ELEMENTS OF ELECTRICAL ENGINEERING
(22215)

CHAPTER-4 Transformer and DC motors - 14 M

CO4 : Connect the transformer and DC motor for specific requirements

By SAROJ DESAI

Content

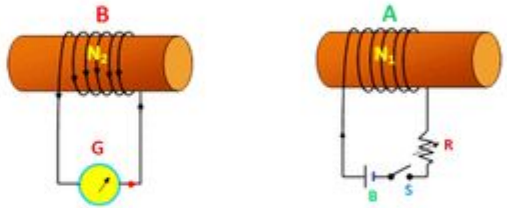
Unit-IV Transformer and DC Motors	4a. Explain the working principle of the given type of transformer. 4b. Distinguish the construction of the given type of transformer. 4c. Describe the construction and working of the given type of DC motor. 4d. Select relevant type of DC motor for the given application with justification.	4.1 Transformer: Working principle, emf equation, Voltage ratio, current ratio and transformation ratio, losses 4.2 Auto-transformer – comparison with two winding transformer, applications 4.3 DC motor construction - parts its function and material used 4.4 DC motor -Principle of operation 4.5 Types of D.C. motors, schematic diagram, applications of dc shunt, series and compound motors

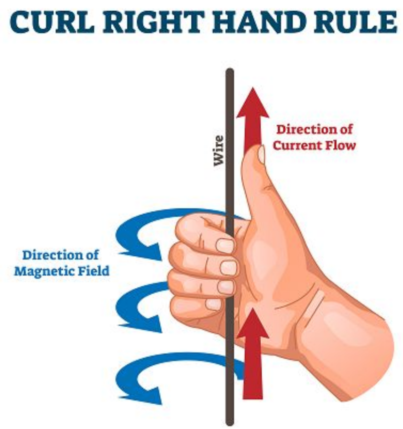
PREREQUISITE: Mutually Induced EMF

- It is the electromagnetic induction produced by one circuit in the nearby second circuits due to the variable flux of the first circuit cutting the conductor of the second circuit

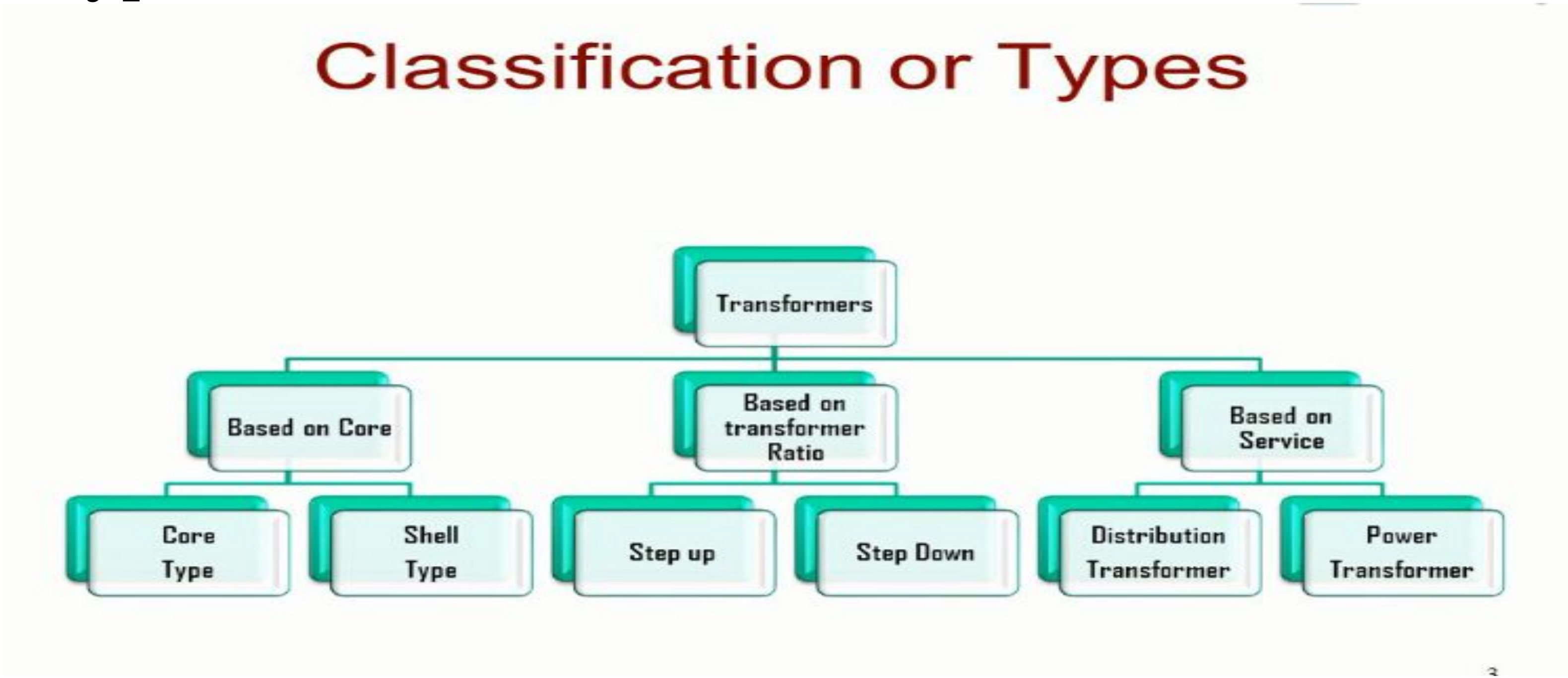
- That means when two coils or circuits are kept n to each other and if current is given to one circuit and it is changed, the flux produced due to that current which is linking both the coils or circuits cuts both the coils, an emf will be produced in both the circuits.

- The production of emf in second coil is due to the variation of current in first coil known as mutual induction.



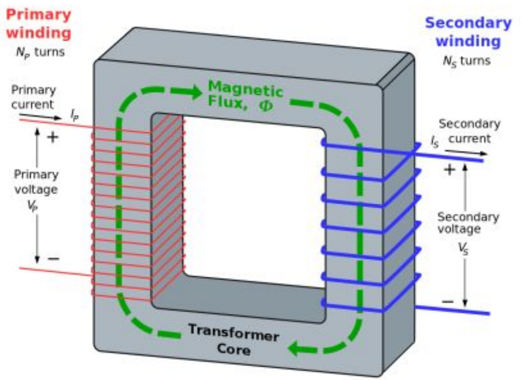


4.1 Types of transformer

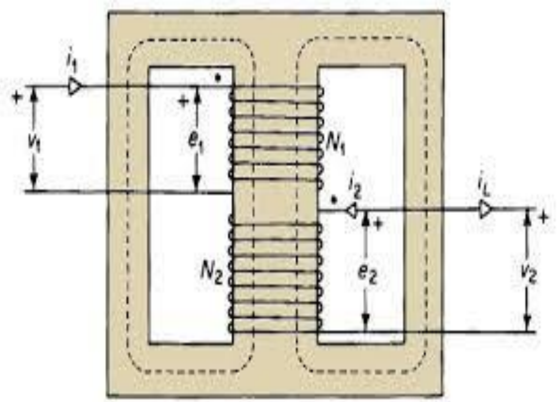


Based on core structured used there are following types of transformer:

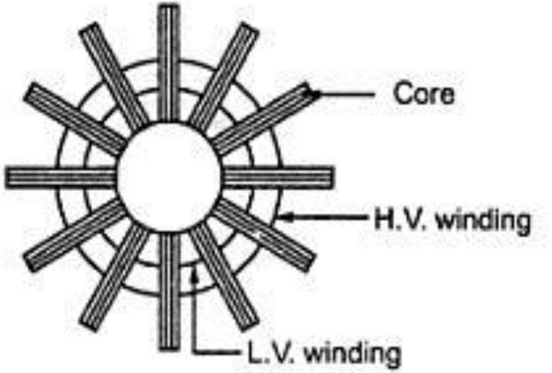
i) Core type of transformer ii) Shell type of transformer iii) Berry type



Core tyoe



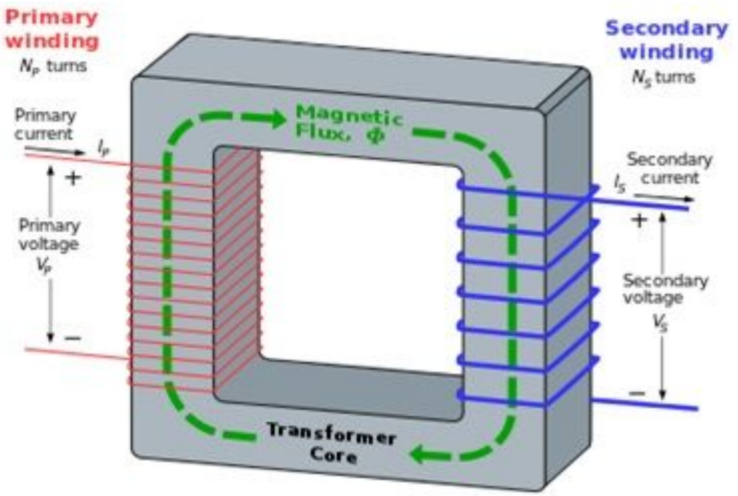
Shell type

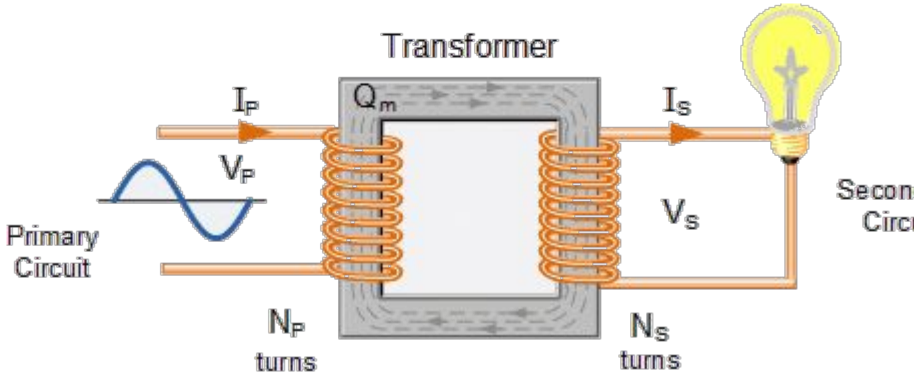


Berry type

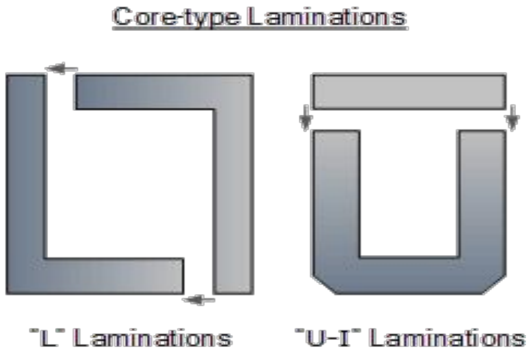
Transformer: working principle

- When an alternating voltage V_1 is applied to the primary, an alternating flux φ is set up in the core.
- This alternating flux links both the windings and induces EMFs E_1 and E_2 in them according to Faraday's Law of Electromagnetic Induction.
- It works on principle of Mutual inductance

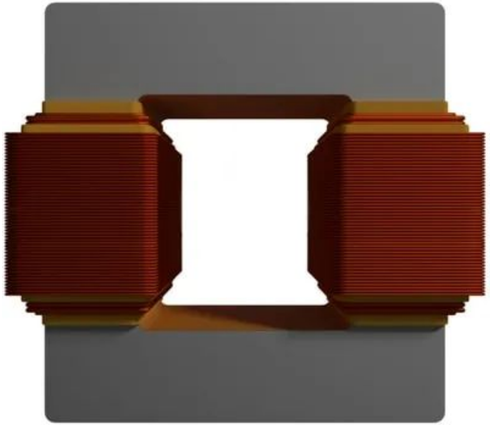




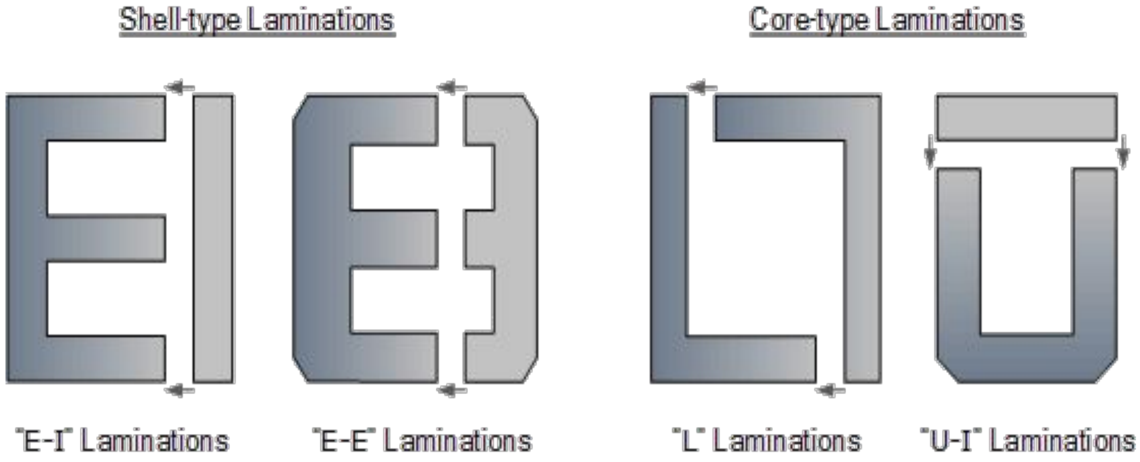
Core type and shell type of transformers

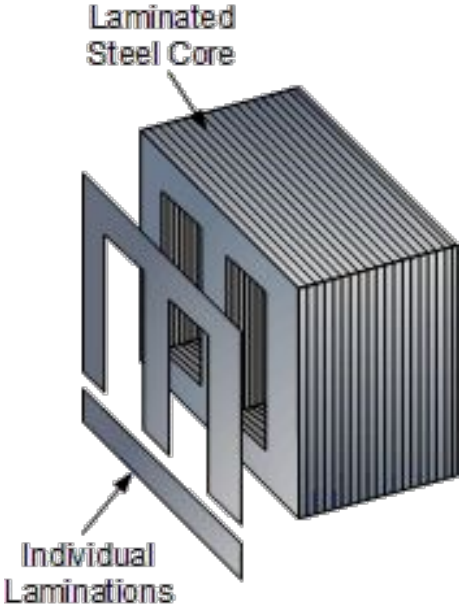


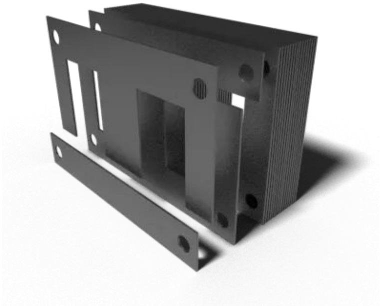
- The core is made up of silicon steel which has low hysteresis loss and high permeability. This core is laminated to reduce eddy current loss. These features reduces the overall iron loss of transformer.
- Both LV and HV windings are wrapped on both limbs. Normally both windings are divided into parts and one part of both windings are wrapped on one limb and other parts or halves are wrapped on the other limb of the core.



Transformer: working principle







shell type of transformers

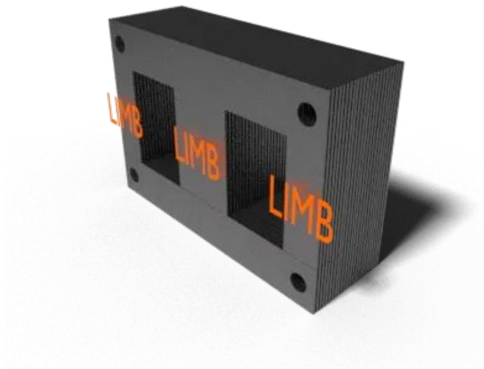
We use ‘E’s and ‘L’s shape laminations to make the core of the **shell-type transformer**.

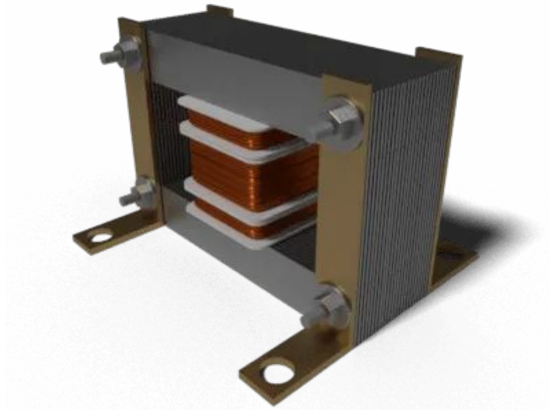
The core of a single phase shell type transformer is constructed with of three limbs (legs).

This design increases the mechanical strength of the core. It also improves the protection of windings from external mechanical shocks.

The HV and LV windings are wound around the central limb. The central limb carries the entire flux (φ), whereas the side limbs carry half of the flux (φ/2). Hence, to accommodate the flux the cross-section of the central limb is twice than that of the side limbs.

HV and LV windings are wound longitudinally along the core alternately. The HV coils are sandwiched between two LV coils as shown in the figure below.

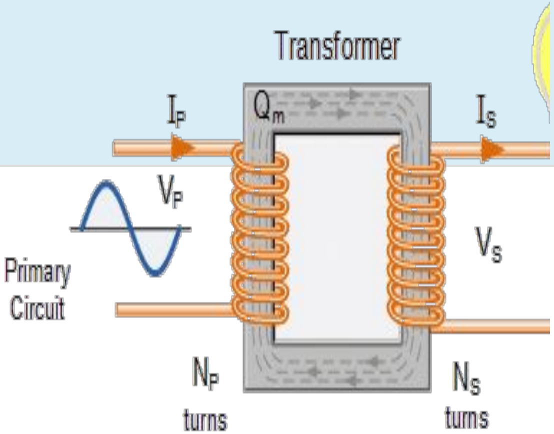
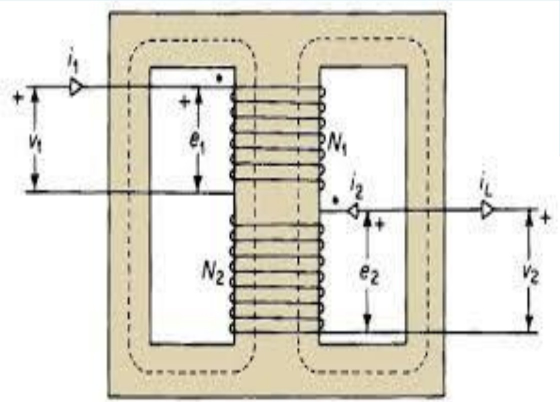




Compare shell type and core type transformer

Basis for Comparison	**Core Type Transformer**	**Shell Type Transformer**
Definition	The winding surround the core.	The core surround the winding.
Lamination Shape	The lamination is cut in the form of the L strips.	Lamination are cut in the form of the long strips of E and L.
Cross Section	Cross-section may be square, cruciform and three stepped	The cross section is rectangular in shape.
Copper Require	More	Less

Compare shell type and core type transformer

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Diagram		

Compare shell type and core type transformer

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Limb	Two	Three
Insulation	More	Less
Flux	The flux is equally distributed on the side limbs of the core.	Central limb carry the whole flux and side limbs carries the half of the flux.
Winding	The primary and secondary winding are placed on the side limbs.	Primary and secondary windings are placed on the central limb
Natural	Does not Exist	Exist

Compare shell type and core type transformer

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Magnetic Circuit	Two	One
Losses	More	Less
Maintenance	Easy	Difficult
Mechanical Strength	Low	High
Natural Cooling	Does not Exist	Exist

https://youtu.be/E7LNCeLLoD4 - CURRENT RATIO OF TRAN

https://youtu.be/_FAAxzOIaGQ - VOLTAGE AND CURRENT

https://youtu.be/vE96TySqXGk - Reversal of direction of Indu

$V_1I_1=V_2I_2$

$I_1/I_2=V_2/V_1=K$

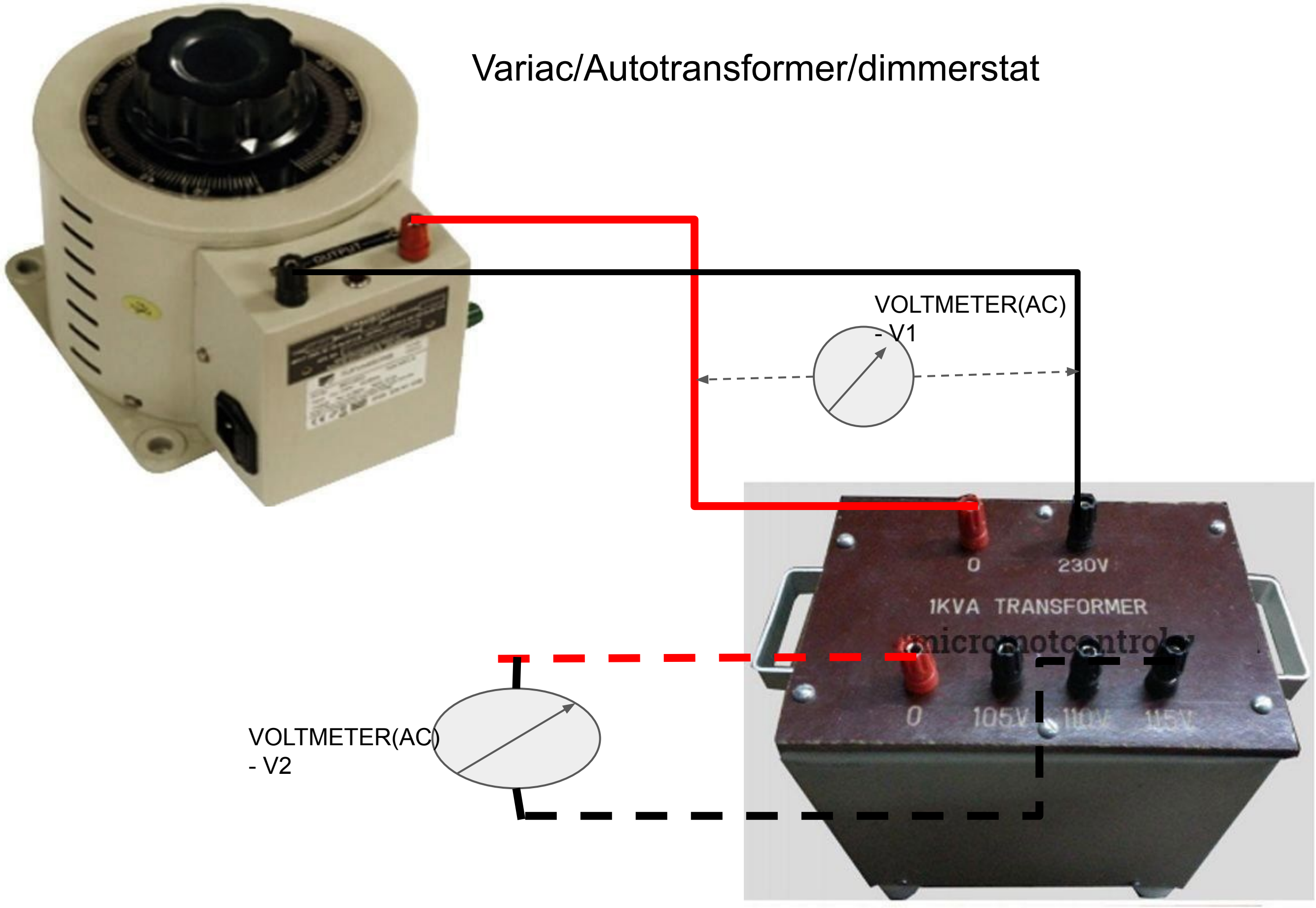
K>1- STEP-UP TRANSFORMER

K<1- STEP-DOWN TRANSFORMER

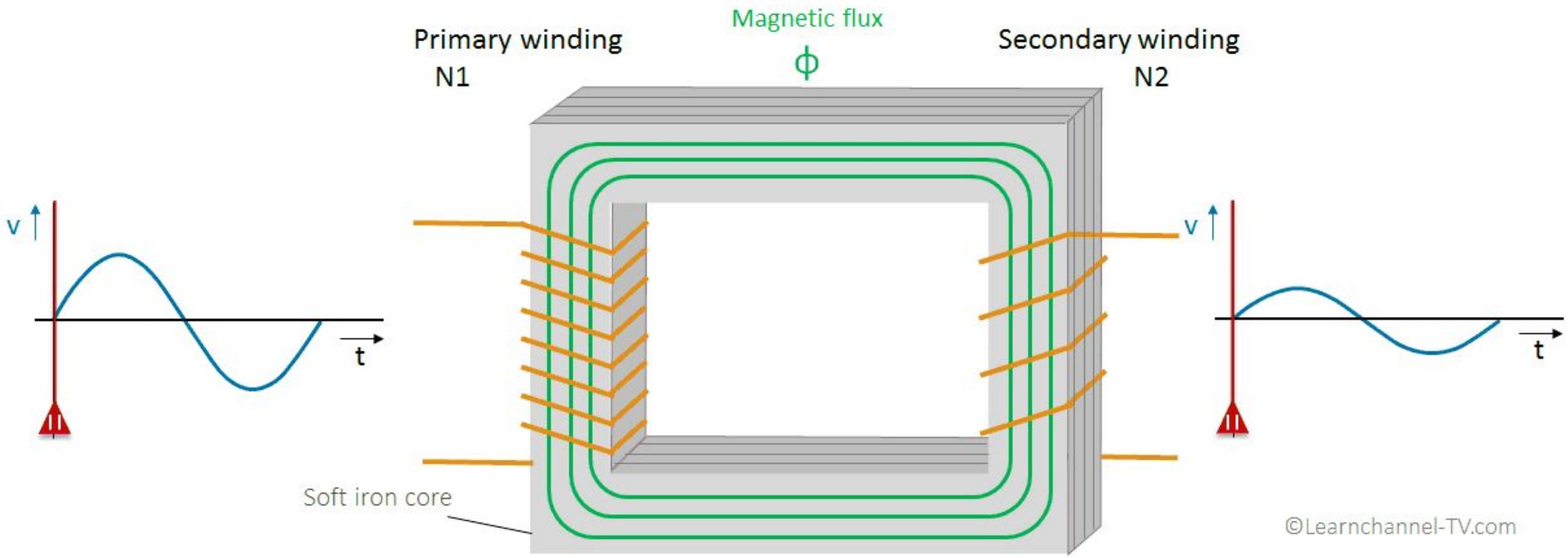
K=1 - 1:1 TRANSFORMER = ISOLATION TRANSFORMER.

Variac/Autotransformer/dimmerstat

Single phase transformer



Working of transformer



EMF equation of transformer

Let,

N_1 = Number of turns in primary winding

N_2 = Number of turns in secondary winding

Φ_m = Maximum flux in the core (in Wb) = (B_m x A)

f = frequency of the AC supply (in Hz)

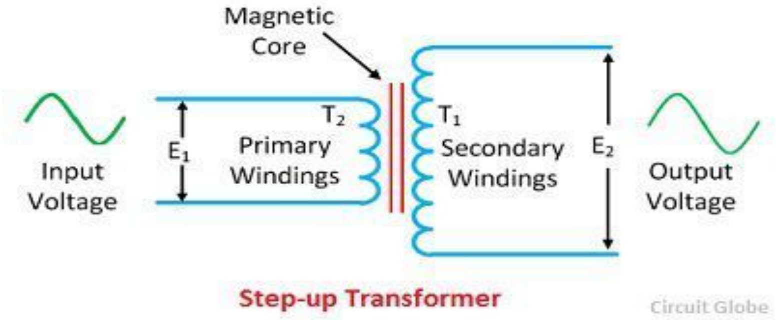
average rate of change of flux = $4f\,\Phi_m$ .... (Wb/s)

RMS value of emf per turn = $1.11 \times 4f\,\Phi_m = 4.44f\,\Phi_m$.

RMS value of induced emf in whole primary winding (E_1) = $E_1 = 4.44f\,N_1\,\Phi_m$ -----1

RMS value of induced emf in whole secondary winding (E_2) = $E_2 = 4.44f\,N_2\,\Phi_m$ ----- 2

Characteristics of transformer



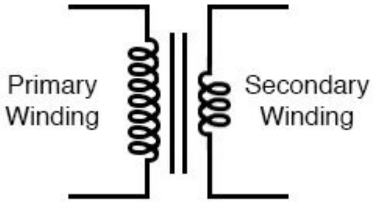
Dividing the equation (1) and (2) we get --------

E1/E2 = $((4.44f\ N_1\ \Phi_m)/(4.44f\ N_2\ \Phi_m)$

E1/E2=N1/N2 --**3**

E1/E2= V1/V2= VOLTAGE RATIO ----4

N1/N2= TURNS RATIO -----5



STEP-DOWN TRANSFORMER

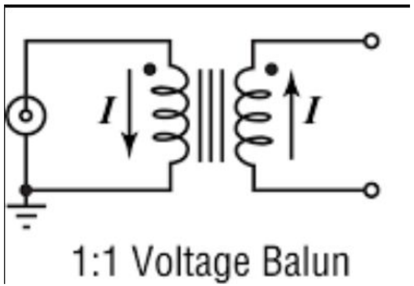
P $=V_1I_1 = V_2I_2$

$I_1/ I_2 = V_2/V_1$ =K--- TRANSFORMATION RATIO----6

V2>V1, K>1 , STEP-UP TRANSFORMER

V2<V1, K<1, STEP-DOWN TRANSFORMER

V2=V1, K=1, 1:1 TRANSFORMER ,ISOLATION TRANSFORMER.



Characteristics of transformer

Equation ---5 defines

$I_1/ I_2 = V_2/V_1$ =K--- TRANSFORMATION RATIO

It shows current ratio is inversely proportional to the voltage ratio**.**

Kilo-Volt-Ampere rating of a transformer:

- When the transformer transfers electrical energy from one circuit to another circuit.
- While transferring electrical energy, some energy is lost in transformer itself.
- This energy appears in the form of heat which raise the temperature of the transformer.
- If the temperature raise beyond specified value, it caused the excessive current in the circuit. So it may damaged insulation of the circuit.
- Base on the maximum current generated the rating of insulation is decided.
- Thus the kVA rating is output power which can deliver at rated voltage and frequency under usual conditions without exceeding the standard limits of the temperature rise.
- Power in kVA rating $=(V_1I_1)/1000 = (V_2I_2)/1000$

Transformer - numericals

- **A single phase transformer is supplied by 50Hz AC signal. It has 300 turns on Primary and 750 turns on secondary side. The net cross sectional area of the core is 64 sq.cm.If the primary induced emf is 440V find**

a. **Maximum flux density in the core**
b. **The secondary voltage on load**

Solution: Given : F= 50Hz, N1= 300, N2=750, A= 64 sq.cm, V1= 440V

a. **Flux density= ϕ/A= 0.0066/(64* 10-4) = 1.03 T**
ϕ= flux density * Area
B. E1=4.44* ϕm*f*N1
440 = 4.44 *ϕm* 50*300
Φm = 440/ (4.44*50*300) = 0.0066wb=6.60x 10-3 wb

b. **V1/V2= N1/N2**

440/V2 = 300/750

V2= 440 *750 /300 =1100V

Transformer - numericals

- **A 50 kVA. 1 phase transformer has a turns ratio of 300/20. The primary winding is connected to a 2200V,50Hz supply. Calculate**

a. **The secondary voltage on load**
b. **The primary and secondary current.**

Solution: Given : Power input - 50kVA, Turns Ratio = N1/N2= 300/20, V1= 2200V, F= 50Hz

a. **V1/V2 = N1/N2------ from eq. 3**

2200/ V2 = 300/20

(2200 * 20)/300 = V2

146.67 V = V2

b. kVA= $(V_1 I_1)/1000$

$50 = (2200 * I_1)/1000$;

$\mathbf{I_1 = (50*1000)/2200 = 22.73A}$

kVA= $(V_2 I_2)/1000$

$50 = (146.67 * I_2)/1000$;

$\mathbf{I_2 = (50*1000)/146.67 = 340.9\ A}$

Transformer - Efficiency

Under Ideal conditions, the output power is equal to the input power of the transformer. But under practical conditions it is not possible .
The input power is always equal to the summation of output power and losses.

Input Power= Output power + losses

Efficiency of a transformer can be defined as the output power divided by the input power.

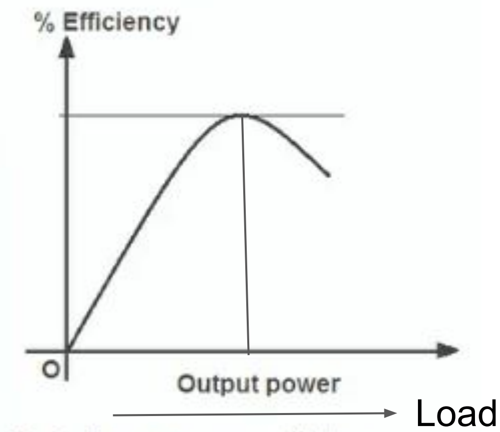
Transformer efficiency is denoted by **η**.

i.e efficiency **η** = output power / input power , %efficiency **η** = (output power / input power)* 100

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\text{output power}}{\text{output power} + \text{losses}}$$

$$\eta = \frac{\text{output power}}{\text{output power} + \text{iron losses} + \text{copper losses}}$$

$$\eta = \frac{V_2 I_2 \text{Cos}\varphi_2}{V_2 I_2 \text{Cos}\varphi_2 + P_i + P_c}$$



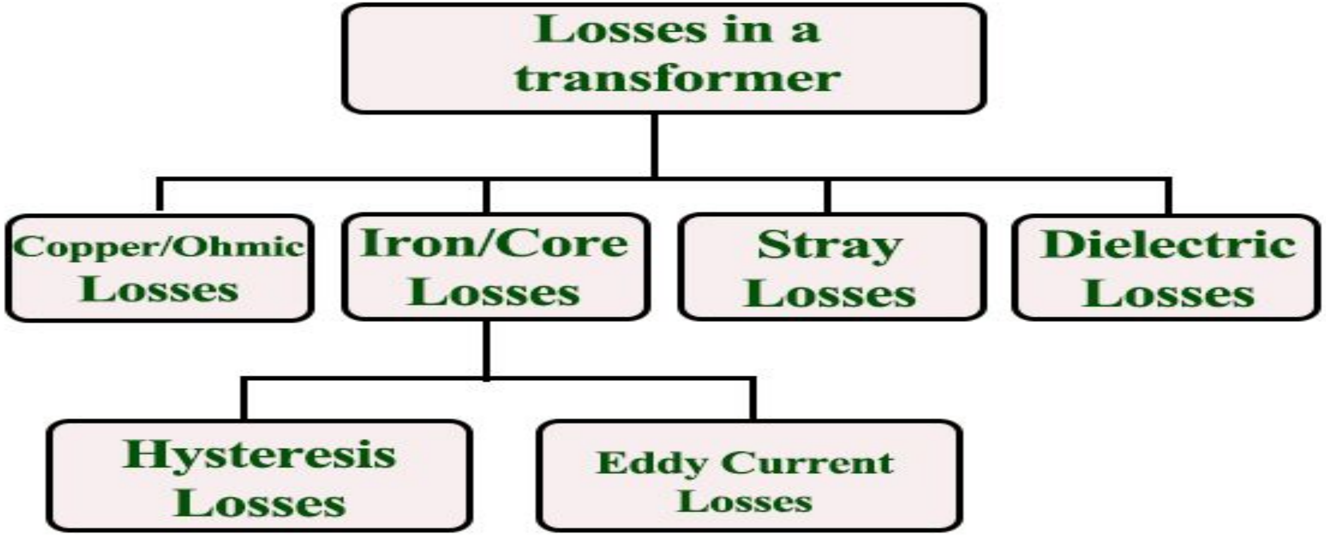
Output power versus efficiency

Condition for maximum efficiency , copper loss = iron loss

Full load kVA * √(iron loss/full load copper loss)

Transformer - losses

There are different kinds of losses that will be occurred in the transformer such as iron, copper, hysteresis, eddy, stray & dielectric. The copper loss mainly occurs due to the resistance in the transformer winding whereas hysteresis losses will be occurred due to the magnetization change within the core.



Transformer - losses

- **Iron/core losses -core loss is known as ‘Magnetizing current Loss’ or Constant Loss‘.**
- It is caused by the generated alternating flux in the transformer core.
- Core loss occurs in two ways.
  - **Eddy Current Loss** caused by the formation of eddy currents in the core material.
  - Eddy current cause by the changing magnetic field in the transformer core.
  - It can be reduced by using core thin lamination.
  - **$Pe= K_eB^2{}_m f^2t^2v$ watt,** f= frequency (Hz), Bm= Maximum flux density, v =volume of the material, K_e =constant
  - **Hysteresis loss** is caused by the motion of the magnetic field. This loss occurs due to the reversal of magnetism.
  - **$P_h= K_hB_m{}^{1.6}$ f v watts** ; where f= frequency (Hz), Bm= Maximum flux density, v =volume of the material, K_h= constant
  - It can be reduced by using silicon materials.

    Both losses produce heat in the transformer.
- **Copper Losses - Copper loss is called as ‘Variable Loss’ or ‘Resistive Loss’.**
  - It occurs in the transformer windings (primary winding and secondary winding) which consists of copper (Cu) conductor. So, sometimes core loss is also known as ‘Winding Loss’.
  - Copper Loss,(Pc)= (Primary winding Cu loss + Secondary winding Cu loss)=

    $= [(I^2{}_1*R_1)+(I^2{}_2*R_2)]$

Transformer - efficiency - numericals

A single phase 50 kVA,2200/220 V, 50 Hz transformer, has an iron loss of 300W. The resistance of its high and low voltage windings are 0.5 **Ω** and 0.005**Ω** respectively. If the power factor of load is 0.8 lagging, calculate efficiency at full load.
Given : Power= 50kVA, f=50Hz, Pi= 300watt, R1= 0.5 **Ω**, R2=0.005**Ω**, power factor =0.8 lagging,

To find = efficiency,η

kVA= V_1I_1/ 1000 **50 = 2200*I_1 /1000** **50*1000 /2200 = I_1 = 22.72A** **kVA= V_2I_2/ 1000 = 227.27A** **Copper loss = [(I^2_1*R_1)+(I^2_2*R_2)]** **= [22.72^2 * 0.5]+ [227.27^2 * 0.005]** **= 516.53 watt = 0.516kW** **Output power at full load = VIcosΦ = 50 *0.8 = 40kW**	**% Efficiency = [output power/ (output power +losses)]*100** = [40 / (40+ 0.3+0.516)]*100 = [40/40.816]*100= 98% **Efficiency,η = 98%**

4.2 Auto- Transformer - Introduction

- An autotransformer, also known as variac or dimmerstat, is a single winding transformer which has a common primary and secondary winding.
- The primary and secondary winding in them is not electrically isolated. They are cheaper, efficient and have a better voltage regulation than the normal transformers.
- hey are much useful in cases in which the voltage ratio is less than 2 and the electrical isolation of winding is not essential.

Auto- Transformer - construction

- An autotransformer consists of three parts: core, winding and moving contact – knob arrangement.

Core

The core is made of high-quality Cold Rolled Grain Oriented (CRGO) silicon steel in order to minimize core losses. The core could be laminated, split, or toroidal type

Winding

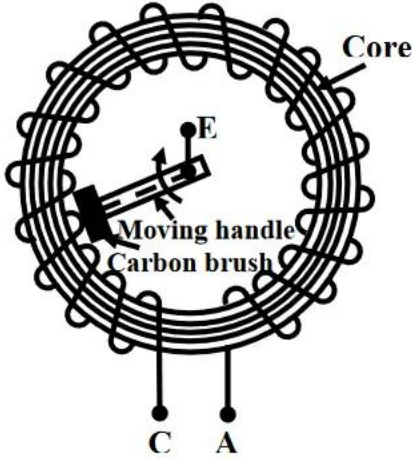
As said earlier, autotransformers have a single copper conductor wound over the core which acts as the primary and secondary.

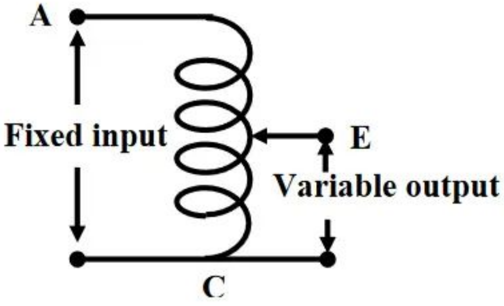
Moving-contact-knob arrangement

A rotary arm like arrangement with carbon brush at its tip and a knob at the top is present in autotransformers. The carbon brush slides over the windings when the knob is rotated. Smooth control of voltage can be attained with the help of the sliding brush.

Auto- Transformer - working

- In an autotransformer single winding serves as both primary and secondary.
- The terminals A and C acts as the input (primary) and the terminals E and C acts as the secondary.
- E is connected to the sliding carbon brush.
- A part of energy transfer between the primary and the secondary is through conduction and the rest is through induction.





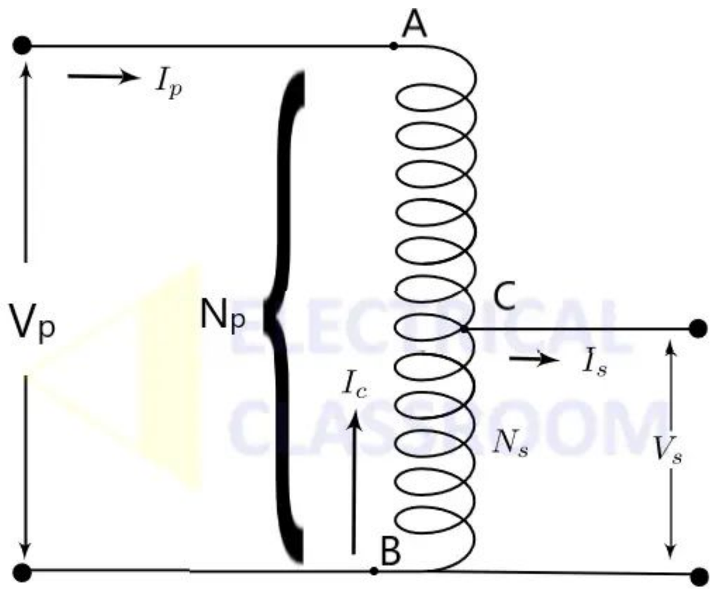
Auto- Transformer - working

In the schematic shown below,

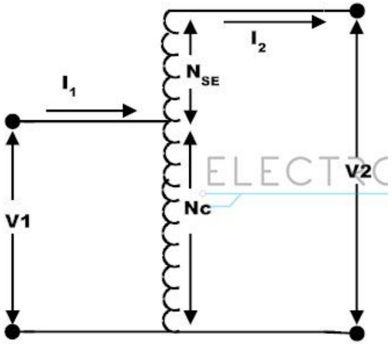
Let Np be the total number of turns wound over the transformer core, the brush is moved to point C to obtain a secondary turns Ns.

Vp and Vs are the voltage measured across the primary and secondary currents respectively.

Ip and Is are the primary and secondary currents.



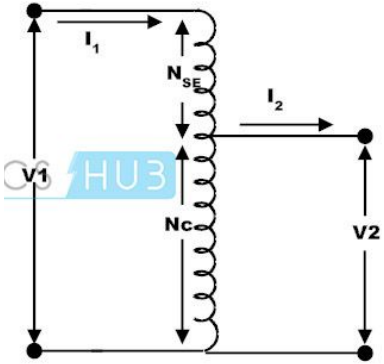
Auto- Transformer - types



(a)Step up Autotransformer

Step Up Auto transformer

In this type of autotransformer input voltage is stepped up to the desired voltage and output voltage will depend on the turn ratio of the auto transformer.



(b)Step down Autotransformer

Step Down Auto transformer

Construction is same for both step up and step down autotransformer but in this configuration primary voltage is high and secondary voltage is low that's why it is called step down transformer.

Auto- Transformer - Advantages and disadvantages

Advantages

- For the same VA rating, an autotransformer requires less copper and less core material.
- Also, it requires less exciting current, has an ohmic loss and is lighter as compared to a two winding transformer.
- Autotransformers have higher efficiency and lower leakage impedance than two winding transformers.
- They have a better voltage regulation than two winding transformers.

Disadvantages

- They are preferred for a voltage ratio of less than 2.
- Break in the part of the winding that is used as both primary and secondary will result in the transformer acts as an inductor in series with the load.
- Autotransformers do not isolate primary and secondary circuits. Hence any failures in the transformer can result in the application of full primary voltage to the load.Due to lesser impedance, the short circuit current in autotransformer is higher than that in two winding transformer.

Auto- Transformer - application

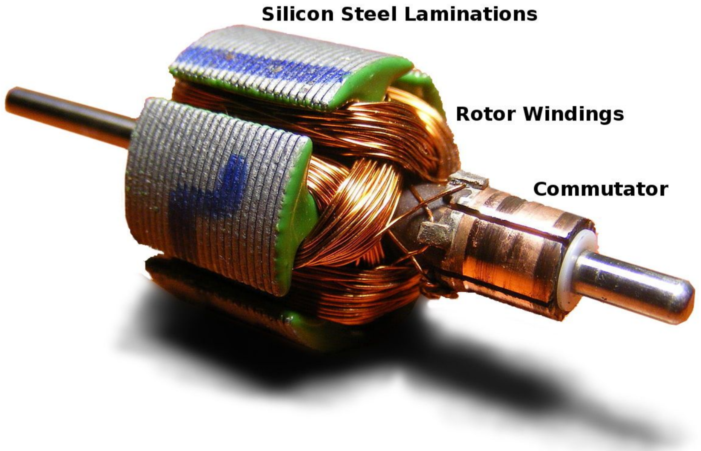
Applications

Autotransformers are widely used in laboratories to obtain variable AC voltage for lab apparatus.

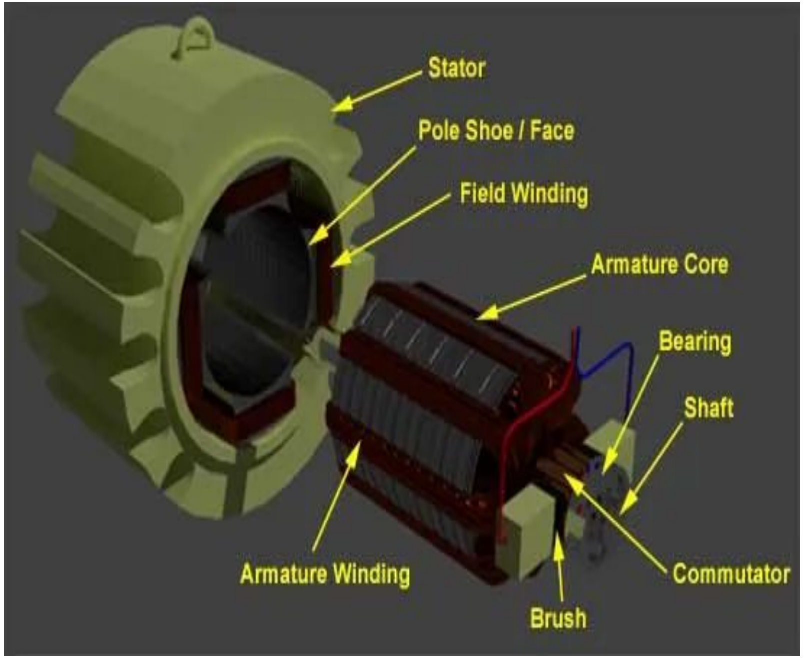
They are used to start induction and synchronous motors.

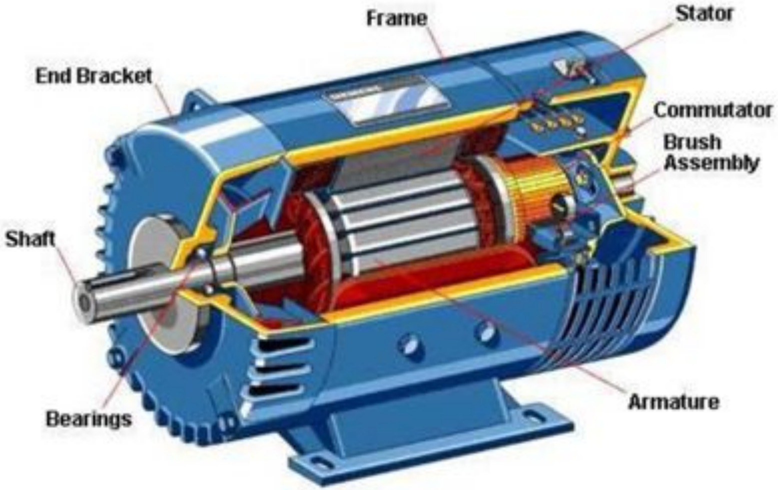
4.3 DC motor part and material used

A DC motor is a device that converts direct current electrical energy to mechanical energy



DC motor



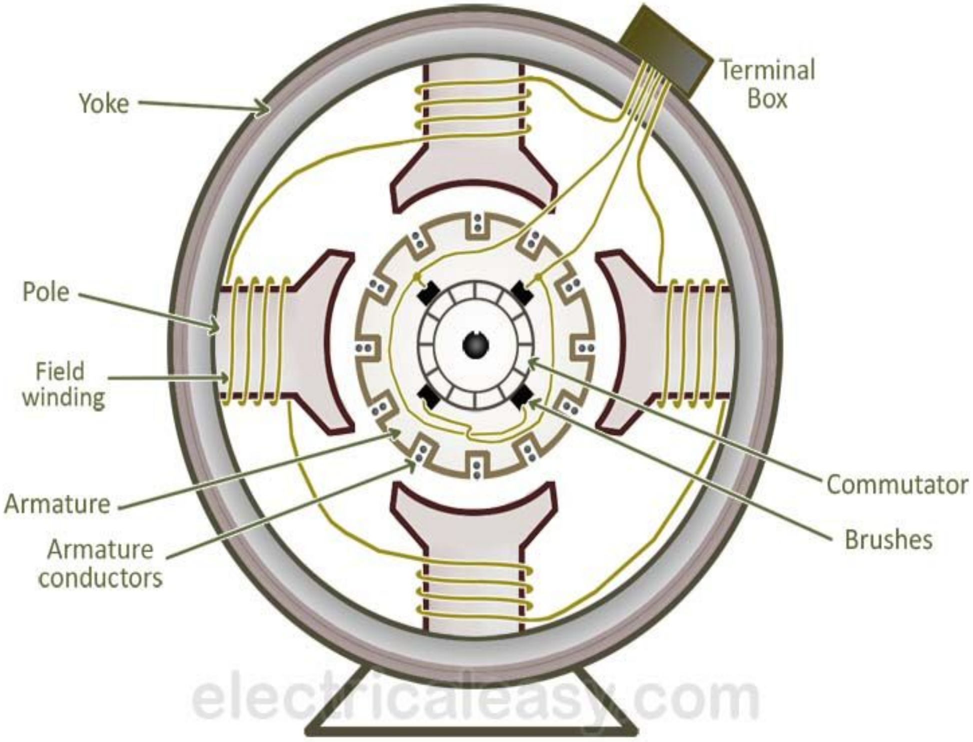


DC Motor Breakdown

4.3 DC motor part and material used

A DC motor is constructed with:

1. A Stator
2. A Rotor
3. A Yoke
4. Poles
5. Field windings
6. Armature windings
7. Commutator
8. Brushes



4.3 DC motor part and material used

A DC motor is constructed with:

1. A Stator
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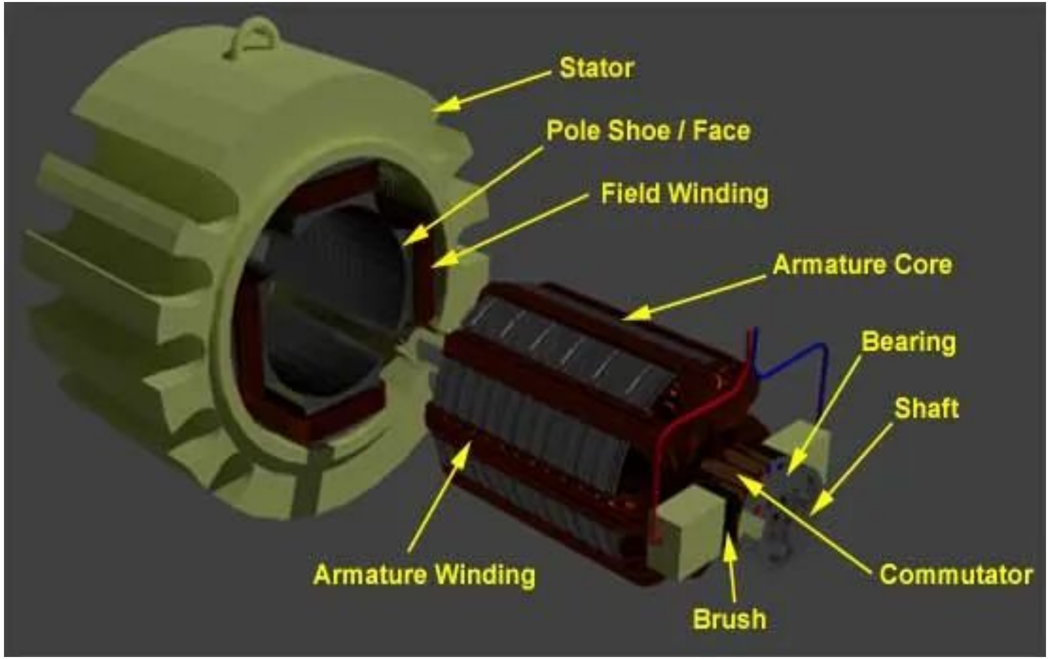


4.3 DC motor part and material used

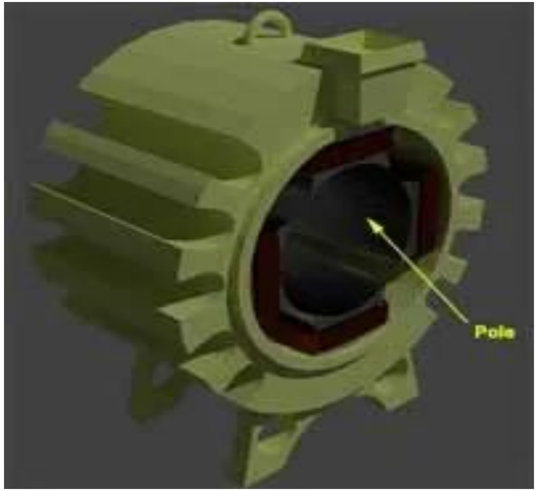
Yoke of DC Motor

The magnetic frame or the **yoke of DC motor** made up of cast iron or steel and forms an integral part of the stator or the static part of the motor.

Its main function is to form a protective covering over the sophisticated inner parts of the motor and provide support to the armature. It also supports the field system by housing the magnetic poles and field winding of the DC motor.

4.3 DC motor part and material used

Poles of DC Motor



The magnetic poles of DC motor are structures fitted onto the inner wall of the yoke with screws. The construction of magnetic poles basically comprises of two parts.

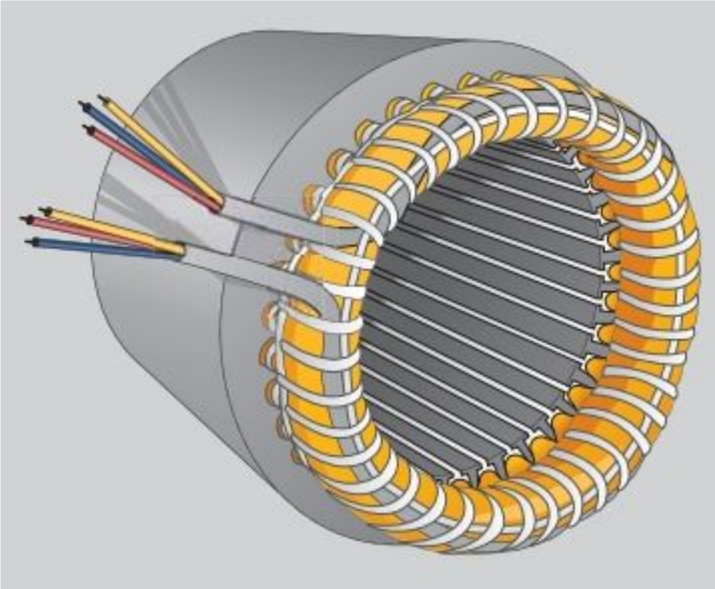
The pole core is of small cross-sectional area and its function is to just hold the pole shoe over the yoke,

The pole shoe having a relatively larger cross-sectional area spreads the flux produced over the air gap between the stator and rotor to reduce the loss due to reluctance. The pole shoe also carries slots for the field windings that produce the field flux.

4.3 DC motor part and material used

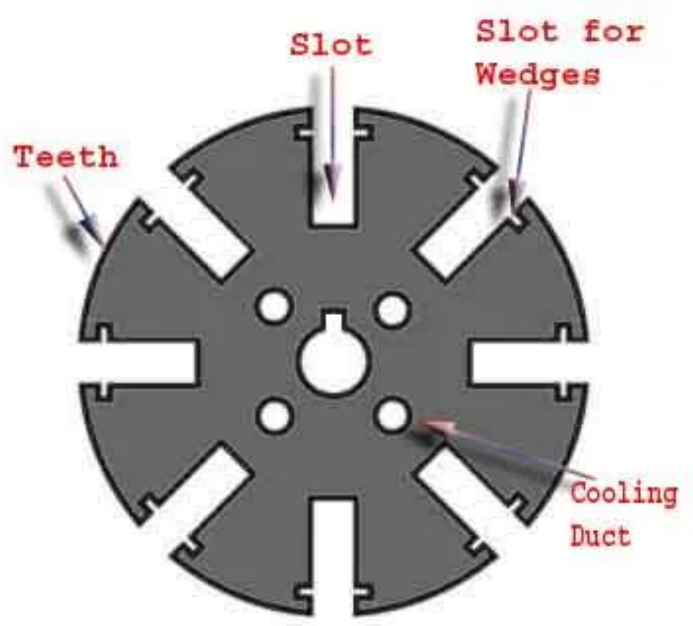
Field Winding of DC Motor

The field winding of DC motor are made with field coils (copper wire) wound over the slots of the pole shoes
The field winding basically form an electromagnet, that produces field flux within which the rotor armature of the DC motor rotates, and results in the effective flux cutting.



4.3 DC motor part and material used

Armature Winding of DC Motor



The armature winding of DC motor is attached to the rotor,
The rotating part of the machine, and as a result is subjected to altering magnetic field in the path of its rotation which directly results in magnetic losses.
For this reason the rotor is made of armature core, that's made with several low-hysteresis silicon steel lamination, to reduce the magnetic losses like hysteresis and eddy current loss respectively.
These laminated steel sheets are stacked together to form the cylindrical structure of the armature core.

4.3 DC motor part and material used

Armature Winding of DC Motor

Lap Winding

In this case the number of parallel paths between conductors A is equal to the number of poles P.

i.e A = P

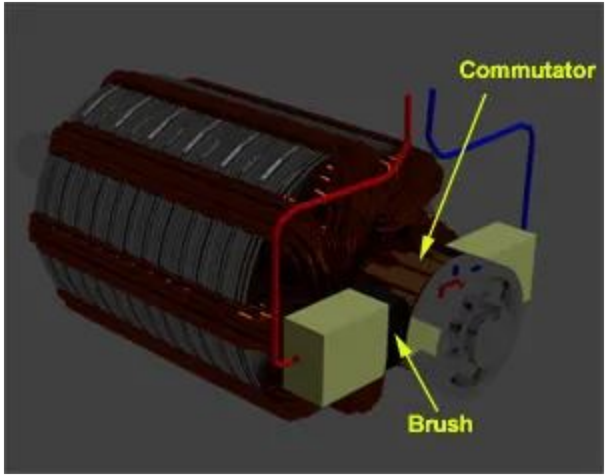
Wave Winding

In this case, the number of parallel paths between conductors A is always equal to 2 irrespective of the number of poles. Hence the machine designs are made accordingly.

4.3 DC motor part and material used

Commutator of DC Motor

The **commutator of DC motor** is a cylindrical structure made up of copper segments stacked together, but insulated from each other by mica. Its main function as far as the DC motor is concerned is to commute or relay the supply current from the mains to the armature winding housed over a rotating structure through the **brushes of DC motor**.

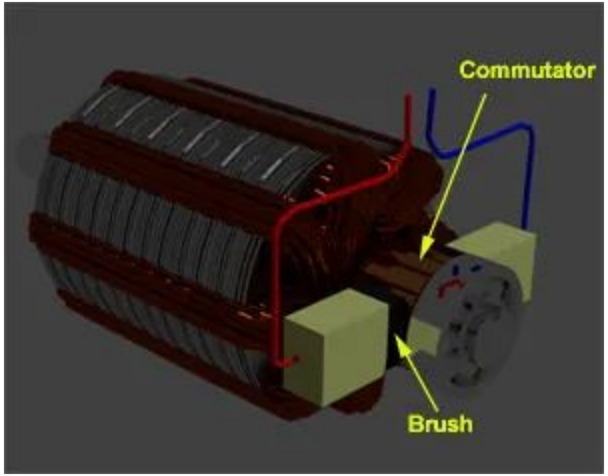


4.3 DC motor part and material used

Brushes of DC Motor

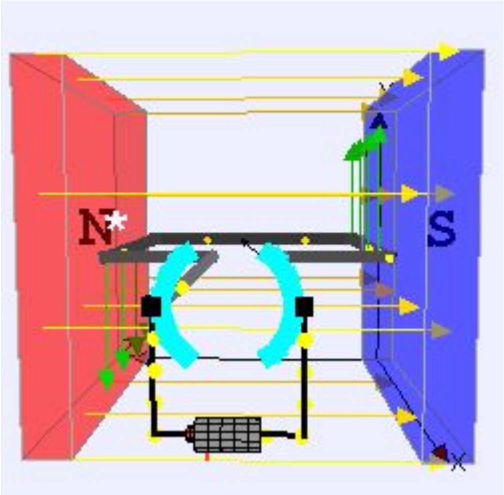
The brushes of DC motor are made with carbon or graphite structures, making sliding contact over the rotating commutator. The brushes are used to relay the current from external circuit to the rotating commutator form where it flows into the armature winding.

The commutator and brush unit of the DC motor is concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.



4.4 DC motor principle of operation

- The basic working principle of a DC motor is: "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming's left-hand rule and its magnitude is given by F = BIL. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.
- When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move.
- In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work.



https://youtu.be/LAtPHANEfQo

4.4 DC motor- operation- back emf

Back EMF

According to fundamental laws of nature, no energy conversion is possible until there is something to oppose the conversion. In case of generators this opposition is provided by magnetic drag, but in case of dc motors there is **back emf**.

When the armature of a motor is rotating, the conductors are also cutting the magnetic flux lines and hence according to the Faraday's law of electromagnetic induction, an emf induced in the armature conductors. The direction of this induced emf is such that it opposes the armature current (I_a). The circuit diagram below illustrates the **direction of the back emf and armature current**.

4.4 DC motor- operation- back emf

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4.4 DC motor- operation- back emf

EMF Equation of a DC Motor

The basic DC motor -E.M.F equation is given below.

$$\mathbf{E_b = P\Phi NZ / 60A \quad ---------1}$$

Where;

- P is the number of poles , Φ is the Flux per pole, N is the Speed of motor in (RPM)
- Z is the Number of conductors , A is the Number of parallel path

In a final designed motor, the number of poles “P”, conductors “Z” and parallel paths “A” are fixed, therefore, the following quantities and parameters remains constant.

$$\mathbf{E_b \propto \Phi N \text{ -------------- } 2}$$

$$\mathbf{E_b = K\Phi N\text{-------------}3}$$

Also voltage equation of DC motor is , $V=E_b + IaRa$ ------------ 4

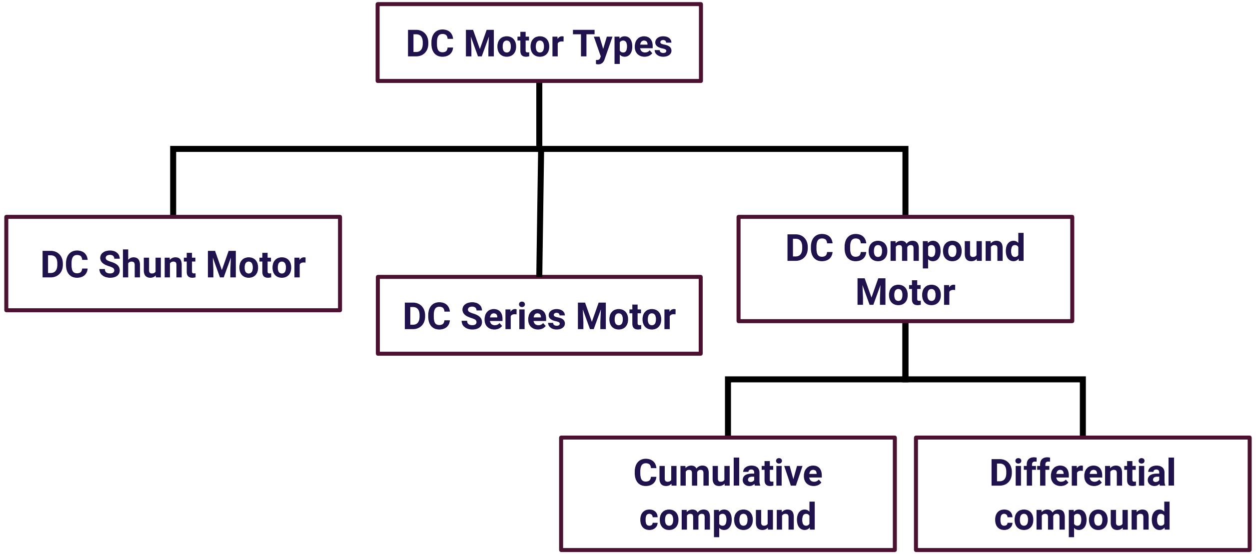
On comparing 4 and 3 we get,

$$\mathbf{K\Phi N = V - IaRa}$$

$$\mathbf{N=V- IaRa/K\Phi\text{---------------}5}$$

So Eq.5 says that Speed N can be controlled by changing either voltage or armature current or flux

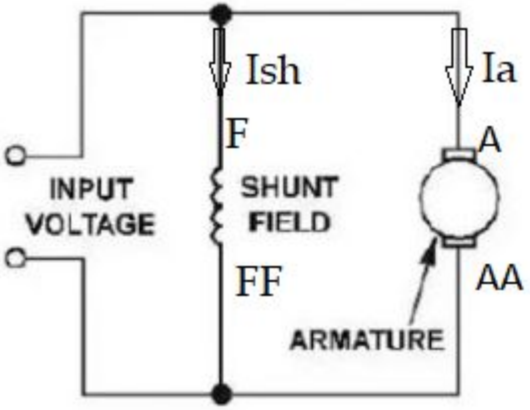
4.5 DC motor- Types and their applications.



4.4 DC motor- Types and their applications.

DC 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

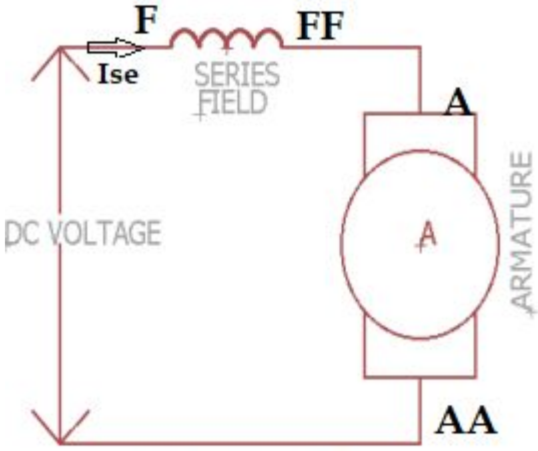


DC Shunt motor

4.4 DC motor- Types and their applications.

DC Series 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

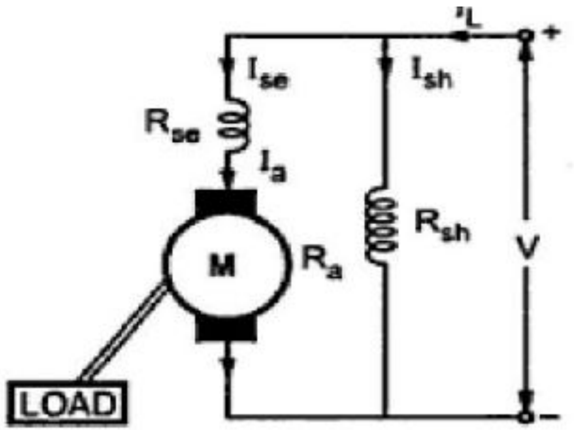


DC Series Motor

4.4 DC motor- Types and their applications.

DC compound motor : Cumulative compound type (long shunt DC compound motor)

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

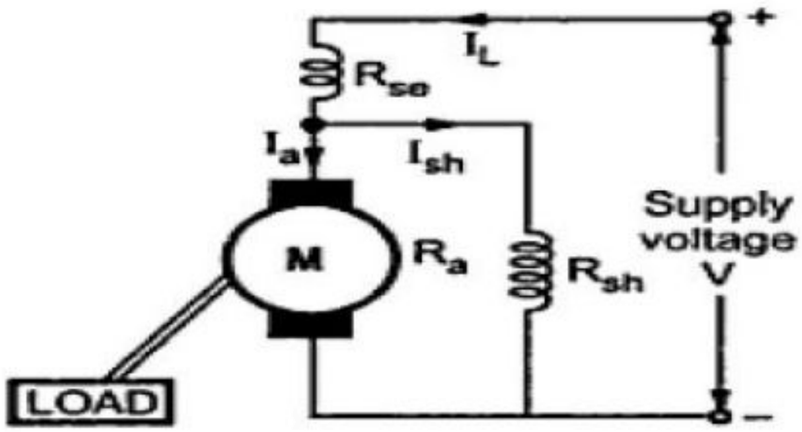


Long shunt DC compound motor

4.4 DC motor- Types and their applications.

DC compound motor : Differential compound type (short shunt DC compound motor)

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



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4.4 DC motor- applications

Shunt DC Motors

Owing to the fairly constant speed and medium starting torque of shunt DC motors, they are used in the following applications:

1. Centrifugal and reciprocating pumps
2. Lathe machines
3. Blowers and Fans
4. Drilling machines
5. Milling machines
6. Machine tools

Series DC Motors

Owing to the high starting torque and variable speed of series DC motors, they are used in the following applications:

- Conveyors
- Hoists, Elevators
- Cranes
- Electric Locomotives

Cumulative Compound DC motors

Owing to the high starting torque of cumulative compound DC motors, they are used in the following applications:

- Shears
- Heavy Planers
- Rolling mills
- Elevators

4.4 DC motor- applications

DC series motors- application

- It is a variable speed motor i.e. very low speed at high torqe and vice versa. However at no load motor tends to occupy dangerous speed. The motor has a very high starting torque. So it is used for :
    - The series DC motor is an industry workhorse for both high and low power, fixed and variable speed electric drives.
    - Applications range from cheap toys to automotive applications.
    - They are inexpensive to manufacture and are used in variable speed household appliances such as sewing machines and power tools.
- Its high starting torque makes it particularly suitable for a wide range of traction applications.
- Industrial uses are hoists, cranes, trolly cars, conveyors, elevators, air compressors, vacuum cleaners, sewing machines etc.

4.4 DC motor- applications

Cumulative Compound DC motors- application

- Compound motors due to their ability to perform better on heavy load changes are used in elevators.
- Due to their high starting torque and better speed control for pressure variations, they are used in shears and punches.
- This kind of motors because of the high starting torque and heavy-duty load is used in steel rolling mills.
- Again due to the capacity of driving heavy loads, they are used in the printing press and cutting machines.
- They are also used in stamping presses to provide high starting torque.
- Their good speed control and high starting torque make them a great choice to be used in mixers.

4.4 DC motor- Numericals

A230v,4 POLd.c motor has an armature circuit resistance of 0.5 ohms.find the back emf in the motor when the

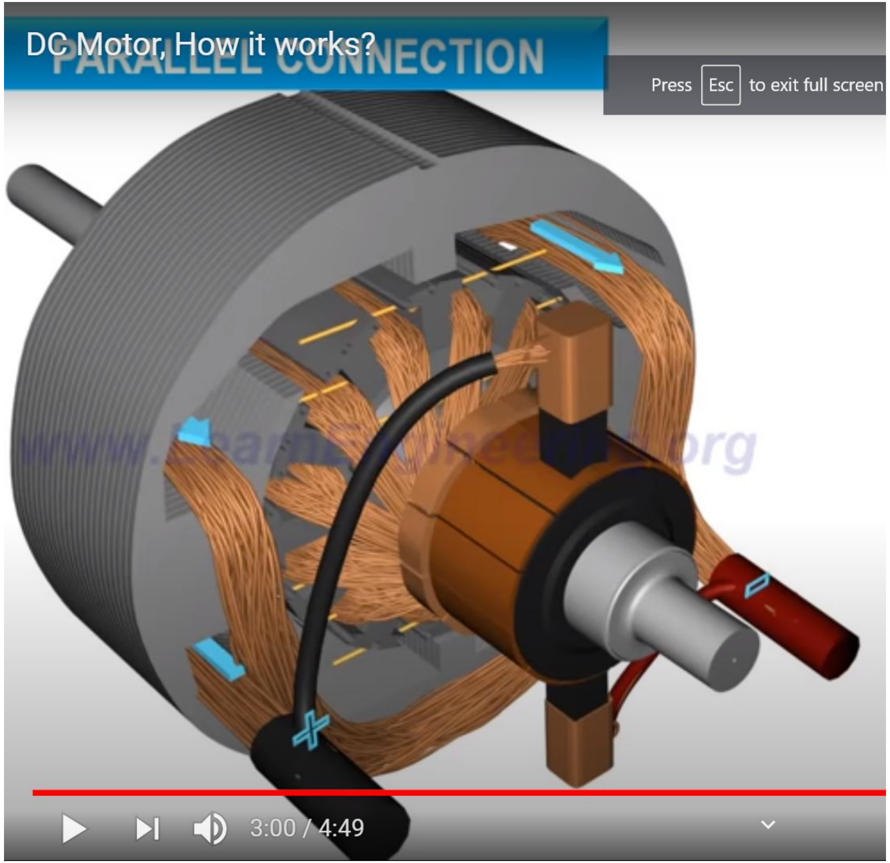
4.4 DC motor-IMPORTANT LINKs

https://youtu.be/VAEe5MEQrjY

https://youtu.be/LAtPHANEfQo

https://youtu.be/j_F4limaHYI

https://youtu.be/VAEe5MEQrjY


DC Motor, How it works?
PARALLEL CONNECTION
Press Esc to exit full screen
www.LearnEngineering.org
3:00 / 4:49


SERIES MOTOR
exit full screen
www.LearnEngineering.org