BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

(Computer *Science Engineering*)

Presented by
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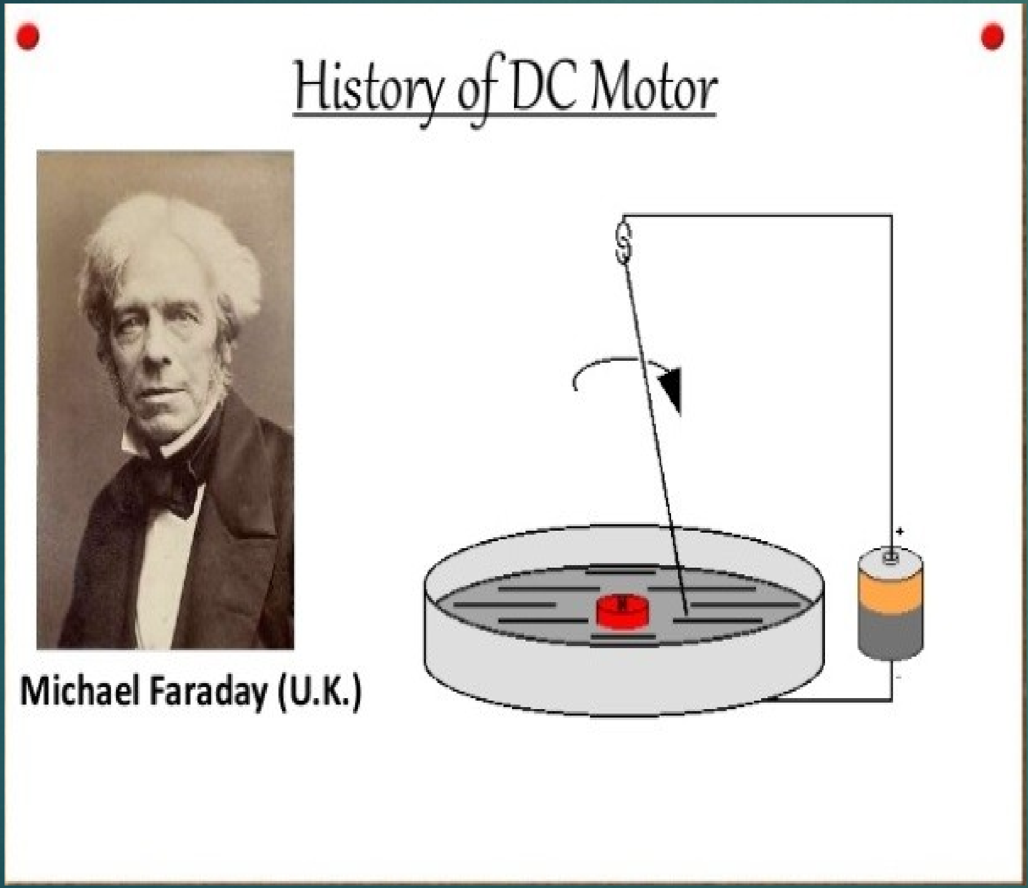
Dept. of ECE

UNIT -3 & 4
DC MACHINES & AC MACHINES

DC MACHINES

- DC Machines :



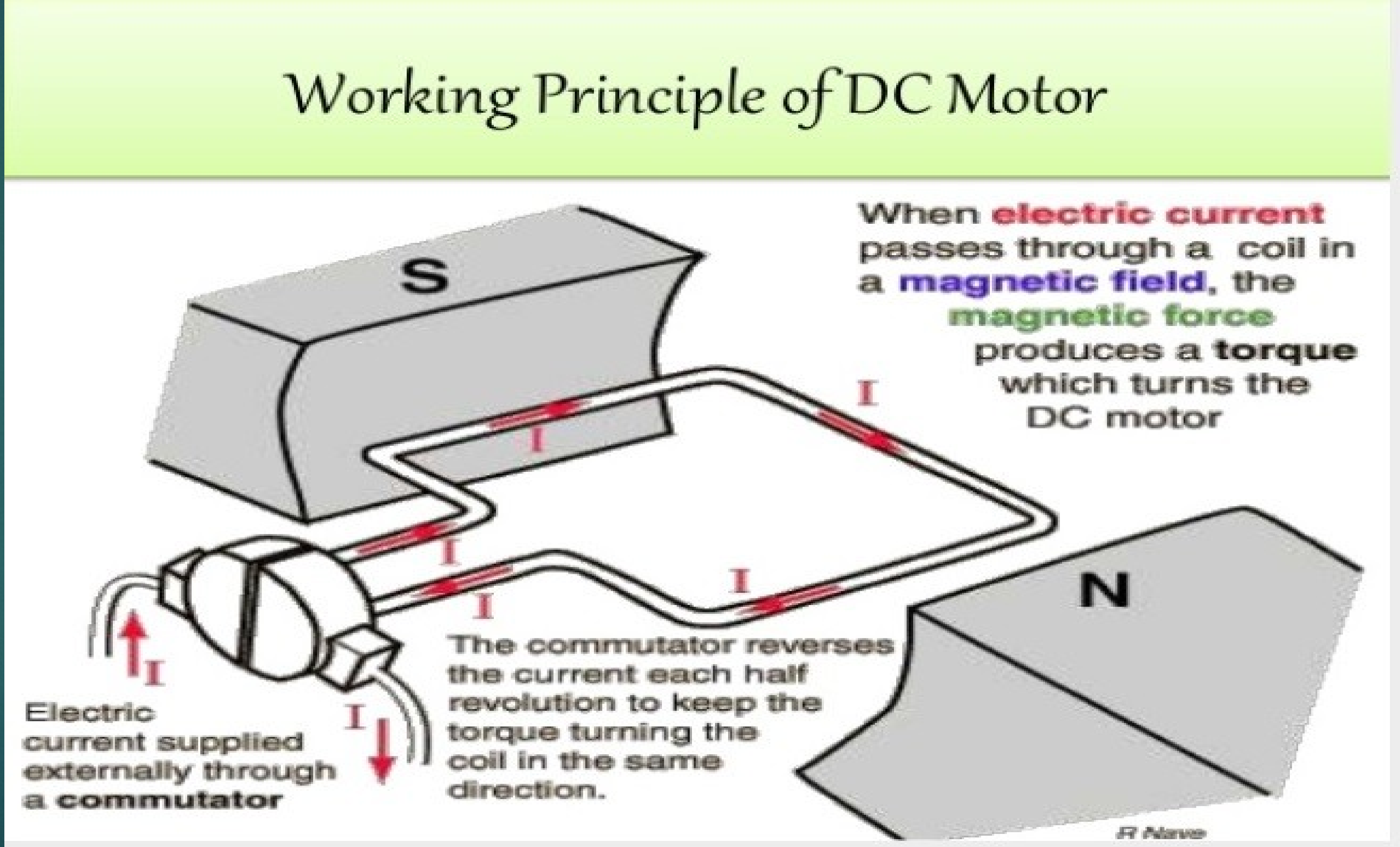
Types of DC Motor:

- Classification of the d.c. motor depends on the way of connecting the armature and field winding of a d.c. motor:

1. DC Shunt Motor
2. DC Series Motor
3. DC Compound Motor
   - Short shunt compound
     - Cumulative compound motor
     - Differential compound motor
   - long shunt compound
     - Cumulative compound motor
     - Differential compound motor

DC MACHINES

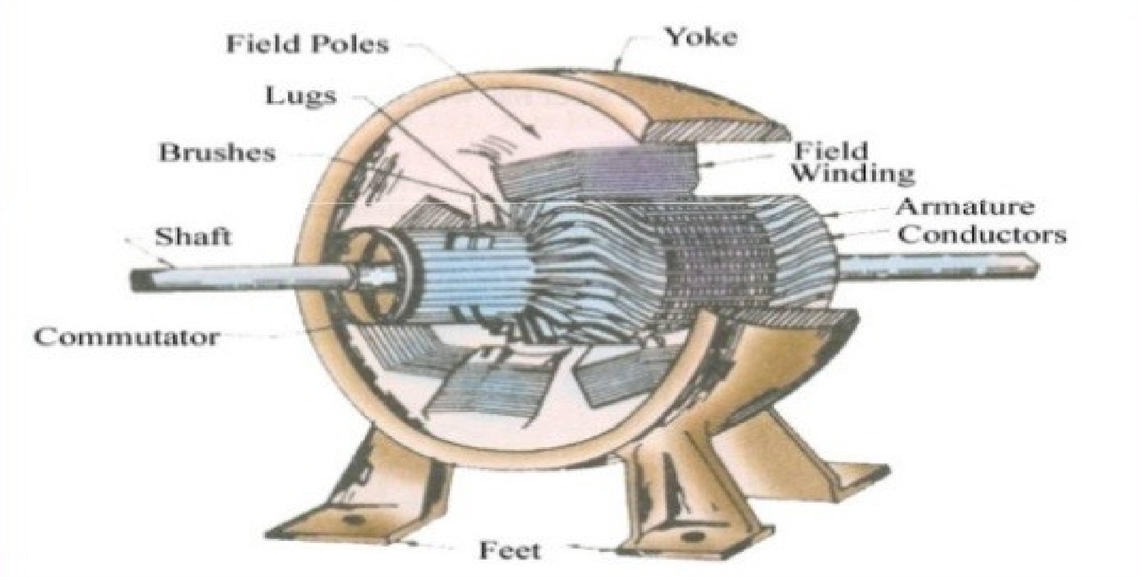
- DC Motor :



DC MACHINES

- DC Machines :

Main construction diagram



Main parts

The two major parts required for construction :

1. Stator

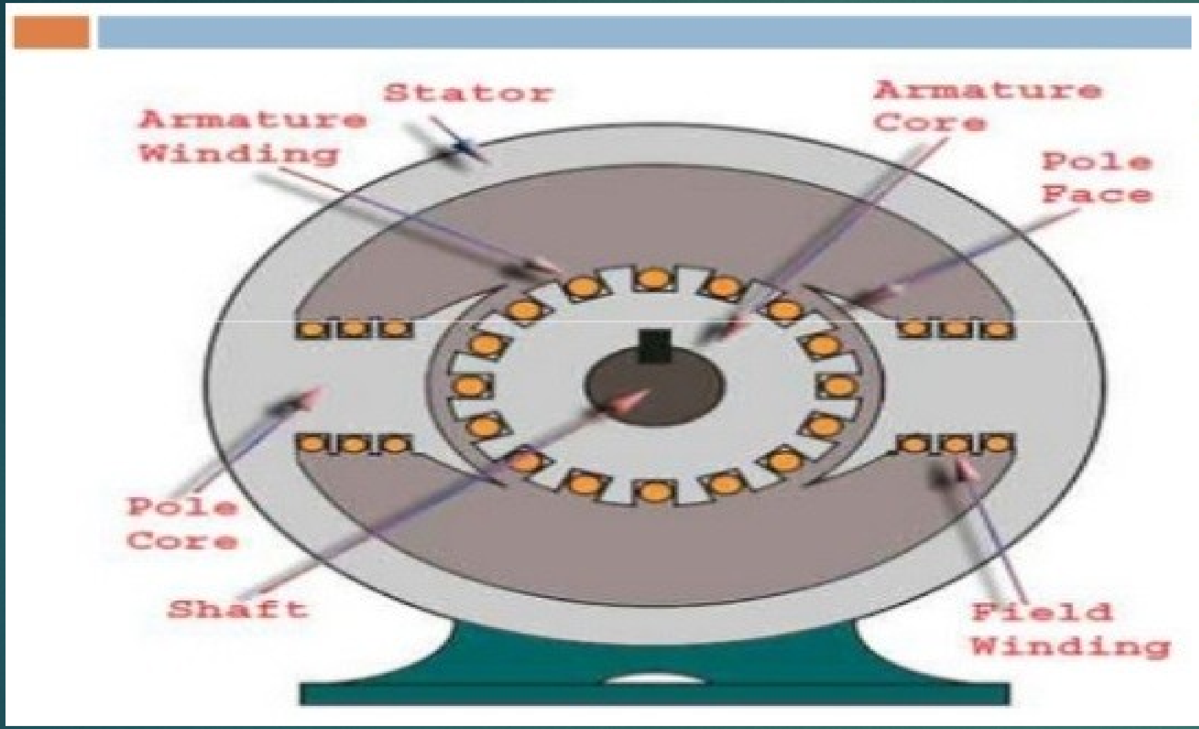
   That houses the field winding

1. Rotor

   Rotating part that rotates in magnetic field

DC MACHINES

- DC Machines :



Other parts

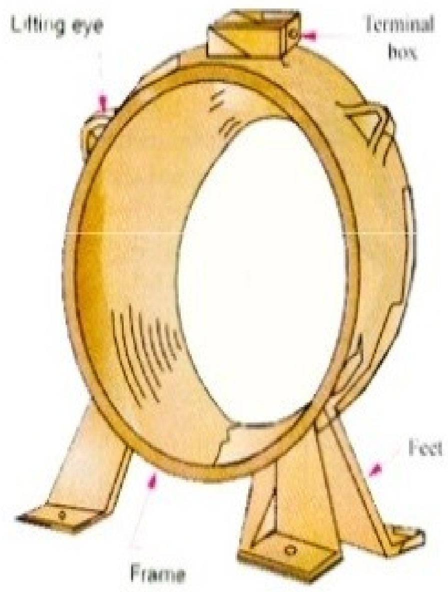
- Yoke
- Poles
- Field winding
- Armature winding
- Commutator
- Brushes

DC MACHINES

- DC Machines :

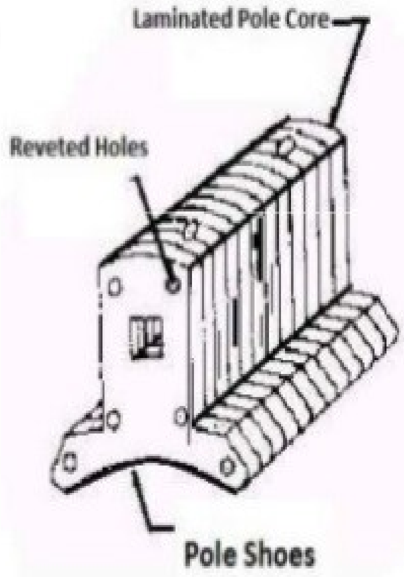
Yoke

- Its main function is to form a protective covering over the inner sophisticated parts of the motor and carries the flux produced by the poles.
- Made up of cast iron or steel.



Poles

- The magnetic poles are structures fitted onto the inner wall of the yoke with screws.
- The construction of magnetic poles basically comprises of two parts namely, the pole core and the pole shoe stacked together under hydraulic pressure and then attached to the yoke.

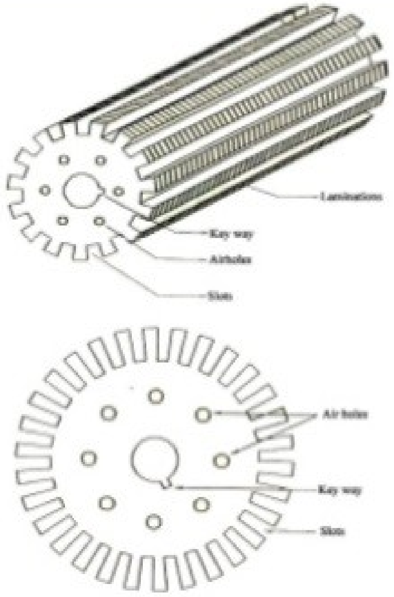


DC MACHINES

- DC Machines :

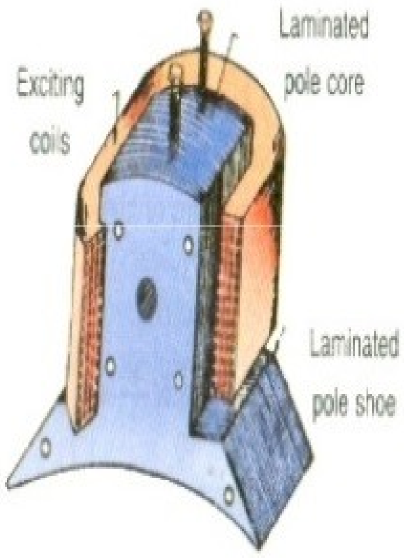
Armature

- The armature core are provided with slots to which the armature windings made with several turns of copper wire distributed uniformly over the entire periphery of the core.



Field winding

- Made with field coils (copper wire) wound over the slots of the pole shoes
- The field windings basically form an electromagnet, that produces field flux



DC MACHINES

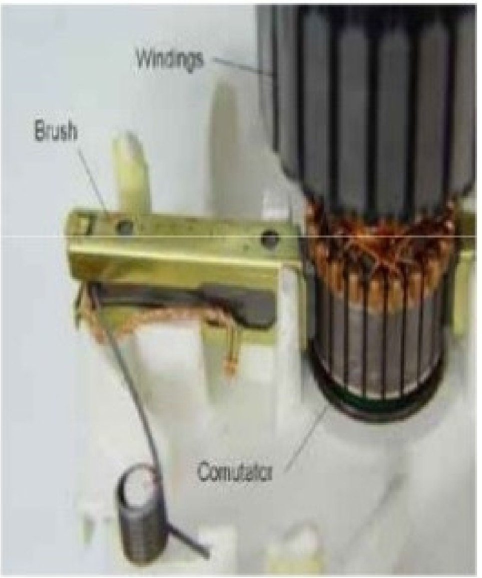
- DC Machines :

Commutator

- It is a cylindrical structure made up of copper segments stacked together, but insulated from each other by mica.
- Collects the current from the armature conductors
- Converts alternating current induced in the armature circuit into unidirectional current.

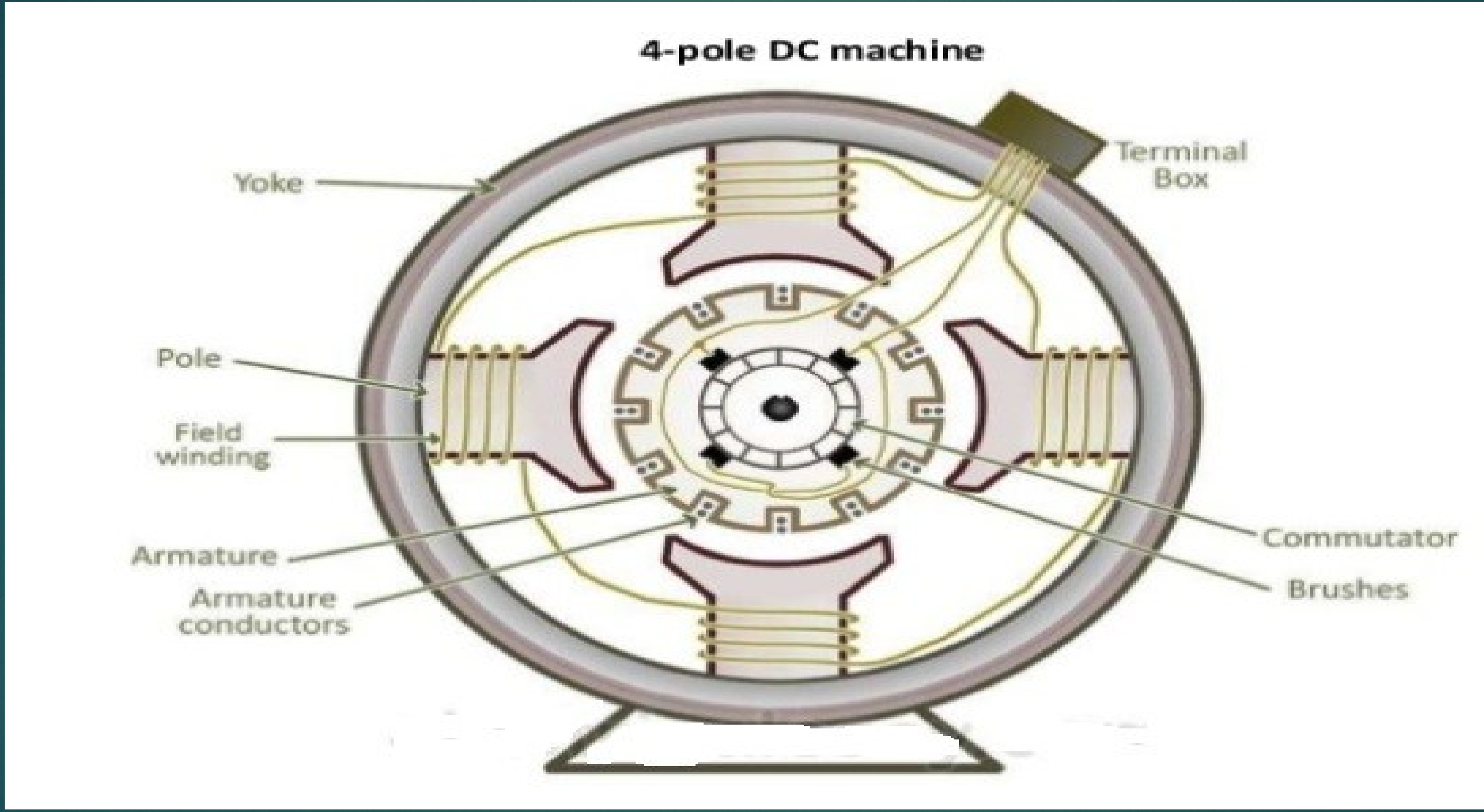
Brushes

- Made with carbon or graphite structures, making sliding contact over the rotating commutator.
- Collects the current from commutator and make it available to the stationary ckt.



DC MACHINES

- DC Machines :



DC MACHINES

- DC Machines :

Armature Core

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.

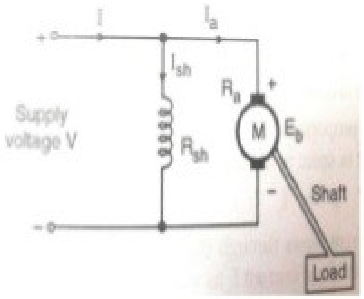
Armature winding:

- ✓ 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.

DC MACHINES

- DC Machines :

DC Shunt Motor:



- In dc shunt motor the armature and field winding are connected in parallel across the supply voltage
- The resistance of the shunt winding R_{sh} is always higher than the armature winding R_a
- Since V and R_{sh} both remains constant the I_{sh} remains essentially constant, as field current is responsible for generation of flux.

  thus $\emptyset \propto I_{sh}$
- So shunt motor is also called as constant flux motor.

Torque and Speed equation of DC Shunt Motor:

As we have seen for dc motor

$$T \propto \emptyset\, Ia$$

But for dc shunt motor :$\emptyset \propto Ish$

And Ish is constant , thus $\emptyset$ is also constant

So torque in dc shunt motor is

$$T \propto Ia$$

For dc motor

$$Eb = \frac{N\emptyset ZP}{A60}$$

$Z, P, A, \emptyset$ and 60 are constants

Thus, $N \propto Eb \propto (V - IaRa)$

DC MACHINES

- DC Machines :

Characteristics of DC Shunt Motor:

To study the performance of the DC shunt Motor various types of characteristics are to be studied.

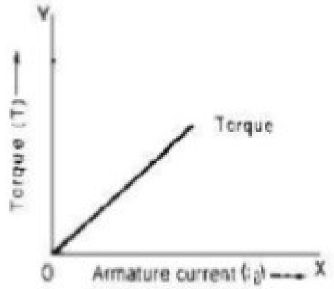
1. Torque Vs Armature current characteristics.
2. Speed Vs Armature current characteristics.
3. Speed Vs Torque characteristics.

Torque Vs Armature current characteristics of DC Shunt motor

This characteristic gives us information that, how torque of machine will vary with armature current, which depends upon load on the motor.

$$T \propto Ia$$

Thus,



DC MACHINES

- DC Machines :

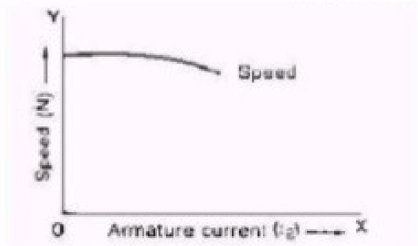
Speed Vs Armature current characteristics of DC Shunt Motor

The back emf of dc motor is $Eb = \frac{N\emptyset ZP}{A60} = V - IaRa$

$$\text{Therefore} \quad N = \frac{(V - I_a R_a)\ 60\ A}{\phi PZ} = \frac{K(V - I_a R_a)}{\phi}$$

where K = 60A/ ZP and it is constant. In dc shunt motor, when supply voltage V is kept constant the shunt field current and hence flux per pole will also be constant.

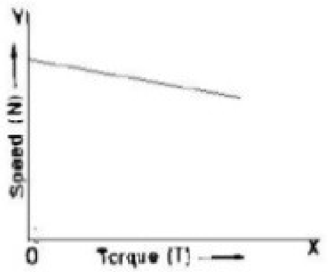
$$\therefore N \propto V - Ia\,Ra$$



Therefore shunt motor is considered as constant speed motor.

Speed Vs Torque characteristics of DC Shunt motor

- From the above two characteristics of dc shunt motor, the torque developed and speed at various armature currents of dc shunt motor may be noted.
- If these values are plotted, the graph representing the variation of speed with torque developed is obtained.
- This curve resembles the speed Vs current characteristics as the torque is directly proportional to the armature current.

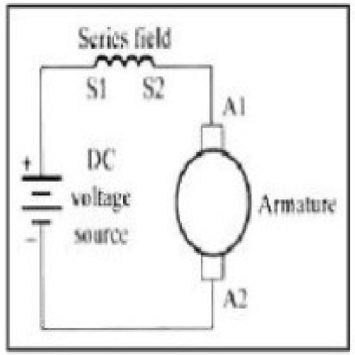


DC MACHINES

- DC Machines :

DC Series Motor:

- In this type of DC motor the armature and field windings are connected in series.
- the resistance of the series field winding Rs is much smaller than the armature resistance Ra



- The flux produced is proportional to the field current but in this $I_f = I_a$ thus $\emptyset \propto Ia$
- Thus flux can never become constant in dc series motor as load changes I_f and I_a also gets changed
- Thus dc series motor is not a constant flux motor.

Torque and Speed equation of DC Series Motor:

As we have seen for dc motor

$$T \propto \emptyset\, Ia$$

But for dc series motor as $I_f = I_a$ thus $\emptyset \propto Ia$

So torque in dc series motor is

$$T \propto Ia^2$$

For dc motor

$$Eb = \frac{N\emptyset ZP}{A60}$$

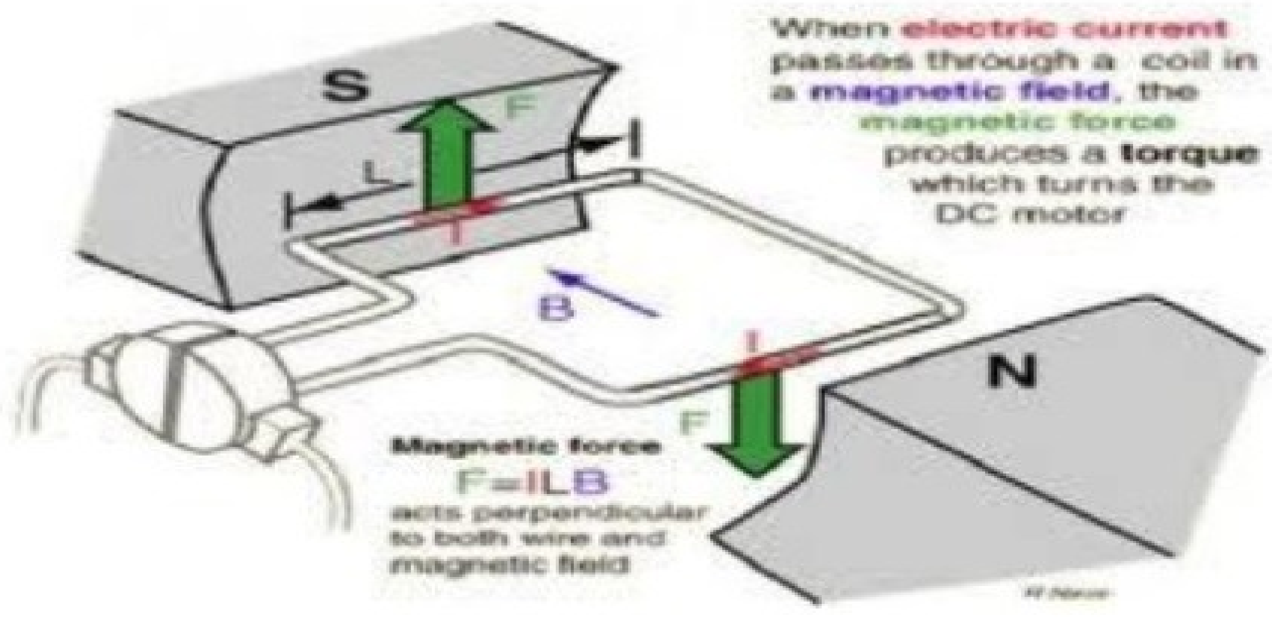
Z, P, A and 60 are constants

Thus, $N \propto \frac{Eb}{\emptyset} \propto \frac{(V - IaRa) - I_s R_s}{\emptyset} = \frac{V - Ia(Ra + R_s)}{\emptyset}$....... as $Ia = I_s$ for dc series motor

DC MACHINES

- DC Machines :

Force acting on the armature conductor(Lorentz force):

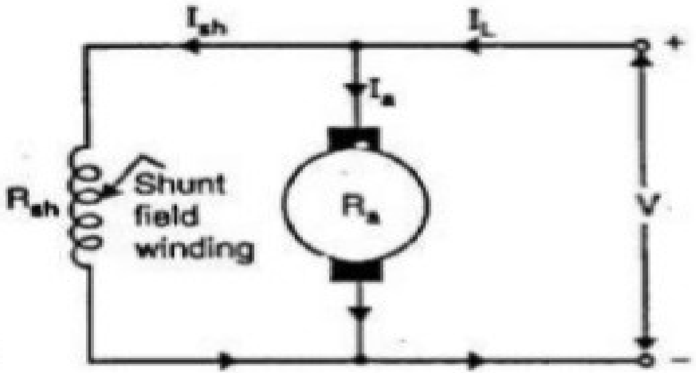


DC MACHINES

- DC Machines :

1. DC SHUNT MOTOR

- The parallel combination of two windings is connected across a common dc power supply.
- The resistance of shunt field winding (R_{sh}) is always higher than that is armature winding.
- This is because the number of turns for the field winding is more than that of armature winding.
- The cross-sectional area of the wire used for field winding is smaller than that of the wire used for armature winding.



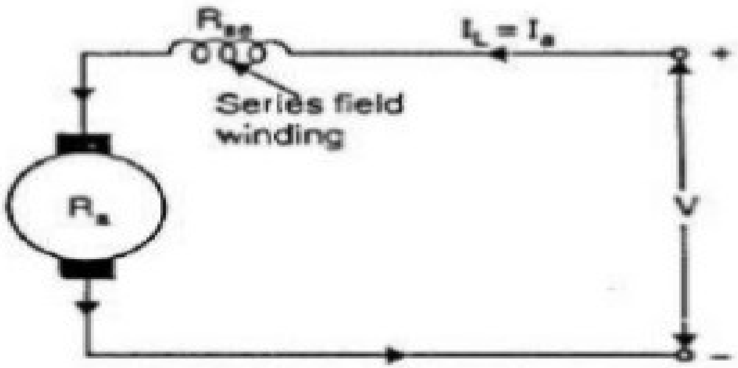
Armature

DC MACHINES

- DC Machines :

2. DC SERIES MOTOR

- The field winding is connected in series with the armature.
- The current passing through the series winding is same as the armature current .
- Therefore the series field winding has fewer turns of thick wire than the shunt field winding.
- Also therefore the field winding will posses a low resistance then the armature winding.



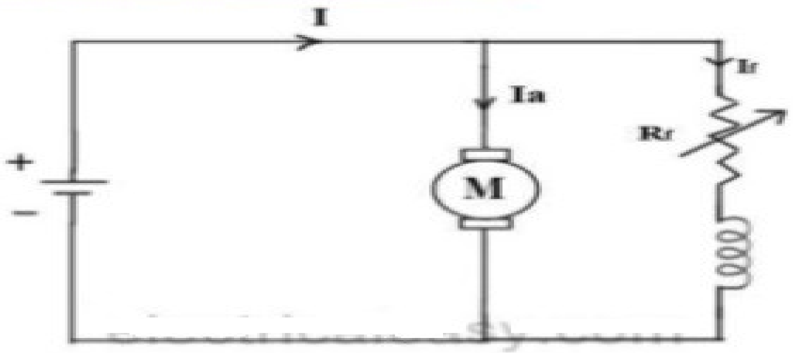
DC MACHINES

- DC Machines :

Speed Control Of Shunt Motor

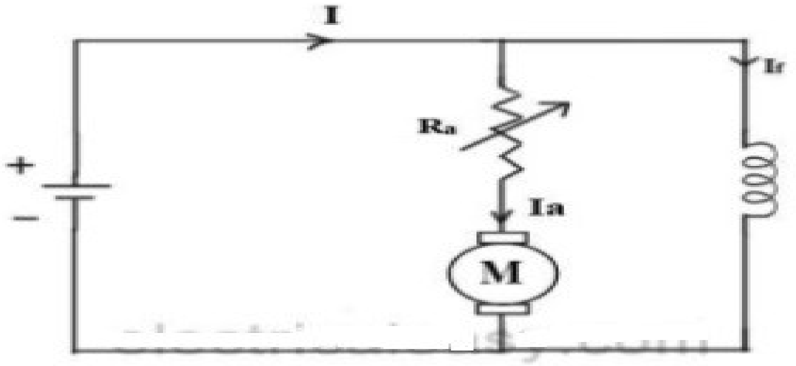
1. Flux Control Method

To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux.



2. Armature Control Method

When the supply voltage V and the armature resistance R_a are kept constant, speed is directly proportional to the armature current I_a. Thus, if we add a resistance in series with the armature, I_a decreases and, hence, the speed also decreases.



DC MOTOR

- DC Motor :

DC MOTOR

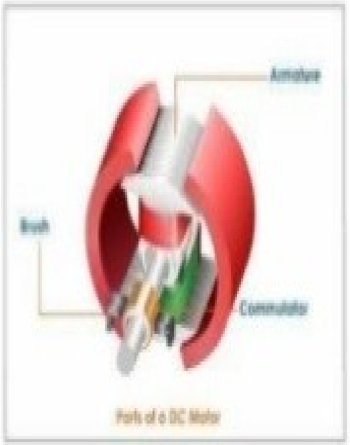
Electrical motor: It is a machine which convert electrical energy into mechanical energy.

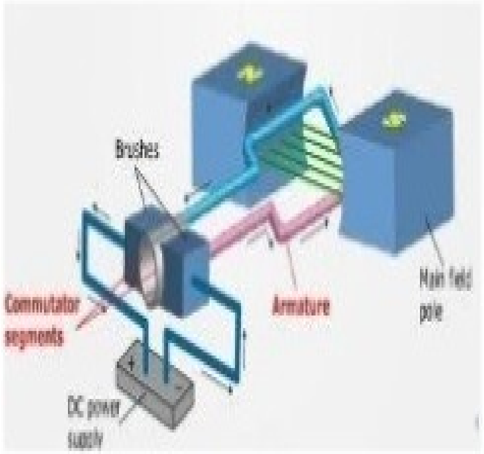
AC Motor: motor that runs on alternating current (AC) electricity.

DC Motor: motor that runs on direct current (DC) electricity.

Principle of operation of DC Motor:

When current carrying conductor is placed in a magnetic field it experience a force.





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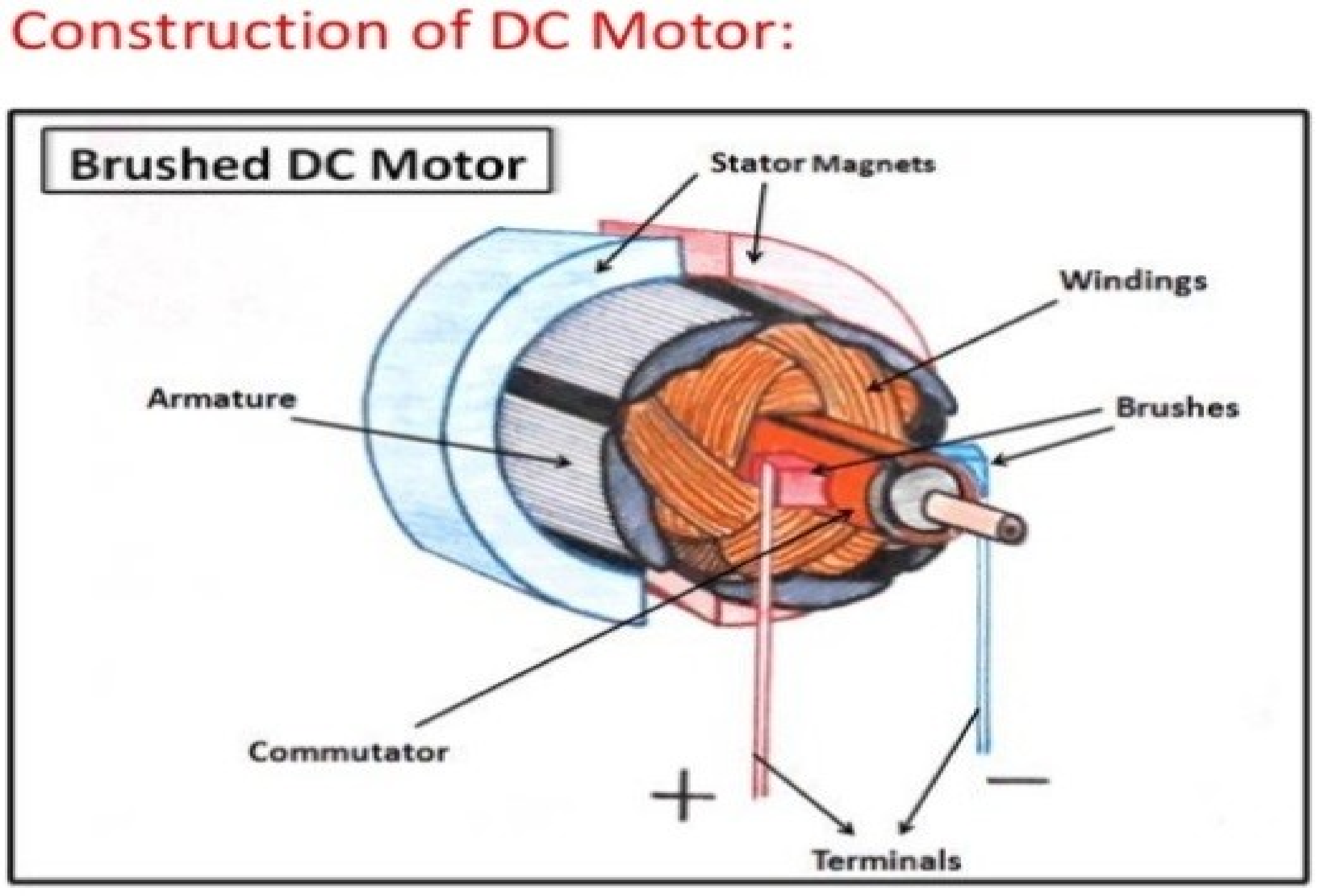
- Construction of DC Motor :



Main parts

The two major parts required for construction :

1. Stator

   That houses the field winding

1. Rotor

   Rotating part that rotates in magnetic field

Continued………

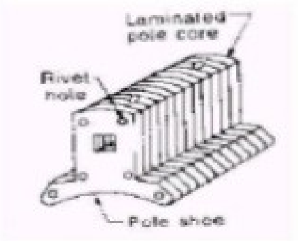
- DC Motor :

Function of each part of DC Motor:

Yoke:

- It is outer cover of dc motor also called as frame.
- It provides protection to the rotating and other part of the machine from moisture, dust etc.
- Yoke is an iron body which provides the path for the flux to complete the magnetic circuit.
- It provides the mechanical support for the poles.
- Material Used: low reluctance material such as cast iron, silicon steel, rolled steel, cast steel etc.

Poles, and pole core:



- Poles are electromagnet, the field winding is wound over it.
- It produces the magnetic flux when the field winding is excited.
- The construction of pole is done using the lamination of particular shape to reduce the power loss due to eddy current.

pole shoe:

- Pole shoe is an extended part of a pole. Due to its typical shape, it enlarges the area of the pole, so that more flux can pass through the air gap to armature.
- Material Used: low reluctance magnetic material such as cast steel or cast iron is used for construction of pole and pole shoe.

Continued………

- DC Motor :

Field winding:

- The coil wound on the pole core are called field coils.
- Field coils are connected in series to form field winding.
- Current is passed through the field winding in a specific direction, to magnetize the poles and pole shoes. Thus magnetic flux is produce in the air gap between the pole shoe and armature.
- Field winding is also called as Exciting winding.
- Material Used for copper conductor is copper.
- Due to the current flowing through the field winding alternate N and S poles are produced.

Armature core:

- Armature core is a cylindrical drum mounted on the shaft.
- It is provided with large number of slots all over its periphery and it is parallel to the shaft axis.
- Armature conductors are placed in these slots.
- Armature core provides low reluctance path to the flux produced by the field winding.
- Material used: high permeability, low reluctance cast steel or cast iron material is used.
- Laminated construction of iron core is used to minimize the eddy current losses.

Continued………

- DC Motor :

Continued………

- DC Motor :

Armature winding:

- Armature conductor is placed in a armature slots present on the periphery of armature core.
- Armature conductor are interconnected to form the armature winding.
- When the armature winding is rotated using a prime mover, it cuts the magnetic flux lines and voltage gets induced in it.
- Armature winding is connected to the external circuit (load) through the commutator and brushes.
- Material Used: Armature winding is suppose to carry the entire load current hence it should be made up of conducting material such as copper.

Commutator:

- It is a cylindrical drum mounted on the shaft along with the armature core.
- It is made up of large number of wedge shaped segments of hard-drawn copper.
- The segments are insulated from each other by thin layer of mica.
- Armature winding are tapped at various points and these tapping are successively connected to various segments of the commutator.

Function of commutator:

- It converts the ac emf generated internally into dc
- It helps to produce unidirectional torque.

Material Used: it is made up of copper and insulating material between the segments is mica.

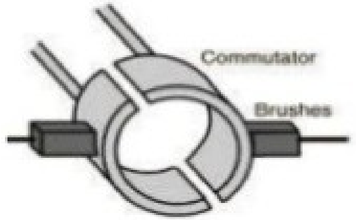
Continued………

- DC Motor :

Brushes:

- Current are conducted from the armature to the external load by the carbon brushes which are held against the surface of the commutator by springs.
- **Function of brushes:** To collect the current from the commutator and apply it to the external load in generator, and vice versa in motor.
- **Material Used:**

Brushes are made of carbon and they are rectangular in shape.

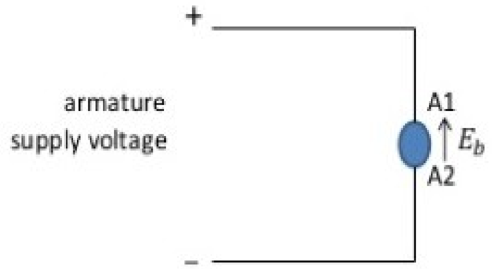


Back emf:

- When the armature winding of dc motor is start rotating in the magnetic flux produced by the field winding, it cuts the lines of magnetic flux and induces the emf in the armature winding.
- According to Lenz's law (*The law that whenever there is an induced electromotive force (emf) in a conductor, it is always in such a direction that the current it would produce would oppose the change which causes the induced emf.*), this induced emf acts in the opposite direction to the armature supply voltage. Hence this emf is called as back emfs.

$$E_b = \frac{N \emptyset Z}{60} \frac{P}{A} \text{Volts}$$

N= speed in rpm
$\emptyset$= flux per pole
Z= no of conductors
P=no of pole pairs
A=area of cross section of conductor
E_b= back emf



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- DC Motor :

Voltage and Power equation of DC Motor:

$$V = Eb + IaRa$$

If we multiply the above equation by Ia, we will get

$$VIa = EbIa + Ia^2Ra$$

$VIa = electrical\ power\ supplied\ to\ the\ motor$

$EbIa = electrical\ equivalent\ of\ the\ mechanical\ power\ produced\ by\ the\ motor$

$Ia^2Ra = power\ loss\ taking\ place\ in\ armature\ winding$

Thus,

$$EbIa = VIa - Ia^2Ra$$

$$= input\ power\text{-}power\ \ loss$$

thus, $EbIa$= Gross mechanical power produce by the motor

= Pm

Continued.........

- Torque equation for DC Motor :

Torque equation of DC Motor:

mechanical power required to rotate the shaft on mechanical side $= T\omega$ .... (1)

T = Torque in Newton-meter

ω = angular velocity in radian /second

gross mechanical power produce by the motor on electrical side $= EbIa$ .... (2)

Eb = back emf in volts

Ia = armature current in ampere

equating eqnuation (1) and (2), we get

$$EbIa = T\omega \quad \ldots\ldots \quad (3)$$

$$\omega = \frac{2\pi N}{60} \quad \ldots\ldots$$

$\frac{2\pi N}{60}$ = Speed in rpm

And $Eb = \frac{N\emptyset ZP}{A60}$

Thus, equation (3) become

$$\frac{N\emptyset ZP}{A60} Ia = T\frac{2\pi N}{60}$$

$$T = \frac{P\emptyset ZIa}{2\pi A} = \frac{0.159P\emptyset ZIa}{A} = \left(\frac{0.159PZ}{A}\right)\emptyset Ia$$

P, Z *and* A are constant, hence we can say

$$T \propto \emptyset Ia$$

Thus torque produce by the DC Motor is proportional to the main field flux $\emptyset$ and armature current Ia

Continued………

- DC Motor :

Types of DC Motor:

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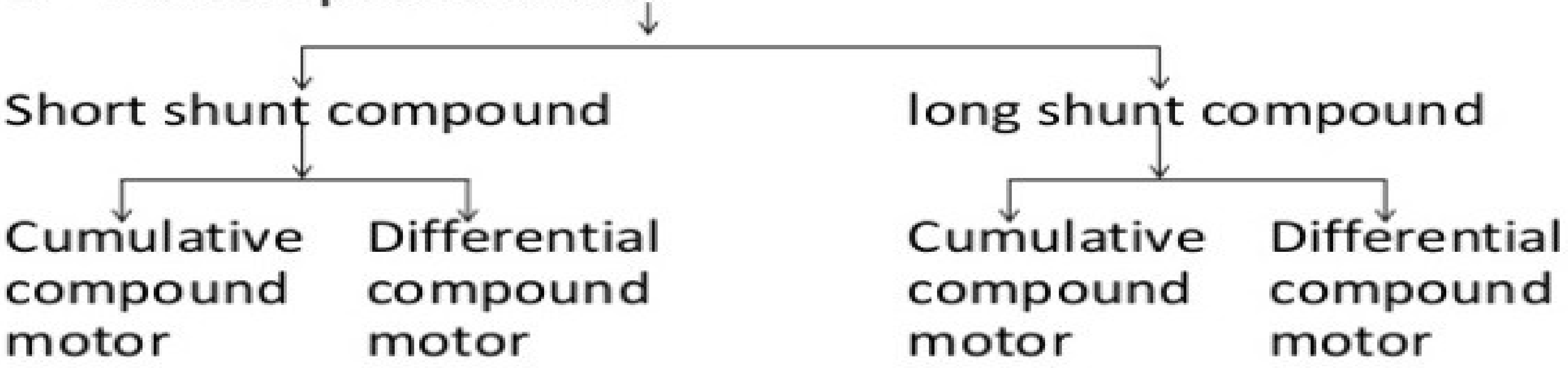
2. DC Series Motor
3. DC Compound Motor



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- DC Motor :

1. DC SHUNT MOTOR

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- The resistance of shunt field winding (R_{sh}) is always higher than that is armature winding.
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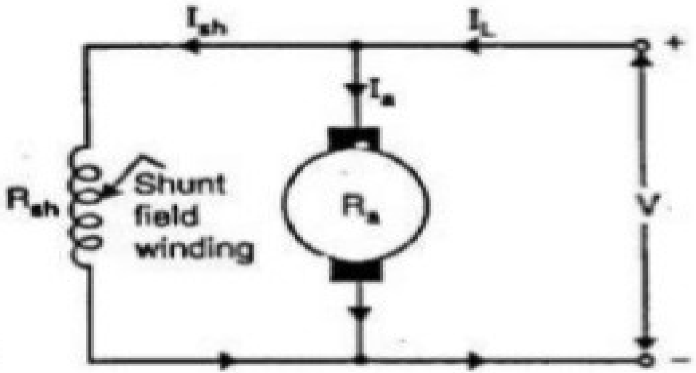


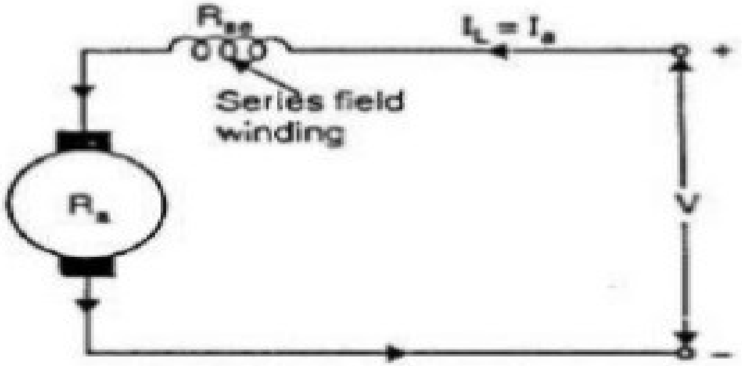
Armature

Continued…….

- DC Motor :

2. DC SERIES MOTOR

- The field winding is connected in series with the armature.
- The current passing through the series winding is same as the armature current .
- Therefore the series field winding has fewer turns of thick wire than the shunt field winding.
- Also therefore the field winding will posses a low resistance then the armature winding.



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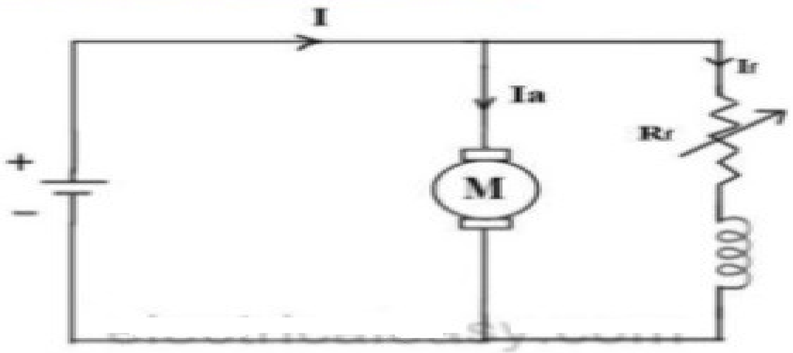
- DC Motor :

Speed Control Of Shunt Motor

1. Flux Control Method

To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux.



2. Armature Control Method

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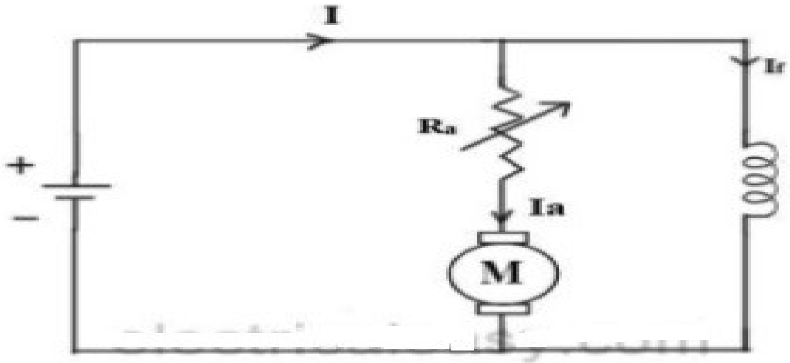
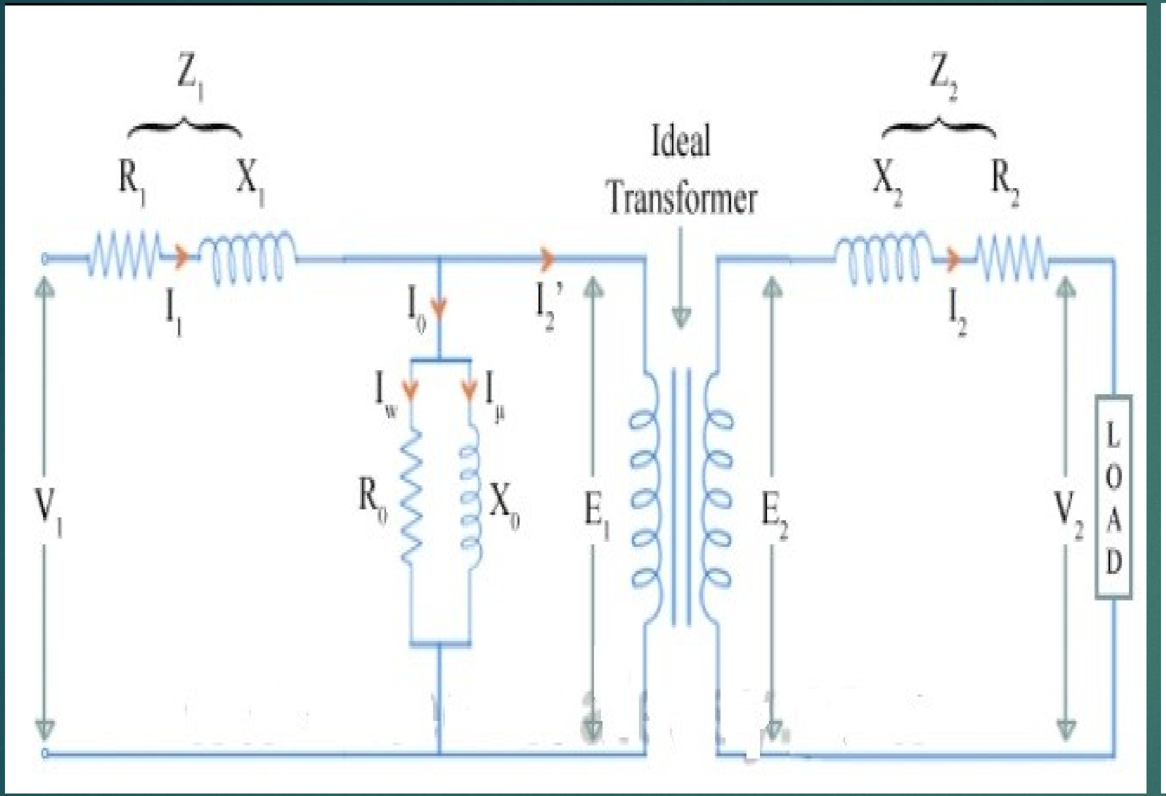
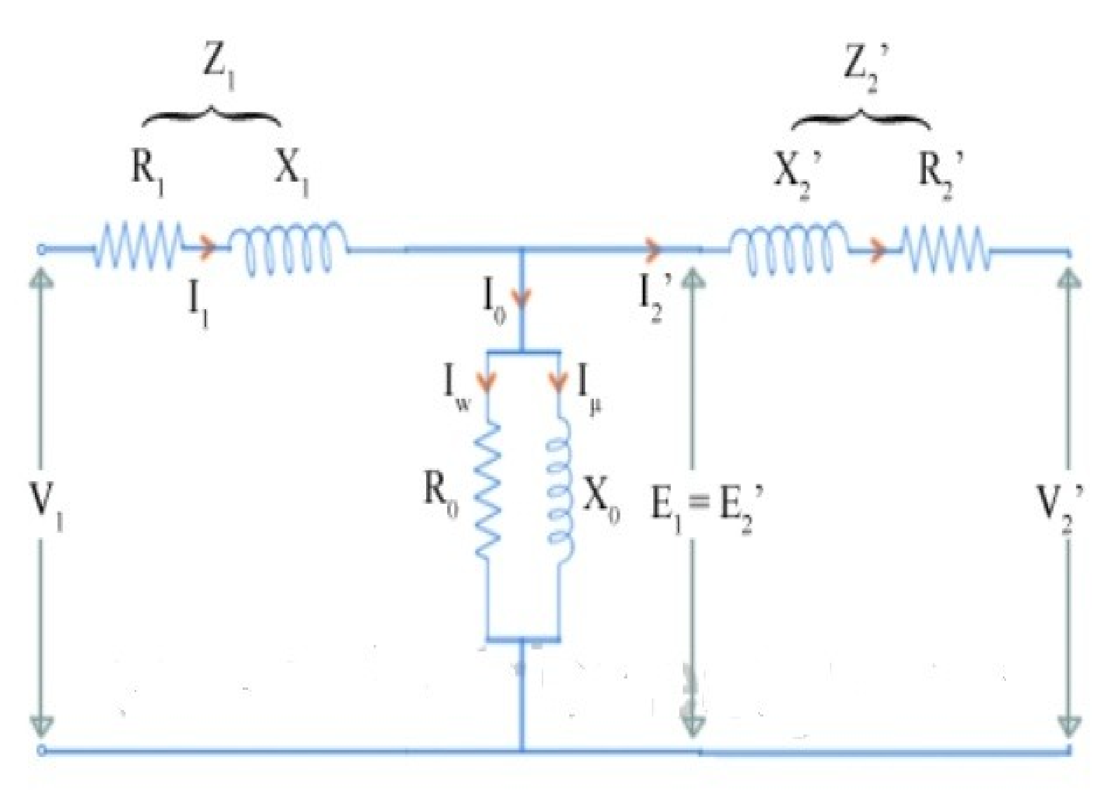


Transformer Equivalent circuit





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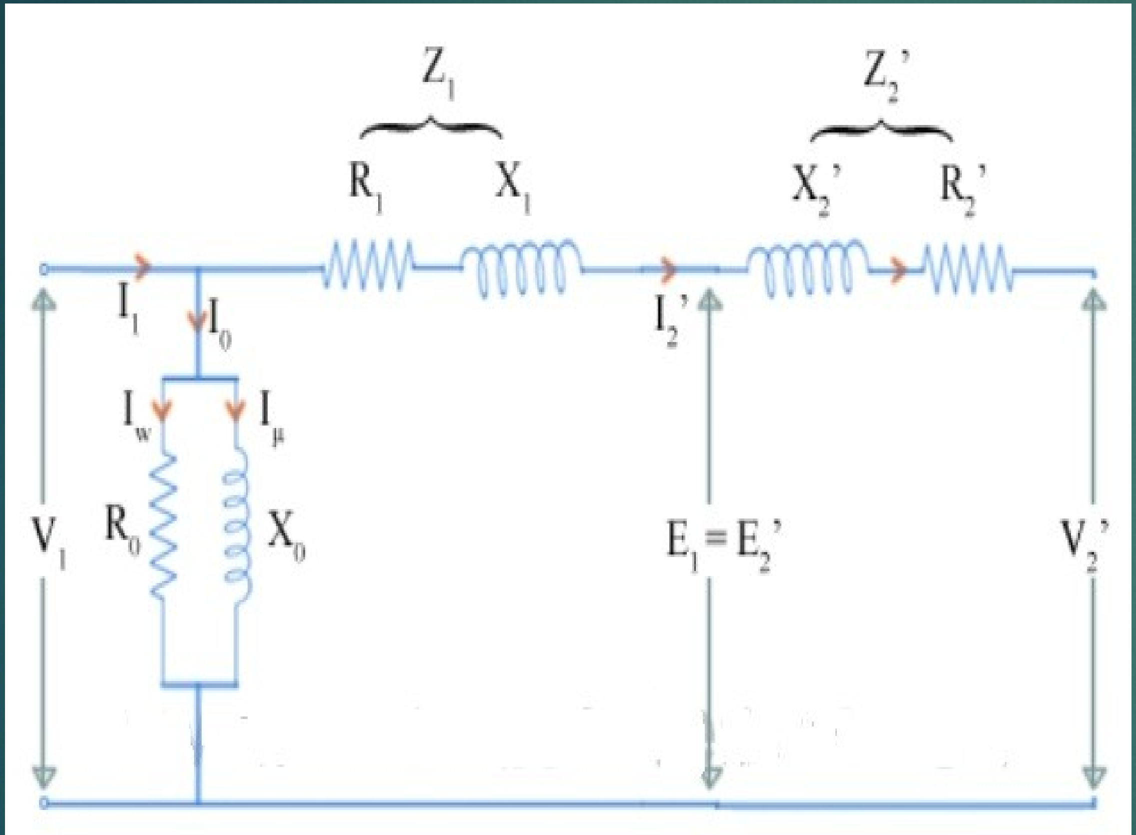
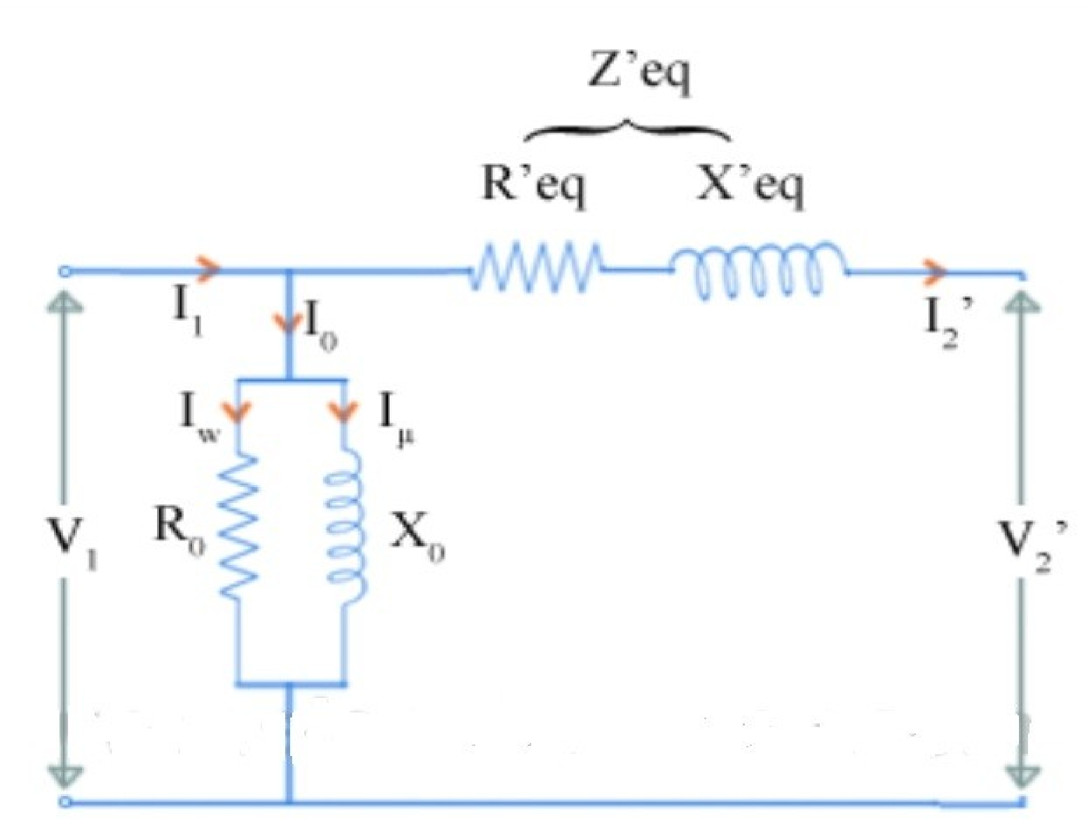
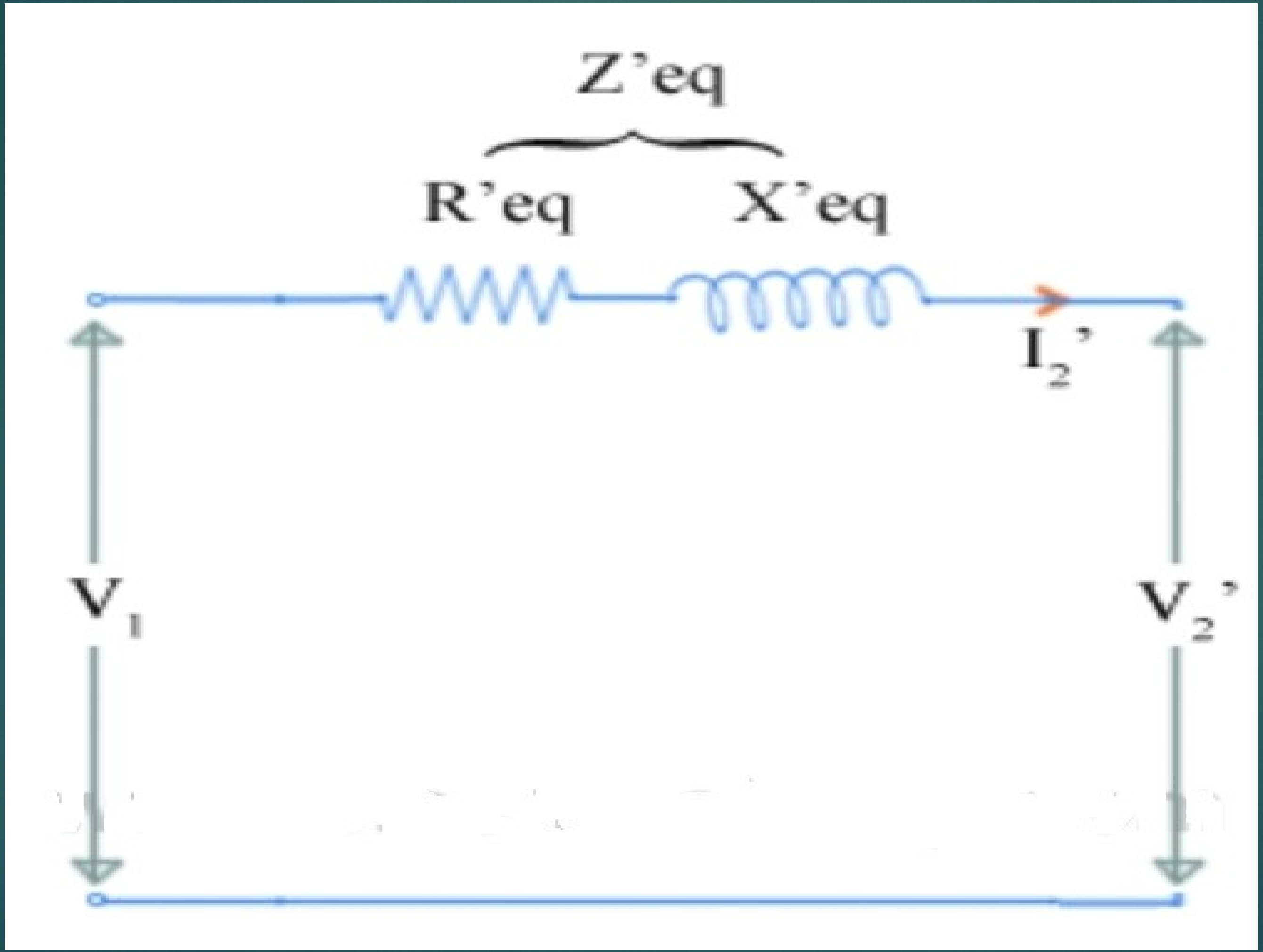


Z1
Z2'
R1
X1
X2'
R2'
I1
I0
I2'
Iw
Iμ
V1
R0
X0
E1 = E2'
V2'



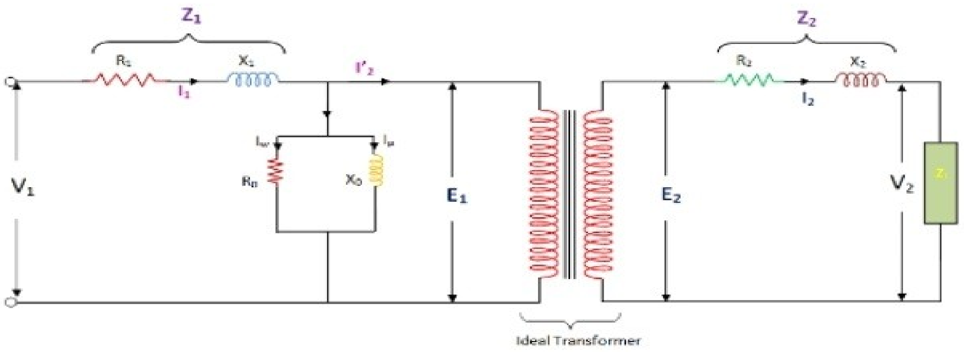
Z'eq
R'eq
X'eq
I1
I0
I2'
Iw
Iμ
V1
R0
X0
V2'

Continued………



Continued………

The equivalent circuit diagram of transformer is given below:-



Equivalent Circuit diagram of Transformer

Where,

R_1 = Primary Winding Resistance.

R_2= Secondary winding Resistance.

I_0= No-load current.

I_μ = Magnetizing Component,

I_W = Working Component,

Where,

R_1 = Primary Winding Resistance.

R_2= Secondary winding Resistance.

I_0= No-load current.

I_μ = Magnetizing Component,

I_W = Working Component,

This I_μ & I_W are connected in parallel across the primary circuit. The value of E_1 (Primary e.m.f) is obtained by subtracting vectorially $I_1 Z_1$ from V_1 . The value of $X_0 = E_1 / I_0$ and $R_0 = E_1 / I_W$. We know that the relation of E_1 and E_2 is $E_2 / E_1 = N_2 / N_1 = K$, (transformation Ratio

Continued………

The secondary circuit is shown in fig-1. and its equivalent primary value is shown in fig- 2,

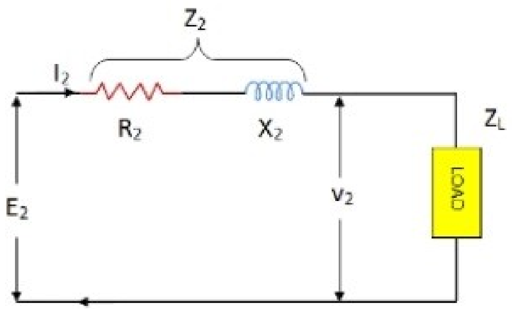


fig-1

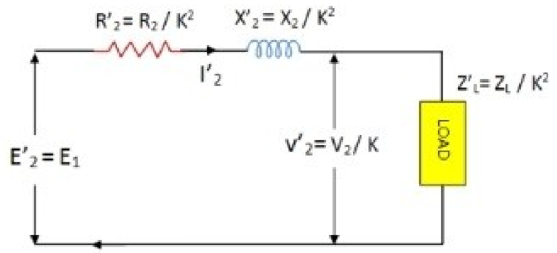


fig-2

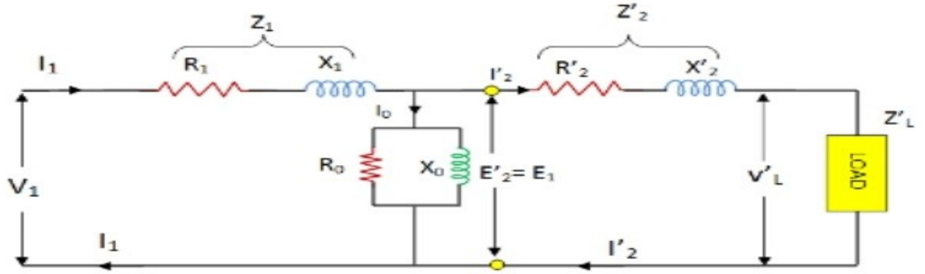
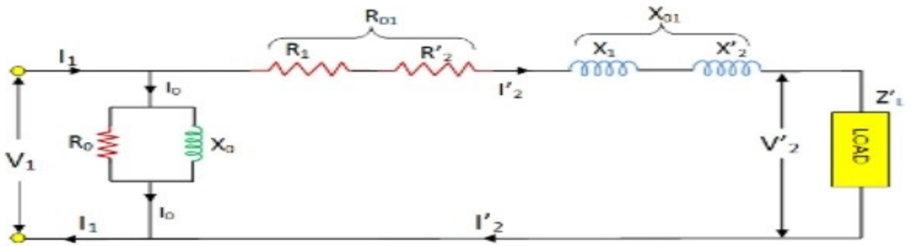


fig-3

And It can be simplified the terminals shown in fig – 4 & further simplify the equivalent circuit is shown in fig.- 5 ,



Continued………

At last, the circuit is simplified by omitting I_0 altogether as shown in fig- 5 .

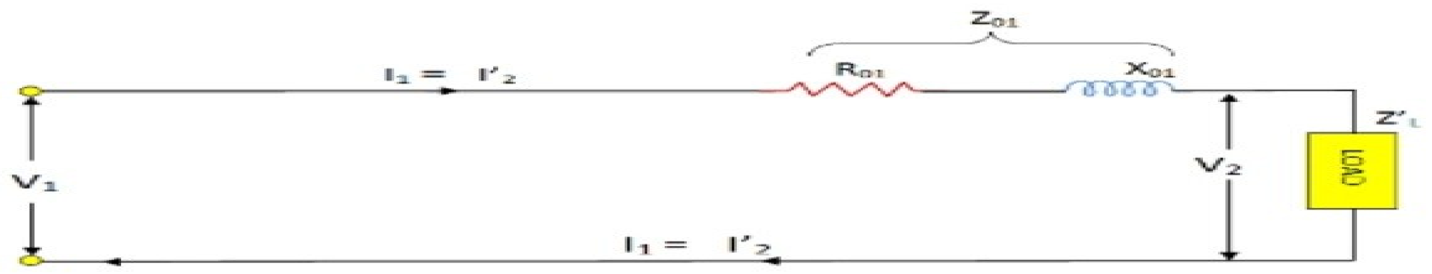


fig-5

From the equivalent circuit which is shown in fig.-3 , the total impedance between the input terminal is ,

$$Z = Z_1 + Z_m \,||\, (Z_2' + Z_L') = \left(z1 + \frac{Z_m\,(Z'_m + Z'_L)}{Z_m + (Z'_2 + Z'_L)} \right)$$

Continued………

- DC Motor :

Continued………

- DC Motor :