of Battery Ignition System. The main purpose of it is to step up battery voltage so that it is sufficient for generates the spark.

It is working as a step-up transformer, and have two winds, one is primary which have a lesser turn, and the other one is secondary which have a higher number of turn.

4 Ballast resistor:

This is used to limit the current in the ignition circuit and generally made of Iron. It is placed in series between the Ignition Switch and Ignition Coil. However, it is used in old automobile vehicles.

5 Contact Breaker:

The contact breaker is an electrical switch which is regulated by the cam and when the breaker is open, current flows through the condenser and charges it.

6 Distributor:

It is used in the multi-cylinder engine, and its purpose is to regulate spark in each spark plug at the correct sequence.

There are two types of distributors.

- Carbon Brush Type
- Gap Type

Carbon Brush Type:

It is consist of Carbon Brush which is slides over the metallic section embedded in the distributor cap.

Gap Type:

In this type, the rotor arm is passed through the metallic section of the distributor cap but it does not touch the surface of the distributor cap. that's why it is called Gap Type Distributor.

7 Capacitor:

A capacitor is a storing device where electrical energy is stored. It is fitted parallel to the contact breaker, when the current drops then it supplied the additional current so that the spark is produced. It is made of two metal plates separated by air or any other insulating material.

8 Spark Plug:

Spark Plug is another important part of Battery Ignition system. Here the actual Spark is generated for the combustion of Fuel or Charge. If there is more then one spark plug exists then each one is connected separately with the distributor and gives the spark in the sequence.

Working Principle of Battery Ignition System:

In Battery Ignition System, when the Ignition Switch is turned on then the current will flows to the primary circuit through ballast register, primary winding and contact breaker

The flowing current induced a magnetic field around the primary winding, the more current we supply the more magnetic filed will generate. At a certain time, the contact breaker opens the current is flowing through the primary winding and fall. This sudden fall of current generates very high voltage around 300 V in the primary winding section.

Due to this immense amount of voltage the capacitor comes into the charging state when the capacitor charged fully then it starts delivering the current towards the battery, due to this reverse flowing of the current and already induced magnetic field in the primary winding, a very high voltage of 15000 V to 30000 V is generated in the secondary winding.

This high voltage current then transferred to the distributor via high tension cable, where already a rotor rotates inside the distributor cap and has metallic segments embedded on it. So when its start rotating then at a certain stage it opens the contact breaker point which allows the high voltage current to transferred to the spark plugs through the metallic segments.

So when the high voltage current reaches the spark plug then its generates a high intensity of spark inside the engine cylinder, which allows the combustion fuel to burn.

Advantages of Battery Ignition System:

These are the following advantages of Battery Ignition System:

- The intensity of spark is good.
- It can also provide a high concentration of spark even in low engine speed or starting of Engine.
- The maintenance of this ignition system is very less compared to others.

Disadvantages of Battery Ignition System:

The disadvantages are:

- Efficiency decreased with a reduction in spark intensity.
- Occupies more space.
- Efficiency decreased with a reduction in spark intensity.
- Need periodic maintenance is needed for Battery only.

Applications of Battery Ignition System:

Here is the application of it:

- Battery Ignition System is used in Automobile (Car, Bus, Truck even in the Bike) to produce the Spark so that Combustion fuel can be burned.

So that’s it for today, I hope you have learned something new from this stuff if you found it is helpful then do share this resource with your friend and your social channels. I hope to see you in any other informative article. till then bye. Stay Healthy and Keep Learning with Us.

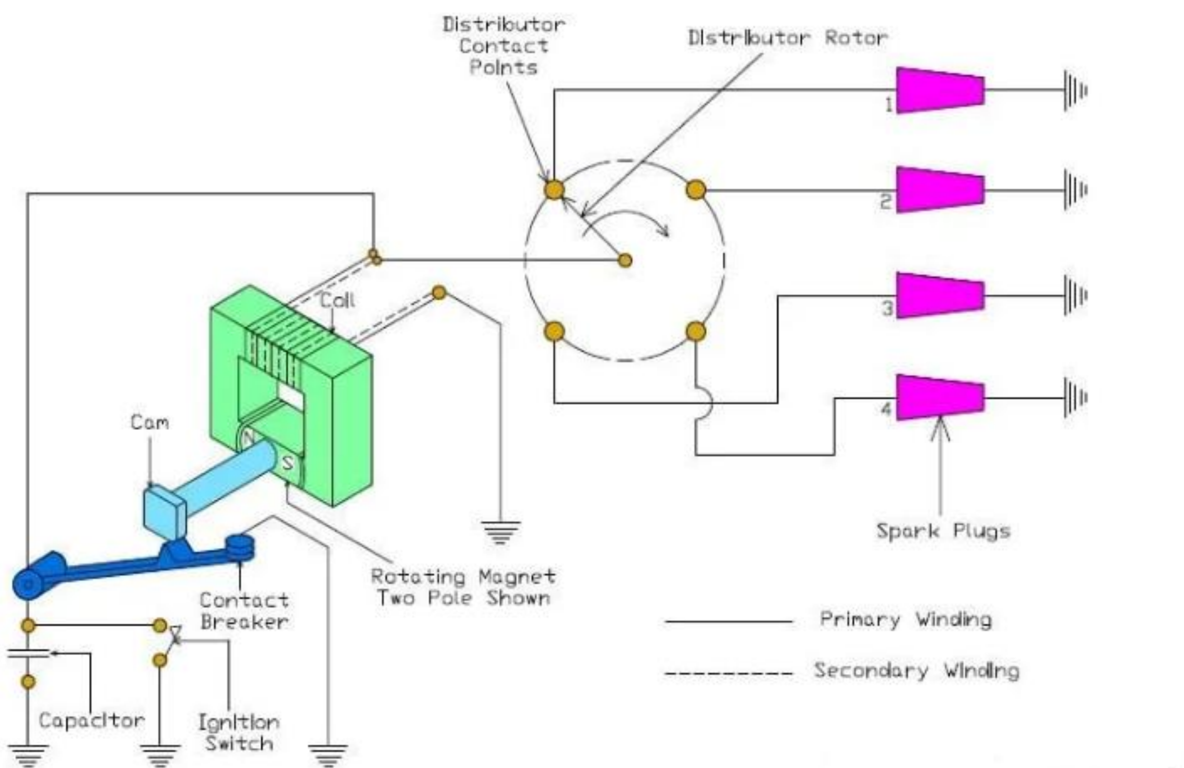
Magneto Ignition System

Magneto ignition system is an ignition system in which magneto is used [produces high volatge] for the generation of electricity and further that electricity is used in several things like to run the vehicles. This is basically used in two-wheeler vehicles (Spark Ignition Engine) nowadays.

Parts of Magneto Ignition System:

The main parts of Magneto Ignition System are:

1. Transformer core
2. Contact Breaker
3. Cam
4. Capacitor
5. Ignition Switch
6. Distributor
7. Spark Plug



(Magneto Ignition System)

1 Transformer core:

There are two types of winding we can see in Magneto Ignition System, those are:

1. Primary Winding: The main function of this winding is to draw the power from the source.
2. Secondary Winding: This winding has more turns of wire (the number is 1000 of turns of wire) as compared to the primary winding. This is connected to the Distributor (Which is having a rotor).
3.

2 Contact Breaker:

The contact breaker is regulated by the cam and when the breaker is open, current flows through the capacitor and charges it.

3 Cam:

Cam is connected to the North and south magnet.

4 Capacitor:

The main work of the capacitor is to Store the charger. The capacitor is used here is a simple electric capacitor.

5 Ignition switch:

Works for of and on the vehicles and this is set to the parallel of the capacitor because it helps to avoid the damage of excessive air.

6 Distributor:

This is connected to the spark plug and Distributor having the rotor.

7 Spark Plug:

The main work of the spark plug is firing the explosive mixture in the IC engine.

Working Principle of Magneto Ignition System:

In the Magneto Ignition System, magneto is used. When the engine of the system starts, it helps the magneto to rotate and thus it's producing the energy in the form of high voltage then, one end of the magneto is grounded through a contact breaker, and the ignition capacitor is connected to its parallel.

The contact breaker is regulated by the cam and when the breaker is open, current flows through the capacitor and charges it.

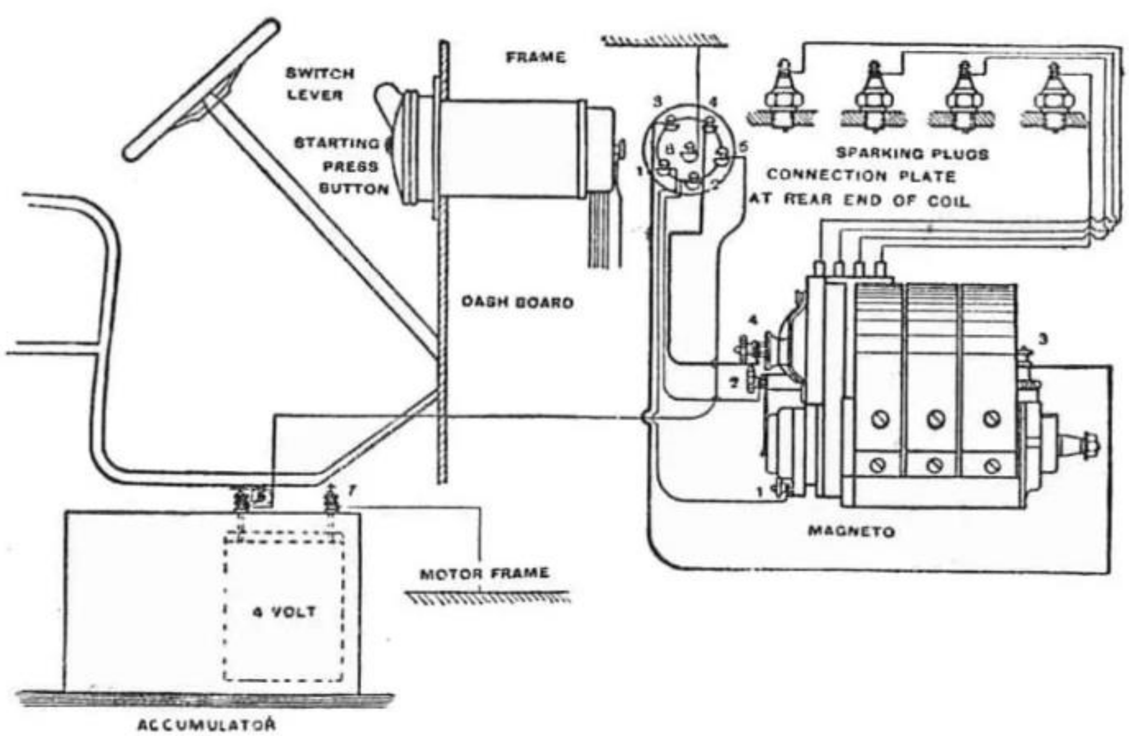
Now the capacitor is acting as a charger now, the primary current flow is reduced, thus reducing the overall magnetic field, generated in the system.

This increases the voltage in the capacitor. This increased high voltage in the capacitor will act as an EMF thus producing the spark, at the right spark plug through the distributor.

And at the starting stage, the speed of the engine is low and hence the voltage generated by the magneto is low.

But as the rotating speed of the engine increases, it also increases the voltage generated by the magneto thus the flow of the current is also increased.

Circuit Diagram of Magneto Ignition System:



Applications of Magneto Ignition System:

Magneto Ignition System nowadays widely used in:

- *This system is used for the generation of electricity (In case of Battery system their Battery is used) and to run the vehicles.*
- *This is basically used in two-wheeler vehicles (SI Engine) nowadays.*
- *A rotating magnet produces high voltage.*
- *And also this is used in various places like: Tractors, Outboard Motors, Washing Machines, Buses, Power Units, Marine Engines, and Natural Gas Engines.*

Advantages of Magneto Ignition System:

These are the following advantages of Magneto Ignition System:

- *This system requires less maintenance as compared to the Battery ignition system.*
- *This is more useful because no battery is used.*
- *It occupies less space.*
- *An electric circuit is generated by the magneto*
- *No battery is needed, so no problem of battery discharge*
- *Efficiency improves due to high-intensity spark.*

Disadvantages of Magneto Ignition System:

Although there are some disadvantages:

- *During starting, the quality of spark is poor due to low speed.*
- *This is a little expensive as compared to another ignition system.*

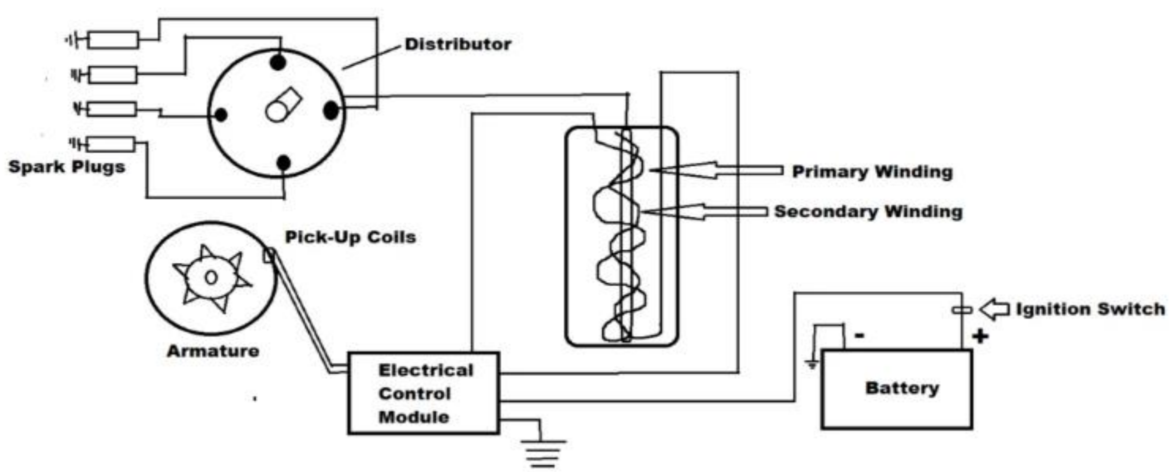
Electronic Ignition System :

As the name indicates "Electronic " the system is fully controlled electronically and that is why we called it an Electronic ignition system.

Electronic Ignition System Parts:

An Electronic ignition system consists of the following parts:

- *Battery*
- *Ignition switch*
- *Electronic control module*
- *Armature*
- *Ignition coil*
- *Distributor*
- *Sparkplug*



Electrical Ignition System

Let's understand one by one,

Battery:

A battery is an electrochemical system, it stores energy and whenever require it gives.

Battery plays an important role here. It is having two terminals positive(+) and negative(-).

The positive terminal is connected to the key (Ignition switch). The negative terminal is connected to the ground.

Ignition switch:

It is connected just after Battery.

Ignition switch works like on and of the system. When it turns ON the power supplied from battery and when it is off, the power not supplying.

Electronic control module:

Here the work starts electronically. It is used to ON and OFF the primary current.

The ignition control module performs the same operation as that contact point performs in another ignition system.

It manages the **dwell period** (remains in a given state) on its own.

Armature:

It plays an important role in generating the magnetic field. Here armature is used instead of contact breaker point in a conventional ignition system.

Ignition coil:

It is a pulse-type transformer, that is capable of producing short fire of high volt for beginning combustion.

It produces high voltage required to make pass the current in the gap at the spark plug.

An ignition coil is set of two sets of winding:

1. Primary Winding (Outer winding).
2. Secondary winding (Inner winding).

Distributor:

From the primary winding the current flows, Distributor controls on and of the cycle of the current flow.

The distributor makes spark occurs at each of the spark plugs and distributes high voltage to it.

Spark plugs:

It uses ignition coil high voltages to ignites the fuel.

Working Principle of Electronic Ignition System:

A battery plays an important role in supplying power. The negative terminal is grounded and a positive terminal is connected to the ignition switch.

Now when we turn on the ignition switch the power supply gets ON and further, the wire is connected to the electronic ignition module.

Here all the work will be controlled electronically.

From here it sends to the ignition coil. In Ignition coil there is two winding:

1. **Primary winding**
2. **Secondary winding**

Both winding are insulated and Primary are thicker than secondary winding. Now, there is one iron rod in between them that generates a magnetic field.

An armature is connected to the electronic module, the power comes and armature rotates.

Here you can see magnetic pick-up. When the magnetic pick-up and armature touches, the voltage signal generates.

and it generates further until a strong voltage signal comes. Here ON and OF process continues.

This voltage comes to the distributor section and here a rotor is connected. When the rotor rotates and touches the spark plug line it supplies the voltage and sparks plug ionized or we can say the distributor distributes the voltages.

Applications of Electronic Ignition System:

These are the applications of the Electronic Ignition System:

- *This system used in aircraft engines.*
- *It also used in modern bikes and cars.*

Advantages of Electronic Ignition System:

These are some advantages of Electronic Ignition System:

- *It has fewer moving parts.*
- *Low maintenance required.*
- *Less emission generates.*
- *Efficiency is good.*
- *It also increases fuel efficiency.*

Disadvantages of Electronic Ignition System:

Also, there are some disadvantages Electronic Ignition System and those are:

- *The cost of this system is high it means expensive in cost.*

So this is all about Electronic Ignition System, I hope you like this resource, feel free to comment down below your doubts or thoughts, I will happy to help you furthermore.

Transistorised Ignition System:

Transistorised Ignition System

A transistor interrupts a relatively high current carrying circuit, i.e, it controls high current in the collector circuit with less current in the base circuit. Therefore, a transistor is used to assist the work of a contact breaker. Hence, this system is known as Transistorassisted ignition system or transistorized ignition system.

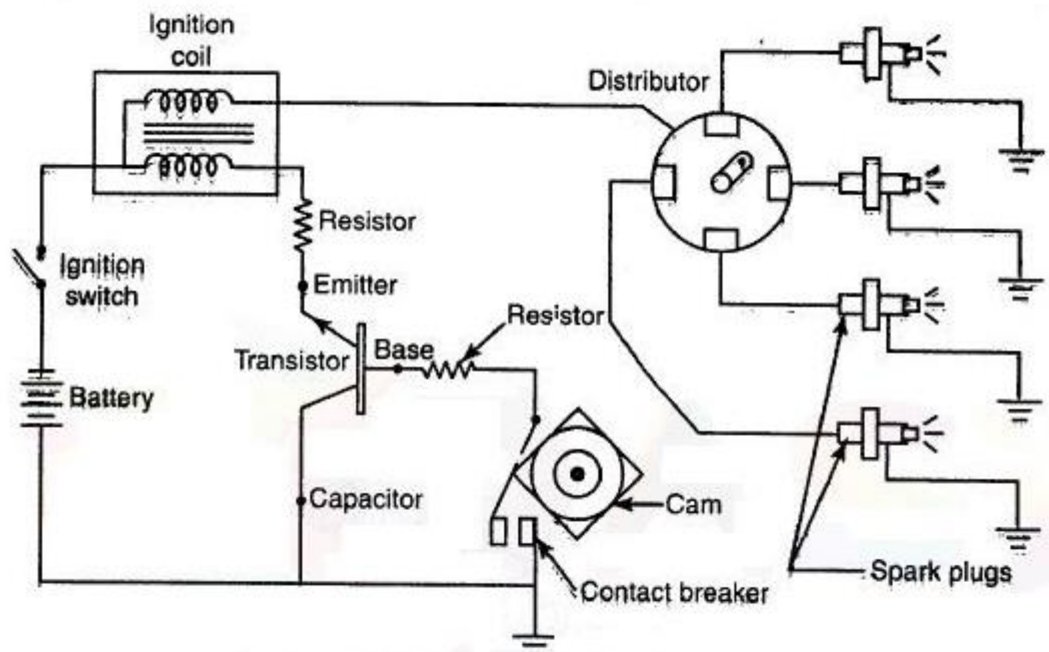
Construction:

It consists of battery, ignition switch, transistor, collector, emitter, ballast resistor, contact breaker, ignition coil. distributor and spark plugs. The emitter of the transistor is connected to the ignition coil through a ballast resistor. A collector is connected to the battery.

Working:

The cam in the distributor is rotated by the engine. It opens and closes the contact breaker points.

Diagram:



Transistorised ignition system

When the contact breaker points are closed:

1. A small current flows in the base circuit of the transistor.
2, A large current flows in the emitter or collector circuit of the transistor and the primary winding of the Ignition coil due to the normal transistor action.
3. A magnetic field is set up in the primary winding of the coil.

When the contact breaker points are Open :

1. The current flow in the base circuit is stopped.
2. The primary current and the magnetic field in the coil collapse suddenly due to immediate reverting of the transistor to the non-conductive state.
3. It produces a high voltage in the secondary circuit.
4. This high voltage is directed to the respective spark plugs through tho rotor of the distributor.
5. This high voltage produces a spark when it is tried to jump the spark plug gap. It ignites air-fuel mixture in the cylinder.

Advantages :

1. It increases the life of contact breaker points.
2. It gives high ignition voltages .

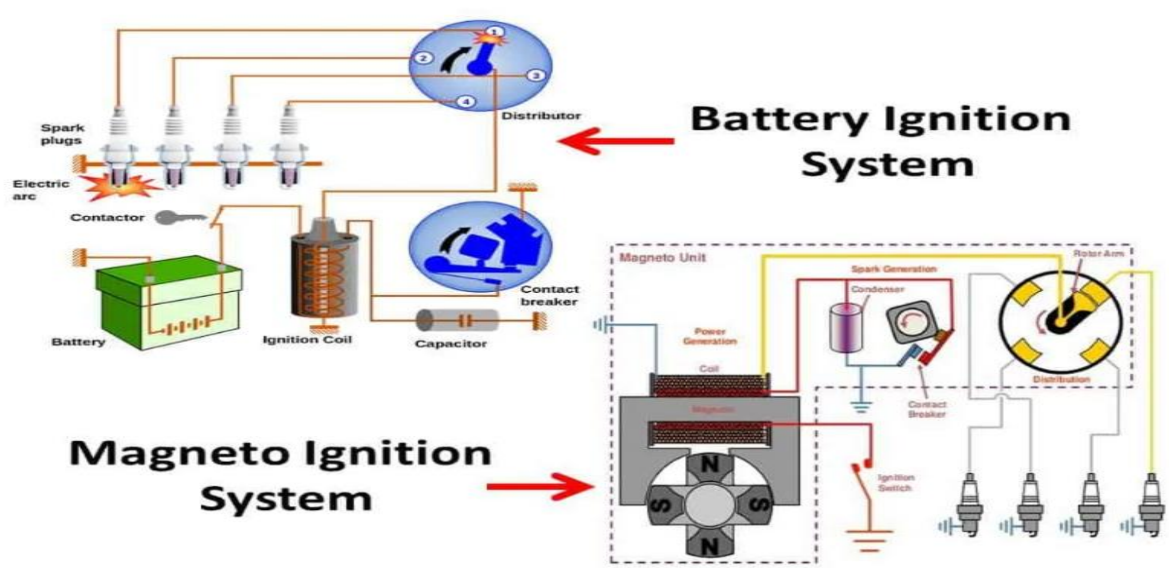
3. It gives longer duration of sparks .
4. It has very accurate control of timing.
5. It needs less maintenance.

Disadvantages :

1. More mechanical points are needed similar to a conventional system.
2. It has a tendency to side tracking .

Difference Between Battery Ignition System and Magneto Ignition System:

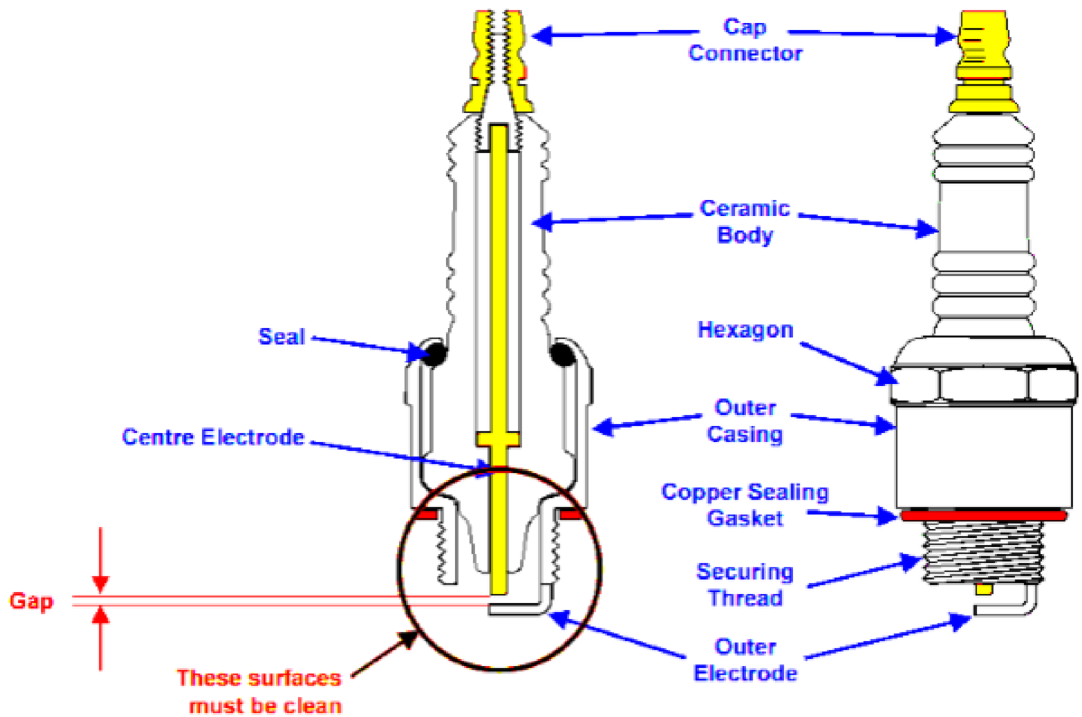
So let’s see what is the difference between Battery Ignition and Magento Ignition System.



Battery Ignition System	Magneto Ignition System
A battery is necessary, so difficult to start the engine when a battery is discharged.	No battery is needed, so no problem of battery discharge.
Maintenance problems are more due to the battery.	Maintenance problems are less because of no battery.
Current for the primary circuit is obtained from the battery.	The electric circuit is generated by the magneto.
Occupies more space.	Occupies less space.
Commonly used in cars and light commercial vehicle.	Mainly used in racing cars and two-wheelers.
Efficiency decreased with a reduction in spark intensity.	Efficiency improves due to high-intensity spark.
A Good spark available.	During starting, quality of spark is poor due to low speed.
In battery ignition system current for a primary circuit is obtained by a battery.	In the magneto ignition system, the required electric current is generated by the magneto, which is an electric generator.

Spark plug:

The spark plug consists of a porcelain insulator in which there is an insulated electrode supported by a metal shell with a grounded electrode. They have a simple purpose of supplying a fixed gap in the cylinder across which the high voltage surges from the coil must jump after passing through the distributor. The spark plugs use ignition coil high voltage to ignite the fuel mixture. Somewhere between 4,000 and 10,000 volts are required to make current jump the gap at the plug electrodes. This is much lower than the output potential of the coil. Spark plug gap is the distance between the center and side electrodes. Normal gap specifications range between .030 to .060 inch. Smaller spark plugs gaps are used on older vehicles equipped with contact point ignition systems. Spark plugs are either resistor or non-resistor types (fig. 2-46). A resistor spark plug has internal resistance (approximately 10,000 ohms) designed to reduce the static in radios. Most new vehicles require resistortype plugs. Non-resistor spark plug has a solid metal rod forming the center electrode. This type of spark plugs is NOT commonly used except for racing and off-road vehicles.



Spark Plug Heat Range and Reach

The heat range of the spark plug determines how hot the plug will get. The length and diameter of the insulator tip and the ability of the spark plug to transfer heat into the cooling system determine spark plug heat range. A hot spark plug has a long insulator tip that prevents heat transfer into the waterjackets. It will also bum off any oil deposits. This provides a self-cleaning action. AUTOMOTIVE ELECTRICAL CIRCUITS AND WIRING 58/ 101 A cold spark plug has a shorter insulator tip and operates at a cooler temperature. The cooler tip helps prevent overheating and preignition. A cold spark plug is used in engines operated at high speeds. Vehicle manufacturers recommend a specific spark plug heat range for their engines. The heat range is coded and given as a number on the spark plug insulator. The larger the number on the plug, the hotter the spark plug tip will operate. For example, a 54 plug would be hotter than a 44 or 34 plug. The only time you should change from spark plug heat range specifications is when abnormal engine or operating conditions are encountered. For instance, if the plug runs too cool, sooty carbon will deposit on the insulator around the center electrode. This deposit could soon build up enough to short out the plug. Then high voltage surges would leak across the carbon instead of producing a spark across the spark plug gap. Using a hotter plug will bum this carbon deposit away or prevent it from forming. Spark plug reach is the distance between the end of the spark plug threads and the seat or sealing surface of the plug. Plug reach determines how far the plug reaches through the cylinder head. If spark plug reach is too long, the spark plug will protrude too far into the combustion chamber and the piston at TDC may strike the electrode. However, if the reach is too short, the plug electrode may not extend far enough into the cylinder head and combustion efficiency will be reduced. A spark plug must reach into the combustion chamber far enough so that the spark gap will be properly positioned in the combustion chamber without interfering with the turbulence of the air-fuel mixture or reducing combustion action.

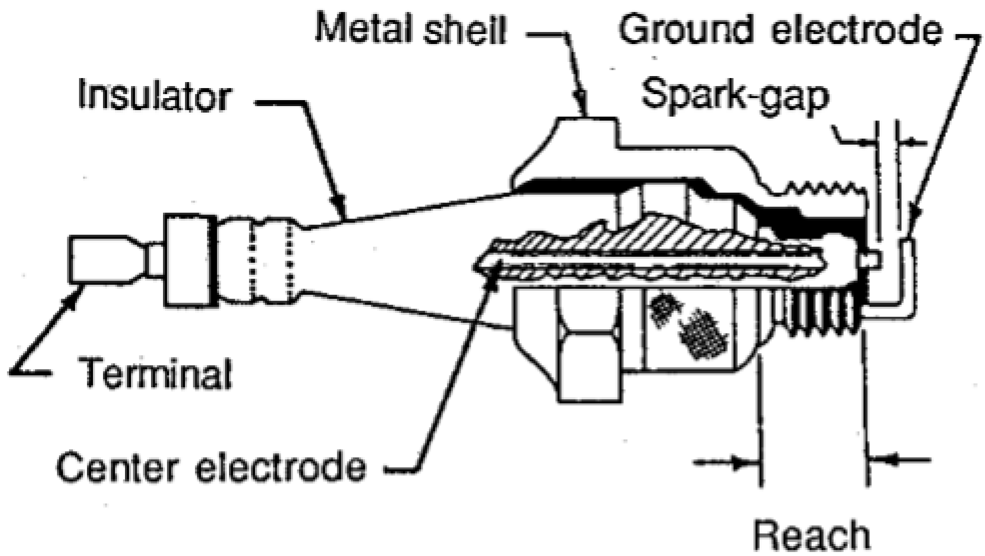


Figure 2-46.- Sectional view of a (A) non-resistor and (B) resistor spark plug.

Electronic spark timing control:

It is a closed-loop type electronic control device that continuously corrects the ignition timing and in effect it re-tunes the engine some few times every second. By providing the correct spark timing all the time, the fuel consumption is reduced considerably.

Setting of Ignition System:

Disconnect the drive to the contact breaker cover. Loosen the clamp of CB casing and distributor unit. Set the piston of cylinder NO.2 on TDC against a fixed mark on engine casing. Secure the CB camshaft in this position. The ignition timing will be set.

Firing Order Setting :

Rotate the crankshaft in correct direction. Note the order in which inlet valves(or exhaust valve) open. This the firing order of the engine

Gap Adjustment of Contact Breaker:

Turn the engine shaft manually until the contacts are freely open. Move the fixed contact plate with the help of adjustor screw till required gap is achived If gap is not correct, loosen the screws of fixed contact plate. Tighten the screw of distributor securing clamp.

CHAPTER - 6 : LIGHT

Vehicle Lighting Systems

Vehicle lighting systems are extremely important specifically from road safety considerations. If headlights suddenly fail at night and at high speed the result would be catastrophic. Many techniques have been incorporated, ranging from automatic changeover circuits, to thermal circuit breakers, which pulse the lights rather than putting them out as a blown fuse would. Most modern wiring systems fuse each bulb filament separately and if the main supply to the headlights were to fail, it is likely that the dim dip would still work.
The vehicle lights must perform two functions, they must allow the driver to see in the dark and allow the vehicle to be seen in the dark (or in conditions of poor visibility). Side lights, tail lights, brake lights and others are relatively straightforward. Headlights present the most problems because on dipped

beam they must provide adequate light for the driver but without dazzling other road users or pedestrians. Even after adoption of many techniques, it is very difficult to overcome the conflict between seeing and dazzling. One of the latest developments, ultra violet lighting, shows some promise.
The environment in which vehicle lights have to survive is hostile to say the least. There are extreme variations in temperature and humidity as well as serious shocks and vibration. This chapter covers the materials to assist with the understanding of vehicle lighting systems.

Some Terms and Definitions

This section first covers terms associated with light itself and then terms relating more specifically to vehicle lights. The definitions presented are generally related to the construction and use of headlights.

Luminous Flux. Luminous flux is defined as the amount of light passing through an area in one second. The unit of luminous flux is the lumen, which is defined as the light falling on a unit area at a unit distance from a light source that has a luminous intensity of one candela.

Luminous Intensity. This is the power to produce illumination at a distance. The unit is the candela, and it is a measure of the brightness of the light rather than the amount of light falling on an object.

Illumination Intensity. Illumination intensity is defined as the luminous flux reaching a surface per unit area. The luminous intensity of a surface, such as a road, is reduced if the light rays are at an angle. The unit is the lux, and this is equivalent to one lumen per square meter or to the illuminance of a surface one meter from a point source of light of one candela. The illumination intensity depends on the brightness, distance from, and angle to a light source.

Brightness or Luminance. Brightness is different from illumination. For example, during night driving the illumination from the vehicle lights remains constant. The brightness or luminance of the road varies depending on its surface colour. Luminance therefore depends not just on the illumination but also on the light reflected back from the surface.

Range of a Headlight. A headlight's range is the distance at which the headlight beam still delivers a specified luminous intensity.

Geometric Range. This range is the distance to the cut-off line on the road surface when the dip beam is set at an inclination of 1% below the horizontal (1 cm per m).

Visual Range. The visual range is defined broadly as the distance within the luminous field of vision, at which an object can still be seen. Since it is affected by many factors it cannot be expressed in units.

Signal Identification Range. The single identification range is the distance at which a light signal can be seen under poor conditions.

Glare or Dazzle. Glare is also difficult to express, as it is perceived differently by different people. A figure is used however, i.e. if the luminous intensity is llx at a distance of 25 m, in front of a dipped headlight at the height of the light centre, then the light is said not to glare or dazzle. In the old British method it is expressed that the lights must be dazzle a person standing on the same horizontal plane as the vehicle at a distance over 25 feets (7.62 m), whose eye level is more than 3 feets 6 inches (1.07 m) above the plane. In principle the lights when on dipped beam must fall below a horizontal line by 1% or one cm/m.

Lighting Circuit

Statutory regulations specify the number, position and specification of many of the external lights fitted to a vehicle. In addition to the obligatory lights, manufacturers and owners of the vehicle often install other supplementary lights to meet other requirements. Various lamps are grouped in separate circuits, which include the following :

(i) Side and rear lamps including lamps for the number plate, glove compartment and instrument panel illumination.
(ii) Main driving lamps (headlamps) incorporating a dipped facility to prevent approaching drivers being dazzled.
(iii) Rear fog lamp(s) to guard the rear of the vehicle in conditions of poor visibility.
(iv) Auxiliary driving lamps including spot lamps for distance illumination and fog lamps to reduce the reflected glare from fog.
(v) Reversing lamps to illuminate the road when the vehicle is moving backwards and warn other drivers of the movement.
(vi) Brake lights to warn a following driver that the vehicle is slowing down.
(vii) Interior light and courtesy lights on doors.
(viii) Instrument panel lights to signal the correct operation of a unit or the presence of a fault in a particular system.
(ix) Directional indicators and hazard warning lights.

Headlight

Headlight Reflectors

The headlight reflector directs the random light rays of the light bulb into a concentrated beam of light. It is consisted of a layer of silver, chrome, or aluminium deposited on a smooth and polished brass or glass surface. The outer surface of this layer soon tranishes in air. Therefore for a glass reflector, the surface in contact with the glass is used as the reflector and its back face is usually painted with shellac varnish or something similar for protection of the coating.

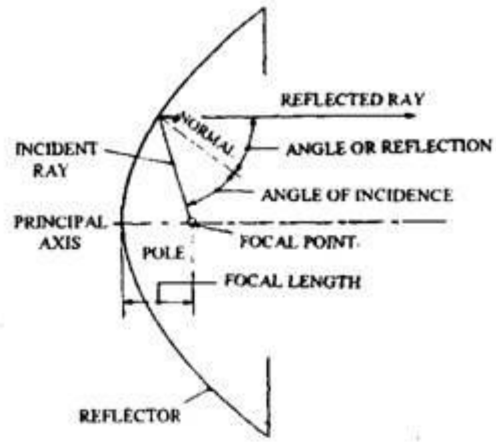


Fig. 29.3. Reflector theory.

Incase of a concave mirror reflector, the centre point on the reflector is called the pole, and a line drawn perpendicular to the surface from the pole is called the principal axis (Fig. 29.3). A point on the principal axis, where the radiating light produces a reflected beam parallel to the principal axis, is known as the focal point. The distance of the focal point from the pole is known as the focal length.

Parabolic Reflector.

For the large and truly spherical concave reflectors many focal points are necessary for all the light rays to be reflected into a parallel beam. Therefore for these reflectors with only one focal point, some of the light would be reflected as a convergent beam (Fig. 29.4A). This characteristic makes the concave spherical reflector unsuitable for headlights, and instead a parabolic reflector is used. A parabolic reflector (Fig. 29.4B) has the characteristic of reflecting rays parallel to the principal axis when a light bulb is placed at its focal point, irrespective of where the rays fall on the reflector and thereby produces a bright parallel reflected beam of constant light intensity.

For a parabolic reflector, $f = (D/2)^2/(4d)$

where, f = focal length

D = aperture diameter

and d = reflector depth.

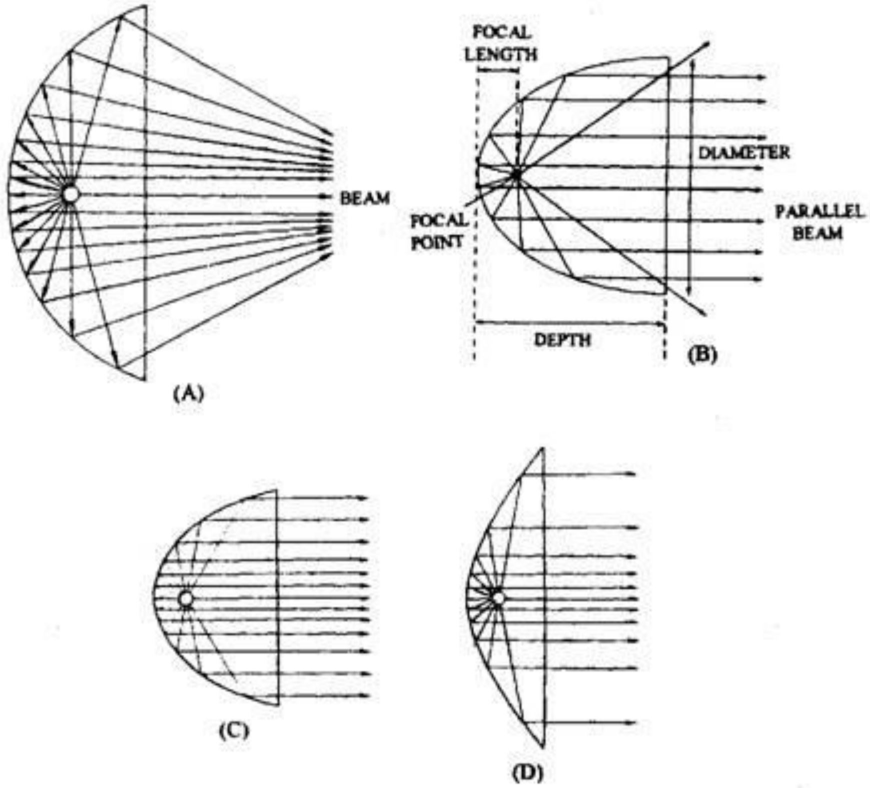


Fig. 29.4. Reflectors.
A. Spherical concave reflector. B. Parabolic reflector.
C. Narrow angled reflector, short focal distance. D. Wide angled reflector, long focal distance.

Deep or Shallow Reflectors.

A parabolic reflector reflects most of the light rays from the light bulb and only a small amount of direct rays disperses as stray light (Fig. 29.4B). The intensity of reflected light is strongest near the beam axis (except for light cut off by the bulb itself), and drops towards the outer edge of the beam. The actual amount of reflected light on the outer fringe of the beam depends to some extent on the depth and 'size of the reflector. A deep narrow angled reflector with small radius of curvature produces a concentrated beam with little stray light, due to which it becomes suitable as spotlights (Fig. 29.4C). On the other hand, a shallow wide angle reflector has more stray light and less concentrated light (Fig. 29.4D). These shallow reflectors, with high filament wattage to intensity the beam, are used for headlights and the scattered light with horizontal spread for illuminating the side of the road.

Filament Position Relative to the Focal Point.

To achieve desired beam direction and shape the location of the bulb relative to the reflector is important. In Fig. 29.5A the light filament is placed at the focal point, hence the reflected beam is parallel to the principal axis. If the filament is positioned between the focal point and the reflector (Fig. 29.5B), the reflected beam diverges along the principal axis. On the other hand, if the filament is placed in front of the focal point (Fig. 29.5C), the reflected beam converges towards the principal axis.

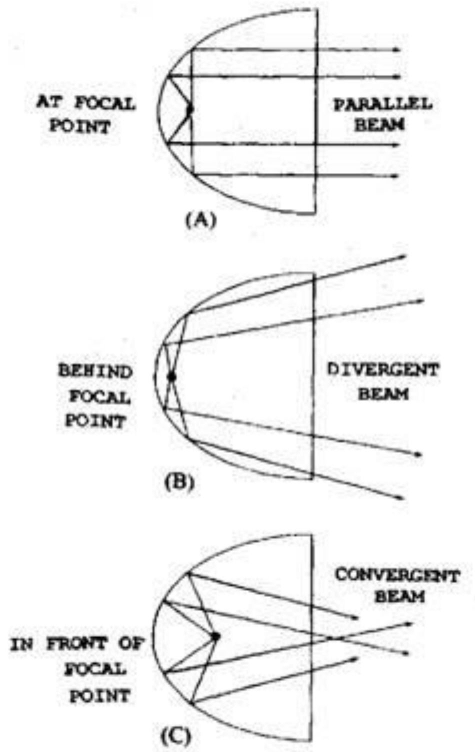


Fig. 29.5. Relationship between bulb position and beam formation.
A. Parallel beam when bulb at focal point. B. Divergent beam when bulb behind focal point. C. Convergent beam when bulb in front of focal point.

Bifocal Reflector.

The bifocal reflector uses two reflector sections with different focal points. This provides the advantage of using the light striking the lower reflector area. The parabolic section incorporated in the lower area reflects light down to improve the illumination of ground just in front of the vehicle. This technique, however, is not suitable for twin filament bulbs and hence is only used on vehicles with four headlights. With the aid of powerful CAD programs, variable focus reflectors can be built with non-parabolic sections to provide a smooth transition between each area (Fig. 29.6).

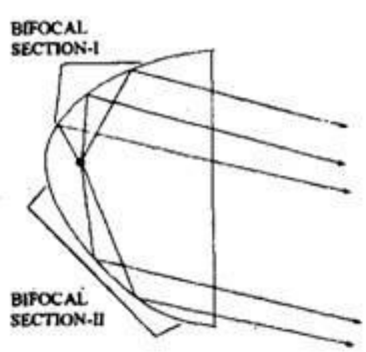


Fig. 29.6. Bifocal reflector.

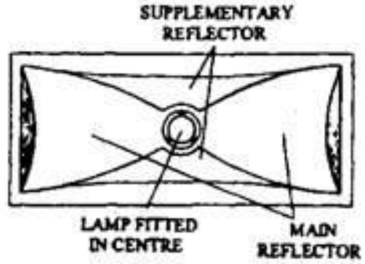


Fig. 29.7 Homi-focal reflector.

Homi-focal Reflector.

A homi-focal reflector is designed with a number of sections each having a common focal point. This technique permits the use of a shorter focal length and hence the light unit has less overall depth. The effective luminous flux is also increased. Therefore this is suitable for a twin filament bulb to provide dip and main beam. The main reflector section delivers the normal long range lighting and the auxiliary reflectors provide near field and lateral lighting (Fig. 29.7).

Headlight Arrangements

Headlight generally uses the double filament (bifocal) pre-focus type bulbs. They, however, differ to some extent in design as follows :

Offset Main and Dipped Beams.

The main-beam and dipped-deam bulb filaments are offset respectively below and above the focal point, due to which the top dipped beam converges in a downward direction and the main beam converges in an upward direction. To obtain correct beam settings, the reflector itself is tilted through a small amount downwards so that main beam is horizontal to the road. This also increases the dipped-beam downward angle so that the road surface is illuminated a little way ahead of the vehicle (Fig. 29.8).

Offset Dipped Beam.

The main filament of this type of bulb (Fig. 29.9) is located at the focal point, and the dipped filament is positioned slightly above it. The main filament is fully focussed, hence the reflected light is parallel to the principal axis, which gives a long concentrated beam. The dipped filament

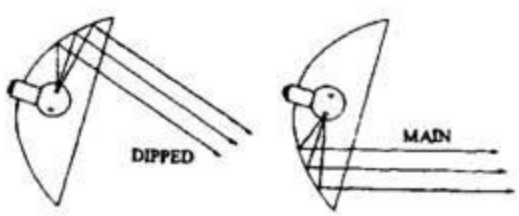


Fig. 29.8. Offset main and dipped beams.

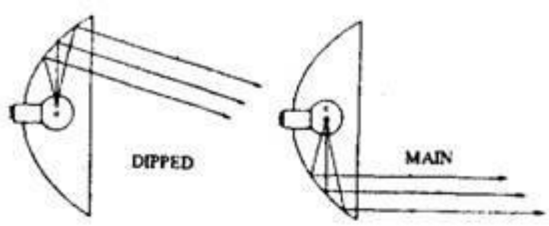


Fig. 29.9. Offset dipped beam.

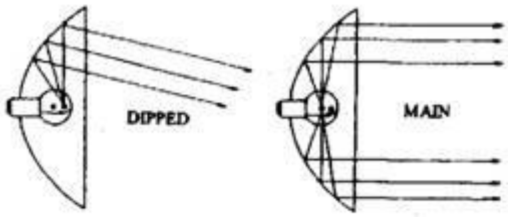


Fig. 29.10. Offset shielded dipped beam.

is out of focus providing somewhat distorted downward beam which, however, after passing through the front lens forms a wide-spread beam on the road.

Offset Shielded Dipped Beam.

This double filament bulb (Fig. 29.10) is most popular. The main filament of this bulb is placed at the focal point of the reflector and the dipped filament brought forward of the focal point. A metal cup or shield is positioned just below this dipped filament. Similar to the other two types of bulb, the main filament provides a reflected long concentrated beam parallel to the principal axis. The dipped filament produces an out-of-focus converging beam, the upper half of which points in a downward direction but the light rays from the lower half is prevent from striking the reflector by the shield, due to which none of these rays can cause dazzle by being reflected upwards.

Sealed-beam Bi-focal Unit.

Sealed beam headlights (Fig. 29.11) can he considered as a further advancement from the separate pre-focussed light bulb and reflector-lens assembly. This unit incorporates the reflector and lens to form a large all-glass sealed envelope filled with an inert gas to replace the conventional glass bulb. The two heating filaments are correctly mounted inside an aluminized glass reflector and the supporting wires are placed in the reflector by ceramic insulators.
These designs provide precise filament focus as well as prevent the entry of dirt, dust, grease, and moisture so that the rapid deterioration of the reflecting properties of the reflector is avoided. Because of the very large reflector area, filament-metal transfer due to evaporation of the tungsten does not blacken the glass lens. The light intensity in this unit only drops off by at the most 3% of its original value during its normal four-year life period, compared with a 40% reduction for the conventional double-filament (bi-focal) light-bulb. Tungsten-halogen sealed-beam headlights are

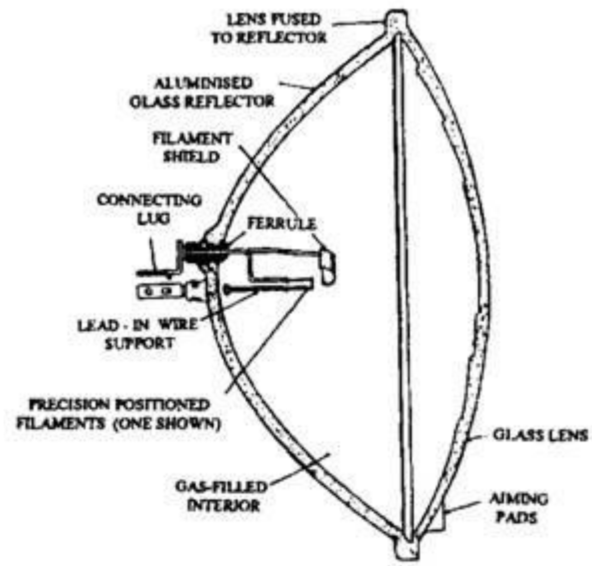


Fig. 29.11. Sealed-beam unit.

also available. However, the whole unit has to be replaced if one of the filaments fails, which is the major disadvantage.

29.3.3.

Headlight Cover Lens

The headlight must provide a powerful far-reaching central beam, around which the light is distributed both horizontally and vertically to illuminate maximum possible area of the road surface. The reflector alone cannot meet these requirements. The beam formations can be substantially improved by passing the reflected light rays through a transparent block of lenses. The lenses also redisribute the reflected light beam and stray rays to certain extent due to which a better overall road illumination is obtained With least glare. One cause the glare is the shape and size of the bulb filament, which cannot be corrected by the reflector. Even if the filament is accurately focussed, since there is no absolute point source of light, some reflected light rays deviate and form both divergent and convergent rays causing dazzle if not controlled.

Block-prism Lens.

Lenses work on the principle of refraction. The headlight front cover glass lens is divided up into a large number of small rectangular zones. Each zone optically represents a concave flute or a combination of flute and prism (Fig. 29.12). When the roughly parallel beam passes through these flutted prim sections, each individual lens element redirects the light rays producing an overall improved light projection.

The total lens-element pattern provides optimum road illumination for both the main and the dipped beam. While one block of prism elements project the rays straight ahead for the main beam, the other blocks of lens elements spread the rays out horizontally due to diverging concave-flute effect (Fig. 29.13A) and also sharply bend these rays downwards to provide diffused lighting just in front of the vehicle by the prismatic-lens effect (Fig. 29.13B).

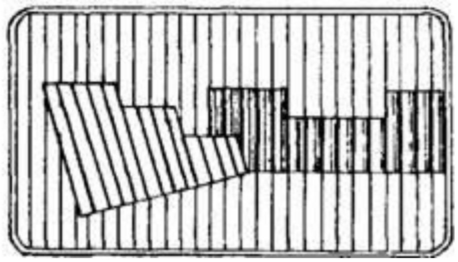


Fig. 29.12. Block-pattern headlight lens.

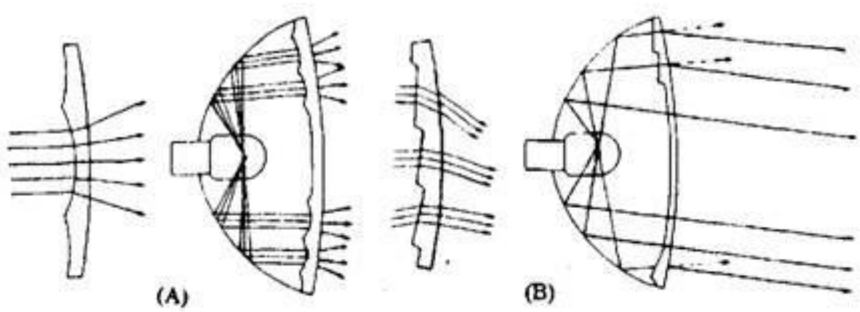


Fig. 29.13. Beam control. A. Horizontal beam. B. Vertical beam.

29.3.4.

Four Headlight System

A two-headlight system with a pre-focus double-filament bulb in each reflector is relatively effective but it compromises in light intensity to certain extent in satisfying both main- and dipped-beam conditions. The light intensity for both the filaments can be maximized by the use of four head-lights, such that, two headlights are placed adjacent to each other on each side of the vehicle. The two inner headlights incorporate single-filament bulb positioned at the focal point, and the outer headlights have pre-focus double filaments, one being on the focal point and the other slightly offset.
When the main beam is switched on, both the inner headlights provide far-searching concentrated beam and additional off-focus broad beams are provided by the outer headlight offset filaments. When the switch is changed from main to dipped beam, the above combination is extinguished, but the outer headlight filaments positioned on the focal point provide a concentrated dipped beam.
29.3.5.

Double-reflector Headlamp

This light source is highly efficient, which combines two bulbs and two reflectors in one headlamp unit. This provides, with precision, the optical requirements for main and dip beams and also satisfies the regulations regarding bulb replacement and dazzle.
SEV Marshal has produced an Ampliflux range of lamps, which delivers over twice the output of the average conventional headlamp. These lamps (Fig. 29.14) use circular or rectangular lead crystal-glass lens and reflector, which are bonded together for excellent weather protection and constant performance over a long period of time. A small inset reflector and bulb, which provides the main beam is placed in front of the main reflector. The back of the main-beam reflector is used to screen the lower half of the dip-beam reflector. This produces a sharp horizontal cut-off to the asymmetrical dipped beam pattern and avoids dazzle.

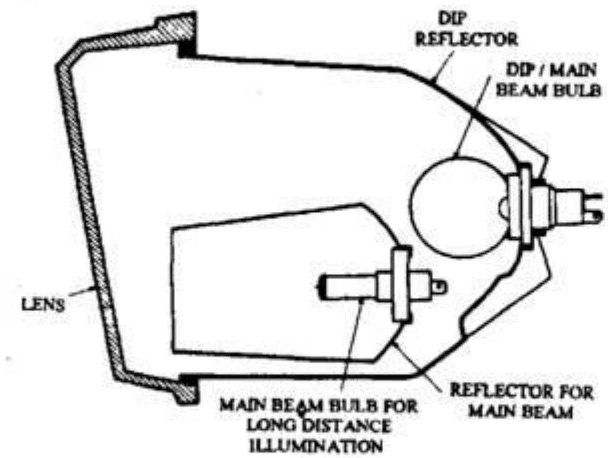


Fig. 29.14. Double-reflector headlamp.
29.3.6.

Headlamp Aiming and a Levelling System

Since 1990 some form of headlight leveller has been mandatory in some countries like Germany. The leveller system works on the principle that the position of the lights changes depending on the load in the vehicle. Figure 29.15 illustrates a simple manual aiming device. An automatic system can also be operated through sensors positioned on a vehicle's suspension. This allows automatic compensation for prevailing load distribution on the vehicle. Figure 29.16 shows the layout of this system. The actuators, which actually move the lights can vary from hydraulic devices to stepper motors.

The principle of headlight aiming is presented in Fig. 29.17. Adjustment is made by moving two screws fitted on the headlights, so that one allows the light to move up and down, and the other allows side to side movement. Many types of beam setting equipment are in use but most

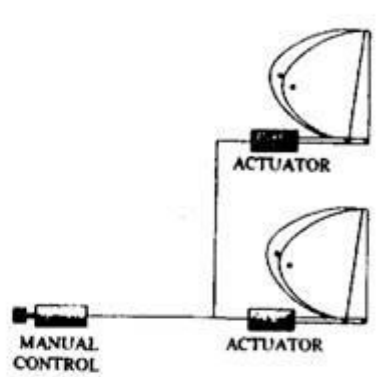


Fig. 29.15. Simple manual hadlight aiming device.

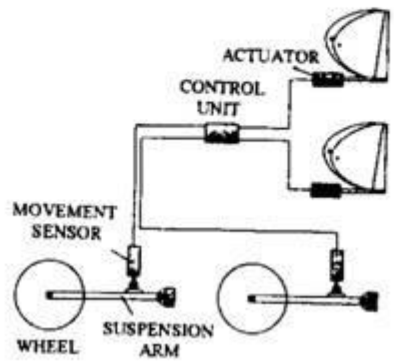


Fig. 29.16. Automatic headlight adjustment.

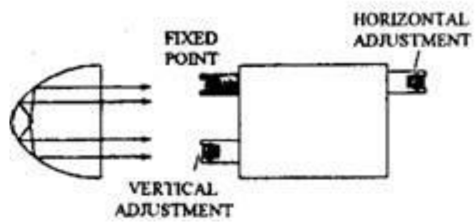


Fig. 29.17. Principle of head light aiming.

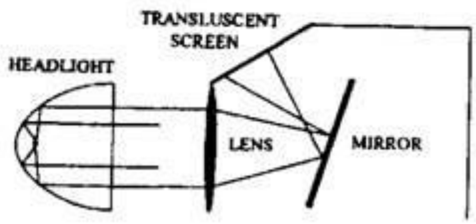


Fig. 29.18. Principle of beam setting equipment.

of them work on the same principle as shown in Fig. 29.18. Also the procedure is the same for using an aiming board, however it is more convenient and accurate, due to easier working and as less room is required.

Figure 29.19 shows one type of optical beam setter, which checks horizontal and vertical aim and also enables the lamps to be set accurately. Adjusters are fitted to each lamp to change the setting. At first the aligner is levelled and positioned parallel with the front of the car. The lamps are switched-on and the light rays from the lamp pass through a condenser lens and are reflected by a mirror on to a small screen. Most lamps are set to dip beam when aligning the lamps.

The procedure for setting the headlights of a car using an aiming board is as the follows.

(i) Park the car on level ground square on to a vertical aiming board at a distance of 10 m if possible. Preferably the car should be unladen except for the driver.

(ii) Mark out the aiming board as shown in Fig. 29.20.

(iii) Bounce the suspension to ensure that it is level.

(iv) With the lights set on dip beam, adjust the cut-offline to the horizontal mark, which is 10 mm below the height of the headlight centre, for every 1 m the car is away from the board. The break-off point should be adjusted to the centre line of each light in turn.

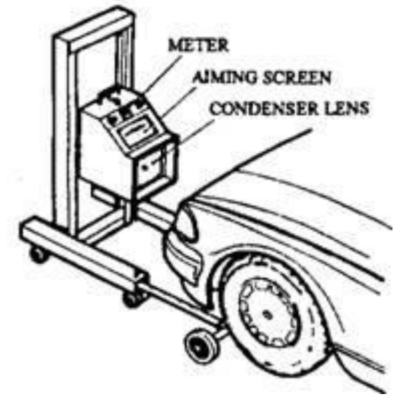


Fig. 29.19. Optical beam setter.

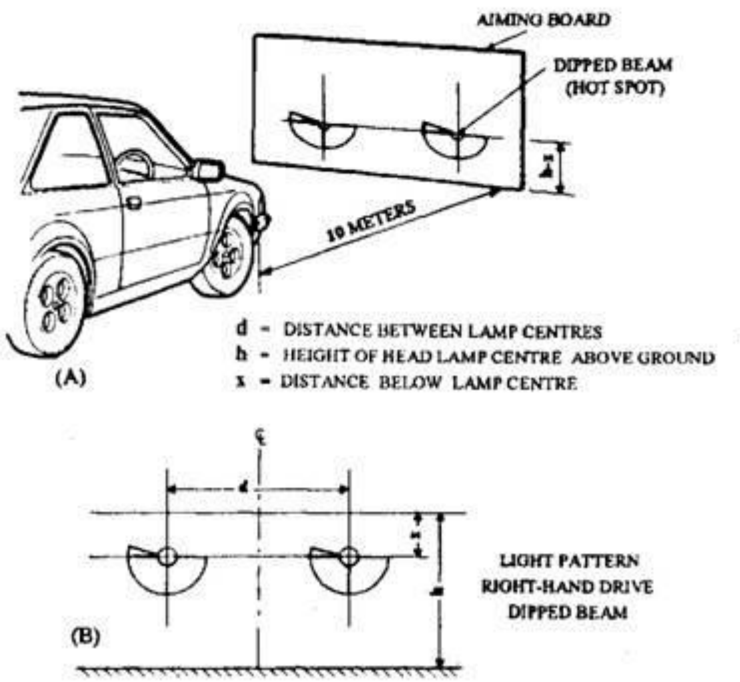


Fig. 29.20. Headlight aiming board.

CHAPTER - 7 : ACCESSORIES & CONTROL

HORN

The horn currently used on automotive vehicles is the electric vibrating type. The electric vibrating horn system typically consists of a fuse, horn button switch, relay, horn assembly, and related wiring. When the operator presses the horn button, it closes the horn switch and activates the horn relay. This completes the circuit, and current is allowed through the relay circuit and to the horn.

Most horns have a diaphragm that vibrates by means of an electromagnetic. When the horn is energized, the electromagnet pulls on the horn diaphragm. This movement opens a set ofcontact points inside the horn. This action allows the diaphragm to flex back towards its normal position. This cycle is repeated rapidly. The vibrations of the diaphragm within the air column produce the note of the horn.

Tone and volume adjustments are made by loosening the adjusting locknut and turning the adjusting nut. This very sensitive adjustment controls the current consumed by the horn. Increasing the current increases the volume. However, too much current will make the horn sputter and may lock the diaphragm.

When a electric horn will not produce sound, check the fuse, the connections, and test for voltage at the horn terminal. If the horn sounds continuously, a faulty horn switch is the most probable cause. A faulty horn relay is another cause of horn problems. The contacts inside the relay may be burned or stuck together.

WINDSHIELD WIPERS

The windshield wiper system is one of the most important safety factors on any piece of equipment. A typical electric windshield wiper system consists of a switch, motor assembly, wiper linkage and arms, and wiper blades. The description of the components is as follows:

The WINDSHIELD WIPER SWITCH is a multiposition switch, which may contain a rheostat. Each switch position provides for different wiping speeds. The rheostat, if provided, operates the delay mode for a slow wiping action. This permits the operator to select a delayed wipe from every 3 to 20 seconds. A relay is frequently used to complete the circuit between the battery voltage and the wiper motor.

The WIPER MOTOR ASSEMBLY operates on one, two, or three speeds. The motor (fig. 2-85) has a worm gear on the armature shaft that drives one or two gears, and, in turn, operates the linkage to the wiper arms. The motor is a small, shunt wound dc motor. Resistors are placed in the control circuit from the switch to reduce the current and provide different operating speeds.

The WIPER LINKAGE and ARMS transfers motion from the wiper motor transmission to the wiper blades. The rubber wiper blades fit on the wiper arms.

The WIPER BLADE is a flexible rubber squeegee-type device. It may be steel or plastic backed and is designed to maintain total contact with the windshield throughout the stroke. Wiper blades should be inspected periodically. If they are hardened, cut, or split, they are to be replaced.

When electrical problems occur in the windshield wiper system, use the service manual and its wiring diagram of the circuit. First check the fuses, electrical connections, and all grounds. Then proceed with checking the components.

There are two basic designs of windshield wiper system used on today's vehicles - a standard two or three speed system or a two-or –three speed system with an intermittent feature. In most cases, the same motor is used for standard and intermittent system.

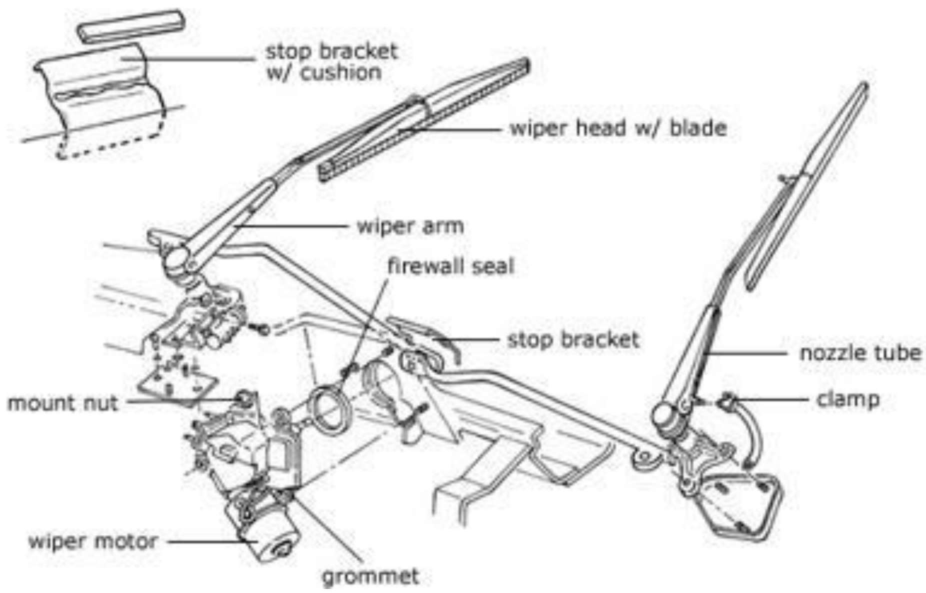
Many wiper systems offer an intermittent mode that provides a variable interval between wiper sweeps, usually controlled through a module mounted on or near the steering column. If the intermittent wiper mode is selected when wipers are in parked position, current is sent to an electronic switch to close the circuit for governor relay which closes the circuit to the low speed brush. The wiper will operate until the switch swings back to park position. The delay between wiper sweeps is determined by amount of resistance the driver puts into potentiometer control. By rotating the intermittent control the resistance value changes.

Windshield Washers:

Windshield washers spray a fluid onto the windshield and work in conjunction with the wiper blades to clean the windshield of dirt. Most systems have a washer pump installed in the fluid reservoir.
Washer systems are activated by holding the washer switch. If the wiper/washer system also has an intermittent control module, a signal is sent to the module when the washer switch is activated. An override circuit in the module operates the wiper at the wiper at low speed for programmed length of time. The wiper will either return to the parked position or will operate in intermittent mode depending upon the design of the system.

Some vehicles have washers that help keep the integral headlight/fog light clean for maximum visibility. Headlight washer systems may operate from their own switch and pump or work from conventional windshield wiper system.

Some vehicles are equipped with a low fluid indicator. The washer fluid level switch closes when the fluid level in reservoir drops below one quarter full. Closing the switch allows power from fuse panel to be applied to indicator.



Lift gate wiper/ washer system:

This system has an on/off switch to control power to the single speed wiper motor. The parking function is completed within the lift gate wiper motor and switch.

FUEL GAUGE:

What is a fuel gauge?

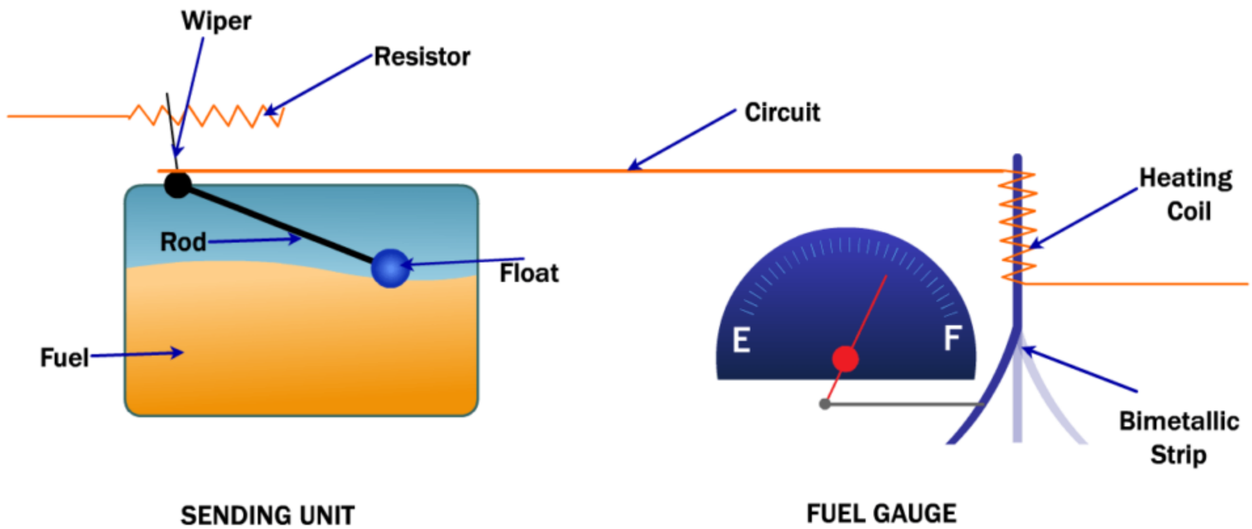
Fuel gauge is a device which indicates the amount of fuel in a tank of vehicle. In Electrical Engineering, the term fuel gauge is used to represent a device which calculates the amount of charge in the accumulators. It is fixed on the dashboard of the vehicle. Fuel gauge shows reading in analog sticks or digital bars.

Need of a fuel gauge?

Sudden shortage of fuel in the vehicle running fast on highways, hundreds of vehicle moving in busy roads of cities, air transportation, and military aircraft serving in fights at the borders can cause various problems like aircraft crashes, major accidents and traffic jams resulting into loss of time, human resources and equipments. Thus, there the need of a device called ***fuel gauge*** which sought to solve all such problems by determining the level of fuel in tank.

Working principle of fuel gauge:

Fuel gauges consists of two parts, one of which is fixed the tank called sender part while the other part fixed on the dashboards of the vehicle called receiver part. The sender part send signal using float arm, or rheostat, bimetal strip or various arrangements and the receiver part shows the amount of fuel in the form of analog sticks or digital bars by understanding those signals.

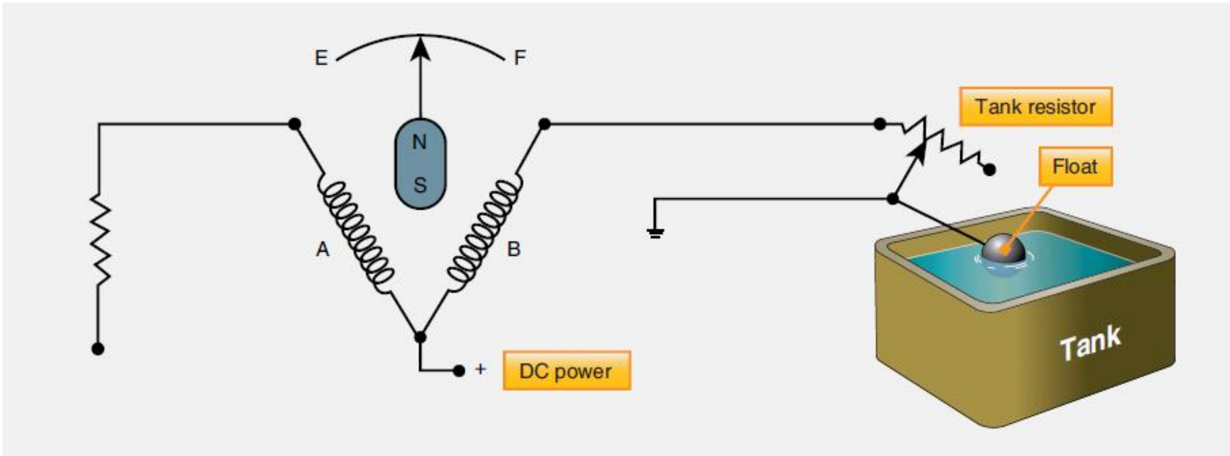


TYPES OF FUEL GAUGES:

From the various fuel gauges available, the one which is to be installed in a particular type of automobile depends on its size and number of tanks in that automobile. For example: automobiles like airplane and aircraft where tanks are made at very large distance from the cockpit, mechanical fuel gauges can't be used. At this much distance use mechanical fuel gauge is practically not possible and they can't be expected to give accurate readings. That is why in such cases electrical or electronic fuel gauges are used.

1. **Electrical fuel gauges**:

As the name suggests, in this type of fuel gauges either the sent signal is electrical or the sending part uses electricity from the battery of the vehicle to send signal. These types of gauges are the most accurate ones.



Electrical fuel gauges

Electrical gauges are further divided into four sub-categories:

(A) Electrical fuel gauge with balanced coils–

It consists of two parts one fixed on the tank and other part is fixed on dashboard. Both the parts are connected through a single wire. The part fixed in the tank consists of a rheostat and a float. The resistance in the rheostat changes as the positions of the float changes in the tank. The other part fixed on the tank consists of two coils, 90 degree apart with an armature and pointer provided at the intersection of the coil axis. On Switching on the ignition the current flows through the coils producing a magnetic field acting on the armature to which pointer is connected.

The resistance in the rheostat is highest when fuel gauge shows that tank is full and the resistance is lowest when tank is empty.

(B) Bimetal type electric fuel gauge–

Like other gauges it also consists of two parts .First is the sender part which is fixed outside the tank and the other part is the receiver part which shows the reading. The two parts are connected through a single wire.

It is made up of heating wire wound around a bimetal strip which is basically a strip used to show temperature change through mechanical displacement. It works on the principle of external float system. As the position of the float changes the height of earthed contact also changes which In turn changes the tension in the bimetal strip. The whole working unit works on the current received from the battery.

When the ignition is on, the current flows through the working part and the heat is generated causing the bimetal strip to bend.

a. **Condition1-When the tank is empty,** there is just a point contact between the two sender part .As the bimetal strip bends, the contact opens and the circuit breaks. The heating coil of the sender and receiver part is made to join in series thus same bending occurs in the bimetal strip of the receiving part, which pulls the pointer to empty.

b. **Condition 2-The float rests on the surface of the fuel**. So when the tank is full, the float and earthed contact raises up, bending the bimetal strip. As the more current is withdrawn to heat the bimetal strip under tension. Same bending of bimetal strip occurs in the receiving part which pulls the pointer to full.

(C) Thermal type electric fuel gauge

The common part of bimetal and thermal electrical gauge is that the construction of both the receiving part is same. In this type of electric gauge, the rheostat is present in a form of sliding contact on a resistance wire which is regulated by float. The two contacts are connected in series to a voltage supply which works when ignition starts.

In this gauge, the resistance is lowest when the tank is full and highest when the tank is empty, unlike the gauge with balanced coils.

When the resistance is least in the rheostat, of the part fixed in tank, the current flows through the circuit causing the bimetal strip to bend fully.

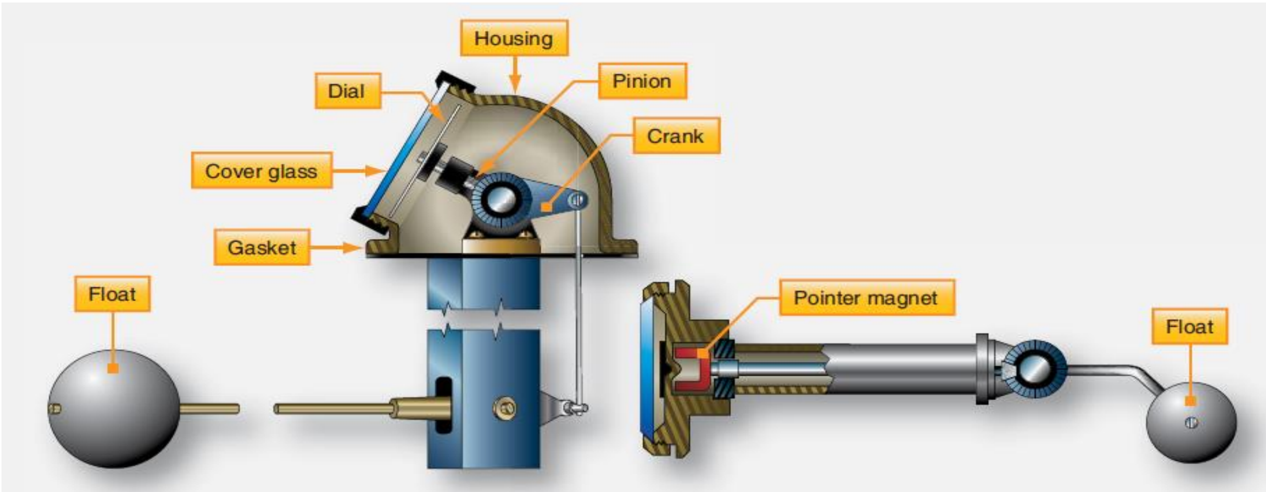
When the resistance is highest, it reduces the current flow to the circuit indicating that tank is empty.

(D) Thermostatic type electric fuel gauge

This type of gauge was used in old models of car. The sender part and the receiver part are connected by two wires. Pair thermostat plates are used in the receiver part, wound by a heating coil. This also works on the current provided by the battery when the ignition Is switched on. The current passes through the coil causing thermostat plates to bend due to heat to move the indicator over the scale.

3. Mechanical type fuel gauge:

They work on the internal float mechanism and are also known as a direct reading gauge. The float rests on the surface of the fuel to which the indicator is connected. The float mechanically controls the indicator. As the height of the fuel changes, the level of floats also changes, thus changing the reading shown on the dashboard.



(Mechanical type fuel gauge)

3. The electronic type fuel gauge:

Unlike the types of fuel gauge we discussed above, It has no moving part like float ,rheostat fixed in the tank. The dielectric property that is property of passing electrical force through it without the movement of particles of substance of fuel and the air vapor above it provides a way to measure fuel quantity. The capacity o tank will depend on the ratio of fuel and vapors in the tank.

(Electronic type fuel gauge)