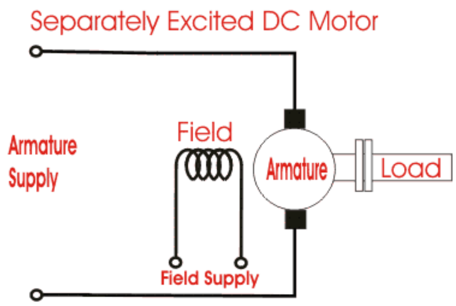
Unit III (ELECTRICAL MACHINES)

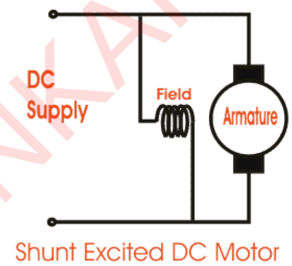
PART-A

1.Draw the circuit for various types of d.c motor.(N/D-2016)

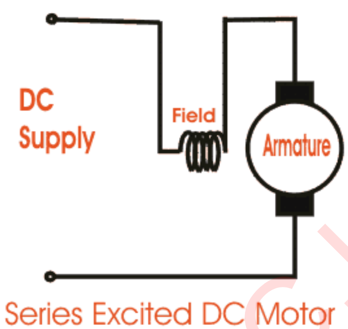
Separately Excited DC Motor



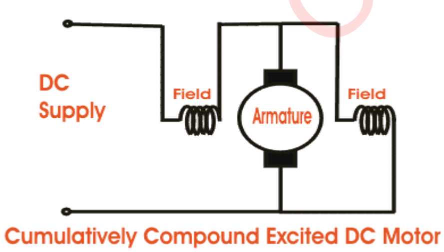
DC Shunt Motor



DC Series Motor



DC Compound Motor



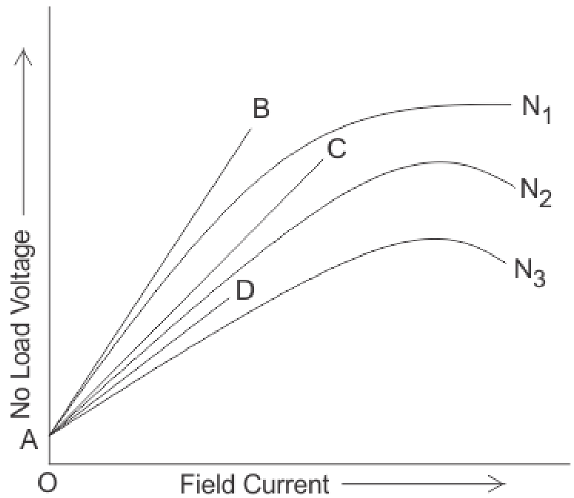
2.Define voltage regulation of transformer.(N/D-2016,M/J-2016)

The voltage regulation of the transformer is the percentage change in the output voltage from no-load to full-load.

3.Sketch the O.C.C of dc shunt generator.(M/J-2016)

Critical Load Resistance of Shunt Wound DC Generator

This is the minimum external load resistance which is required to excite the shunt wound generator



Magnetic or Open Circuit Characteristic

4.Write down the EMF equation of a transformer..(M/J-2016)

. E1 = 4.44*N1* f* Bm*A and E2 = 4.44*N2*f*Bm*A

5.list out the types of induction motor.(N/D-2015)

Induction motor types:

- Polyphase cage rotor.
- Polyphase wound rotor.
- Two-phase servo motor.
- Single-phase induction motor.
- Polyphase synchronous motor.
- Single-phase synchronous motor.
- Hysteresis synchronous motor.

6.Give some application of D.C motor.(A/M-2015,N/D-2016)

Shunt :driving constant speed, lathes, centrifugal pumps, machine tools, blowers and fans, reciprocating pumps

Series :electric locomotives, rapid transit systems, trolley cars, cranes and hoists, conveyors

Compound :elevators, air compressors, rolling mills, heavy planners

7.Why a single phase induction motor does not self start?(A/M-2015,A/M-2017,N/D-2016)

When a single phase supply is fed to the single phase induction motor. Its stator winding produces a flux which only alternates along one space axis. It is not a synchronously revolving field, as in the case of a 2 or 3phase stator winding, fed from 2 or 3 phase supply.

8.Mention the application of DC generator?(A/M-2017)

- general lighting.

- Used to charge battery because they can be made to give constant output voltage.
- They are used for giving the excitation to the alternators.
- used for small power supply.

9.What is the significance of back EMF?(A/M-2017)

- When the motor is running on no load, small torque is required to overcome the friction and windage losses. Therefore, the armature current Ia is small and the back emf is nearly equal to the applied voltage.
- If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore, the speed at which the armature conductors move through the field is reduced and hence the back emfEb falls. The decreased back emf allows a larger current to flow through the armature and larger current means increased driving torque. Thus, the driving torque increases as the motor slows down. The motor will stop slowing down when the armature current is just sufficient to produce the increased torque required by the load.
- If the load on the motor is decreased, the driving torque is momentarily in excess of the requirement so that armature is accelerated. As the armature speed increases, the back emf Eb also increases and causes the armature current Ia to decrease. The motor will stop accelerating when the armature current is just sufficient to produce the reduced torque required by the load.

10.Write the principle of DC Motor?(N/D-2015)

Fleming's left hand rule to determine the direction of force acting on the armature conductors of DC motor. If a current carrying conductor is placed in a magnetic field perpendicularly, then the conductor experiences a force in the direction mutually perpendicular to both the direction of field and the current carrying conductor. Fleming's left hand rule says that if we extend the index finger, middle finger and thumb of our left hand perpendicular to each other, in such a way that the middle finger is along the direction of current in the conductor, and index finger is along the direction of magnetic field i.e. north to south pole, then thumb indicates the direction of created

11. What is the main purpose of commutator and brushes?

Commutator:

The commutator converts the alternating emf into unidirectional or direct emf.

Brushes:

The brushes collect the current from the commutator

12. **State the principle of operation of a transformer.**

Transformer operates on the principle of mutual induction between inductively coupled coils. When A.C source is connected to one coil flux is produced in the core which links both the coils. As per the Faraday's laws of electromagnetic induction EMF is induced in the secondary coil also. if the external circuit is closed power is supplied.

13. **Write down the EMF equation of a single phase transformer.**

EMF induced in primary, E1= 4.44 Ø f N1 volts where

f = Frequency of supply main

Ø = Flux linking both the primary and secondary winding

14. **Write any two differences between single phase and three phase transformers.**

i. Single phase transformer has two windings. Three phase transformer has six windings. ii. Single phase supply is directly connected across the single primary winding where as the 3-phase transformer windings are connected in star or delta according to the design.

15. Distinguish between induction motor and synchronous motor? (A/M 2015)

- A three phase Synchronous motor is a doubly excited machine, whereas an induction motor is a single excited machine.
- The armature winding of the Synchronous motor is energized from an AC source and its field winding from a DC source. The stator winding of Induction Motor is energized from an AC source.
- Synchronous Motor always runs at synchronous speed, and the speed of the motor is independent of load, but an induction motor always runs less than the synchronous speed. If the load increased the speed of the induction motor decreases.
- The induction motor has self-starting torque whereas the synchronous motor is not self starting. It has to be run up to synchronous speed by any means before it can be synchronized to AC supply.

16. What is the working principle of Synchronous generator?

The principle of operation of synchronous generator is electromagnetic induction. If there exits a relative motion between the flux and conductors, then an emf is induced in the conductors.

17. Write the EMF equation of an alternator? (N/D-2016)

$$E = 4.44 \times f\ \Phi\ T_{ph}\ \text{volts}$$

This is the basic e.m.f. equation for an induced e.m.f. per phase for full pitch, concentrated type of winding.

Where T_{ph} = Number of turns per phase

$T_{ph} = Z_{ph}/2$

Total flux cut in one revolution is $\Phi \times P$

Time taken for one revolution is $60/N_s$ seconds.

$\therefore$ e_{avg} per conductor = $\Phi P / (60/N_s)$

$= \Phi\ (PN_s/60)$ .... (1)

But $f = PN_s/6120$

$\therefore$ $PN_s/60 = 2f$

18. Define voltage regulation of the alternator?

It is defined as the increase in terminal voltage when full load is thrown off, assuming field current and speed remaining the same.

$\%\ reg = [(E - V)/V] \times 100$

Where E = no terminal voltage V = full load rated terminal voltage

19. What is meant by armature reaction in Alternators?

The interaction between flux set up by the current carrying armature and the main is defined as the armature reaction.

20. Why a synchronous motor is a constant speed motor?

Synchronous motor work on the principle of force developed due to the magnetic attraction established between the rotating magnetic field and the main pole feed. Since the speed of rotating magnetic field is directly proportional to frequency the motor operates at constant speed.

21. Name any two methods of starting synchronous motors

By an extra 3 phase cage induction motor

By providing damper winding in pole phases

By operating the pilot excitor as a dc motor

22. State the principle of 3 phase IM?

While starting, rotor conductors are stationary and they cut the revolving magnetic field and so an emf is induced in them by electromagnetic induction. This induced emf produces a current if the circuit is closed. This current opposes the cause by Lenz's law and hence the rotor starts revolving in the same direction as that of the magnetic field.

23. What type of single phase induction motor would you use for the following applications? (i) Ceiling fan (ii) Wet grinder

Ceiling fan – capacitor start and run motor Wet
Grinder – capacitor start motor

PART-B

1. With a neat circuit diagram Explain the construction and principle of operation of DC Motor. (N/D-2016,N/D-2015,M/J-2017)

DC MOTOR – INTRODUCTION:

A machine that converts dc power into mechanical energy is known as dc motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of the force is given by Fleming's left hand rule.

WORKING OF DC MOTOR:

There are different kinds of D.C. motors, but they all work on the same principles.When a permanent magnet is positioned around a loop of wire that is hooked up to a D.C.power source, we have the basics of a D.C. motor. In order to make the loop of wire spin, we have to connect a battery or DC power supply between its ends, and support it so it can spin about its axis.

To allow the rotor to turn without twisting the wires, the ends of the wire loop are connected to a set of contacts called the commutator, which rubs against a set of conductors called the brushes. The brushes make electrical contact with the commutator as it spins, and are connected to the positive and negative leads of the power source, allowing electricity to flow through the loop. The electricity flowing through the loop creates a magnetic field that interacts with the magnetic field of the permanent magnet to make the loop spin

PRINCIPLES OF OPERATION:

It is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left- hand rule and whose magnitude is given by

Force, $F = B\ I\ l$ newton

Where,

B is the magnetic field in weber/m2

I is the current in amperes and

l is the length of the coil in meter

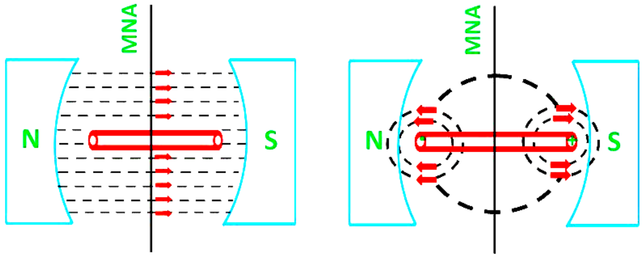


Figure A Figure B

The force, current and the magnetic field are all in different directions. If an Electric current flows through two copper wires that are between the poles of a magnet, an upward force will move one wire up and a downward force will move the other wire down.

2. Explain the construction, working principle of single phase Induction motor.(N/D-2016)

Single phase motors are very widely used in home, offices, workshops etc. as power delivered to most of the houses and offices is single phase. In addition to this, single phase motors are reliable, cheap in cost, simple in construction and easy to repair.

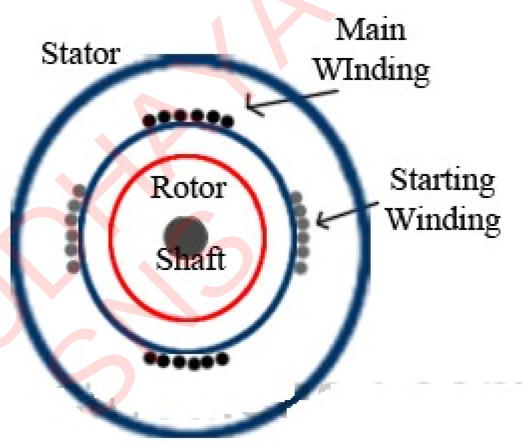
Single phase electric motors can be classified as:

1. Single phase induction motor (Split phase, Capacitor and shaded pole etc)
2. Single phase synchronous motor
3. Repulsion motor etc.

Single Phase Induction Motor

CONSTRUCTION:

Construction of a single phase induction motor is similar to the construction of three phase induction motor having squirrel cage rotor, except that the stator is wound for single phase supply. Stator is also provided with a 'starting winding' which is used only for starting purpose. This can be understood from the schematic of single phase induction motor at the left.



Working Principle Of Single Phase Induction Motor:

When the stator of a single phase motor is fed with single phase supply, it produces alternating flux in the stator winding. The alternating current flowing through stator winding causes induced current in the rotor bars (of the squirrel cage rotor) according to Faraday's law of electromagnetic induction.

This induced current in the rotor will also produce alternating flux. Even after both alternating fluxes are set up, the motor fails to start (the reason is explained below). However, if the rotor is given a initial start by external force in either direction, then motor accelerates to its final speed and keeps running with its rated speed. This behavior of a single phase motor can be explained by double-field revolving theory.

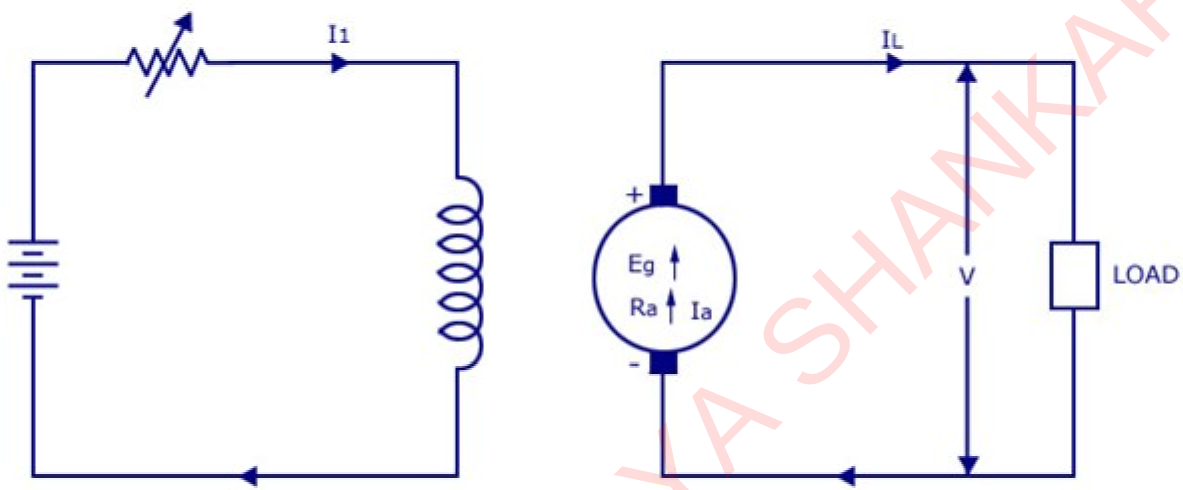
3. Describe various types self excited of DC generator with their circuit layout.(M/J-2016)

DC generators are classified based on their method of excitation. So on this basis there are two types of DC generators:-

Self excited DC generator can again be classified as 1) DC Series generator 2) DC Shunt generator and 3) DC Compound generator.

1. Separately excited DC generator

As you can guess from the name itself , this dc generator has a field magnet winding which is excited using a separate voltage source (like battery). You can see the representation in the below image. The output voltage depends on the speed of rotation of armature and field current. The higher the speed of rotation and current – the higher the output e.m.f

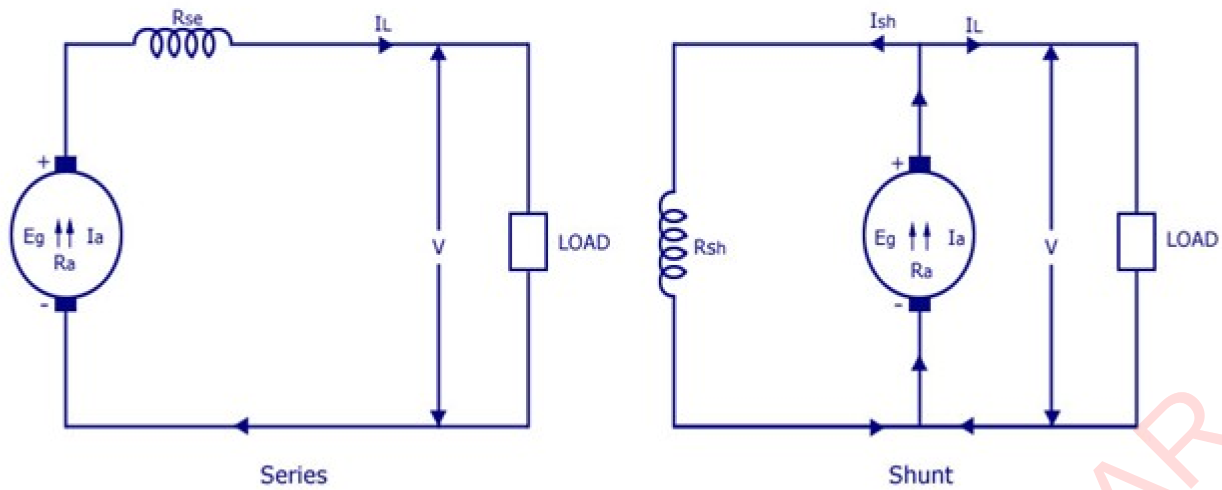


2.Self Excited DC Generator

These are generators in which the field winding is excited by the output of the generator itself. As described before – there are three types of self excited dc generators – they are 1) Series 2) Shunt and 3) Compound.

A series DC generator is shown below in fig (a) – in which the armature winding is connected in series with the field winding so that the field current flows through the load as well as the field winding.Field winding is a low resistance,thick wire of few turns. Series generators are also rarely used!

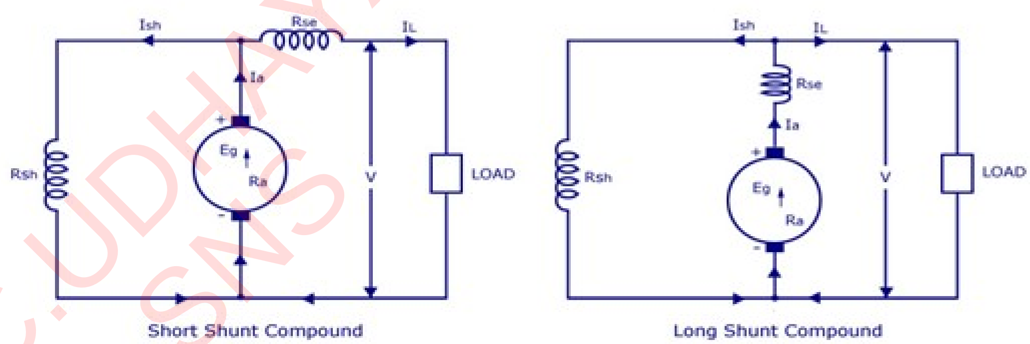
A shunt DC generator is shown in figure (b), in which the field winding is wired parallel to armature winding so that the voltage across both are same. The field winding has high resistance and more number of turns so that only a part of armature current passes through field winding and the rest passes through load.



A compound generator is shown in figure below. It has two field findings namely Rsh and Rse. They are basically shunt winding (Rsh) and series winding (Rse). Compound generator is of two types – 1) Short shunt and 2) Long shunt

Short shunt:- Here the shunt field winding is wired parallel to armature and series field winding is connected in series to the load. It is shown in fig (1)

Long shunt:- Here the shunt field winding is parallel to both armature and series field winding (Rse is wired in series to the armature). It is shown in figure (2)

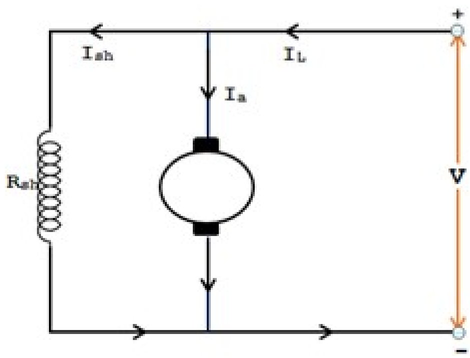


4. Explain the characteristics of dc shunt motor.(M/J-2016)

Characteristics of DC Shunt Motor:

The three important shunt characteristic curves are

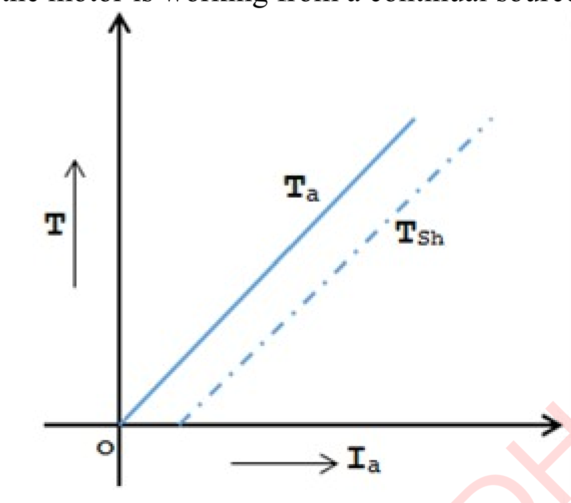
1. Torque V_s Armature current characteristic (T_a/I_a)
2. Speed V_s Armature current characteristic (N/I_a)
3. Speed V_s Torque characteristic (N/T_a)



The fig above shows the circuit diagram of shunt motor. In this circuit the field winding is directly connected to the source voltage, so the field current I_{sh} and the flux in a shunt motor are constant.

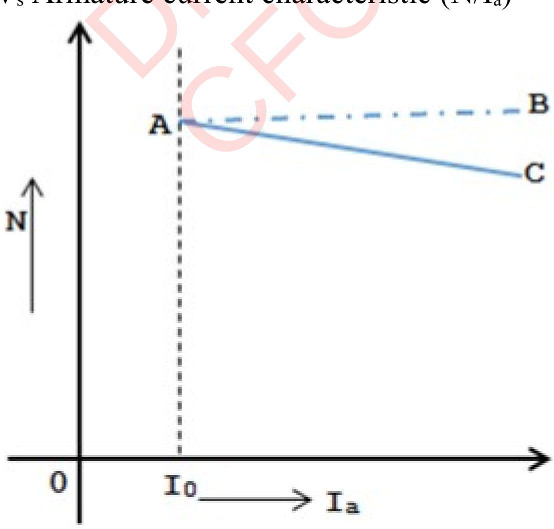
1. Torque V_s Armature current characteristic (T_a/I_a)

We know that in a DC Motor $T_a \propto \Phi I_a$. In this the flux Φ is continuous by ignoring the armature reaction, since the motor is working from a continual source voltage.



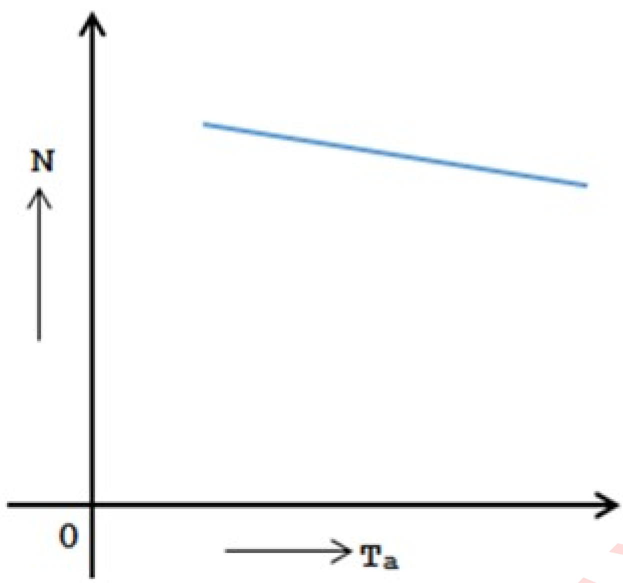
Therefore the curve drawn between torque V_s armature current is a straight line transitory through the origin which is shown in fig. The shaft torque(T_{sh}) is a smaller amount than armature torque and is shown in the fig by a dotted line. From this curve it is proved that to start a heavy load very large current is requisite. Hence the shunt DC motor should not be started at full load.

2. Speed V_s Armature current characteristic (N/I_a)



At normal condition the back EMF E_b and Flux Φ both are constant in a DC Shunt motor. Hence the armature current differs and the speed of a DC Shunt motor will continue constant which is shown in the fig (dotted Line AB). Whenever the shunt motor load is increased
$E_b=V-I_aR_a$ and flux reduces as a result drop in the armature resistance and armature reaction. On the other hand, back EMF reduces marginally more than that the speed of the shunt motor decreases to some extent with load.

3. Speed V_s Torque characteristic (N/T_a)



This curve is drawn between the speed of the motor and armature current with various amps as shown in the fig. From the curve it is understood that the speed reduces when the load torque increases.
With the above three characteristic it is clearly understood that when the shunt motor runs from no load to full load there is slight change in speed. Thus, it is essentially a constant speed motor. Since the armature torque is directly proportional to the armature current, the starting torque is not high

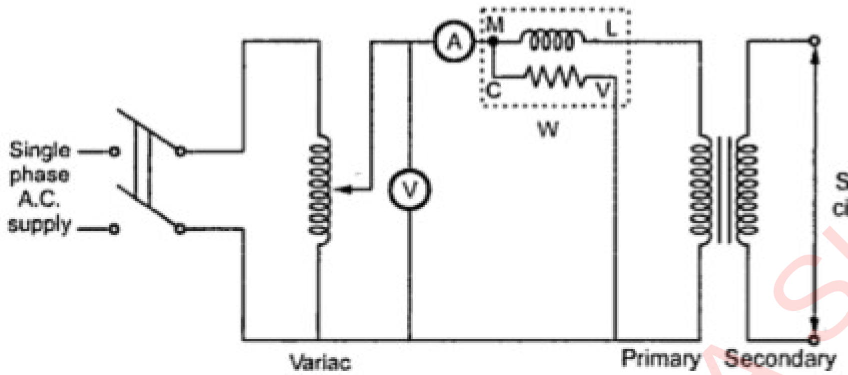
5. Explain the tests on a single phase transformer and develop an equivalent from the above tests. (M/J-2016)

1.Open Circuit Test on Transformer
The connection diagram for open circuit test on transformer is shown in the figure. A voltmeter, wattmeter, and an ammeter are connected in LV side of the transformer as shown. The voltage at rated frequency is applied to that LV side with the help of a variac of variable ratio auto transformer.

The HV side of the transformer is kept open. Now with the help of variac, applied voltage gets slowly increased until the voltmeter gives reading equal to the rated voltage of the LV side. After reaching at rated LV side voltage, all three instruments reading (Voltmeter, Ammeter and Wattmeter readings) are recorded.

The ammeter reading gives the no load current I_e. As no load current I_e is quite small compared to rated current of the transformer, the voltage drops due to this current that can be taken as negligible. Since, voltmeter reading V_1 can be considered equal to secondary induced voltage of the transformer, the input power during test is indicated by watt-meter reading. As the transformer is open circuited, there is no output, hence the input power here consists of core losses in transformer and copper loss in transformer during no load condition. But as said earlier, the no load current in the transformer is quite small compared to full load current, so copper loss due to the small no load current can be neglected. Hence, the wattmeter reading can be taken as equal to core losses in transformer. Let us consider wattmeter reading is P_o.

$$P_o = \frac{V_1}{R_m^2}$$



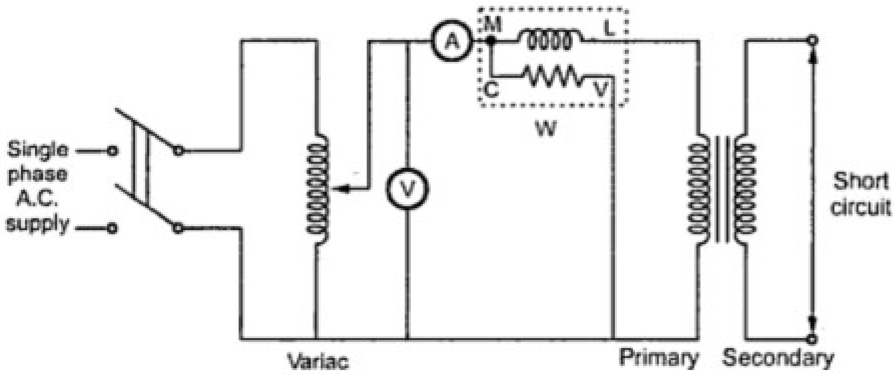
Therefore, if shunt branch reactance of transformer is X_m,

$$Then, \left(\frac{1}{X_m}\right)^2 = \left(\frac{1}{Z_m}\right)^2 - \left(\frac{1}{R_m}\right)^2$$

2. Short Circuit Test on Transformer:

The connection diagram for short circuit test on transformer is shown in the figure. A voltmeter, wattmeter, and an ammeter are connected in HV side of the transformer as shown. The voltage at rated frequency is applied to that HV side with the help of a variac of variable ratio auto transformer.

The LV side of the transformer is short circuited. Now with the help of variac applied voltage is slowly increased until the ammeter gives reading equal to the rated current of the HV side. After reaching at rated current of HV side, all three instruments reading (Voltmeter, Ammeter and Watt-meter readings) are recorded. The ammeter reading gives the primary equivalent of full load current I_L. As the voltage applied for full load current in short circuit test on transformer is quite small compared to the rated primary voltage of the transformer, the core losses in transformer can be taken as negligible here.



Let's say, voltmeter reading is V_{sc}. The input power during test is indicated by watt-meter reading. As the transformer is short circuited, there is no output; hence the input power here consists of copper losses in transformer. Since, the applied voltage V_{sc} is short circuit voltage in the transformer and hence it is quite small compared to rated voltage, so core loss due to the small applied voltage can be neglected. Hence the wattmeter reading can be taken as equal to copper losses in transformer. Let us consider wattmeter reading is P_{sc}.

$$P_{sc} = R_e I_L^2$$

These values are referred to the HV side of transformer as because the test is conduced on HV side of transformer. These values could easily be referred to LV side by dividing these values with square of transformation ratio.

Therefore it is seen that the short circuit test on transformer is used to determine copper loss in transformer at full load and parameters of approximate equivalent circuit of transformer

6. Describe the construction details of single phase transformer.(A/M-2017,M/J-2017,N/D-2015,A/M-2015)

TRANSFORMER – INTRODUCTION

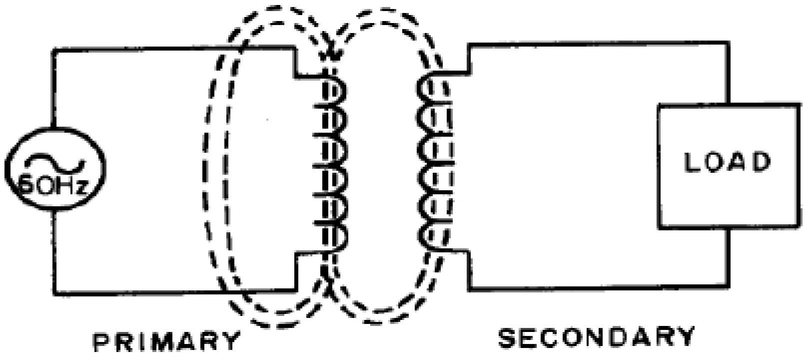
A TRANSFORMER is a device that transfers electrical energy from one circuit to another by electromagnetic induction (transformer action). The electrical energy is always transferred without a change in frequency, but may involve changes in magnitudes of voltage and current. Because a transformer works on the principle of electromagnetic induction, it must be used with an input source voltage that varies in amplitude. There are many types of power that fit this description; for ease of explanation and understanding, transformer action will be explained using an ac voltage as the input source.

➢ **BASIC OPERATION OF A TRANSFORMER:**

Its most basic form a transformer consists of: A primary

- Coil or winding.
- A secondary coil or winding.
- A core that supports the coils or windings

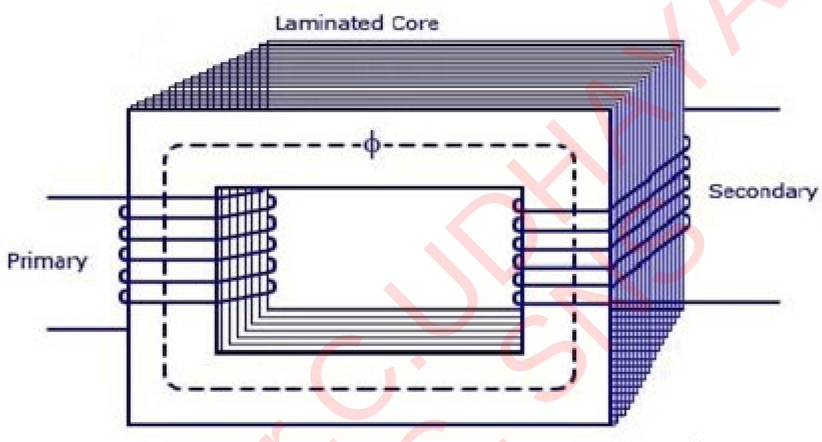
The primary winding is connected to a 60 hertz ac voltage source. The magnetic field (flux) builds up (expands) and collapses (contracts) about the primary winding. The expanding and contracting magnetic field around the primary winding cuts the secondary winding and induces an alternating voltage into the winding. This voltage causes alternating current to flow through the load. The voltage may be stepped up or down depending on the design of the primary and secondary windings.



BASIC WORKING PRINCIPLE OF TRANSFORMER

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below



As shown above the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance

Faraday's laws of Electromagnetic Induction as

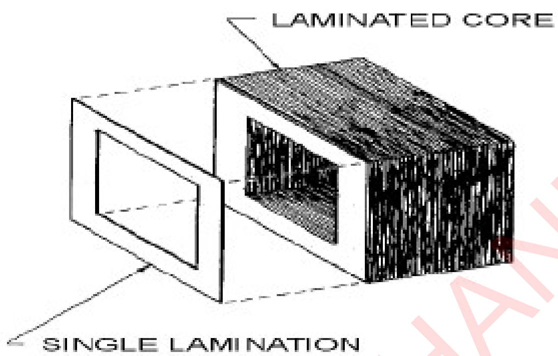
$$e=M*dI/dt$$

TRANSFORMER CONSTRUCTION:

Two coils of wire (called windings) are wound on some type of core material. In some cases the coils of wire are wound on a cylindrical or rectangular cardboard form. In effect, the core material is air and the transformer is called an air-core transformer. Transformers used at low frequencies, such as 60 hertz and 400 hertz, require a core of low- reluctance magnetic material, usually iron. This type of transformer is called an iron-core transformer. Most power transformers are of the iron-core type.

The principle parts of a transformer and their functions are:

- The core, which provides a path for the magnetic lines of flux.
- The primary winding, which receives energy from the ac source.
- The secondary winding, which receives energy from the primary winding and delivers it to the load.
- The enclosure, which protects the above components from dirt, moisture



CORE

There are two main shapes of cores used in laminated-steel-core transformers. One is the HOLLOWCORE, so named because the core is shaped with a hollow square through the center. This shape of core. Notice that the core is made up of many laminations of steel it shows how the transformer windings are wrapped around both sides of the core.

WINDINGS

As stated above, the transformer consists of two coils called WINDINGS which are wrapped around a core. The transformer operates when a source of ac voltage is connected to one of the windings and a load device is connected to the other. The winding that is connected to the source is called the PRIMARY WINDING. The winding that is connected to the load is called the secondary winding. The primary is wound in layers directly on a rectangular cardboard form.

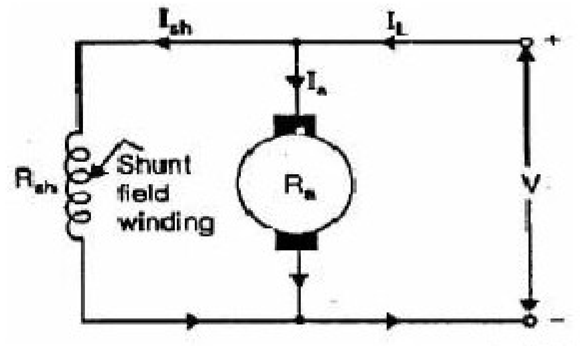
7. Explain the different types of dc motor with neat sketch.(N/D-2016)

❖ DC MOTOR TYPES

- Shunt Wound
- Series Wound
- Compound wound

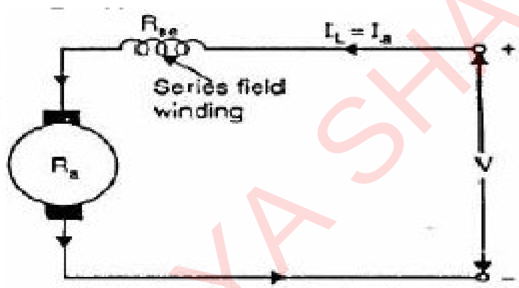
1.Shunt Motor

In shunt wound motor the field winding is connected in parallel with armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current



2.Series Motor:

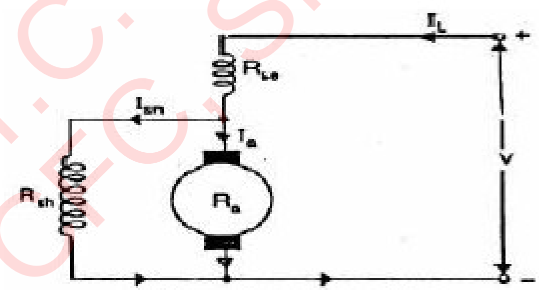
In series wound motor the field winding is connected in series with the armature. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same mmf. Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance.



3.Compound Wound Motor: Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections

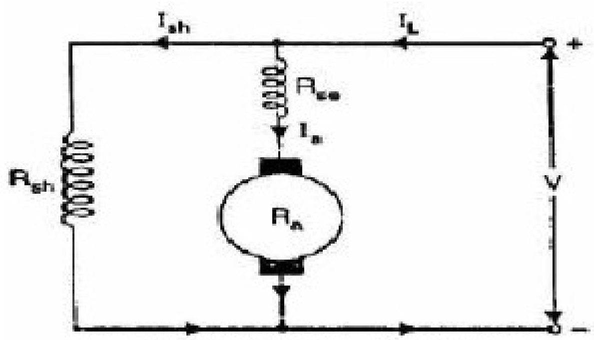
1. Short-shunt connection
2. Long shunt connection

When the shunt field winding is directly connected across the armature terminals it is called short-shunt connection.



Short-shunt connection

When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.



Long-shunt connection

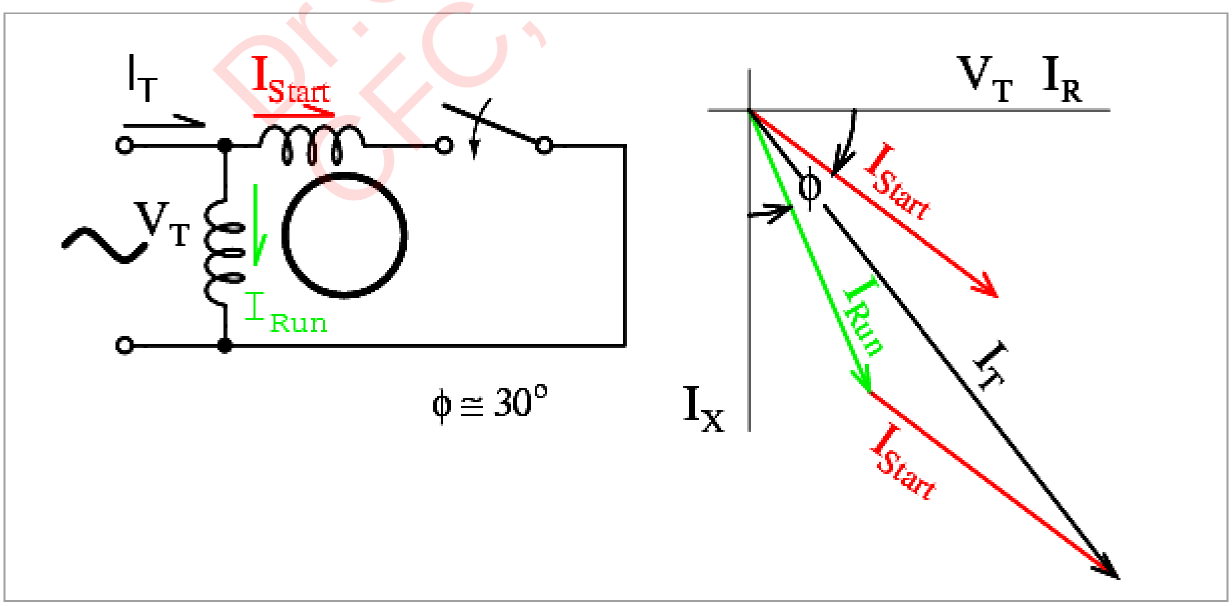
8. Explain the working principle of various types of single phase induction motor with neat circuit diagram.(M/J-2016)

The single phase induction motors are made self starting by providing an additional flux by some additional means. Now depending upon these additional means the single phase induction motors are classified as:

1. Split phase induction motor.
2. Capacitor startinductor motor.
3. Capacitor start capacitor runinduction motor (two value capacitor method).
4. Permanent split capacitor (PSC) motor .
5. Shaded pole induction motor.

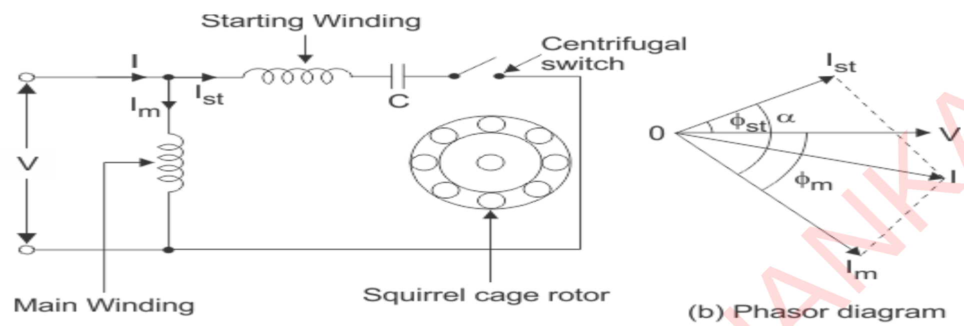
1.Split Phase Induction Motor In addition to the main winding or running winding, the stator of single phase induction motor carries another winding called auxiliary winding or starting winding. A centrifugal switch is connected in series with auxiliary winding. The purpose of this switch is to disconnect the auxiliary winding from the main circuit when the motor attains a speed up to 75 to 80% of the synchronous speed.

We know that the running winding is inductive in nature. Our aim is to create the phase difference between the two winding and this is possible if the starting winding carries high resistance.



2.Capacitor Start IM and Capacitor Start Capacitor Run IM

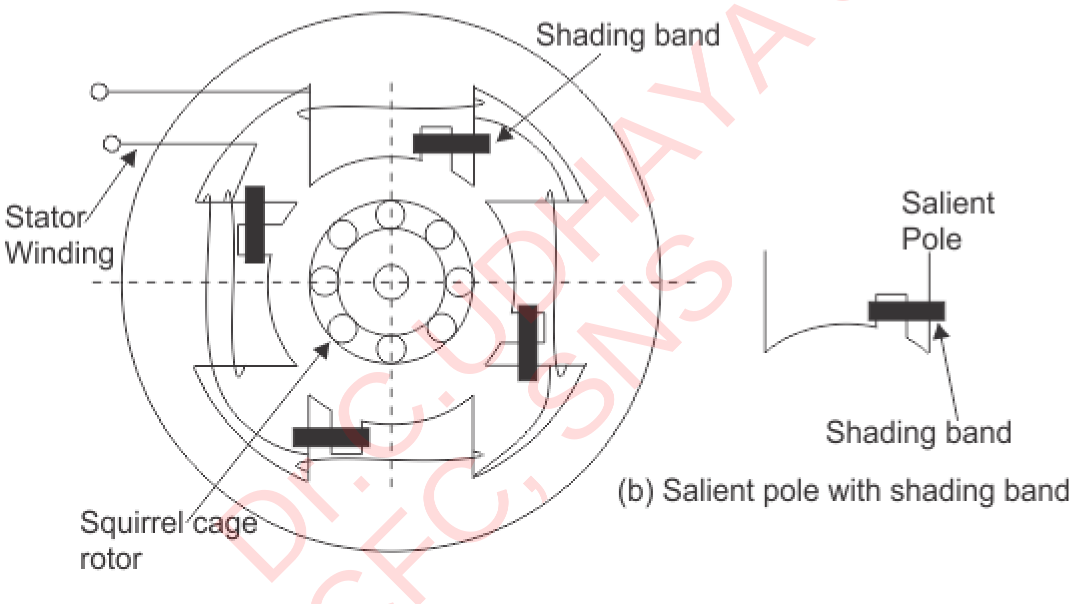
The working principle and construction of Capacitor start inductor motors and capacitor start capacitor run induction motors are almost the same. We already know that single phase induction motor is not self starting because the magnetic field produced is not rotating type. In order to produce rotating magnetic field there must be some phase difference. In case of split phase induction motor we use resistance for creating phase difference but here we use capacitor for this purpose. We are familiar with this fact that the **current** flowing through the capacitor leads the voltage. So, in **capacitor start inductor motor** and **capacitor start capacitor run induction motor**



(a) Schematic representaion

(b) Phasor diagram

3. Shaded Pole Single Phase Induction Motors



(b) Salient pole with shading band

(a) 4-pole shaded pole construction

The stator of the shaded pole single phase induction motor has salient or projected poles. These poles are shaded by copper band or ring which is inductive in nature. The poles are divided into two unequal halves. The smaller portion carries the copper band and is called as shaded portion of the pole.

ACTION: When a single phase supply is given to the stator of shaded pole induction motor an alternating flux is produced. This change of flux induces emf in the shaded coil. Since this shaded portion is short circuited, the current is produced in it in such a direction to oppose the main flux. The flux in shaded pole lags behind the flux in the unshaded pole.

The phase difference between these two fluxes produces resultant rotating flux. We know that the stator winding current is alternating in nature and so is the flux produced by the stator current. In order to clearly understand the working of shaded pole induction motor consider three regions-

1. When the flux changes its value from zero to nearly maximum positive value.
2. When the flux remains almost constant at its maximum value.
3. When the flux decreases from maximum positive value to zero.

9. Write shorts notes on the types of dc machines.(N/D-2015)

TYPES OF DC MACHINES:

i) DC generator

ii)DC motor

i) DC generator

An electrical generator is a rotating machine which usually converts mechanical energy into electrical energy for doing work. The energy changing is based on the principle of electromagnetic induction. According to Faraday's laws of electromagnetic induction, Whenever a conductor is feel motion in a magnetic field, emf induced dynamically in the conductor. When an external load is connected to the conductor this induced emfmake a current flow in the load.

Thus the mechanical energy which is given in the form of movement to the conductor is converted into electrical energy.

Dc generators can be classified as per their methods of field excitation. There are two types of dc generators on the basis of excitation.

Power delivered to the source is V*I(a).**Separately excited Dc generators:-**

If the field winding is excited by a separate dc supply from the external source, then the generator is called separately excited dc generators.

Self excited Dc generators:-

If the field winding energy is supplied from the armature of the generator it self, then it is called self excited dc **generators**. Self excited dc generators are further classified as

Series generator:-

In series generator field winding is connected series to the **armature**it self.

The voltage generated in series field generator is E(generated)=V(terminal voltage)+I(a)*R(a)+I(se)*R(se) +V(brush).

Power generated is E(g)*I(a).

Shunt generator:

In shunt generator field winding is connected across the armature or parallel to the armature.

The generated emf in shunt field generator is E(generated)=V(terminal voltage)+I(a)*R(a).

Power generated is E(g)*I(a).

Power delivered to the source is V*I(a).

Compound generator

The compound generator consists of both shunt field and series field winding on its structure. One winding is series and other is in parallel with the armature of the generator.

ii)DC Motor:

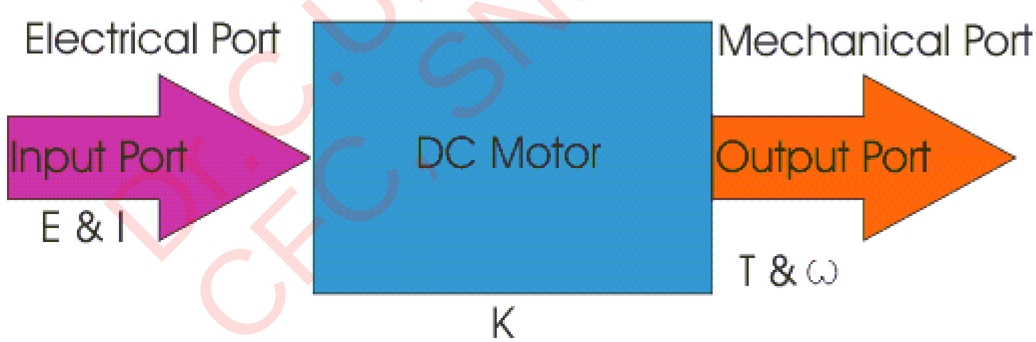
electric motors are everywhere around us. Almost all the electro-mechanical movements we see around us are caused either by a AC or a **DC motor**. Here we will be exploring DC motors. This is a device that converts DC electrical energy to a mechanical energy.

Principle of DC Motor

This DC or direct current motor works on the principal, when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. This is known as motoring action. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact they produce a mechanical force, and based on that the working principle of DC motor is established.

The direction of rotation of a this motor is given by Fleming's left hand rule, which states that if the index finger, middle finger and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of magnetic field, middle finger indicates the direction of current, then the thumb represents the direction in which force is experienced by the shaft of the DC motor.

Structurally and construction wise a direct current motor is exactly similar to a DC generator, but electrically it is just the opposite. Here we unlike a generator we supply electrical energy to the input port and derive mechanical energy from the output port. We can represent it by the block diagram shown below.



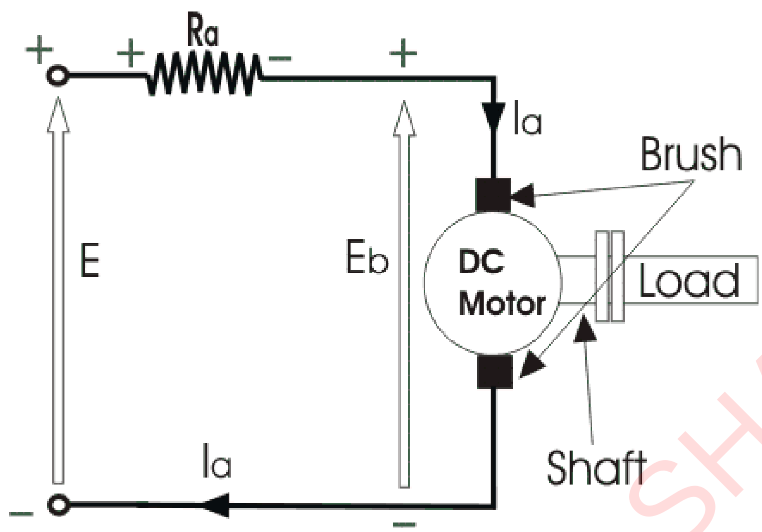
Here in a DC motor, the supply voltage E and current I is given to the electrical port or the input port and we derive the mechanical output i.e. torque T and speed ω from the mechanical port or output port.

The input and output port variables of the direct current motor are related by the parameter K.
$T = KI \text{ and } E = K\omega$

So from the picture above we can well understand that motor is just the opposite phenomena of a DC generator, and we can derive both motoring and generating operation from the same machine by simply reversing the ports.

Detailed Description of a DC Motor

The direct current motor is represented by the circle in the center, on which is mounted the brushes, where we connect the external terminals, from where supply voltage is given. On the mechanical terminal we have a shaft coming out of the Motor, and connected to the armature, and the armature-shaft is coupled to the mechanical load. On the supply terminals we represent the armature resistance R_a in series.



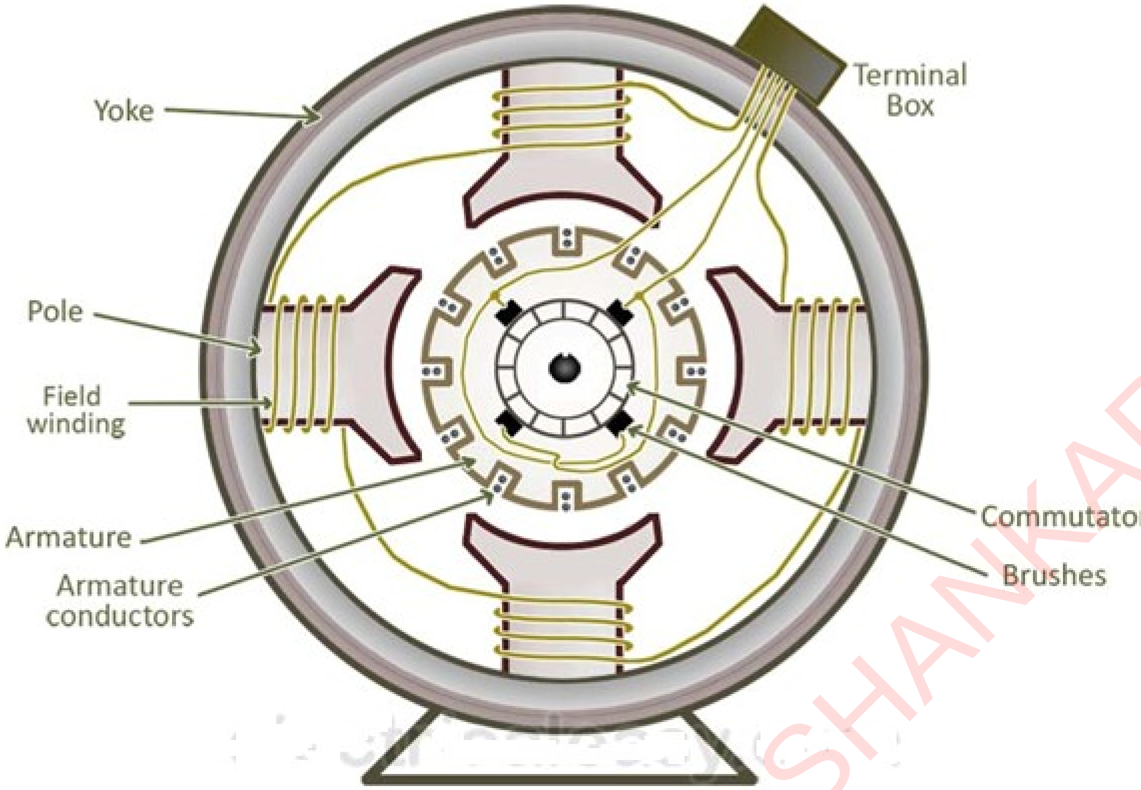
10.With a neat circuit diagram Explain the construction and principle of operation of DC Generator. (N/D-2015)

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. This article outlines basic construction and working of a DC generator.

Construction of a DC generator:

A DC generator can be used as a DC motor without 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. These basic constructional details are also valid for the construction of a DC motor. Hence, let's call this point as construction of a DC machine instead of just 'construction of a dc generator'**.**



The above figure shows the constructional details of a simple **4-pole DC machine**. A DC machine consists two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below.

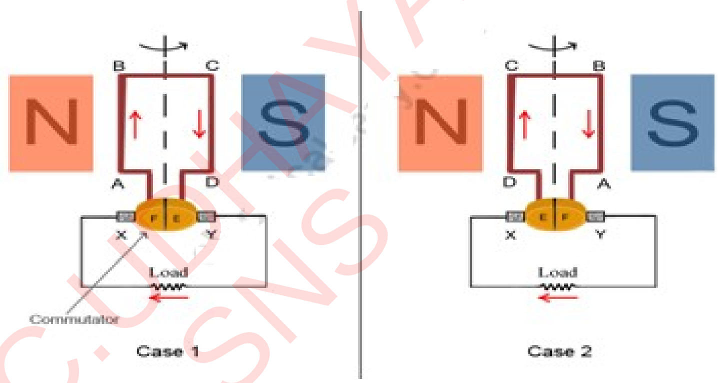
1. **Yoke:** The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.
2. **Poles and pole shoes:** Poles are joined to the yoke with the help 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.
3. **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.
4. **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.
5. **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.
6. **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.

Working principle of a DC generator:

According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of dc generator. If the conductor is provided with the closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. The direction of induced current is given by Fleming's right hand rule.

according to Fleming's right hand rule, the direction of induced current changes whenever the direction of motion of the conductor changes. Let's consider an armature rotating clockwise and a conductor at the left is moving upward. When the armature completes a half rotation, the direction of motion of that particular conductor will be reversed to downward.



Hence, the direction of current in every armature conductor will be alternating. If you look at the above figure, you will know how the direction of the induced current is alternating in an armature conductor. But with a split ring commutator, connections of the armature conductors also gets reversed when the current reversal occurs. And therefore, we get unidirectional current at the terminals.

11. Describe the construction of an induction motor with neat diagrams. (M/J 2016)
Explain the construction of three phase induction motor with neat diagram? (A/M 2017)

Construction of Induction Motor

The three phase induction motor is a preferable type of motor. It is mostly used in industrial drives because it is very reasonable and vigorous, economical and reliable. It is also called asynchronous motor because it does not run at a synchronous speed. The induction motor requires very little maintenance and also it has high overloading capacity.

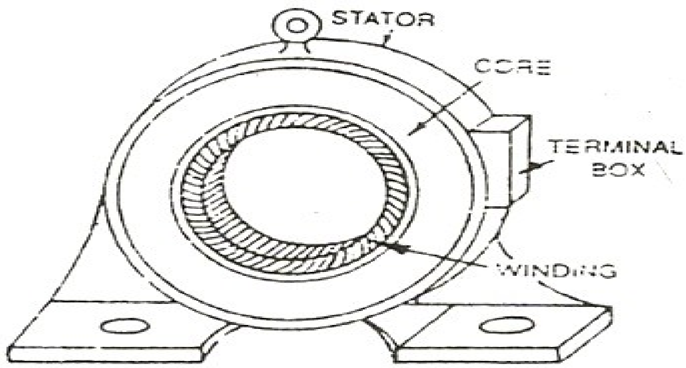
- Construction of Stator
- Construction of Rotor

A three phase **Induction motor** mainly consists of two parts called as the **Stator** and the **Rotor**. The stator is the stationary part of the induction motor, and the rotor is the rotating part. The construction of the stator is similar to the three-phase synchronous motor, and the construction of rotor is different for the different machine. The construction of the induction motor is explained below in detail.

Construction of Stator

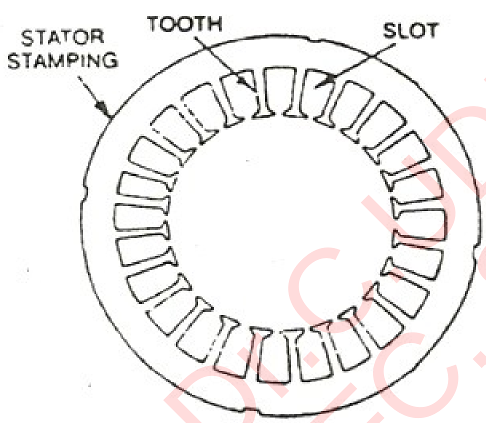
The stator is built up of high-grade alloy steel laminations to reduce eddy current losses. It has three main parts, namely outer frame, the stator core and a stator winding.

Outer frame



Stator Core

The stator core is built of high-grade silicon steel stampings. Its main function is to carry the alternating magnetic field which produces hysteresis and eddy current losses. The stampings are fixed to the stator frame. Each stamping are insulated from the other with a thin varnish layer. The thickness of the stamping usually varies from 0.3 to 0.5 mm. Slots are punched on the inner side of the stampings as shown in the figure below.



Stator windings

The core of the stator carries three phase windings which are usually supplied from a three-phase supply system. The six terminals of the windings (two of each phase) are connected in the terminal box of the machine. The stator of the motor is wound for a definite number of poles, depending on the speed of the motor. If the number of poles is greater, the speed of the motor will be less and if the number of poles is less than the speed will be high. As the relationship between the speed and the pole of the motor is given as

$$N_S \propto \frac{1}{P} \quad \text{or} \quad N_S = \frac{120f}{P}$$

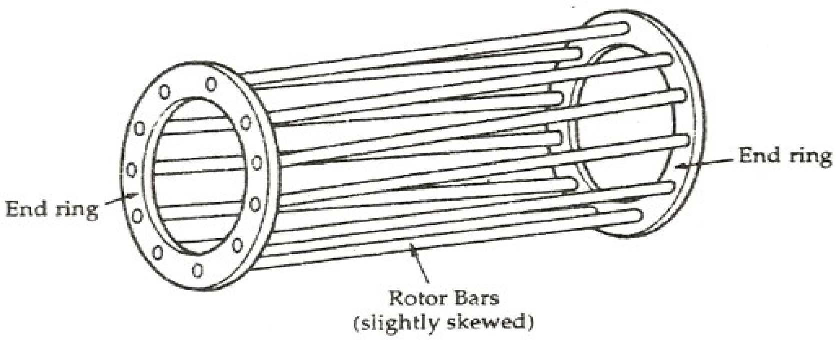
The windings may be connected in start and delta.

Construction of Rotor

The rotor is also built of thin laminations of the same material as the stator. The laminated cylindrical core is mounted directly on the shaft. These laminations are slotted on the outer side to receive the conductors. There are two types of rotor.

Squirrel Cage Rotor

A squirrel cage rotor consists of a laminated cylindrical core. The circular slots at the outer periphery are semi-closed. Each slot contains uninsulated bar conductor of aluminium or copper. At the end of the rotor the conductors the short-circuited by a heavy ring of copper or aluminium. The diagram of the cage rotor is shown below.

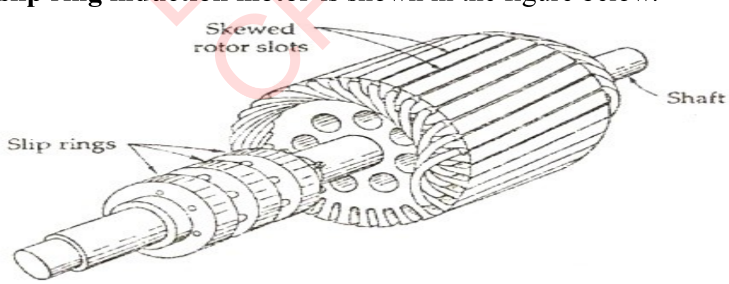


The rotor slots are usually not parallel to the shaft but are skewed. The skewing of the rotor conductors has the following advantages given below.

- It reduces humming and provide smooth and noise free operation.
- It results in a uniform torque curve for different positions of the rotor.
- The locking tendency of the rotor is reduced. As the teeth of the rotor and the stator attract each other and lock.
- It increases the rotor resistance due to the increased length of the rotor bar conductors.
- Advantages of Squirrel Cage Rotor
- The following advantages of the cage rotor are given below.
- The cage rotor is cheaper, and the construction is robust.
- The absence of the brushes reduces the risk of sparking.
- Its Maintenance is less.
- The power factor is higher
- The efficiency of the cage rotor is higher.

Phase Wound Rotor

The Phase wound rotor is also called as Slip Ring Rotor. It consists of a cylindrical core which is laminated. The outer periphery of the rotor has a semi-closed slot which carries a 3 phase insulated windings. The rotor windings are connected in star.
The **slip ring induction motor** is shown in the figure below.



The slip rings are mounted on the shaft with brushes resting on them. The brushes are connected to the variable resistor. The function of the slip rings and the brushes is to provide a means of connecting external resistors in the rotor circuit. The resistor enables the variation of each rotor phase resistance to serve the following purposes given below.

- It increases the starting torque and decreases the starting current.
- It is used to control the speed of the motor.

- In this type also, the rotor is skewed. A mild steel shaft is passed through the center of the rotor and is fixed to it. The purpose of the shaft is to transfer mechanical power.
- Advantages of Phase Wound Rotor
- Following are the advantages of the Phase Wound Rotor.
- High starting torque and low starting current.
- For controlling the speed of the motor, an external resistance can be added in the circuit.

12. Derive the EMF equation for the alternator? (A/M 2017)

EMF Equation of a Synchronous Generator

The generator which runs at a synchronous speed is known as the synchronous generator. The synchronous generator converts the mechanical power into electrical energy for the grid.The Derivation of **EMF Equation** of a synchronous generator is given below.

Let,

- P be the number of poles
- ϕ is Flux per pole in Webers
- N is the speed in revolution per minute (r.p.m)
- f be the frequency in Hertz
- Z_{ph} is the number of conductors connected in series per phase
- T_{ph} is the number of turns connected in series per phase
- K_c is the coil span factor
- K_d is the distribution factor

Flux cut by each conductor during one revolution is given as **Pϕ** Weber. Time taken to complete one revolution is given by **60/N** sec

Average EMF induced per conductor will be given by the equation shown below

$$\frac{P\varphi}{60/N} = \frac{P\varphi N}{60} \quad \text{volts}$$

Average EMF induced per phase will be given by the equation shown below

$$\frac{P\varphi N}{60} \times Z_{ph} = \frac{P\varphi N}{60} \times 2T_{ph} \quad \text{and}$$

$$T_{ph} = \frac{Z_{ph}}{2}$$

$$\text{Average EMF} = 4 \times \varphi \times T_{ph} \times \frac{PN}{120} = 4\varphi f T_{ph}$$

The average EMF equation is derived with the following assumptions given below.

- Coils have got the full pitch.
- All the conductors are concentrated in one stator slot.

Root mean square (R.M.S) value of the EMF induced per phase is given by the equation shown below.

E_{ph} = Average value x form factor

Therefore,

$$E_{ph} = 4\varphi f T_{ph} \times 1.11 = 4.44\, \varphi\, f\, T_{ph} \quad \text{volts}$$

If the coil span factor K_c and the distribution factor K_d, are taken into consideration than the Actual EMF induced per phase is given as

$$E_{ph} = 4.44\, K_c K_d \varphi\, f\, T_{ph} \quad \text{volts} \;\ldots\ldots\ldots (1)$$

Equation (1) shown above is the EMF equation of the Synchronous Generator.