UNIT-I

Construction and operation of Dc Machines

→ Construction and principle of operation of Dc machine.
→ emf equation for generator.
→ classification of Dc machines based on excitation
→ occ of Dc shunt generator
→ applications of Dc Generator.

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→ What is Machine :-

Machine is the devise that comprises of the stationary Parts and moving parts combined together to generate, transform (or) utilize the mechanical energy.

All the machines are made up of elements (or) Parts and units. Each element is a separate Part of the machine and it may have to designed separately and in assembly.

Each Element in turn can be Complete Part or made up of several small pieces which are joined together by riveting, Welding etc. Several machine Parts are assembled together to form what we call as Complete machine.

Examples of the machines :-

1. Lathe :- It utilizes machanical energy to cut the materials. The other types of machine tools also perform the same task.
2. Turbines :- They produce Mechanical energy.
3. Compressors :- They use mechanical energy to compress the air.
4. Engines :- They Consume the fuel and produce mechanical Energy.
5. Refrigerators & air - Conditioners :- They use mechanical engineering to produce Cooling effect.
6. Washing Machine :- They use mechanical energy to wash the clothes.

⇒ What is Electrical Machine

An electrical machine is a device which converts mechanical energy into Electrical Energy (or) vice - versa.

Electrical Energy ⟷ Mechanical Energy

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Introduction:-

Electrical supply is available in two forms such as (i) Dc supply (ii) Ac supply. Based on supply the machines are classified into two types such as

(i) Dc Machines

(ii) Ac Machines.

Machines

- Dc machines
- Ac Machines.

→ In today's world, almost all land-based electrical Power supply networks are Ac system of generation, transmission, transformation, transmission and distribution.

→ Dc machines are one of the most commonly used machines for ~~electrical~~ electro-mechanical energy Conversion. Converters which are used continuously to convert electrical input to mechanical o/p (or vice versa are ~~eta~~ called Electric machines. An electric machine is there for a link b/w electrical s/m and a mechanical system.

Dc machines

- DC Generators
- DC Motors.

→ The machine which produces Dc Electrical Power is known as dc generator. An Electric generator is a machine which Converts mechanical Energy/Power into electrical energy/Power.

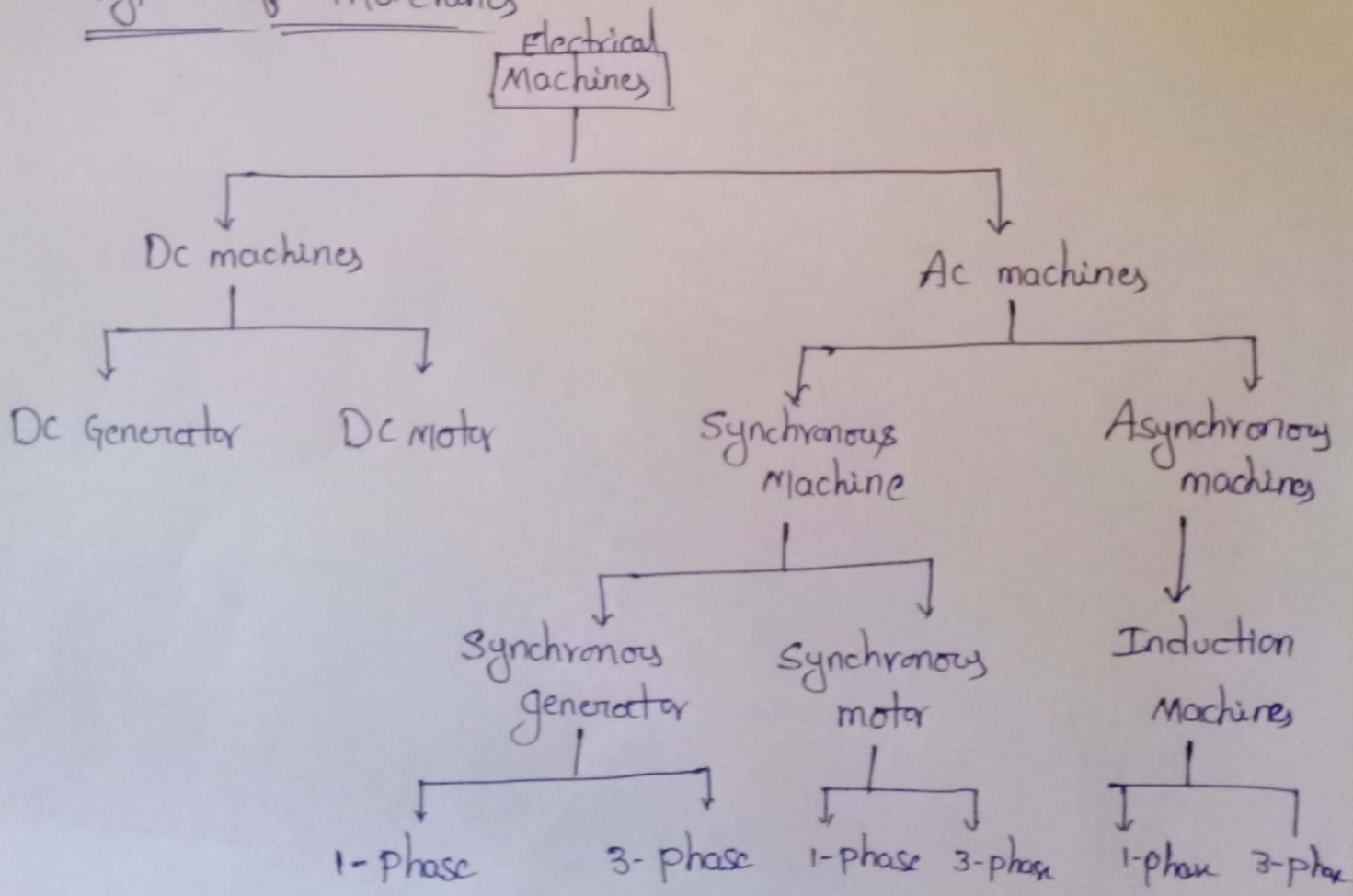
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→ The machine which produces mechanical power is known as Dc motor

→ An electrical motor is a machine which converts electrical energy / power into mechanical electrical energy / power.

→ A Dc machine works as a Dc generator when it's driven by a prime mover. The same machine works as a Dc motor when electrical energy is supplied to it. Therefore, the constructional features of a Dc generator and Dc motor are the same.

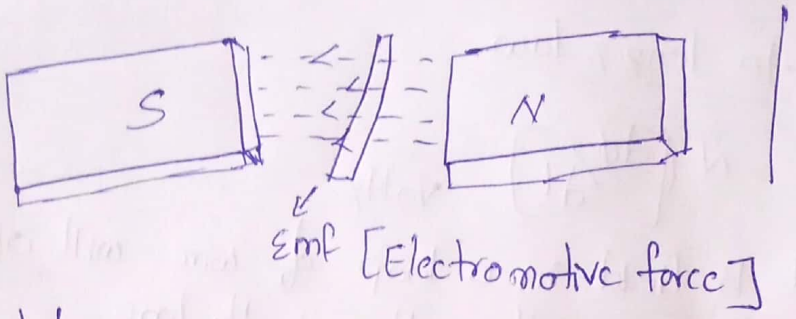
⇒ Types of Machines



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→ Faraday's laws of Electromagnetic induction:- by [Michael Faraday]

Faraday's laws of Electromagnetic induction consists of two laws. The First law describes the induction of emf in a conductor and the second law quantifies the emf produced in the conductor.



Faraday's First law:-

Whenever a conductor is placed in a varying magnetic field, Emf induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.

Faraday's second law:-

The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Based on his experiments we now have faraday's law of electromagnetic induction according to which the amount of voltage induced in a coil is proportional to the number of turns and changing magnetic field of the coil.

So now, the induced voltage is as follows:-

$$e = N * \frac{d\phi}{dt}$$

Where e, is the induced voltage

N - is the number of turns in the coil

ϕ - is the magnetic flux

t - is the time

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Lenz's law of Electromagnetic Induction :-

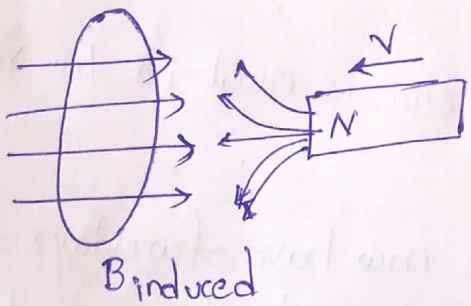
lenz law of electromagnetic induction states that, When an emf induces according to Faraday's laws the polarity (direction) of that induced emf is such that it opposes the cause of its production.

According to lenz's law.

$$E = -N\left[\frac{d\phi}{dt}\right] \text{ volts.}$$

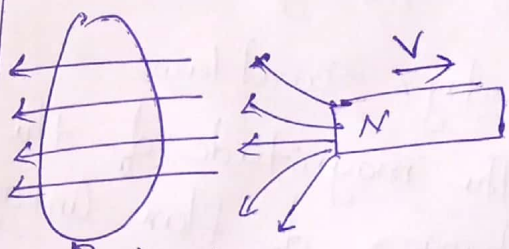
→ The induced B field in a loop of wire will oppose the change in magnetic flux through the loop.

* If you try to increase the flux through a loop, the induced field will oppose that increase



B induced

* If you try to decrease the flux through a loop, the induced field will replace that decrease



B induced.

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⇒ Fleming's right hand rule :-

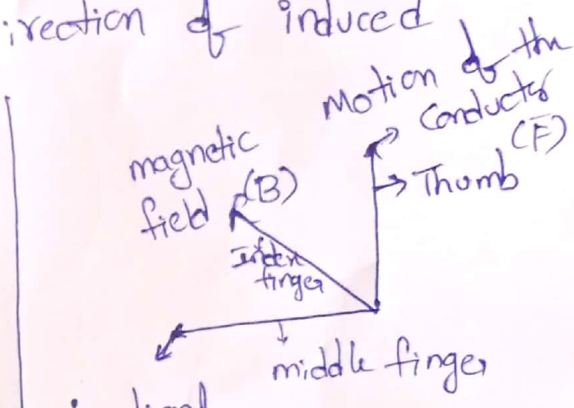
Fleming's right hand rule states to hold the forefinger, middle finger, and thumb of right hand mutually perpendicular to each other. so that

→ The forefinger points in the direction of external magnetic field.

→ Thumb points in the direction in which of motion of conductor.

→ middle finger points in the direction of induced current in the conductor.

Fleming's right hand rule is used to determined the direction of induced current in the conductor when a conductor moves in a region of magnetic field.



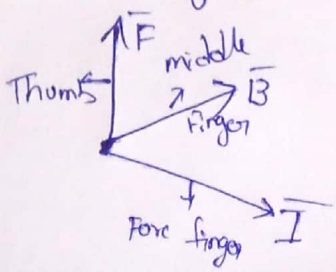
⇒ Fleming's left hand Rule :-

Fleming's left hand rule states that if we stretch the thumb, the forefinger and the middle finger of our left hand such that they are mutually perpendicular to each other. ~~If the fore~~

→ If the Forefinger gives the direction of current [I]

→ middle finger points in the direction of magnetic field [B]

→ Thumb points towards the direction of the force of motion of conductor.



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Wherever a current carrying conductor comes under a magnetic field, there will be a force acting on the conductor. The direction of this force can be found using Fleming's left hand rule.

NOTE:-

→ Fleming's left-hand rule is mainly applicable to electric motors

→ Fleming's Right-hand rule is mainly applicable to electric generators.

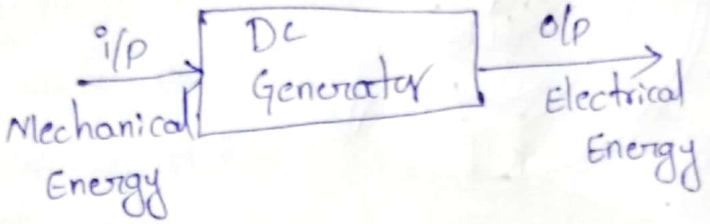
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⇒ Construction and principle of operation of Dc Machine:-

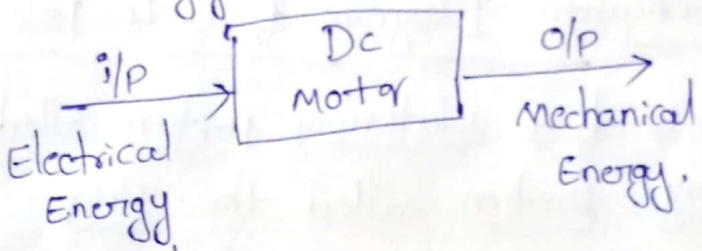
Dc Machine

Dc Generator Dc Motor.

Dc Generator:- A generator is an electrical device that is used to convert energy from mechanical to Electrical Energy.



Dc Motor:- A Motor is a device that converts Electrical Energy into Mechanical Energy



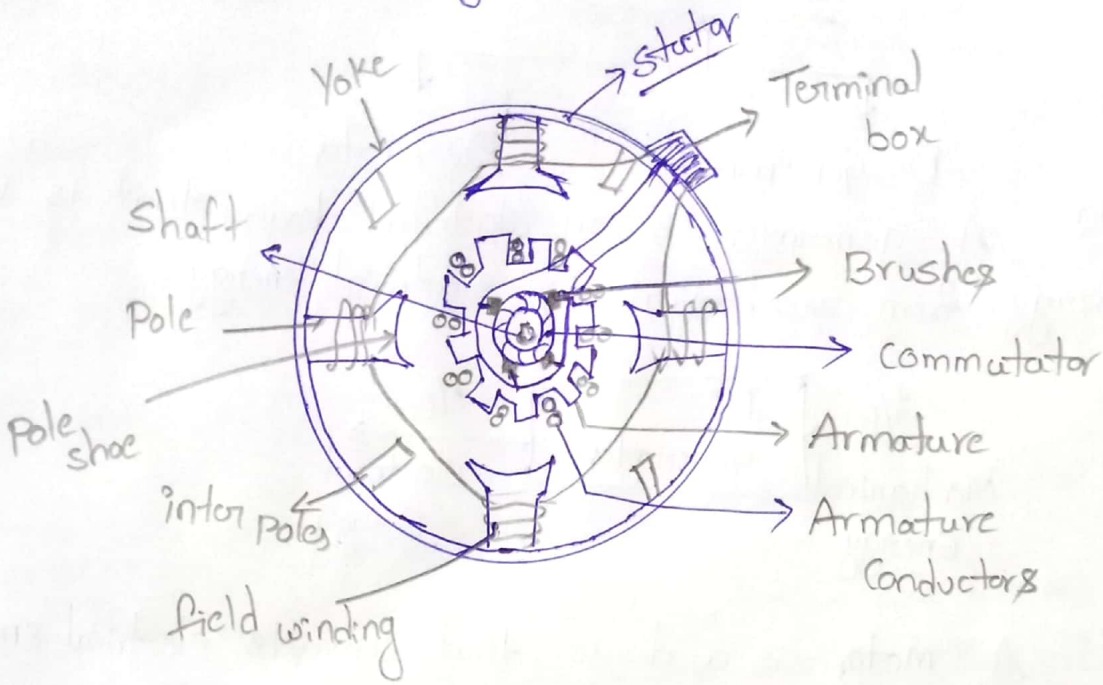
→ What is a Dc Machine:-

It is a rotating device which can be either a motor (or) a generator. Depending upon its construction and operation it is classified as a Motor or a generator.

*Note:- Theoretically, a Dc generator can be used as a Dc motor with out any constructional changes and vice-versa is also possible. Thus a Dc generator (or) a Dc Motor can be broadly termed as a Dc Machine.

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→ Dc machine whether a generator or motor with four poles is shown in the fig.



fig(1):- Schematic Diagram of a 4-Pole Dc machine

→ A generator consists of a stationary portion called the stator and the rotating portion called the Rotor.

→ There are two windings in the machine namely field winding and armature winding. The arrangement of these windings can be done like this, the field winding is arranged on the stator whereas the armature winding is arranged on the rotor.

→ Dc machine consists of the following main parts:-

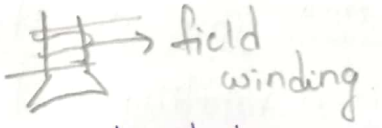
1. Magnetic frame or Yoke
2. Armature core or stack.
3. Armature winding.
4. Field poles
5. Field coils or Field winding.
6. Commutator
7. Brushes and Brush holder
8. Shaft and Bearings
9. Inter Poles

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① Magnetic Frame (or) Yoke :-

The Yoke is a circular steel ring, which supports the field poles mechanically and provides the necessary magnetic path between the poles. The Yoke can be solid or laminated. In many Dc machines, The Yoke also serves as the frame. In small machines, Yoke are made of cast iron. But for large machines usually cast steel or rolled steel is employed.

② Field Coils (or) Field winding :-



The field coils are those windings, which are located on the poles and set up magnetic field in the machine. They also usually consist of copper wire, are insolated from the poles. The field winding is made up of some conducting materials like aluminum, copper etc The field coils may be either shunt windings [in Paralled with the armature winding] or series windings [in series with the armature winding] or a combination of both.

③ Field Poles :-

Each field pole is divided into two parts namely Pole core and Pole shoe. In modern design the complete pole cores and pole shoes are made of thin laminations of annealed steel or cast iron. which are pressed together and riveted and are secured to the Yoke by means of screw, bolted into steel rod as shown in the following fig.

* The main function of Pole core is to establish the required magnetic flux.

The Pole shoe serves the following two functions :-

① It distributes the magnetic flux uniformly in the air gap and reduces the reluctance of the magnetic path due to its larger cross section.

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② It supports the field winding

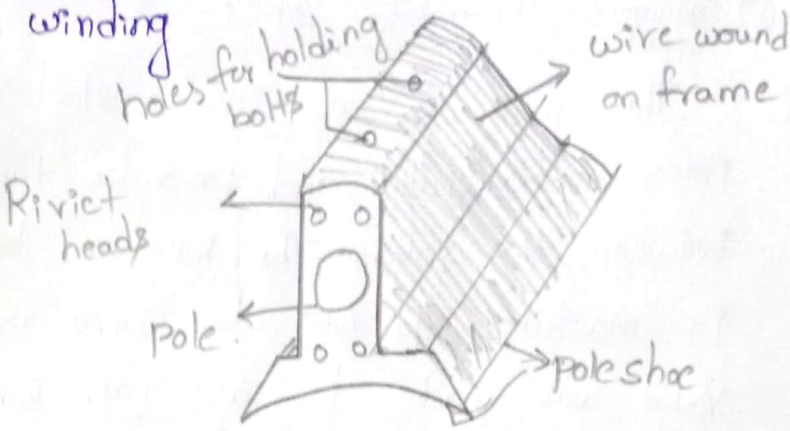
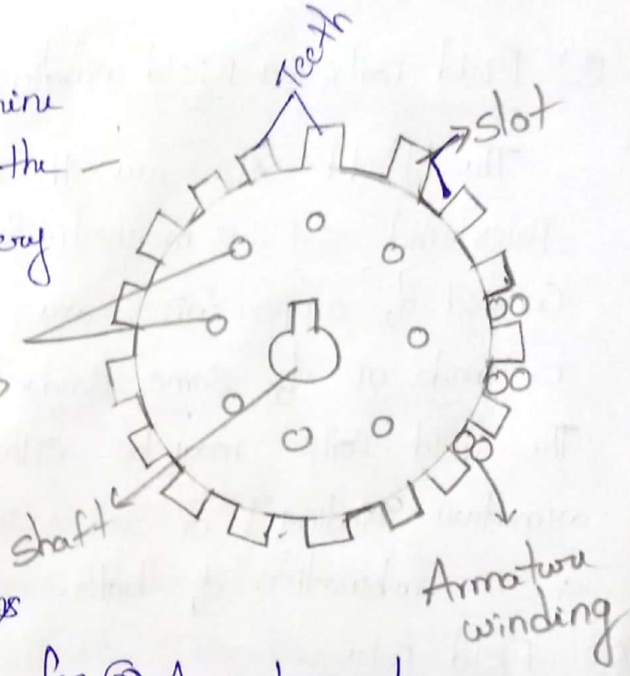


fig ② Construction Details of a Field Pole.

⇒ Armature Core or Stack

It is a rotating part of the Dc machine It is cylindrical in shape and mounted on the shaft. It consists of slots on its periphery and the air ducts to permit the air flow through armature, which serves as a cooling purpose as shown in fig③.



It is made up of silicon steel laminations having thickness of 0.3 mm to 0.5 mm. in order to reduce the eddy current losses. The laminations are welded, riveted, bolted or bonded together.

fig ③ Armature of a Dc machine

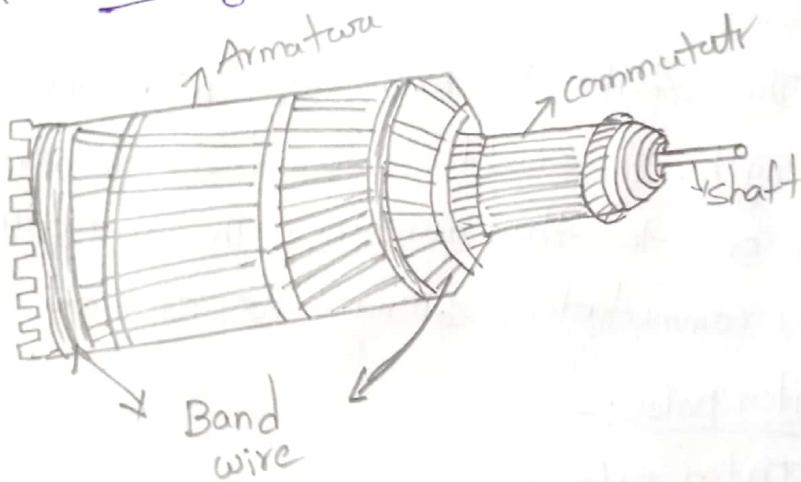
→ Armature winding :-

The armature winding is the winding, which fits in the armature slots and is eventually connected to the commutator. It either generates or recieves the voltage depending on whether the unit is a generator or motor. The armature winding usually consists of copper wire, either round or rectangular and is insolated from the armature stack. As the armature winding carries entire current which depends on external load and so it is made up of conducting materials like copper.

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→ Commutator :-

The Commutator is the mechanical rectifier, which changes the Ac voltage of the rotating Conductors to Dc voltage. The Commutator is cylindrical in structure and it is made up of Copper or bronze. It consists of a number of segments normally equal to the number of slots. The segments are separated from each other by thin mica insulation



→ Brushes and Brush

→ Brushes and Brush Holder :-

- Brushes Conduct the current from the Commutator to the external circuit. There are many types of brushes. A brush holder is usually a metal box that is rectangular in shape. The brush holder has a spring that holds the brush in contact with the Commutator. Each brush usually has a flexible copper shunt or pig-tail, which extends to the lead wires. often, the entire brush assembly is insulated from the frame and is made movable as a unit about the Commutator to allow for adjustment.

The brush is made up of carbon because

① It has high reliability to draw the current.
② since it has highly resistive material, Spark can be avoided.
③ as it is a hard material, it can not be wasted while rubbing at the surface of Commutator.

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→ Bearings:- The ball or roller bearings are fitted on the end housings. The function of the bearings is to reduce friction b/w the rotating and stationary parts of the machine. Mostly high carbon steel is used for the construction of bearings as it is a very hard material.

→ shaft:-

The shaft is made of mild steel with a maximum breaking strength. The shaft is used to transfer mechanical power from or to the machine. The rotating parts like armature core, commutator, colling fans, etc are keyed to the shaft.

→ inter poles:-

Inter poles are similar to the main field poles and located on the yoke b/w the main field poles. They have windings in series with the armature winding. Inter poles have the function of reducing the armature reaction effect in the commutating zone. The eliminate the need to shift the brush assembly.

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⇒ Induced Emf

Generally induced ε.m.f is two types.

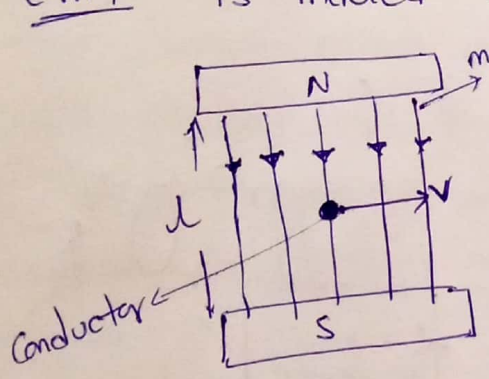
① Dynamically induced emf

② statically induced emf

- Self Induced ε.m.f
- Mutually Induced emf.

① Dynamically induced ε.m.f

In dynamically induced electromotive force the magnetic field system is kept stationary, and the conductor is moving, or the magnetic field system is moving, and the conductor is stationary. Thus by following either of the two process the conductor cuts across the magnetic field and the e.m.f is induced in the coil.



l = length (m)

B = magnetic field [wb/m²]

V = velocity (m/s)

dx = Small distance

dt = time [sec]

Change in flux = Flux. density * Area (height [h x bridgth])

$$d\phi = B \times [l \times dx]$$

According to Faraday's laws $e = N \cdot d\phi/dt$

$$e = N \cdot \frac{B \cdot l \cdot dx}{dt}$$

Where N = 1 → using one Conductor

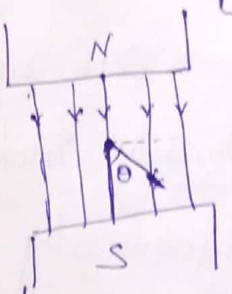
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$e = Bl\left[\frac{dx}{dt}\right]$

Where $\frac{dx}{dt} = v$ [velocity]

$\boxed{e = Blv}$ volts

Conductor is moved in stationary magnetic field at angle θ with the direction of flux which is shown in fig.



Then the induced emf is $\boxed{e = Blv\sin\theta}$ volts.

Ex:- The Generator works on the production of dynamically induced emf

⇒ Statically Induced emf:-

statically Induced emf is of two types. They are

① self induced emf
② Mutually induced emf

① Self Induced e.m.f.-

Self Induced is that phenomenon where by a change in the current in a conductor induces an emf in the conductor itself. ie when a conductor is given current, flux will be produced, and if the current is changed the flux also changes, as per Faraday's law when there is a change of flux, an emf will be induced. This is called self induced emf.

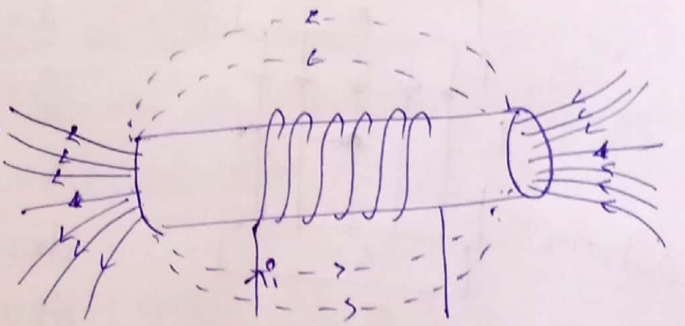


fig ⓐ self-Induced emf

* The induced emf will be always opposite in direction to the applied e.m.f. The opposing emf thus produced is called the counter emf of self induction

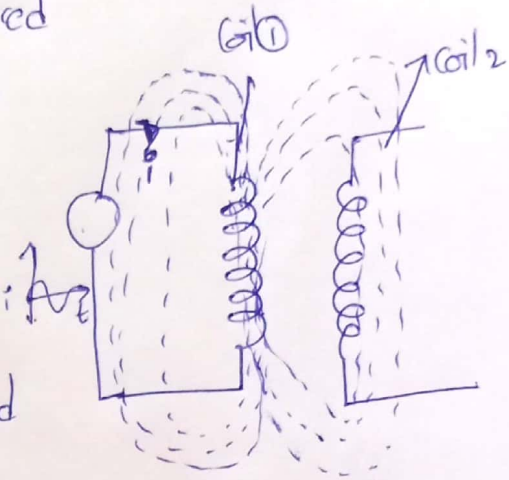
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Uses of self induction

① In regulators, to give reduced voltage to the fans.
② In lightning arrestor.
③ In auto-transformers.
④ In smooth choke which is used in welding plant.

Mutually Induced Emf

It is the electromagnetic Induction produced by one circuit in the near by second circuits due to the variable flux of the first circuit cutting the conductor of the second circuit, that means when two coils or circuits are kept near to each other and if current is given to one circuit and it is changed, the flux produced due to that current which is linking both the coils; an emf will be produced in both the circuits. The production of emf in second coil is due to the variation of current in first coil known as mutual induction.



fig⑥ mutually induced emf

Uses:—
① It is used in ignition coil which is used in motor car.
② It is also used in Inductance furnace.
** ③ It is used for the principle of transformer.

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(2) Self-induced e.m.f

Self-induced e.m.f which is produced in the coil due to the change of its own flux linked with it. If the current of the coil is changed, then the flux linked with its own turns will also change which will produce an e.m.f that is called self-induced e.m.f.

Dc Generator :-

An electric generator is a machine that converts mechanical energy into electrical energy. An electric generator is based on the principle that whenever flux is cut by a conductor, an e.m.f. is induced which will cause a current to flow if the conductor circuit is closed. The direction of induced e.m.f (and hence current) is given by Fleming's right hand rule. Therefore, the essential Components of a generator are: (a) magnetic field.

(b) Conductor (or) a group of Conductors.

(c) Motion of Conductor w.r.t magnetic field.

⇒ Operating Principle of a Dc Generator:-

An electric generator is a machine which converts mechanical Energy (or power) into electrical energy (or power). It is based on the principle of production of dynamically (or Motionally) induced e.m.f (electromotive force). Whenever a conductor cuts magnetic flux, dynamically induced e.m.f is produced in it according to Faraday's laws of Electromagnetic Induction.

This emf causes a current to flow if the Conductor circuit is closed. Therefore, the essential Components of a generator are.

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

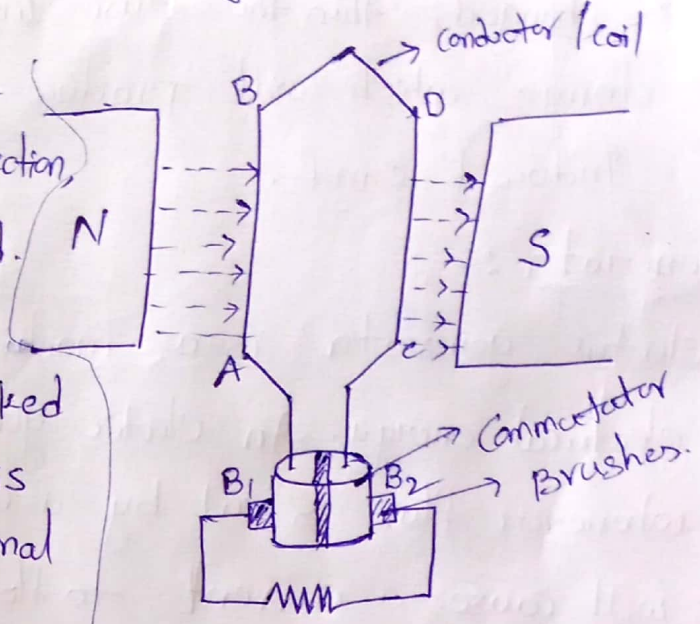


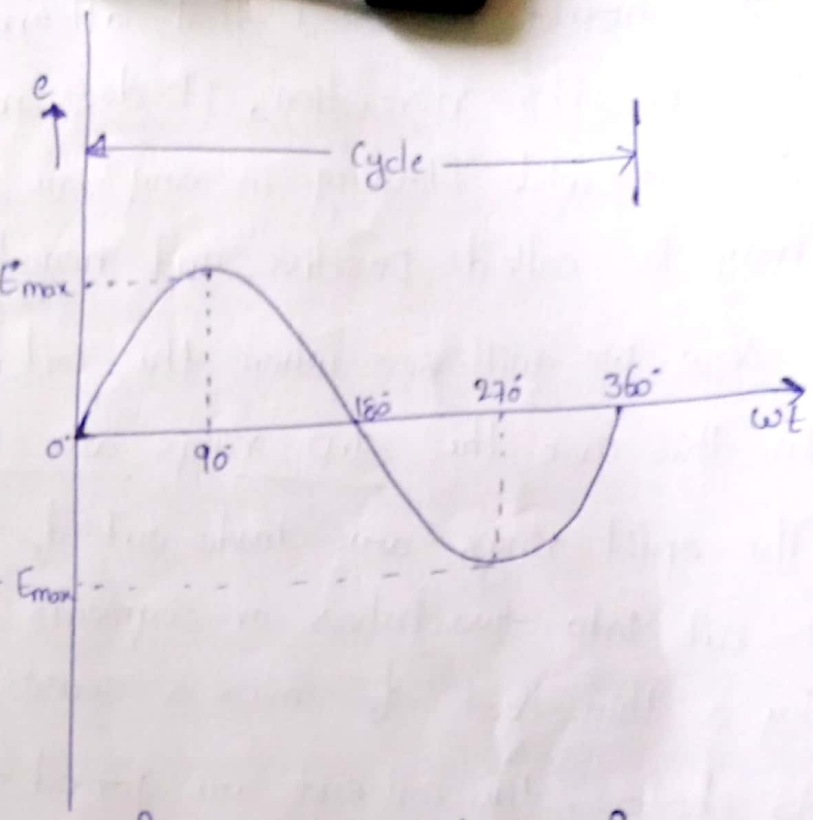
fig (a). Simple loop diagram of a Dc Generator.

In fig(a) see the case when the coil is rotating in clockwise direction, which is placed in a magnetic field. As the coil assumes successive position in the field, the flux linked with it changes. Hence an e.m.f is induced in it which is proportional to the rate of change of flux linkages $[e = -N \cdot d\phi/dt]$. When the plane of the coil is at the right angles to the lines of flux, then flux linked with the coil is maximum, but the rate of change of flux linkages is minimum. It is so because in this position, the coil sides do not cut (or) shear the flux, rather they slide along them. i.e they move parallel to them. Hence there is no induced e.m.f in the coil.

Generally this no emf is taken as the ~~first~~ starting position i.e zero degrees position. The angle of rotation (or) time will be measured from this position. As the coil continuosly rotating further, the rate of change of flux linkages (and hence induced e.m.f in it) increase till the coil rotates 90° from its starting position. Here the coil plane is horizontal. i.e parallel to the lines of flux, As seen, the flux linked with the coil is minimum but rate of change of flux linkages is maximum. Hence, maximum e.m.f induced in the coil at this position.

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In the next quarter revolution i.e from 90° to 180°, the flux linked with the coil gradually increases, but the rate of change of flux linkages decreases. Hence, induced e.m.f decreases gradually till it becomes zero. So, we find that in the first half revolution of the coil, no e.m.f is induced in it at 0°, maximum when the coil is at 90° position and no e.m.f when coil is at 180°. The direction of this induced e.m.f can be found by applying Fleming's Right hand rule which gives its direction from A to B and C to D.



fig(b): Sinusoidal waveform

→ In the next half revolution i.e from 180° to 360°, the variations in the magnitude of e.m.f are similar to those in the first half revolution. Its value is maximum when the coil is at 270° and minimum when the coil is at 360° position. But it will be found that the direction of induced e.m.f from D to C and B to A. Thus the alternating e.m.f is produced. Due to this alternating e.m.f an alternating current is flowing through the external load. If the circuit is closed.

→ We find that the current which we obtain from such a simple generator reverses its direction after every half revolution. Such a current undergoing periodic reversals is known as alternating current [Ac].

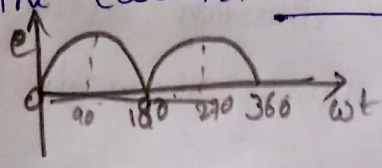
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→ It should be noted that alternating current not only reverse its direction, it does not even keep its magnitude constant while flowing in any one direction. The two-half cycles may be called positive and negative half cycles respectively.

Now, we will see when the coil is rotating with Commutator. In this case the slip rings are replaced by split rings. The split rings are made out of a conducting cylinder which is cut into two halves or segments insulated from each other by a thin sheet of mica or some other insulating material. As before, the coil ends are joined to these segments on which rest the carbon (or) copper brushes. In case of split rings, the position of the segments of ~~slip~~ split rings have also reversed when the current induced in the coil reverses. i.e. when the current direction reverses the brushes also comes in Contact with reverse segments as that of positive half-cycle. Hence this current is unidirectional. It should be noted that the position of the brushes is so arranged that the change over of segments from one brush to other takes place.

→ When the plane of the rotating coil is at right angles to the plane of the line flows. It is so because, in that position, the induced e.m.f in the coil is zero. You can observe this, in two cases by pausing the waveform.

Note:- Now the current induced in the coil is alternating as before. Due to the rectifying action of the split-rings [also called Commutator] the current becomes unidirectional in the external circuit.



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