DC Generator

LEARNING OBJECTIVES

- Upon completion of the chapter the student should be able to:
  - State the principle by which machines convert mechanical energy to electrical energy.
  - Discuss the operating differences between different types of generators
  - Understand the principle of DC generator as it represents a logical behavior of dc motors.

Contents

Principle operation of Generator

- Whenever a conductor is moved within a magnetic field in such a way that the conductor cuts across magnetic lines of flux, voltage is generated in the conductor.
- The AMOUNT of voltage generated depends on:

i. the strength of the magnetic field,

ii. the speed at which the conductor is moved, and

iii. the length of the conductor within the magnetic field

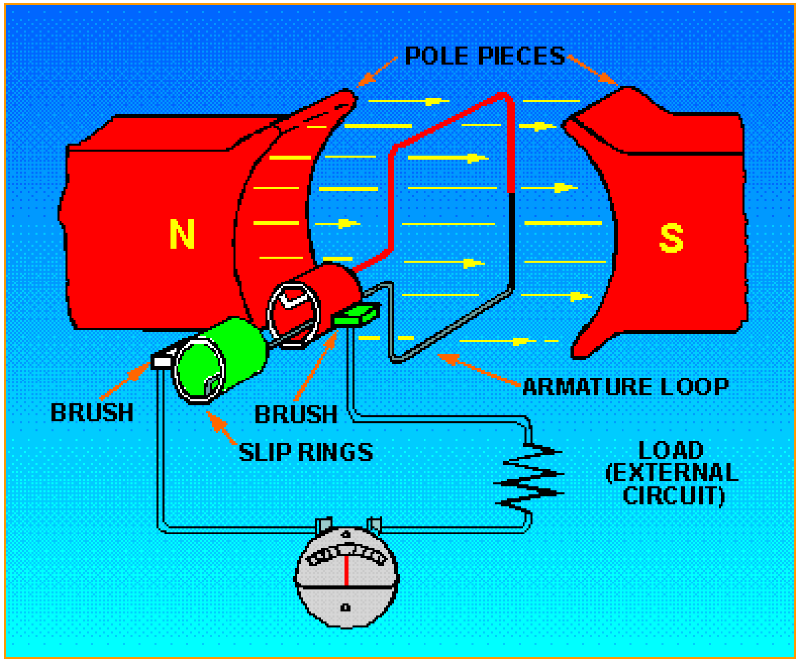
iv. the angle at which the conductor cuts the magnetic field,

The direction of induced emf is known from Fleming's right hand rule.

THE ELEMENTARY GENERATOR

- The simplest elementary generator that can be built is an ac generator. Basic generating principles are most **easily explained** through the use of the elementary ac generator. For this reason, the ac generator will be discussed first. The dc generator will be discussed later.

- An elementary generator consists of a wire loop mounted on the shaft, so that it can be rotated in a stationary magnetic field. This will produce an induced emf in the loop. Sliding contacts (brushes) connect the loop to an external circuit load in order to pick up or use the induced emf.



Elementary Generator

THE ELEMENTARY GENERATOR (Cont)

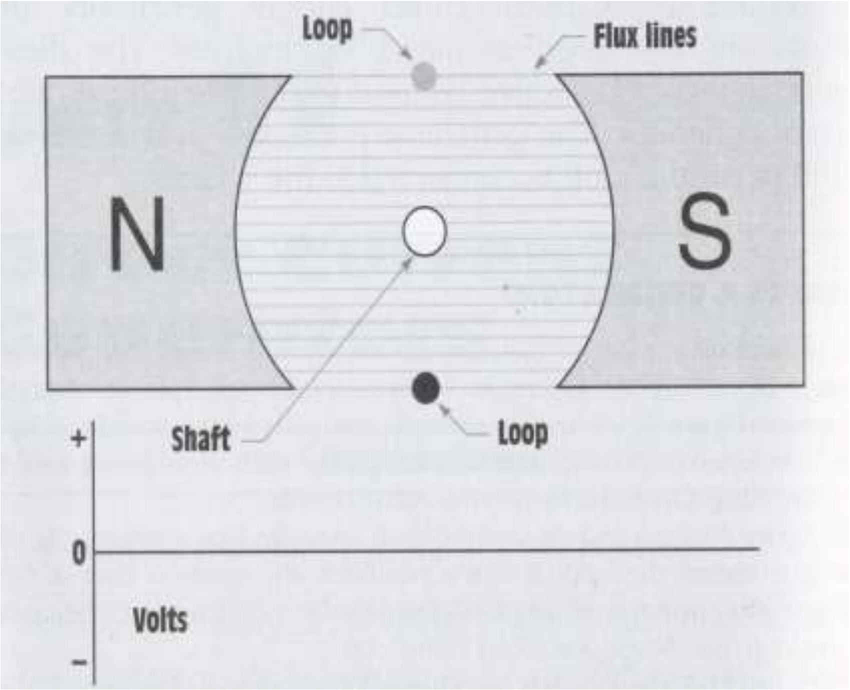
- The pole pieces (marked N and S) provide the magnetic field. The pole pieces are shaped and positioned as shown to concentrate the magnetic field as close as possible to the wire loop.

- The loop of wire that rotates through the field is called the ARMATURE. The ends of the armature loop are connected to rings called SLIP RINGS. They rotate with the armature.

- The brushes, usually made of carbon, with wires attached to them, ride against the rings. The generated voltage appears across these brushes. (These brushes transfer power from the battery to the commutator as the motor spins – discussed later in dc elementary generator).

THE ELEMENTARY GENERATOR (A)

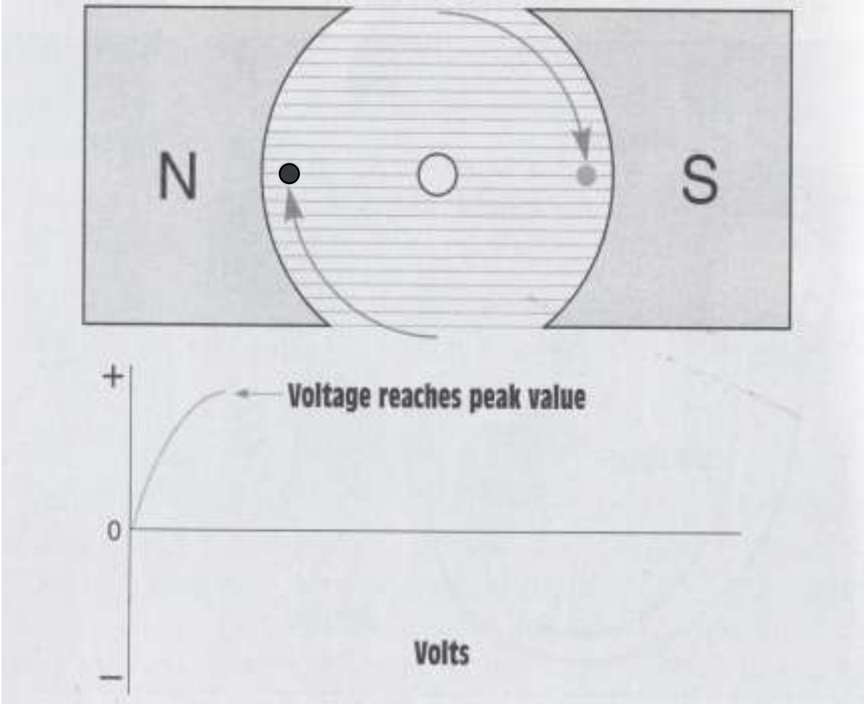
- An end view of the shaft and wire loop is shown. At this particular instant, the loop of wire (the black and white conductors of the loop) is parallel to the magnetic lines of flux, and no cutting action is taking place. Since the lines of flux are not being cut by the loop, no emf is induced in the conductors, and the meter at this position indicates zero.
- This position is called the NEUTRAL PLANE.



0^0 Position (Neutral Plane)

THE ELEMENTARY GENERATOR (B)

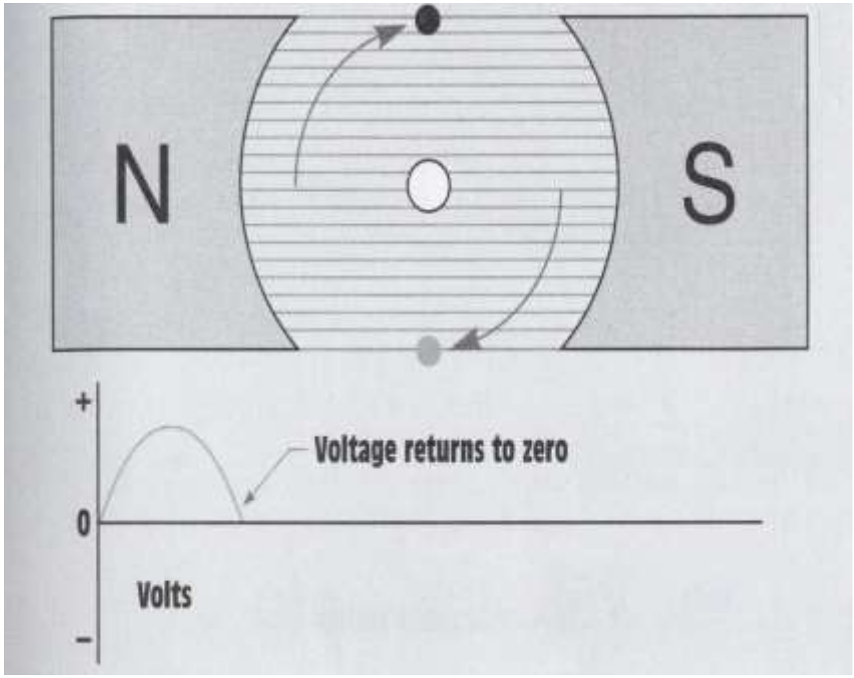
- The shaft has been turned 90^0 clockwise, the conductors cut through more and more lines of flux, and voltage is induced in the conductor.
- at a continually increasing angle , the induced emf in the conductors builds up from zero to a maximum value or peak value.
- Observe that from 0^0 to 90^0, the black conductor cuts DOWN through the field. At the same time the white conductor cuts UP through the field. The induced emfs in the conductors are series-adding. This means the resultant voltage across the brushes (the terminal voltage) is the sum of the two induced voltages. The meter at position B reads maximum value.



90^0 Position

THE ELEMENTARY GENERATOR (c)

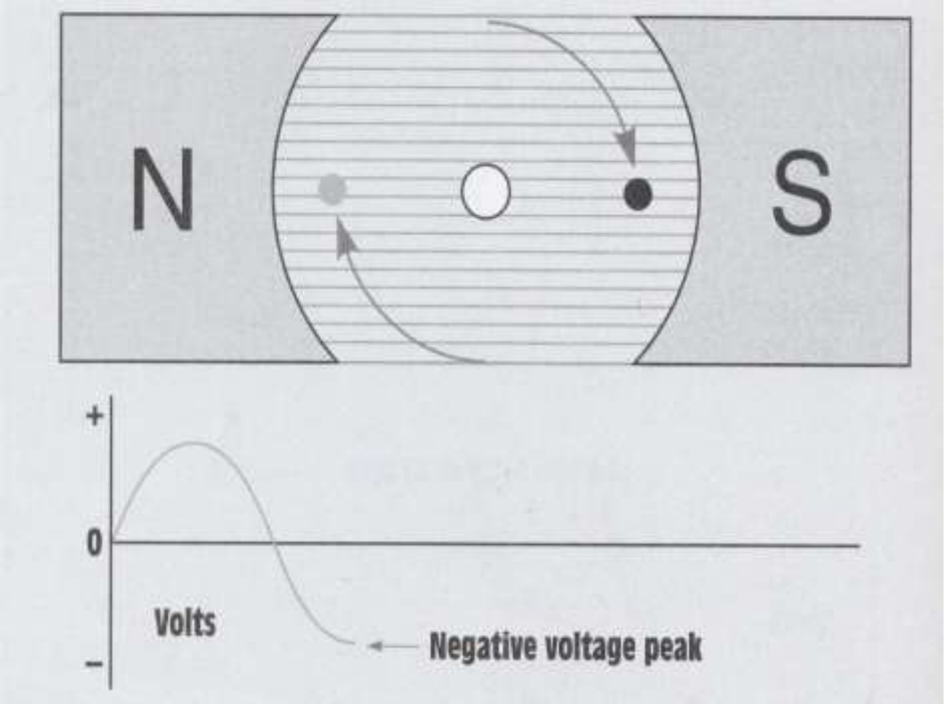
- After another 90^0 of rotation, the loop has completed 180^0 of rotation and is again parallel to the lines of flux. As the loop was turned, the voltage decreased until it again reached zero.
- Note that : From 0^0 to 180^0 the conductors of the armature loop have been moving in the same direction through the magnetic field. Therefore, the polarity of the induced voltage has remained the same



180^0 Position

THE ELEMENTARY GENERATOR (D)

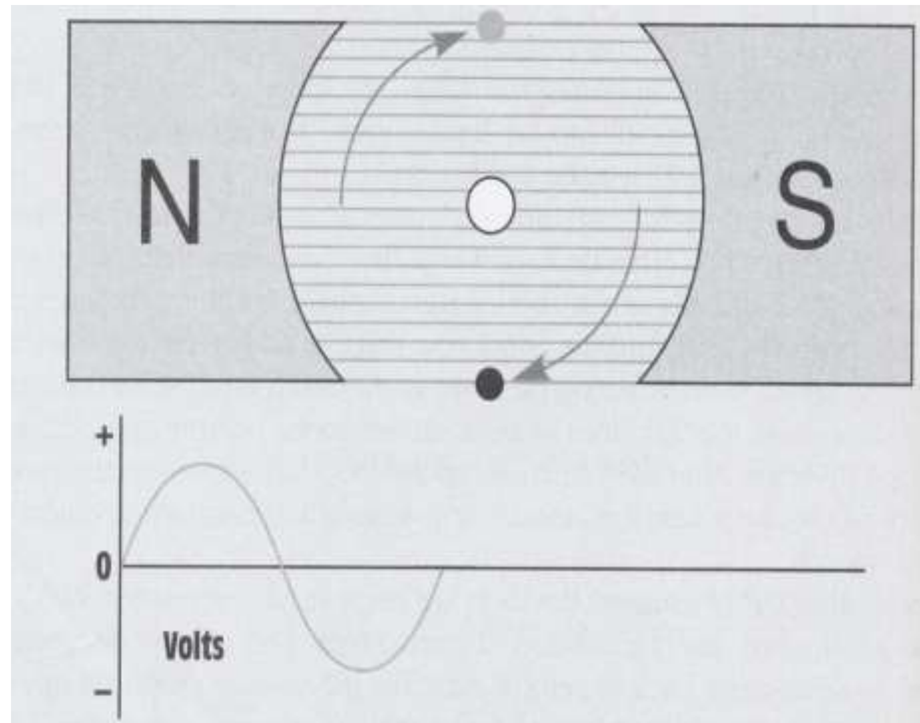
- As the loop continues to turn, the conductors again cut the lines of magnetic flux.
- This time, however, the conductor that previously cut through the flux lines of the south magnetic field is cutting the lines of the north magnetic field, and vice-versa.
- Since the conductors are cutting the flux lines of opposite magnetic polarity, the polarity of the induced voltage reverses. After 270' of rotation, the loop has rotated to the position shown, and the maximum terminal voltage will be the same as it was from A to C except that the polarity is reversed.



270^0 Position

THE ELEMENTARY GENERATOR (A)

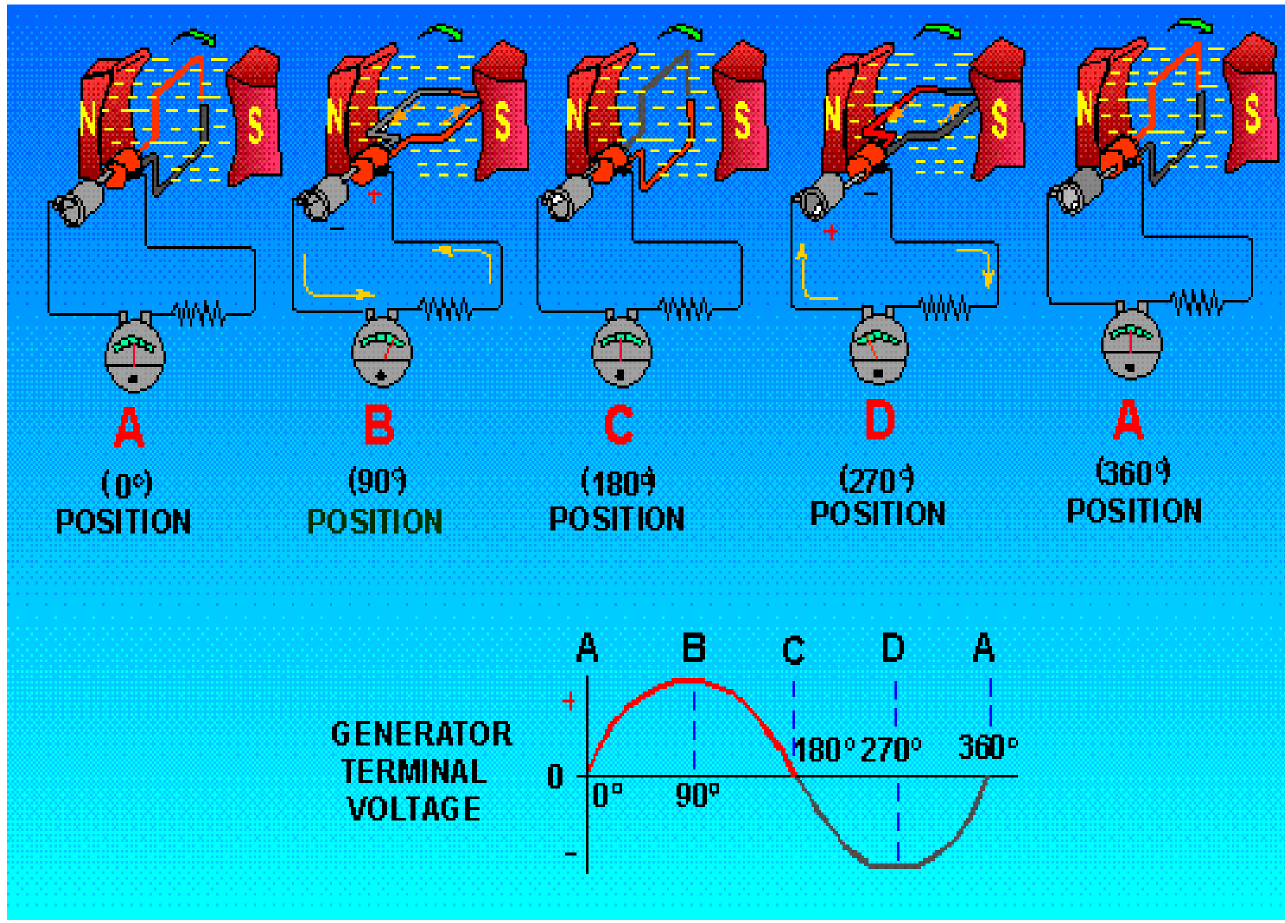
- After another 90^0 of rotation, the loop has completed one rotation of 360^0 and returned to its starting position.
- The voltage decreased from its negative peak back to zero.
- Notice that the voltage produced in the armature is an alternating polarity. The voltage produced in all rotating armatures is alternating voltage.



360^0 Position

Elementary Generator (Conclusion)

- Observes
  - The meter direction
  - The conductors of the armature loop
  - Direction of the current flow



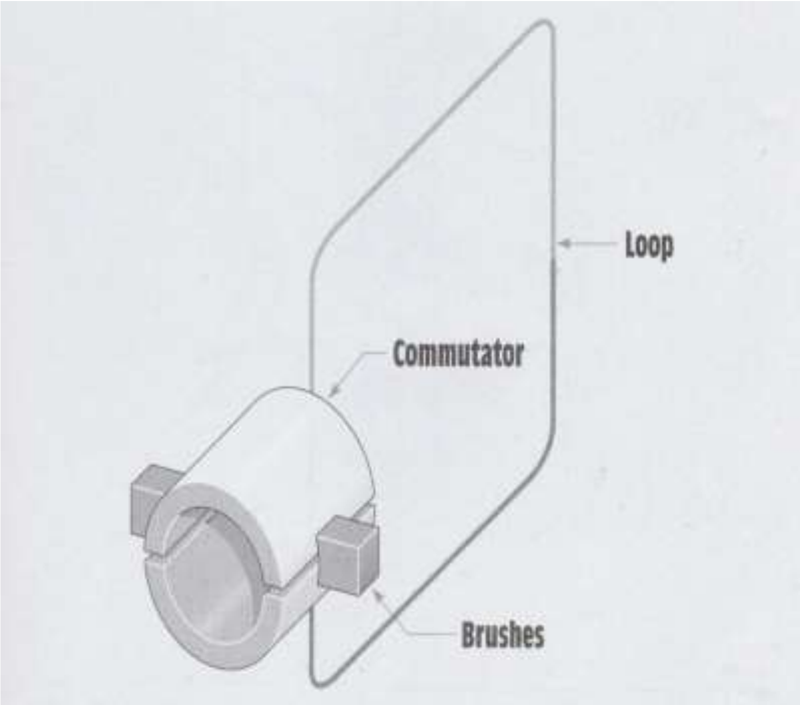
Output voltage
of an elementary generator
during one revolution

THE ELEMENTARY DC GENERATOR

- Since DC generators must produce DC current instead of AC current, a device must be used to change the AC voltage produced in the armature windings into DC voltage. This job is performed by the **commutator.**

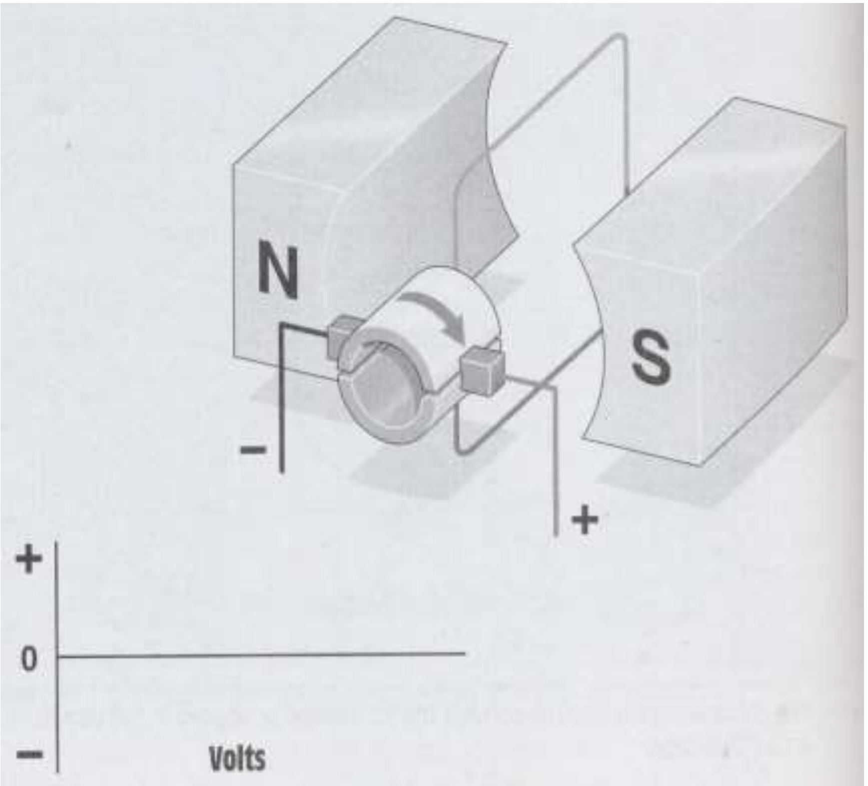
- The commutator is constructed from a copper ring split into segments with insulating material between the segments (See next page). Brushes riding against the commutator segments carry the power to the outside circuit.

- The commutator in a dc generator replaces the slip rings of the ac generator. This is the main difference in their construction. The commutator mechanically reverses the armature loop connections to the external circuit.



THE ELEMENTARY DC GENERATOR

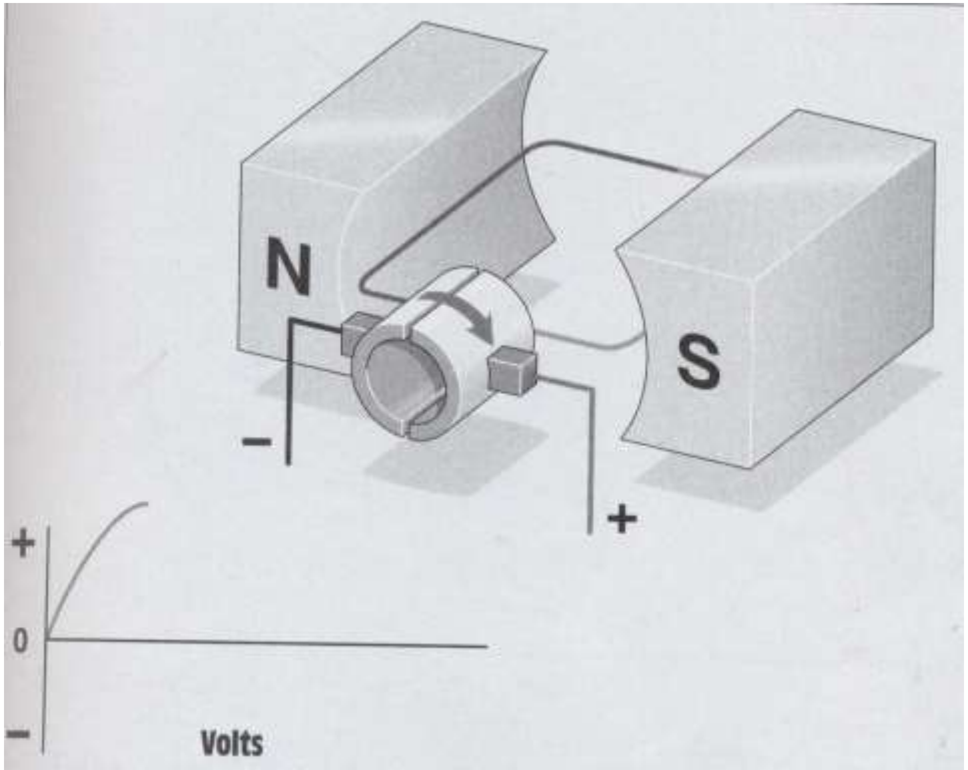
- The loop is parallel to the magnetic lines of flux, and no voltage is induced in the loop
- Note that the brushes make contact with both of the commutator segments at this time. The position is called neutral plane.



0^0 Position (DC Neutral Plane)

THE ELEMENTARY DC GENERATOR

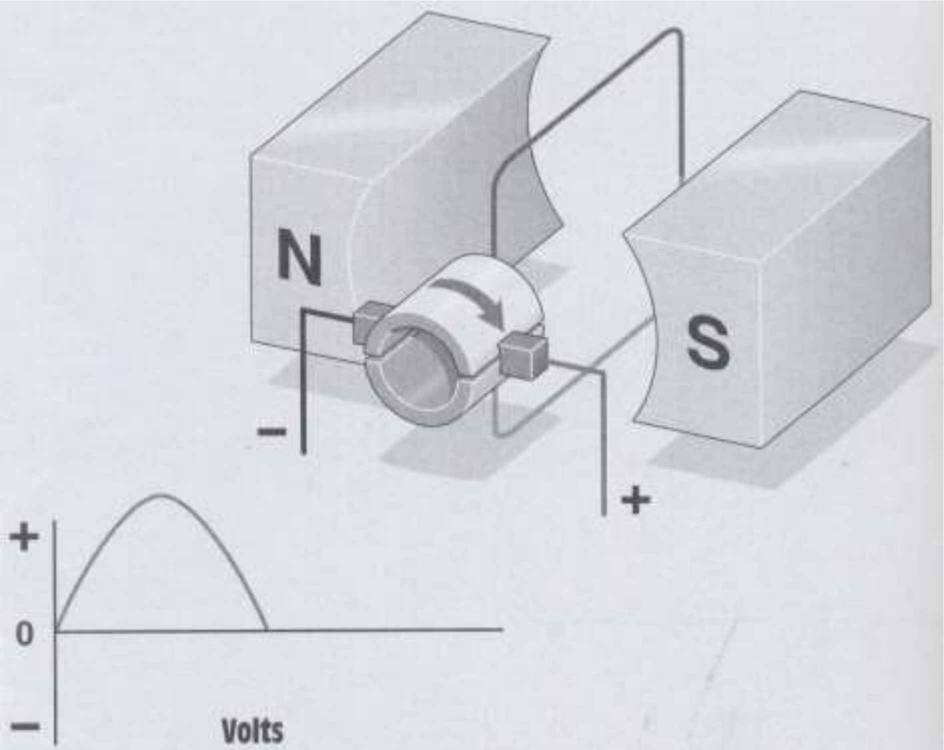
- As the loop rotates, the conductors begin to cut through the magnetic lines of flux.
- The conductor cutting through the south magnetic field is connected to the positive brush, and the conductor cutting through the north magnetic field is connected to the negative brush.
- Since the loop is cutting lines of flux, a voltage is induced into the loop. After 90^0 of rotation, the voltage reaches its most positive point.



90^0 Position (DC)

THE ELEMENTARY DC GENERATOR

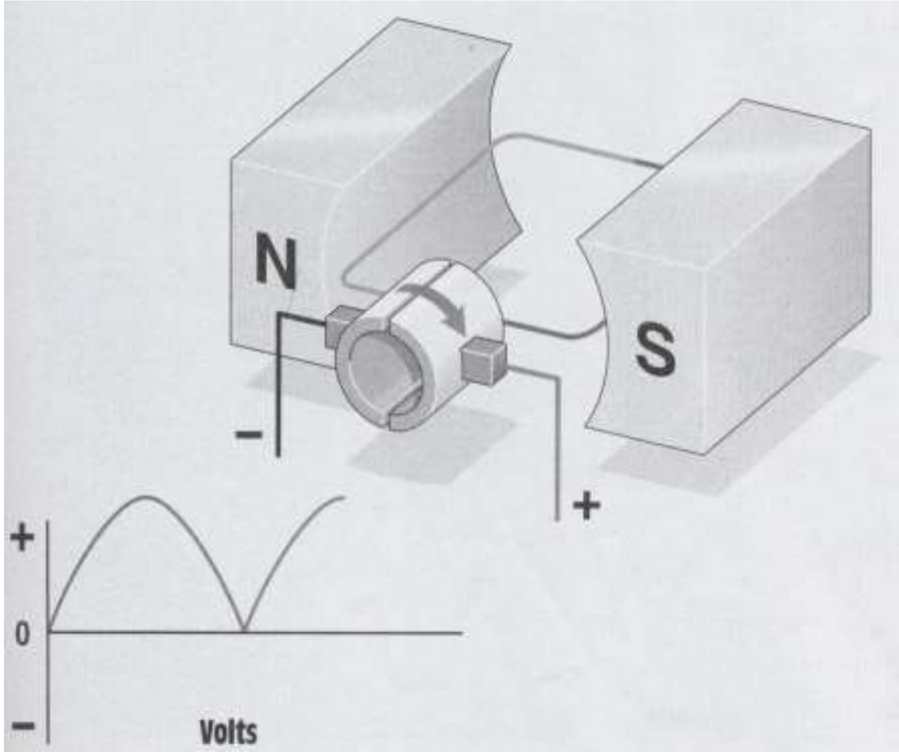
- As the loop continues to rotate, the voltage decreases to zero.
- After 180^0 of rotation, the conductors are again parallel to the lines of flux, and no voltage is induced in the loop.
- Note that the brushes again make contact with both segments of the commutator at the time when there is no induced voltage in the conductors



180^0 Position (DC)

THE ELEMENTARY DC GENERATOR

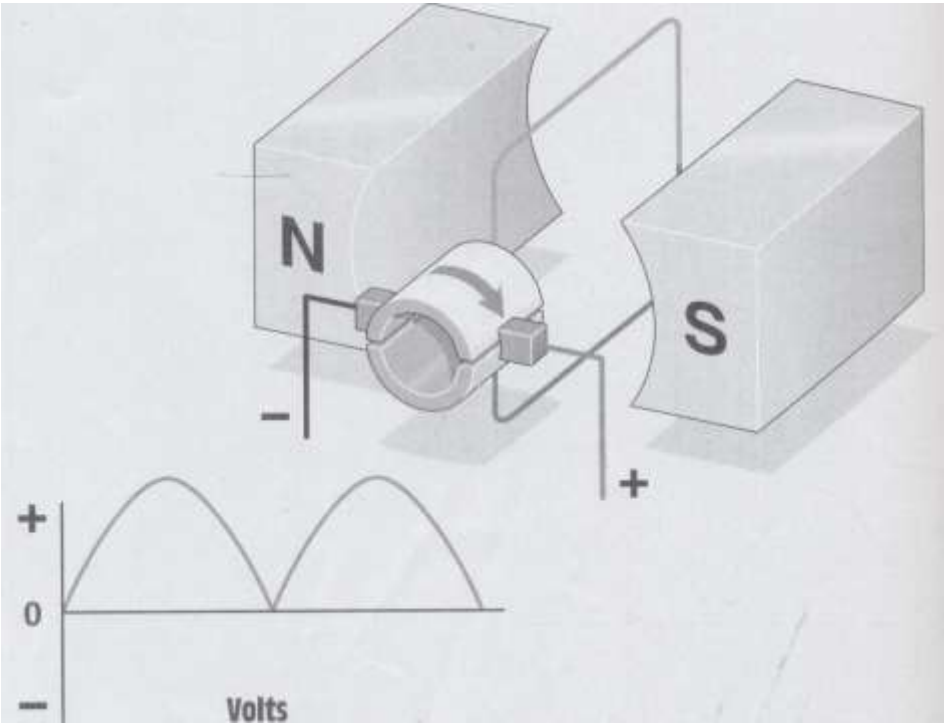
- During the next 90^0 of rotation, the conductors again cut through the magnetic lines of flux.
- This time, however, the conductor that previously cut through the south magnetic field is now cutting the flux lines of the north field, and vice-versa. .
- Since these conductors are cutting the lines of flux of opposite magnetic polarities, the polarity of induced voltage is different for each of the conductors. The commutator, however, maintains the correct polarity to each brush.
- The conductor cutting through the north magnetic field will always be connected to the negative brush, and the conductor cutting through the south field will always be connected to the positive brush.
- Since the polarity at the brushes has remained constant, the voltage will increase to its peak value in the same direction.



270^0 Position (DC)

THE ELEMENTARY DC GENERATOR

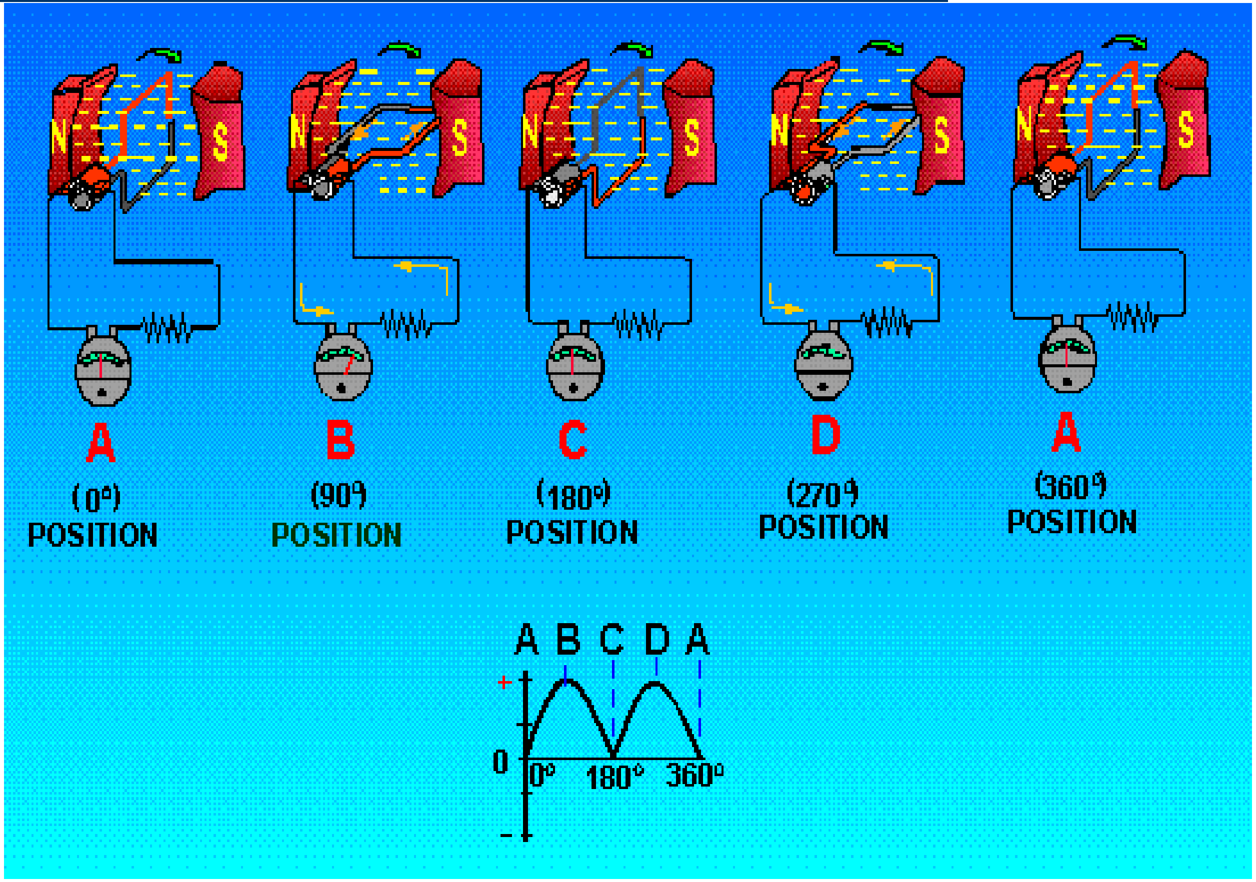
- As the loop continues to rotate, the induced voltage again decreases to zero when the conductors become parallel to the magnetic lines of flux.
- Notice that during this 360^0 rotation of the loop the polarity of voltage remained the same for both halves of the waveform. This is called rectified DC voltage.
- The voltage is pulsating. It does turn on and off, but it never reverses polarity. Since the polarity for each brush remains constant, the output voltage is DC.



0^0 Position (DC Neutral Plane)

THE ELEMENTARY DC GENERATOR

- Observes
  - The meter direction
  - The conductors of the armature loop
  - Direction of the current flow

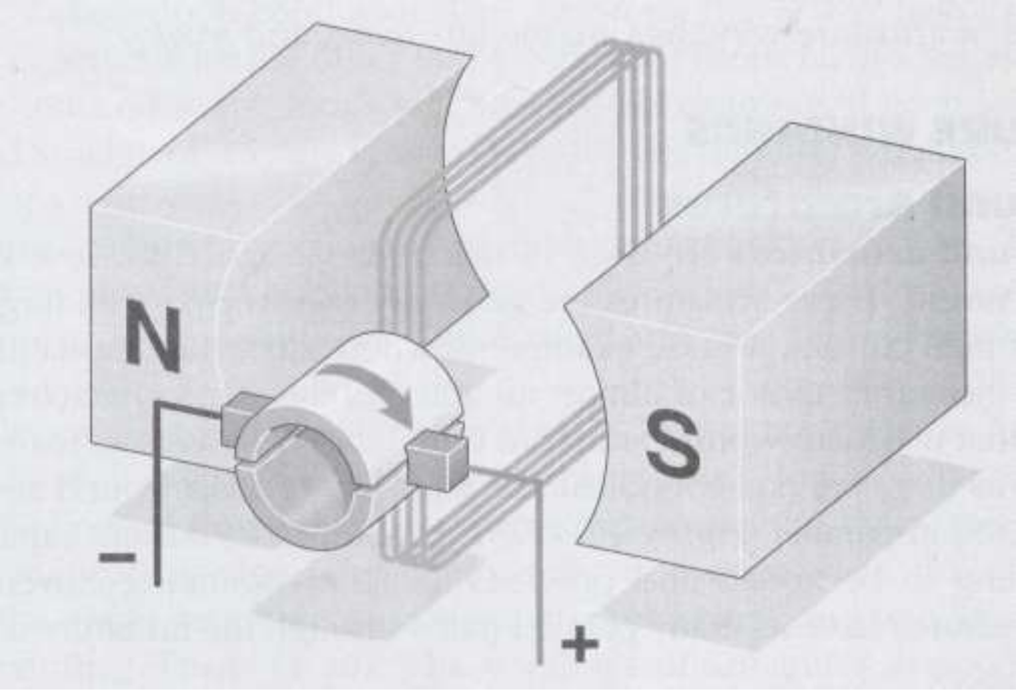


Effects of commutation

http://www.sciencejoywagon.com/physicszone/lesson/otherpub/wfendt/generatorengl.htm

Effects of additional turns

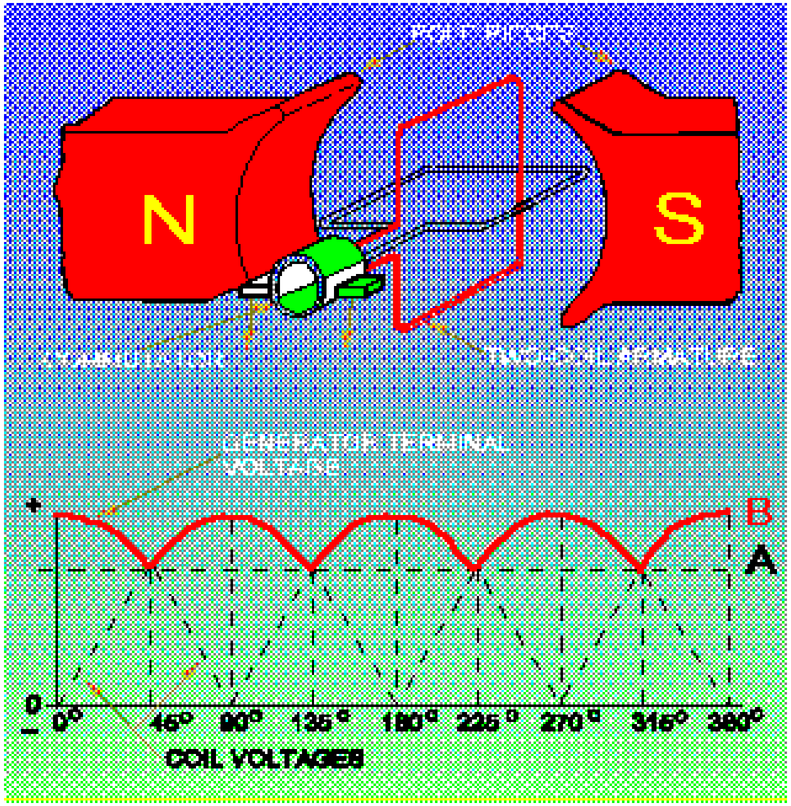
- To increase the amount of output voltage, it is common practice to increase the number of turns of wire for each loop.
- If a loop contains 20 turns of wire, the induced voltage will be 20 times greater than that for a single-loop conductor.
- The reason for this is that each loop is connected in series with the other loops. Since the loops form a series path, the voltage induced in the loops will add.
- In this example, if each loop has an induced voltage of 2V, the total voltage for this winding would be 40V (2V x 20 loops = 40 V).



Effects of additional turns

Effects of additional coils

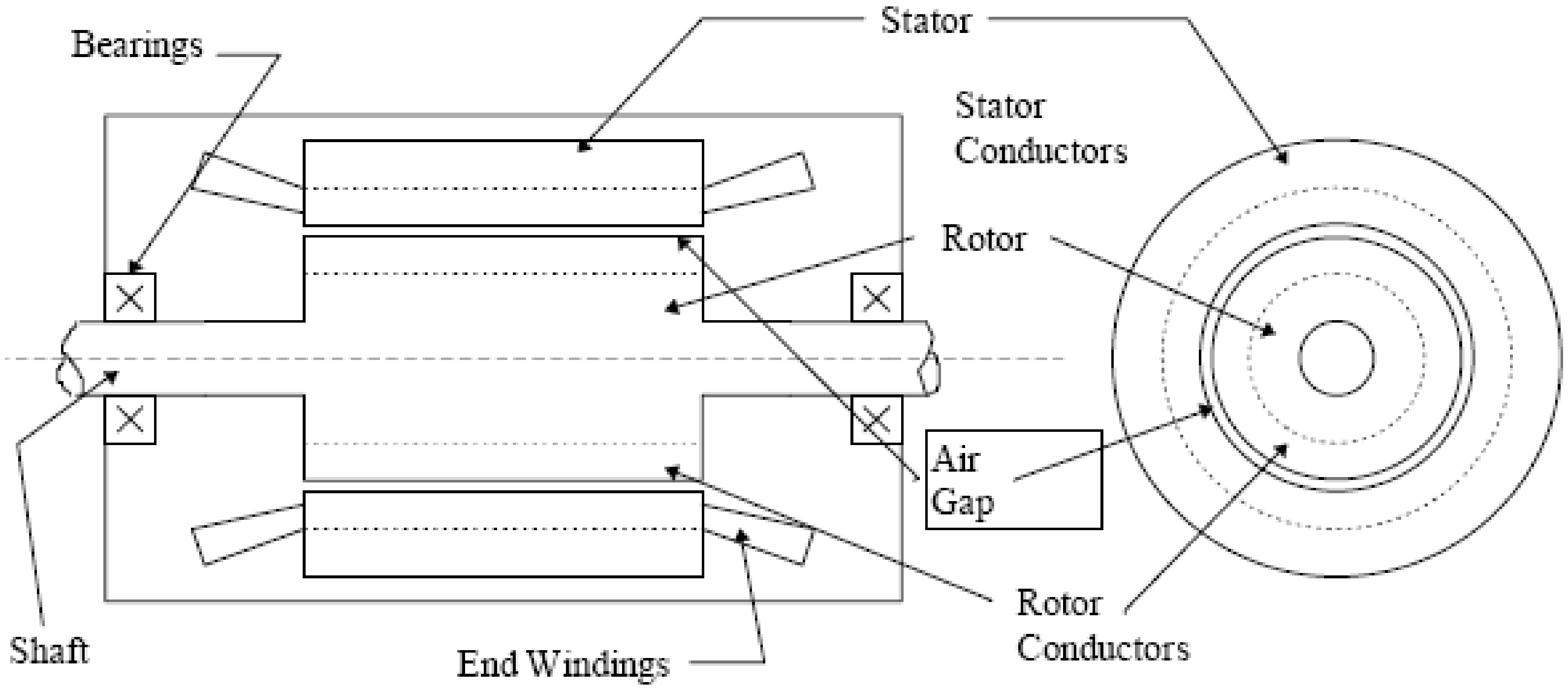
- When more than one loop is used, the average output voltage is higher and there is less pulsation of the rectified voltage.
- Since there are four segments in the commutator, a new segment passes each brush every 90^0 instead of every 180^0.
- Since there are now four commutator segments in the commutator and only two brushes, the voltage **cannot fall any lower than at point A.**
- Therefore, the ripple is limited to the rise and fall between points A and B on the graph. By adding more armature coils, the ripple effect can be further reduced. **Decreasing ripple in this way increases the effective voltage of the output.**



Effects of additional coils

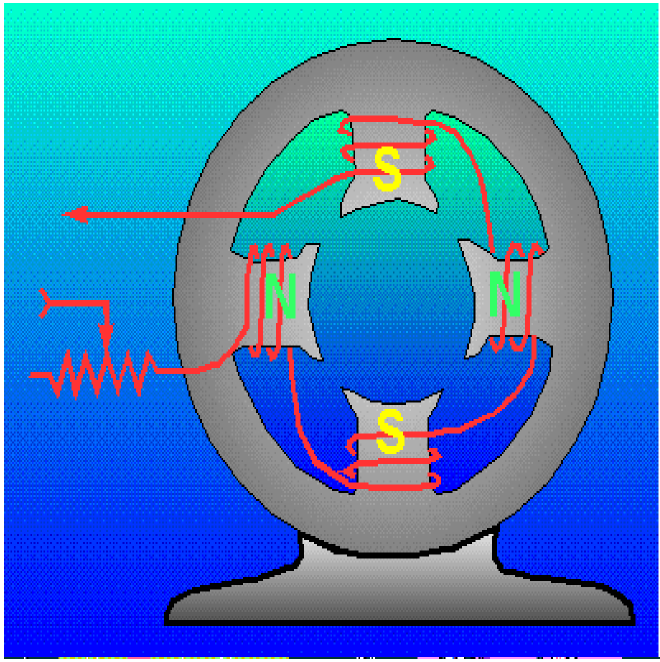
Construction

- Major parts are rotor (armature) and stator (field).



The field system for Practical DC Generator

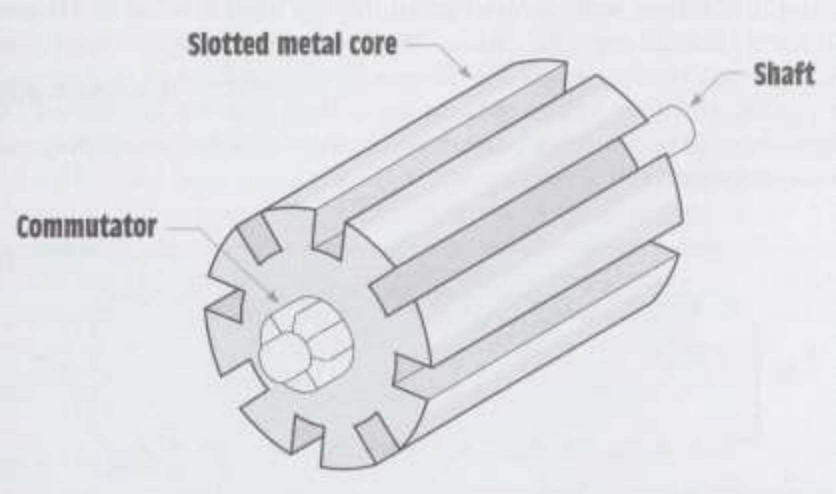
- The actual construction and operation of a practical dc generator differs somewhat from our elementary generators
- Nearly all practical generators use electromagnetic poles instead of the permanent magnets used in our elementary generator
- The main advantages of using electromagnetic poles are:
  - (1) increased field strength and
  - (2) possible to control the strength of the fields. By varying the input voltage, the field strength is varied. By varying the field strength, the output voltage of the generator can be controlled.



Four-pole generator (without armature)

ARMATURE

- More loops of wire = higher rectified voltage
- In practical, loops are generally placed in slots of an iron core
- The iron acts as a magnetic conductor by providing a low-reluctance path for magnetic lines of flux to increase the inductance of the loops and provide a higher induced voltage. The commutator is connected to the slotted iron core. The entire assembly of iron core, commutator, and windings is called the armature. The windings of armatures are connected in different ways depending on the requirements of the machine.

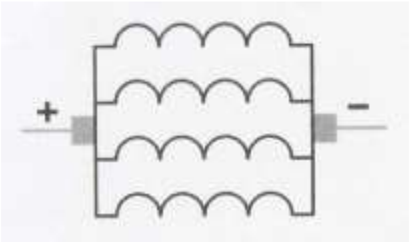


Loops of wire are wound around slot in a metal core

DC machine armature

ARMATURE WINDINGS

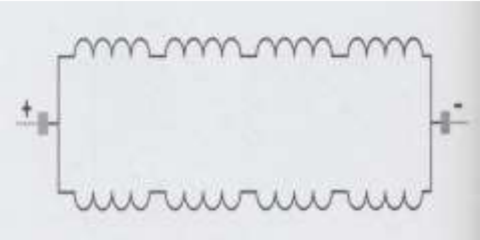
- Lap Wound Armatures
  - are used in machines designed for low voltage and high current
  - armatures are constructed with large wire because of high current
  - Eg: - are used is in the starter motor of almost all automobiles
  - The windings of a lap wound armature are connected in parallel. This permits the current capacity of each winding to be added and provides a higher operating current
  - No of current path, a**=p** ; p=no of poles



Lap wound armatures

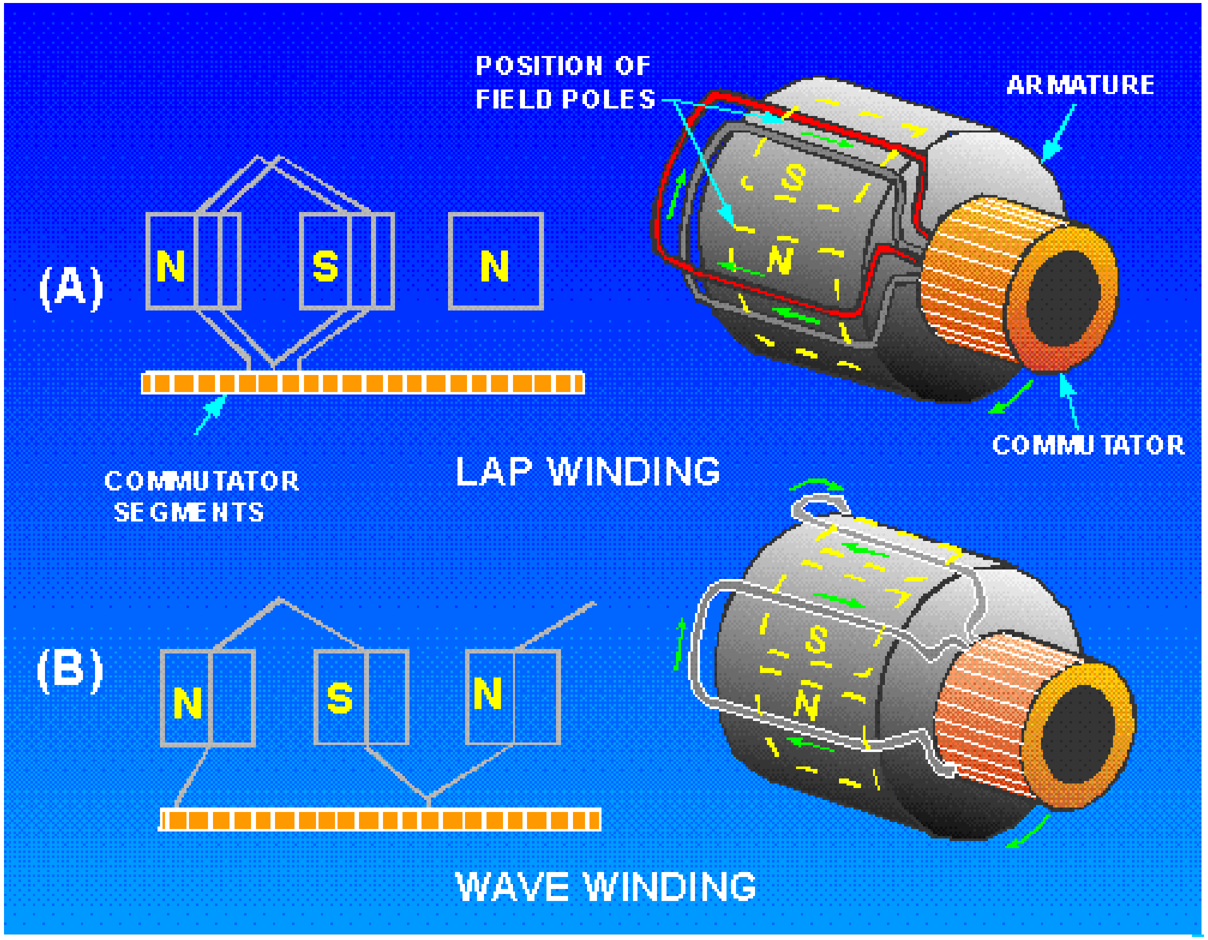
ARMATURE WINDINGS (Cont)

- Wave Wound Armatures
  - are used in machines designed for high voltage and low current
  - their windings connected in series
  - When the windings are connected in series, the voltage of each winding adds, but the current capacity remains the same
  - are used is in the small generator in hand-cranked megohmmeters
  - No of current path, a=2



Wave **wound armatures**

ARMATURE WINDINGS (Cont)

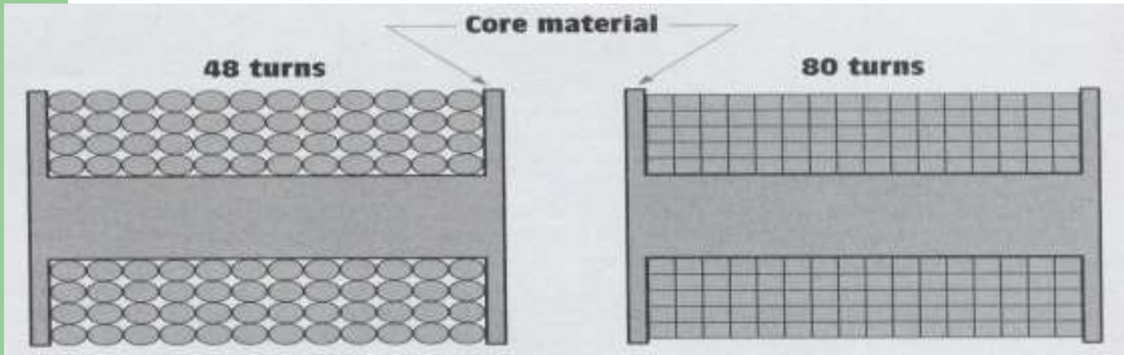


FIELD WINDINGS

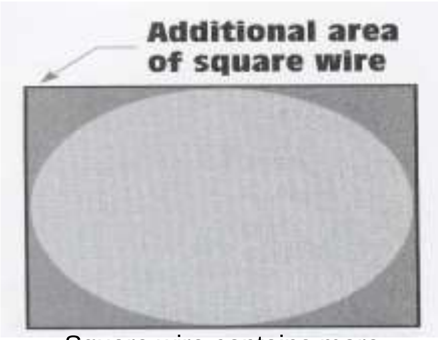
- Most DC machines use wound electromagnets to provide the magnetic field.
- Two types of field windings are used :
  - series field
  - shunt field

FIELD WINDINGS (Cont)

- Series field windings
  - are so named because they are connected in series with the armature
  - are made with relatively few windings turns of very large wire and have a very low resistance
  - usually found in large horsepower machines wound with square or rectangular wire. The use of square wire permits the windings to be laid closer together, which increases the number of turns that can be wound in a particular space
  - Square and rectangular wire can also be made physically smaller than round wire and still contain the same surface area



Square wire permits more turns than round wire in the same area



Square wire contains more surface than round wire

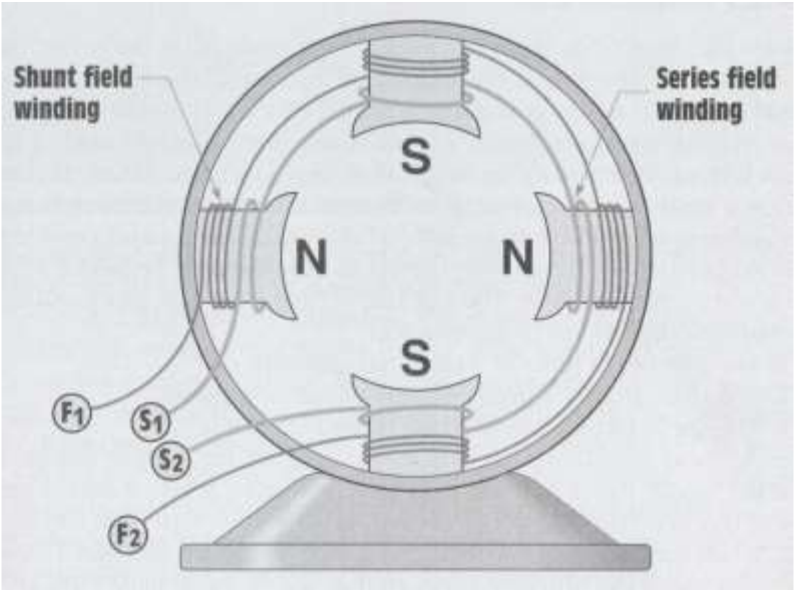
FIELD WINDINGS (Cont)

- Shunt field windings
  - is constructed with relatively many turns of small wire, thus, it has a much higher resistance than the series field.
  - is intended to be connected in parallel with, or shunt, the armature.
  - high resistance is used to limit current flow through the field.

FIELD WINDINGS (Cont)

- When a DC machine uses both series and shunt fields, each pole piece will contain both windings.

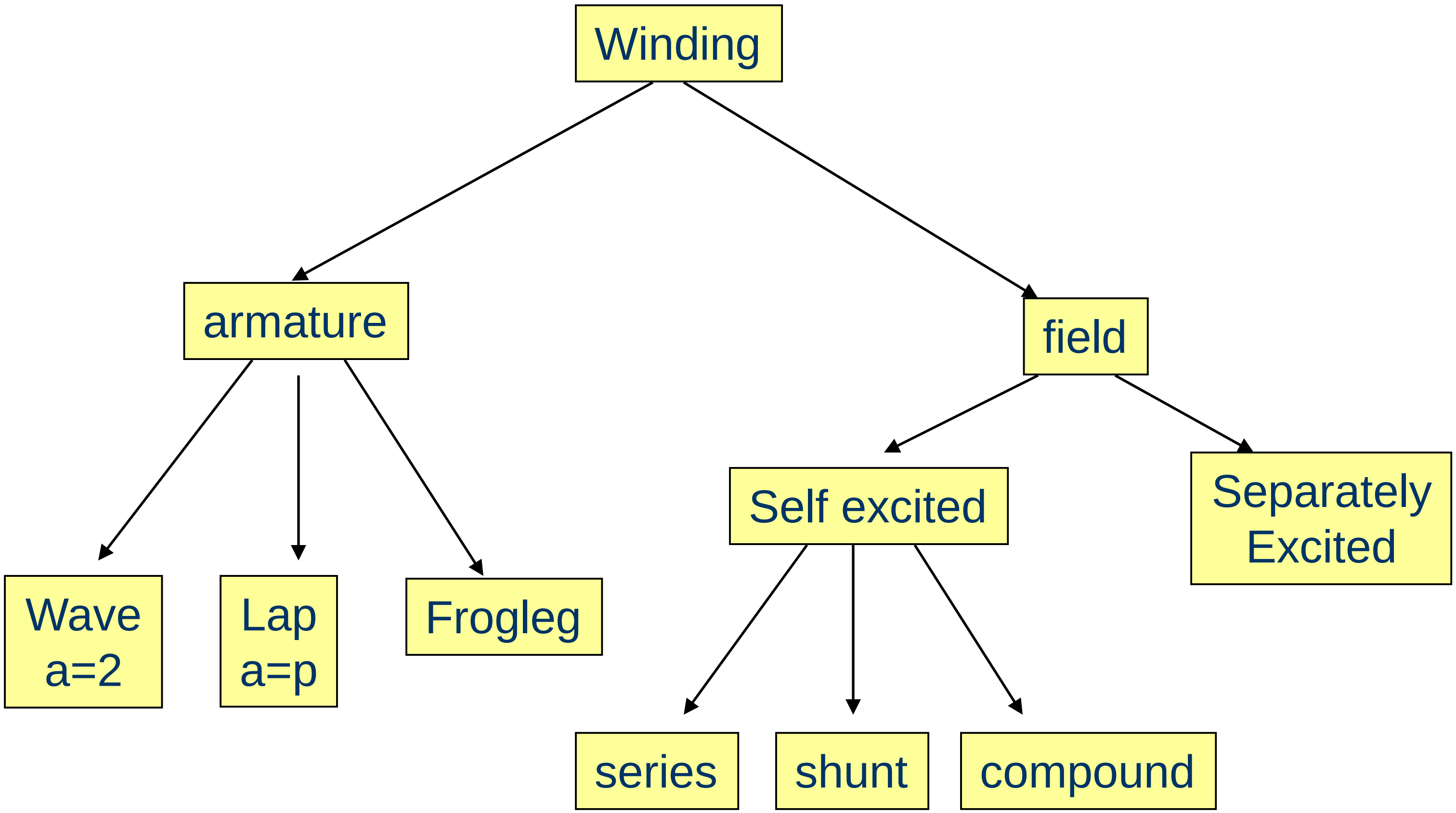
- The windings are wound on the pole pieces in such a manner that when current flows through the winding it will produce alternate magnetic polarities.



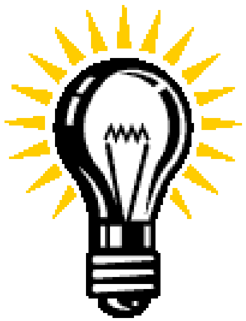
Both series and shunt field windings are contained in each pole piece

S – series field
F – shunt field

MACHINE WINDINGS OVERVIEW



Notes !!!



- If you ever have the chance to take apart a small electric motor, you will find that it contains the same pieces described above: two small permanent magnets, a commutator, two brushes, and an electromagnet made by winding wire around a piece of metal. Almost always, however, the rotor will have **three poles** rather than the two poles as shown in this article. There are two good reasons for a motor to have three poles:
  - It causes the motor to have better dynamics. In a two-pole motor, if the electromagnet is at the balance point, perfectly horizontal between the two poles of the field magnet when the motor starts, you can imagine the armature getting "stuck" there. That never happens in a three-pole motor.
  - Each time the commutator hits the point where it flips the field in a two-pole motor, the commutator shorts out the battery (directly connects the positive and negative terminals) for a moment. This shorting wastes energy and drains the battery needlessly. A three-pole motor solves this problem as well.
- It is possible to have any number of poles, depending on the size of the motor and the specific application it is being used in.