Basic Electrical Engineering KEE101/201

Department of Engineering
Uttar Pradesh Textile Technology Institute
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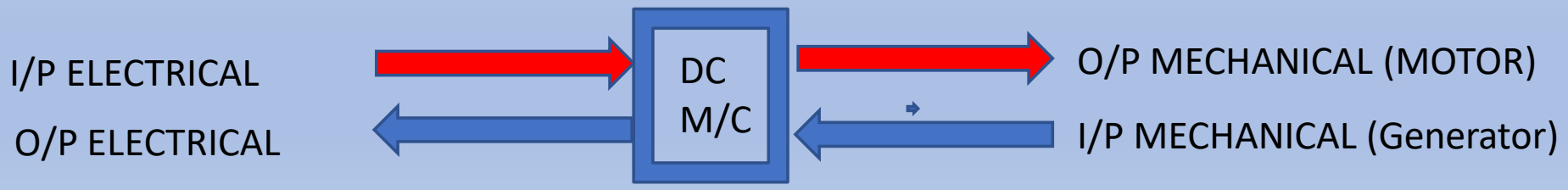
DC Machines

DC Machines are similar to the transformer.

- In Transformer Energy is moving from Electrical Domain to other Electrical Domain through magnetic domain.
- In DC machines Energy is moving from Electrical domain to mechanical domain and vice versa through magnetic domain and air gap.

Motor Vs Generator

- If input is electrical energy and output is mechanical energy, The machine is a Motor and
- If Input is Mechanical energy and out put is electrical energy then the machine is generator. I/P Mechanical (Generator)



The basic underlying principles

To start with electrical Rotating Machines we need to recall two basic principles

1. Faraday's Laws of Electro-magnetic induction.

If there is a field and a coil and somehow the flux linked with the coil is changing then an emf will be induced in the coil conductors and in turn a current will flow in the coil if we complete the circuit by means of some load. The change in flux may be in two ways:

1. Either field is varying or
2. there is motion in the coil

The induced emf is given by

e = Blv Volts

Where B is Magnetic Flux Density in Wb/m^2

l is length of the conductor and

V is speed (tangential) at which the conductor is moving in m/s

2.Another underlying principle is Lorentz Force.

If there is a current carrying conductor kept in the field it will experience a force

F= Bil

Where F is force on Conductor (Newton)

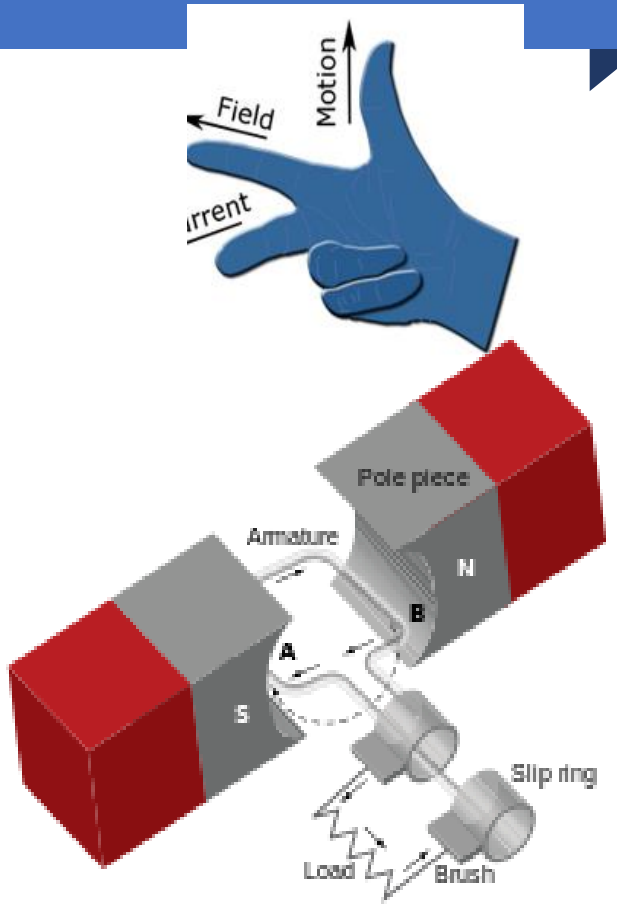
i is current through Conductor (Ampere)

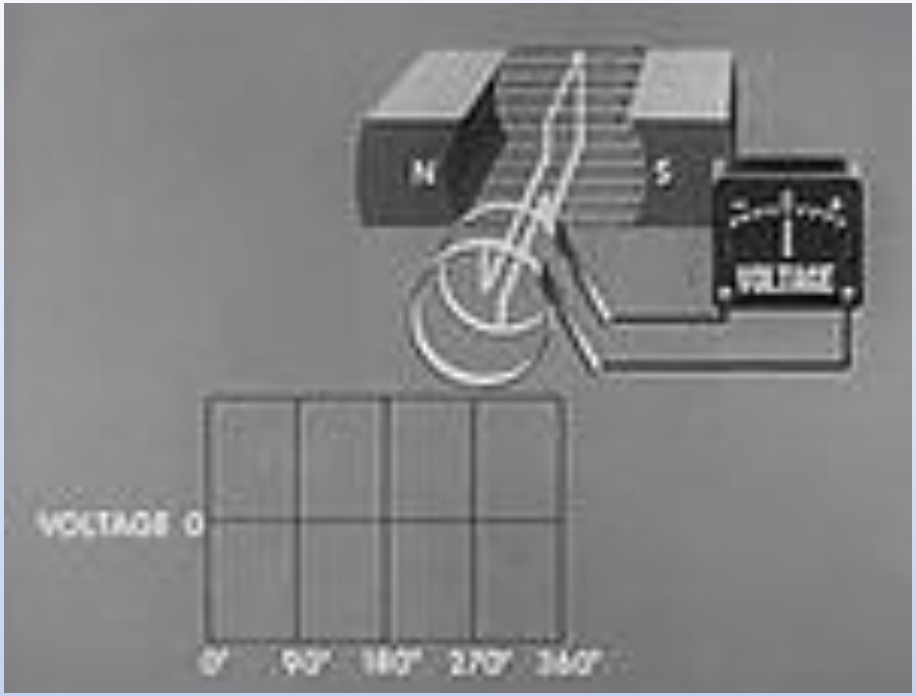
l is active length of the Conductor (meter)

DC Machine
(Starting From elementary ac Generator)

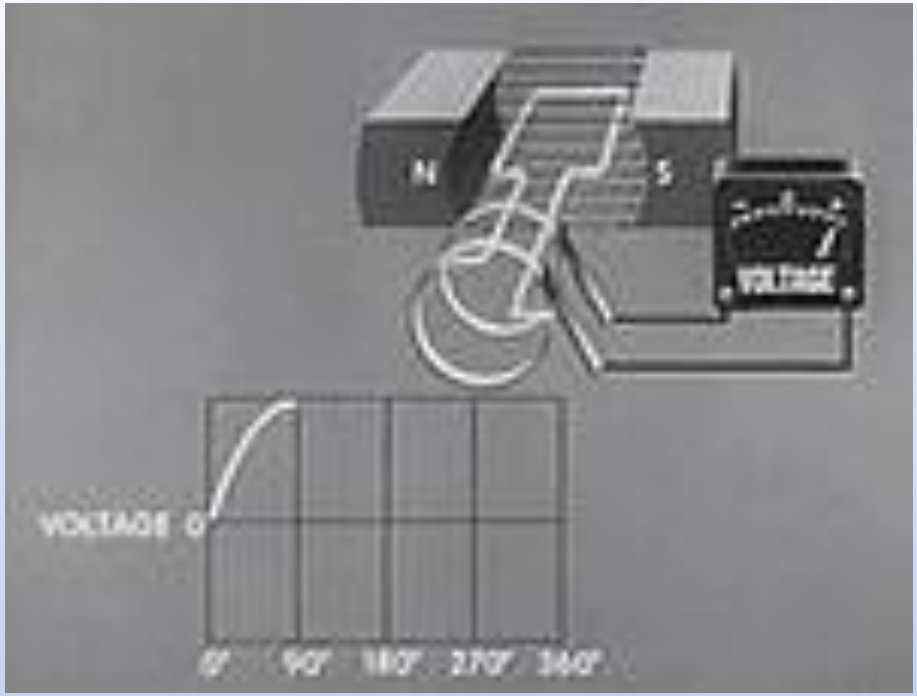
Now say in Generator

- Coil is placed on the rotor so if we rotate the rotor by some prime mover like diesel engine the emf e= blv volts will be induced in both the conductors of the coil.
- But the direction of current in the conductor under the south pole will be from A to B and under north pole from C to D
- So the Total Emf induced in the coil is 2Blv Volts and The Voltage wave will be as shown in Figure in next slide.

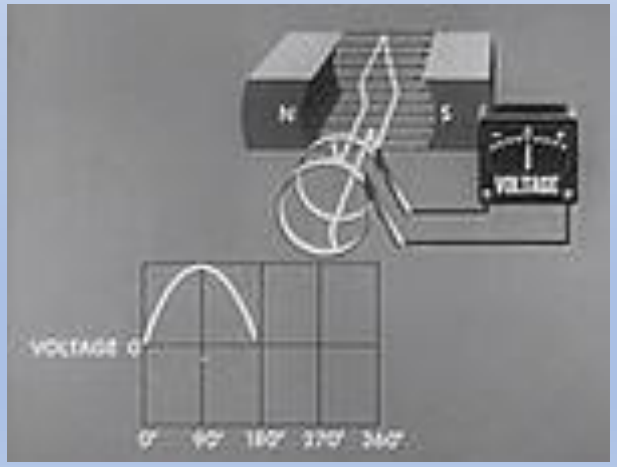




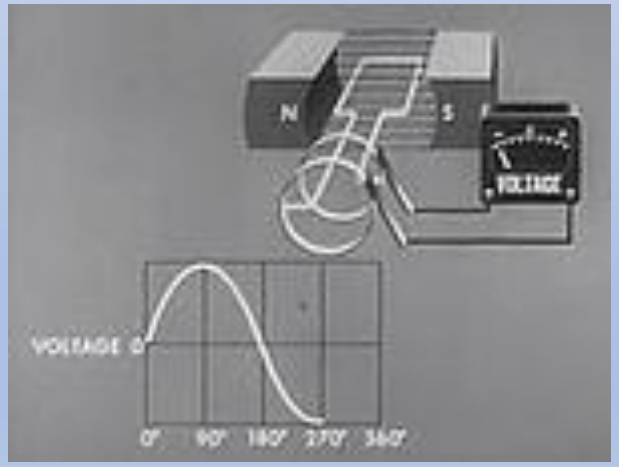
Armature at 0^0.



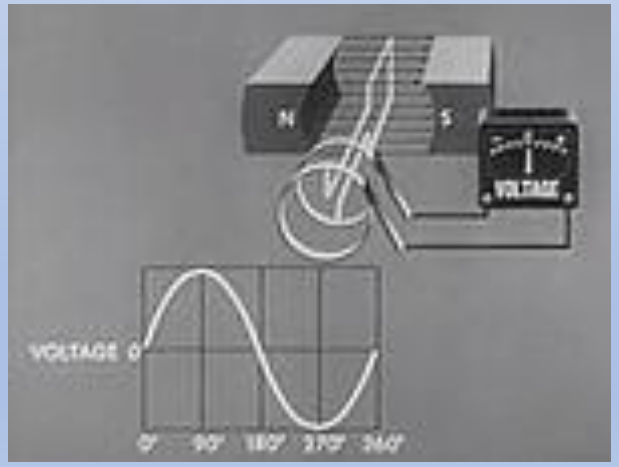
Armature at 90^0



Armature at 180^0.



Armature at 270^0.



Armature at 360^0.

The basic constructional overview

When the permanent magnet pole pieces are made part of the stationary outer body of the machine it becomes **Stator.**

The coil as such cannot be hanged in the air and hence it needs to be housed on a body. This body will be rotating and hence named **Rotor.**

The rotor body is mounted over a shaft which rotates on its axis. In Both rotor body and stator body the magnetic part which carries flux will be made of iron stampings for the reason already discussed in the transformer section.

The magnetic poles (N and S) shown in the figure are of Salient (Projected) Type. Another type of Poles are cylindrical type.

The basic constructional overview

The magnetic poles shown here are permanent magnets but for large machines these permanent magnets will be replaced by electromagnets.

Electromagnets are formed by placing coils around the poles in specific manner such that one current flows through the coil one pole becomes South pole and another becomes North Pole.

The rotor poles may also be salient type or cylindrical types. The coil shown in the picture may be housed in the slots over the periphery of rotor yoke.

In cylindrical type stator or rotor pole slots are made at the periphery of rotor and stator. The coils are housed in these slots.

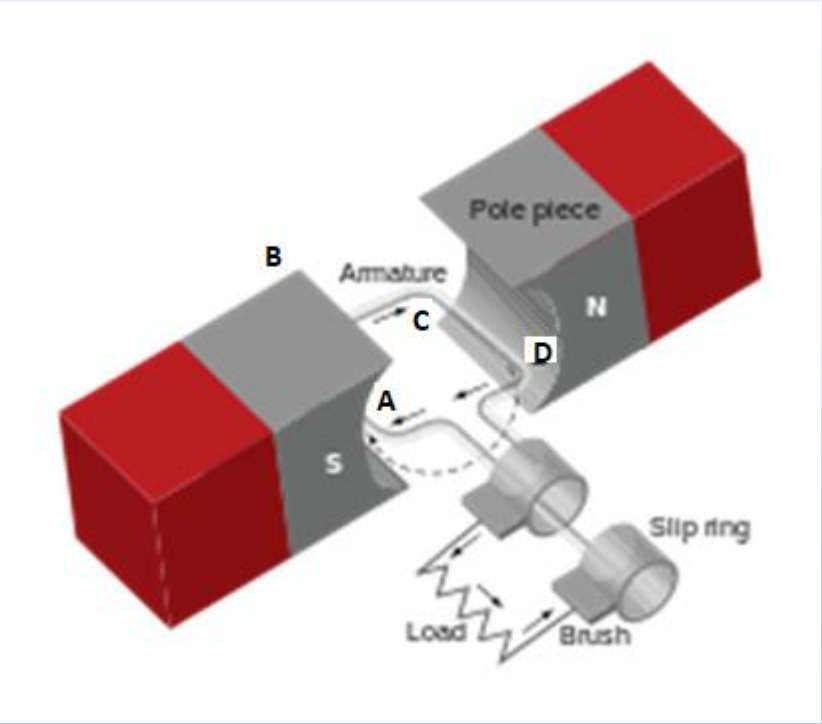
There may be two types of windings:

(1) Lap Winding
(2) Wave Winding

Let us have a look on the previous figure once again.

We can see the following:

- The coil in which emf induces is mounted on the rotor periphery
- The rotor is rotating in clockwise direction with speed v m/s by some external prime mover.
- Emf induced will result in some current in the coil when connected to the external load.
- The Generated emf and current waves are ac and sinusoidal



Question: *How to connect terminals of moving (Rotating) Coil to the terminals of an external stationary electrical Load??*

Ans: *By the use of Slip Rings and Carbon Brushes !!!*

Slip Rings and Carbon Brushes

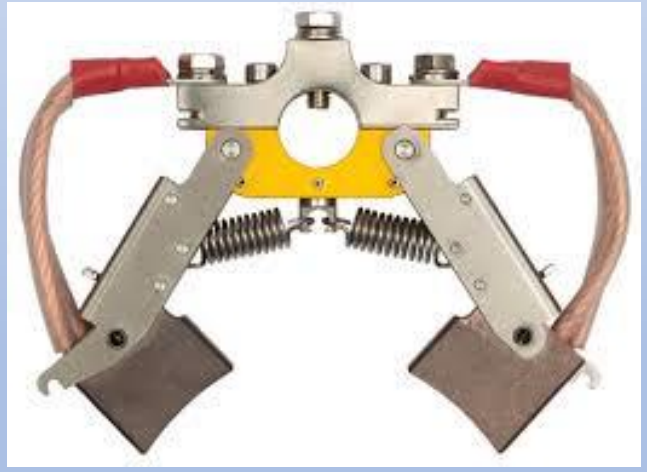
Slip Rigs are Copper rings and shown in Figure

Machine Shaft has two ends

- One end where Mechanical load is coupled in case of motor or Prime mover is connected in case of Generator
- Other end is rear end where machine accessories are mounted like slip ring/Split ring/Commutator etc.
- Slip rings are mounted on the shaft at one end.

Slip Rings (2 Rings for 1-phase M/c)

Slip Rings mounted on Shafts Three rings for 3 phase M/c



Carbon Brushes with Holder One set is required for each ring

Slip Rings and Carbon Brushes

On single phase two pole motor structure discussed above, two slip rings are required.

Carbon Brushes:

- Two small blocks of carbon are pushed upon each slip ring though spring action which is connected to the stator of the machine.
- In this way when rotor rotates the brushed rest upon rotating slip rings.
- One connection from each brush set is brought out. Two slip rings means two connections are available outside machine
- These are used to provide supply in case of motor of to collect ac supply in case of generator
- Supply received at these brushes is invariably alternating Current (AC)
- The above model depicts a simple ac generator.

Different Types of Carbon Brushes

Slip Ring Vs Split Ring
Collecting Dc instead of ac at the carbon brushes

By now you are aware of the fact that

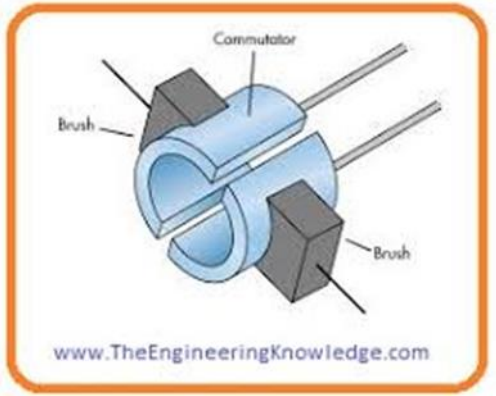
- In an electrical machine if a coil rotates under the influence of field created by permanent magnet (or electromagnet energized by a dc source), ac voltage is generated in the coil.
- This ac can be taken out of the machine with the help of slip rings. One end of the coil is connected to one slip ring and another end of the coil is connected to the other slip ring.
- For a single coil there will be two ends so two slip rings will be needed.

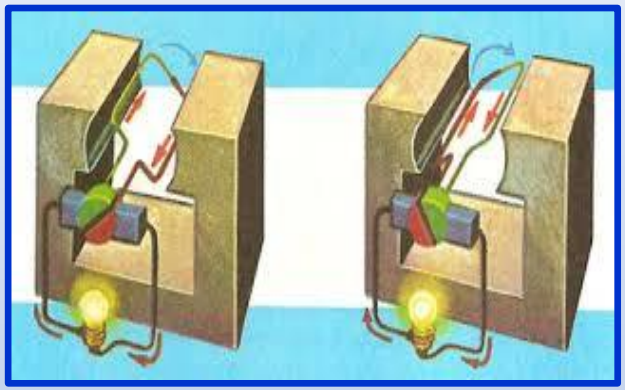
Now what if for one coil we use only one slip ring which is cut from the center?

- It will become split ring with two halves mounted on shaft.
- One half will be connected to one end of the coil and another half is connected to the other end of the coil. Remember now no two rings!!! One ring split into two halves as shown in picture.

In the figure split rings are used in place of Slip ring.

One ring is split into two halves and each end of the coil is connected to different half of split ring internally.



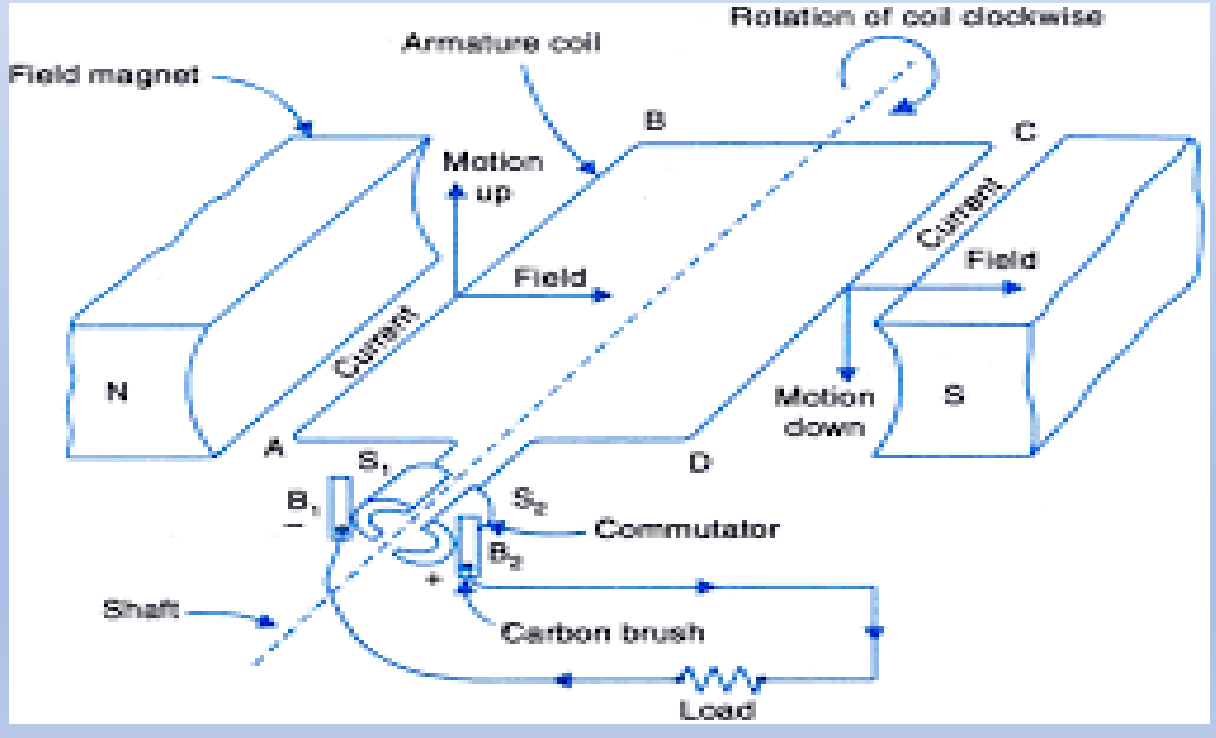


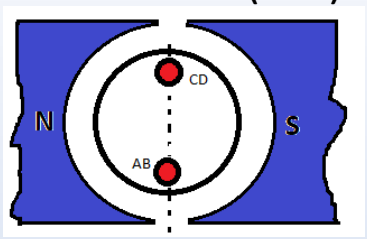
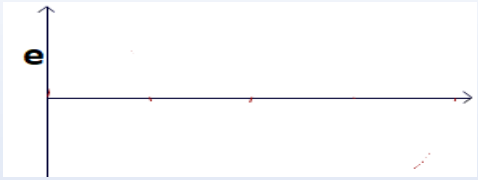
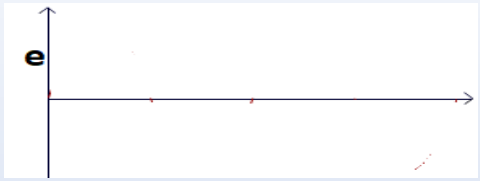
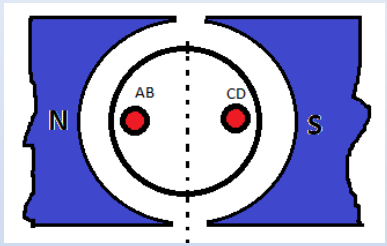
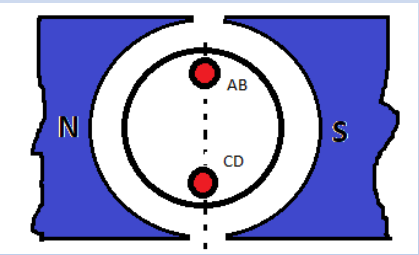
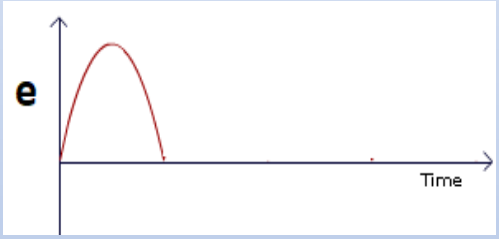
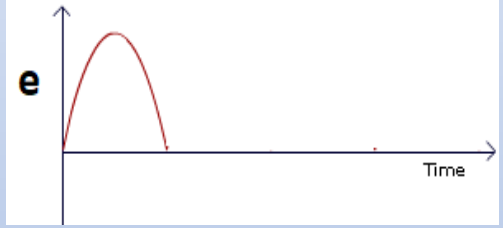
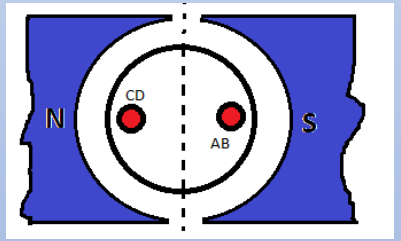
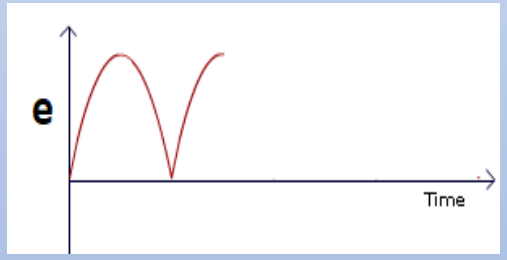
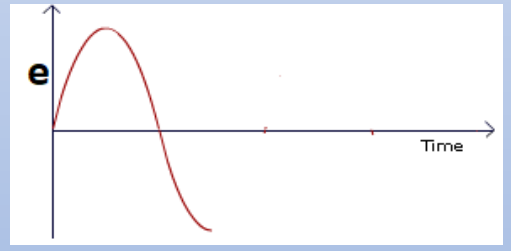
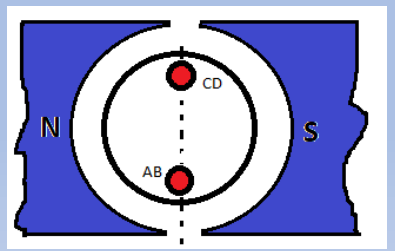
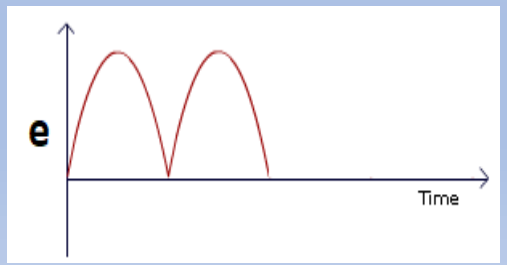
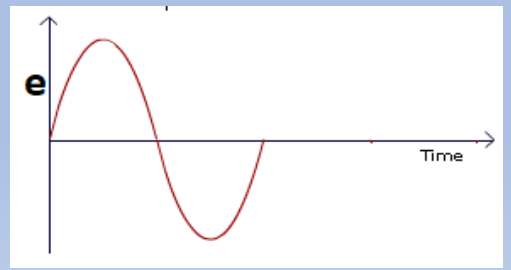
- Carbon brushes are placed in such a way that the brush axis is in quadrature of Coil axis.
- Halves of the split ring is placed with its axis parallel to the plane of the coil.
- Brushes are fixed on the stator in such a way that when they short the two splits of ring, coil is perpendicular to pole axis

When we were collecting current with slip ring, the current at one slipring was positive for half rotation and negative for another half rotation hence the alternating wave was observed at the brush terminals. (See Slide 6)

Now we are using split rings. Please see carefully the following figure and figures on the next slide

We can observe that conductor
AB is connected to split ring portion S1 and
CD is connected to S2



Coil Rotation (CW)	Position	Output at Split Rings (DC)	Output at Slip Rings (AC)
	1		
	2		
	3		
	4		
	1		

Brush B1 at Split Ring S1 is taken as Positive and Brush B2 at Split ring S2 is taken as Negative. Now see movement as:

Position 1

Conductor AB and CD are in such position where there is no magnetic field so zero induced voltage in the coil. Brush Bi will have +0 V and B2will have -0 V

Position 2

Coil rotates clockwise. Conductor AB is in such position that Max voltage +V is induced in it. As it increases from 0 to +V when coil moves from position 1 to 2, the corresponding waveform is shown at Bi and B2.

Position 3

AB moves from position 2 to 3 so induced emf in AB reduces from Max Voltage +V to 0 as shown in waveform. The point to be noticed is that up till now the split ring S1 Conductor AB) was under influence of N pole and was in contact of +ve Brush B1.

Position 4.

Now coil moves from position 3 to 4 and the following changes are observed:

1. AB is under influence of south pole and CD is under North Pole.
2. Split ring S2 is now in contact with B1

Under such situation the conditions are same as were with previous half cycle. A positive voltage will be induced (in the same direction as earlier in AB) in CD and hence the polarity at B1 will be the same positive. So the wave form as shown will be produced.

AB moves from position 4 to 1 again and the wave form completes and repeats in this way

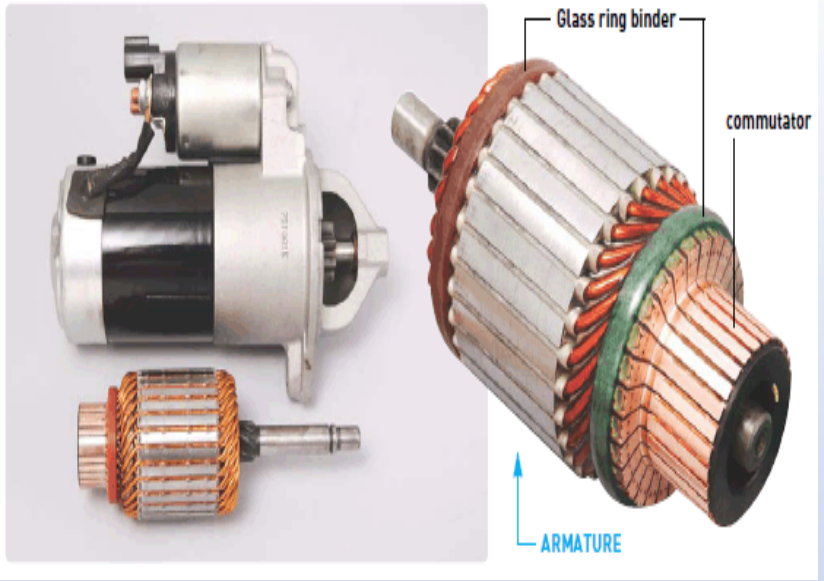
The waveform produced is the unidirectional pulsating wave. This is basic principle of generation of DC

Points to be noted:

1. The carbon brushes are actually not brushes these are blocks of graphite. These have self lubricating properties so the friction between these and split ring is very less. However over a period of time these carbon(Graphite) brushes wear out and needs to be changed periodically.
2. Earlier these were made like a brush of thin flexible copper wires hence name brushes was used and being carried till today.
3. This split ring is named as commutator.
4. Commutator is the most important part of a DC machine.
5. Any electrical machine internally generates ac only. It is the commutator which converts ac into dc at brush terminals.
6. We have seen the basic machine where there is only one coil. In fact the wave form generated by one coil is not sinusoidal The flux density in space is rectangular but alternating. Below one pole it is positive and below other it is negative.

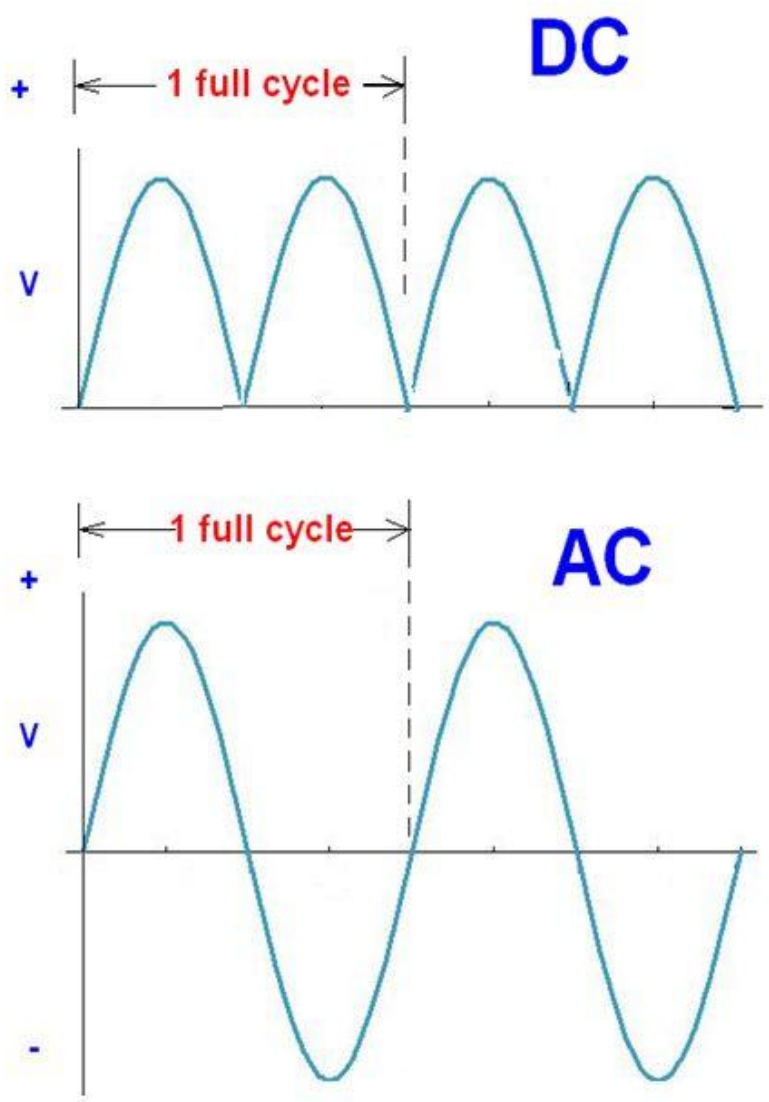
7. As we are interested in ac wave, the number of coils are increased on the rotor. There will be several coils distributed evenly over the periphery of the rotor. As the number of coils are increased, the resultant flux density wave produced by all the coils tends to be sinusoidal.
8. Even we are using only two poles in this basic machine but with the increase in number of poles, the flux density wave tends to improve (to become Sinusoidal).
9. For all practical purpose at this stage we assume the flux density wave as sinusoidal without going into the details.
10. The induced voltage in the coil follows the form of flux density wave. Hence when it is assumed sinusoidal, the voltage generated is also sinusoidal. This is to be understood for all electrical machines. It will be again required when studying Induction Machine.

11. *These split rings are termed as (Commutator segments". With the increase in number of coils, The segments required will be increase. For an actual dc machine the number of segments may be as high as 720.*
12. *Here is the figure showing an actual commutator mounted over the shaft of the rotor.*



13. Conventionally the rotor on which coils where voltage is to be induced are placed is known as "Armature".
14. The stator part is stationary and electromagnets are placed on this. Coils for magnetizing electromagnets to create the field are wound on stator and these coils are known as Field Coils.
15. The commutator converts ac into dc when it is rotating and hence it is known as rotating rectifier.
16. Now-days we have diodes/ Thyristor etc like electronic devices for rectification from ac to dc but in earlier days these were not available and hence invention of commutator was a breakthrough

DC and AC generators



- The only real difference between AC and DC generators is in the type of connection used to source the induced current from the coils in the rotor (slip or split rings).
- This difference results in a very different type of current signal being produced by each as is shown here.
- In a single coil DC generator the current is induced in the coil for a half a turn. The maximum voltage is reached when the coil is completely parallel to the magnetic field.
- When the split in the commutator touches the brushes no current flows or is generated, hence the voltage available drops to zero to start again as the commutator moves on. The result is a current flowing in one direction only.
- In a single coil AC generator, with the brushes running on slip rings a constant connection is maintained with the external circuit. This means that the polarity changes every half-turn and a current that changes direction is produced.