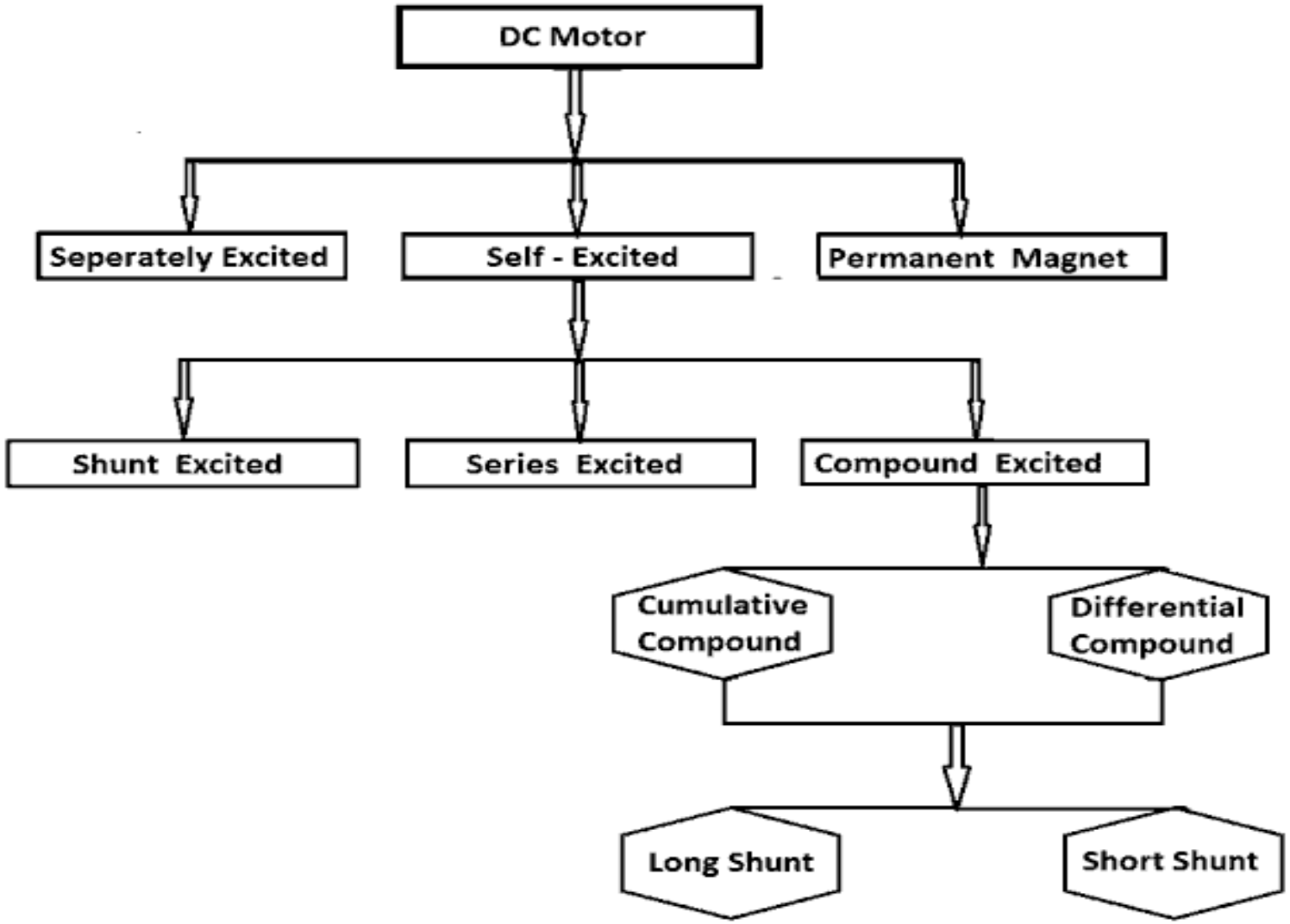
Classification of DC Motors

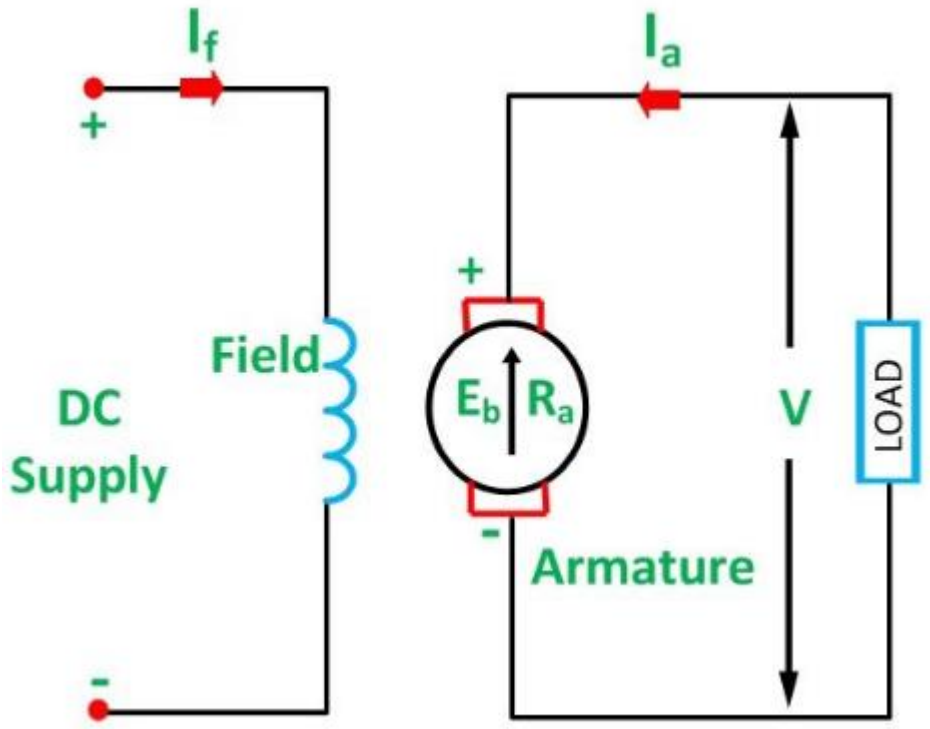


Separately Excited DC Motor

- As the name signifies, the field coils or field windings are energized by a separate DC source.

Applications:

- Separately excited DC motors are often used in trains and automotive traction applications.

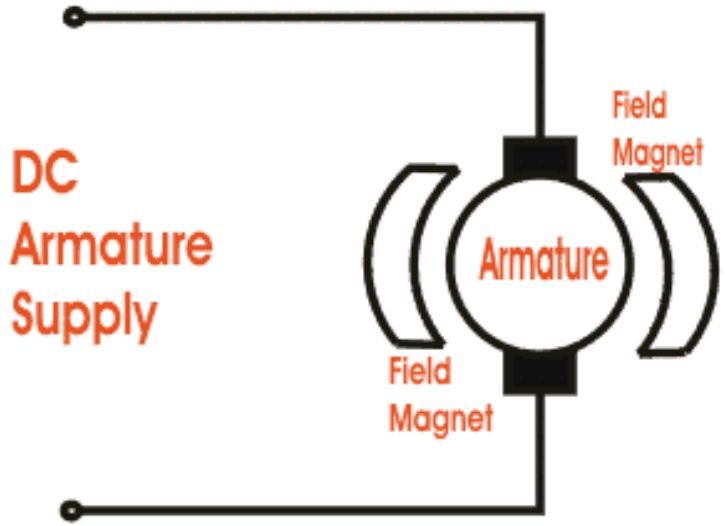


Permanent Magnet DC Motor

- consists of an armature winding as in case of an usual motor, but does not contain the field windings.
- Magnetic field strength is fixed.

Applications:

1. used in toy industries.
2. electric toothbrushes, portable vacuum cleaners.
3. portable electric tool such as drilling machines.



QUICK QUIZ (POLL)

The magnetic field strength remains constant in

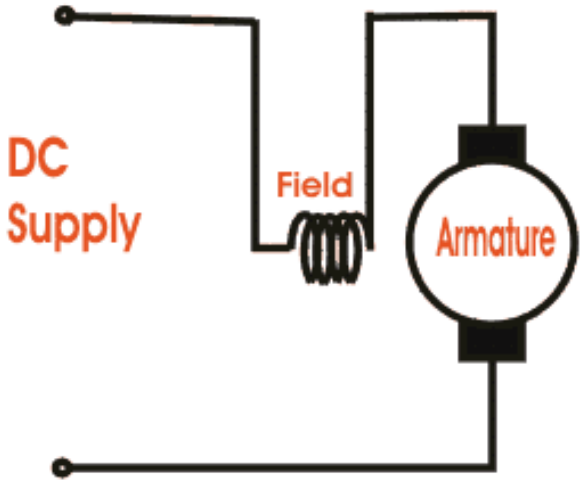
A. Shunt dc motor
B. series dc motor
C. PMDC Motor
D. Compound dc motor

Series DC Motor (Self-Excited)

- The armature and field winding are connected in series.
- Field resistance should be low, otherwise armature current would decrease. That results in lower value of torque.
- This is achieved by using field windings of thick wire and lesser number of turns.

Important Properties:

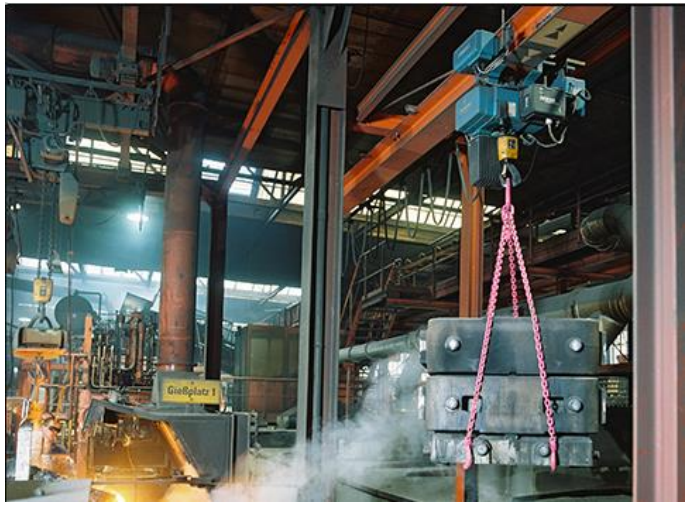
- High starting torque.



Applications of DC Motors

Series Motor:

- Cranes
- Hoists , Elevators
- Trolleys
- Conveyors
- Electric locomotives

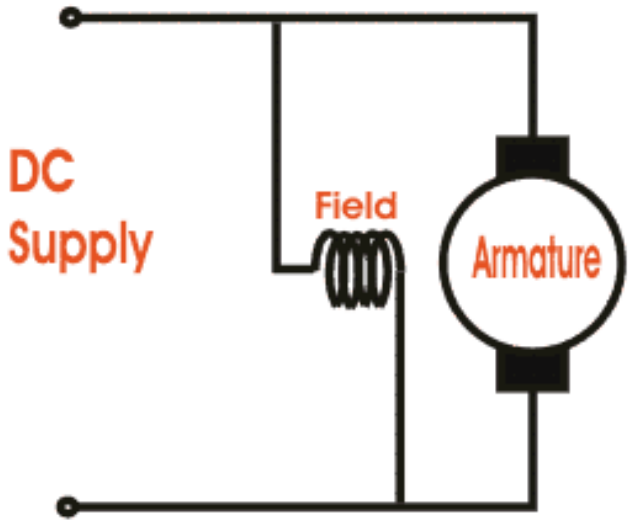


Shunt DC Motor (Self-Excited)

- in which the field winding is connected in parallel with the armature.
- Field resistance should be high, otherwise maximum current would flow across the field winding. That results in lower value of torque.
- This is achieved by using field windings of thin wire and more number of turns.

Important Properties:

- Constant Speed of Operation.



Applications of DC Motors

Shunt Motor:

- Blowers and fans
- Lathe machines
- Machine tools
- Milling machines
- Drilling machines

QUICK QUIZ (POLL)

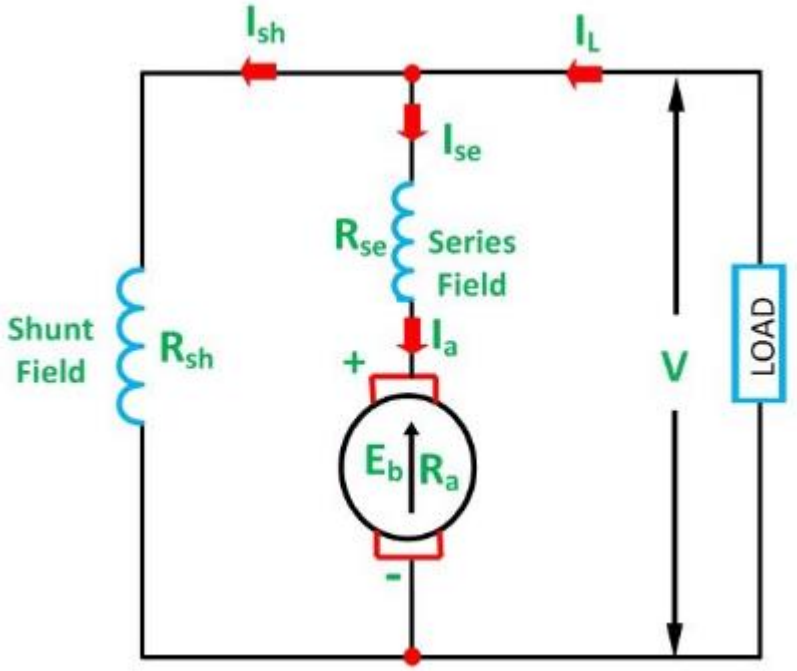
Which of the following motors is used in blowers?

A. Shunt dc motor
B. series dc motor
C. PMDC Motor
D. Compound dc motor

Cumulatively Compound DC Motor (Self-Excited)

- A DC Motor having both shunt and series field windings is called a Compound Motor.
- In a cumulative compound motor the flux produced by both the windings is in the same direction, i.e.

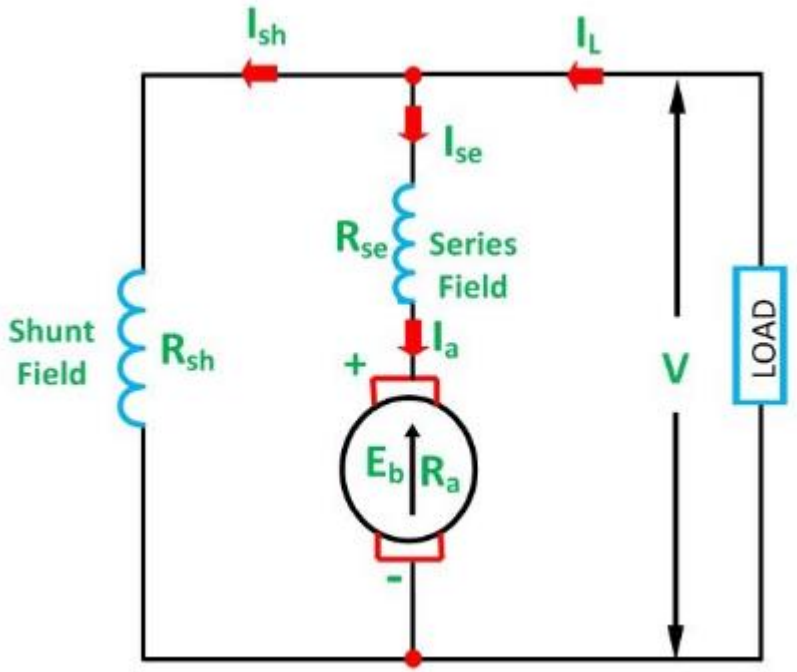
$$\phi_{total} = \phi_{series} + \phi_{shunt}$$



Differentially Compound DC Motor (Self-Excited)

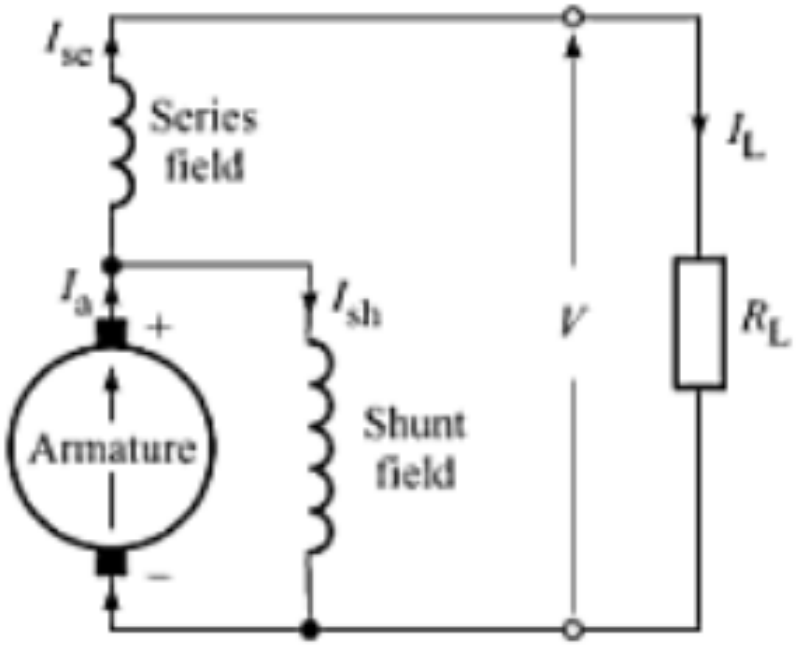
- A DC Motor having both shunt and series field windings is called a Compound Motor.
- In differential compound motor, the flux produced by the series field windings is opposite to the flux produced by the shunt field winding, i.e.

$$\phi_{total} = \phi_{series} - \phi_{shunt}$$

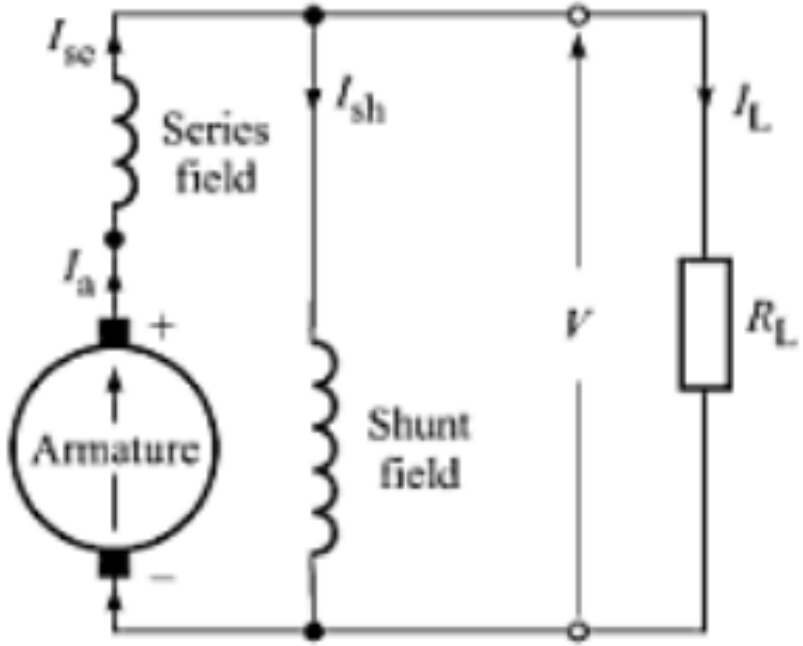


Long Shunt and Short Shunt Compound DC Motors (Self Excited)

If the shunt field winding is only parallel to the armature winding and not the series field winding then its known as short shunt DC motor or more specifically short shunt type compound wound DC motor.



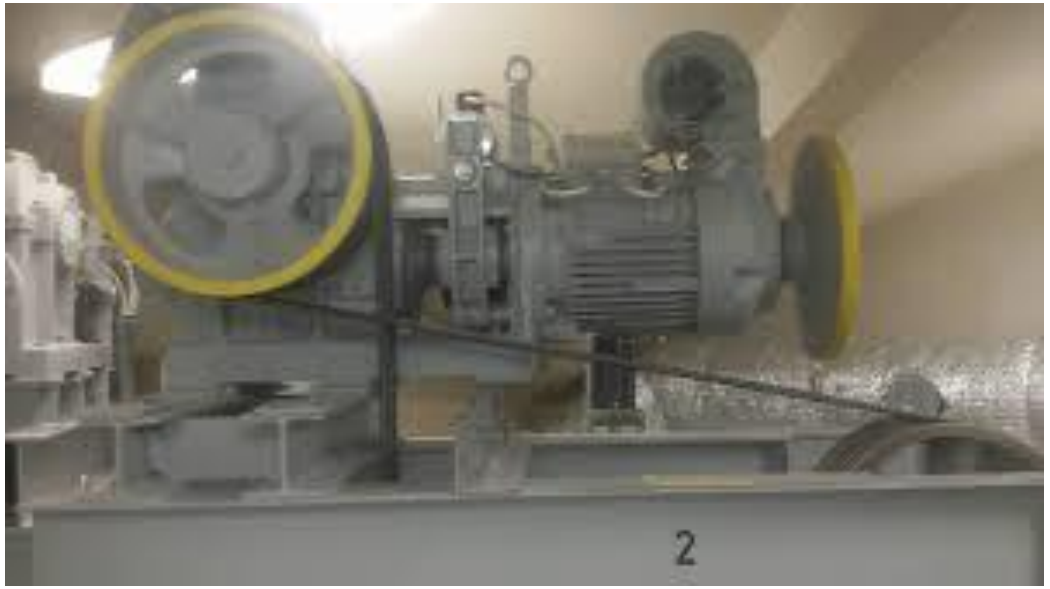
If the shunt field winding is parallel to both the armature winding and the series field winding then it's known as long shunt type compounded wound DC motor or simply long shunt DC motor.



Applications of DC Motors

Cumulative compound Motor:

- Rolling mills
- Punches and Shears
- Elevators



Induction Motors

- An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.
- Also called as **Asynchronous Motors**.
- Depending on the number of phases, it can be classified as:

1. Single Phase Induction Motor
2. Three Phase Induction Motor

Three Phase Induction Motor

- Three-phase AC induction motors are widely used in industrial and commercial applications.
- Induction motors are used in industry and domestic appliances because these are rugged in construction requiring hardly any maintenance, that they are comparatively cheap, and require supply only to the stator.
- These are of two types, squirrel cage and slip ring motors.
- Squirrel cage motors are widely used due to their **rugged construction and simple design**.
- Slip ring motors require external resistors to have high starting torque.

Construction of 3 Phase Induction Motor

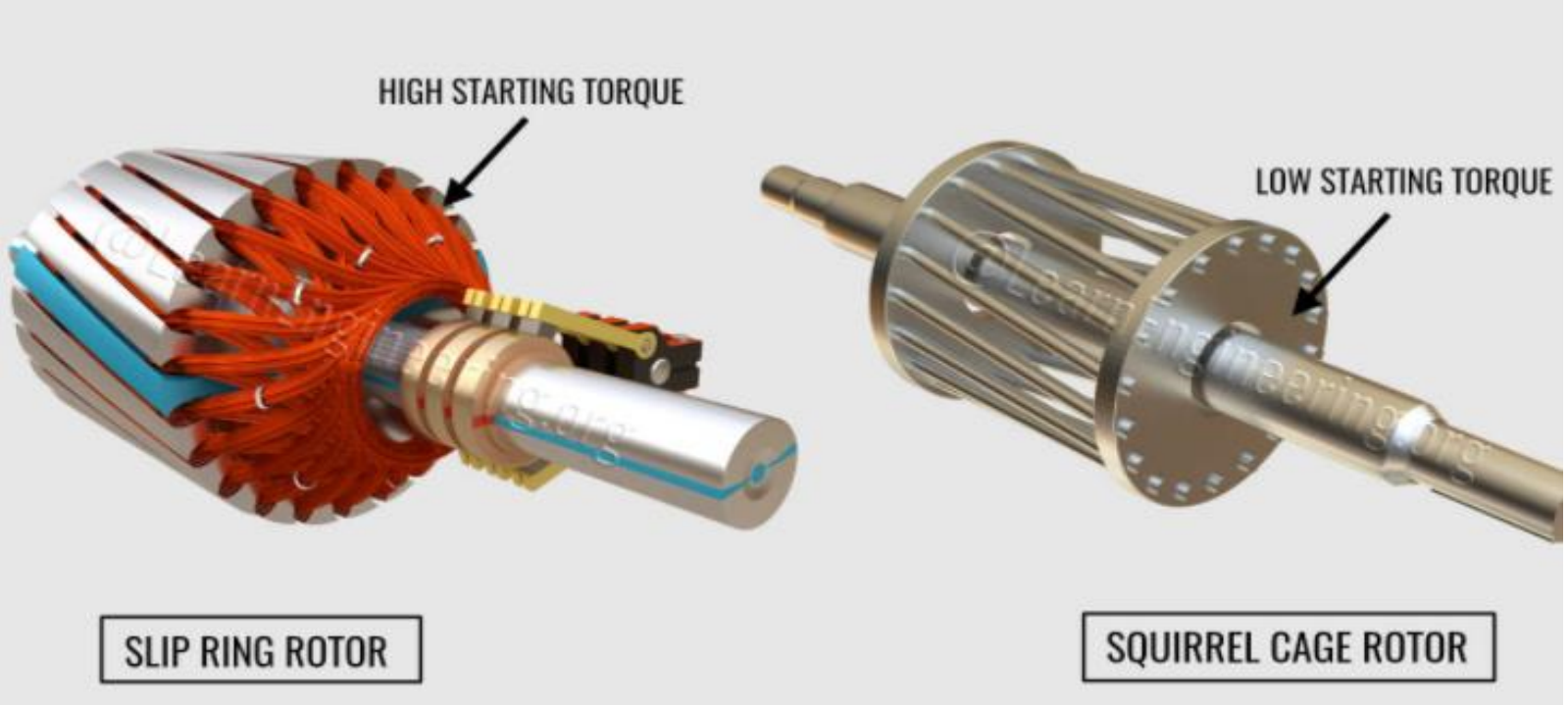
STATOR

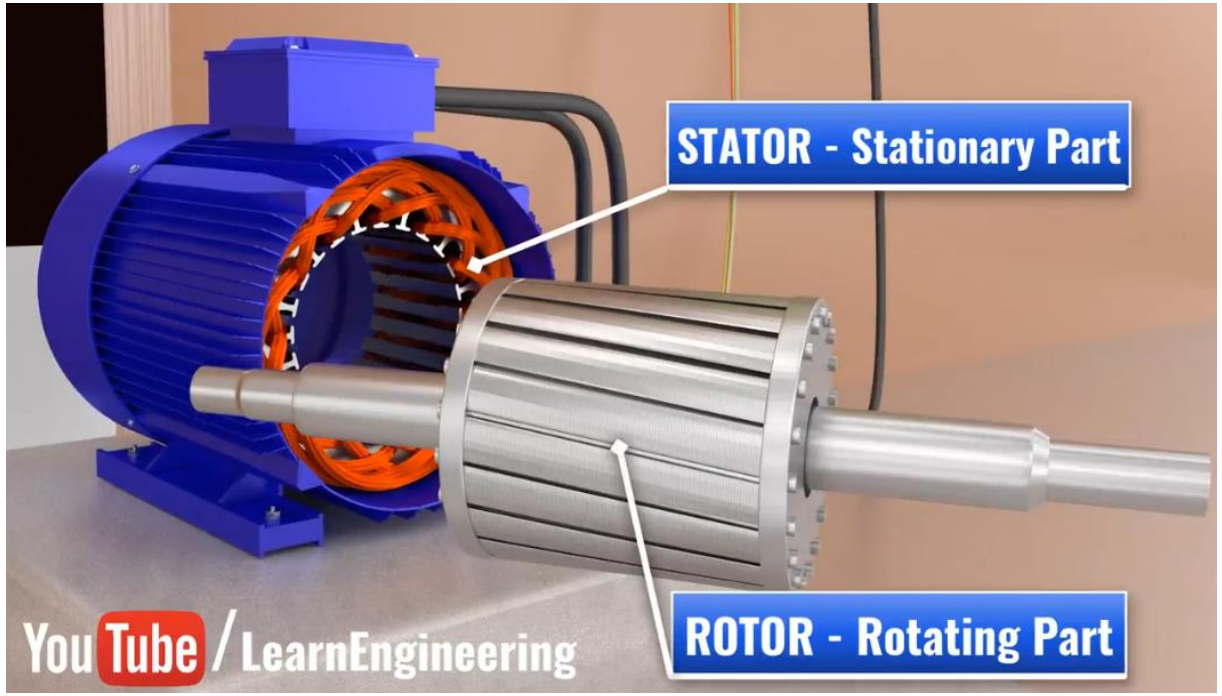
- Consists of outer frame, core and the stator windings
- Carries a 3-phase winding (3-Phase Induction Motor) OR
- The revolving magnetic flux induces an e.m.f. in the rotor by mutual induction.

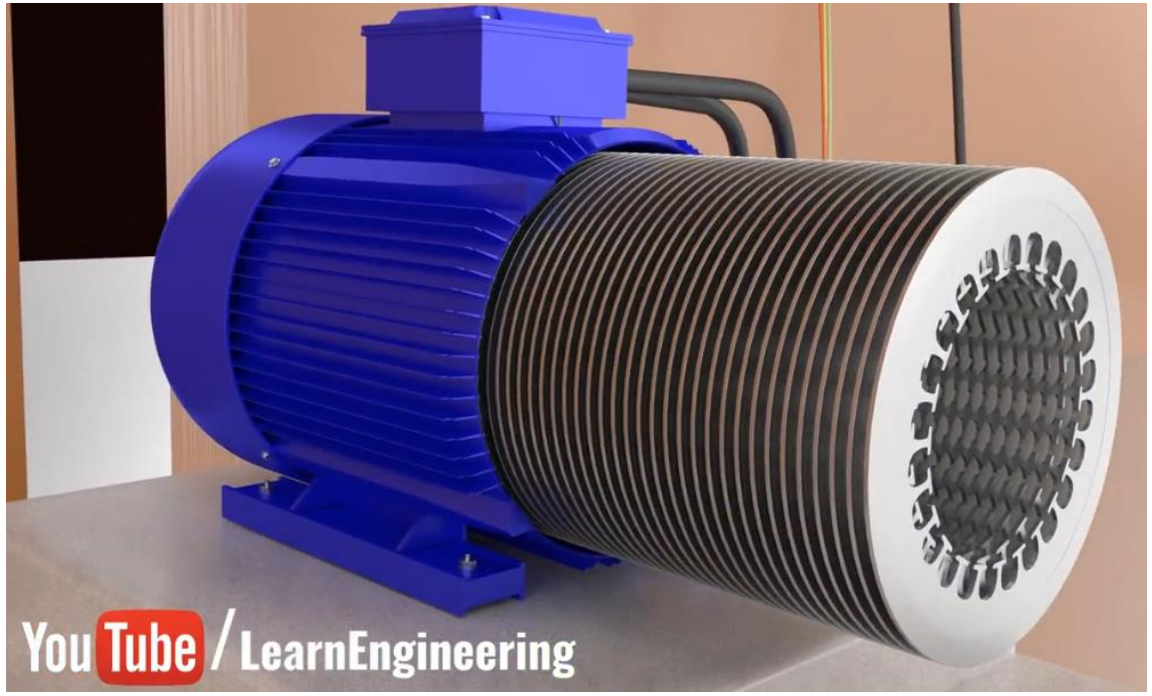
ROTOR

- The squirrel cage rotor consists of **aluminum, brass or copper** bars. These bars are called rotor conductors and placed in the slots on the periphery of the rotor. The copper or aluminum rings permanently short the rotor conductors called the end rings.
- As end rings **permanently short** the bars, the rotor electrical resistance is very small and it is not possible to add external resistance as the bars get permanently shorted.

Slip Ring Rotor and Squirrel Cage Rotor




STATOR - Stationary Part
ROTOR - Rotating Part
YouTube / LearnEngineering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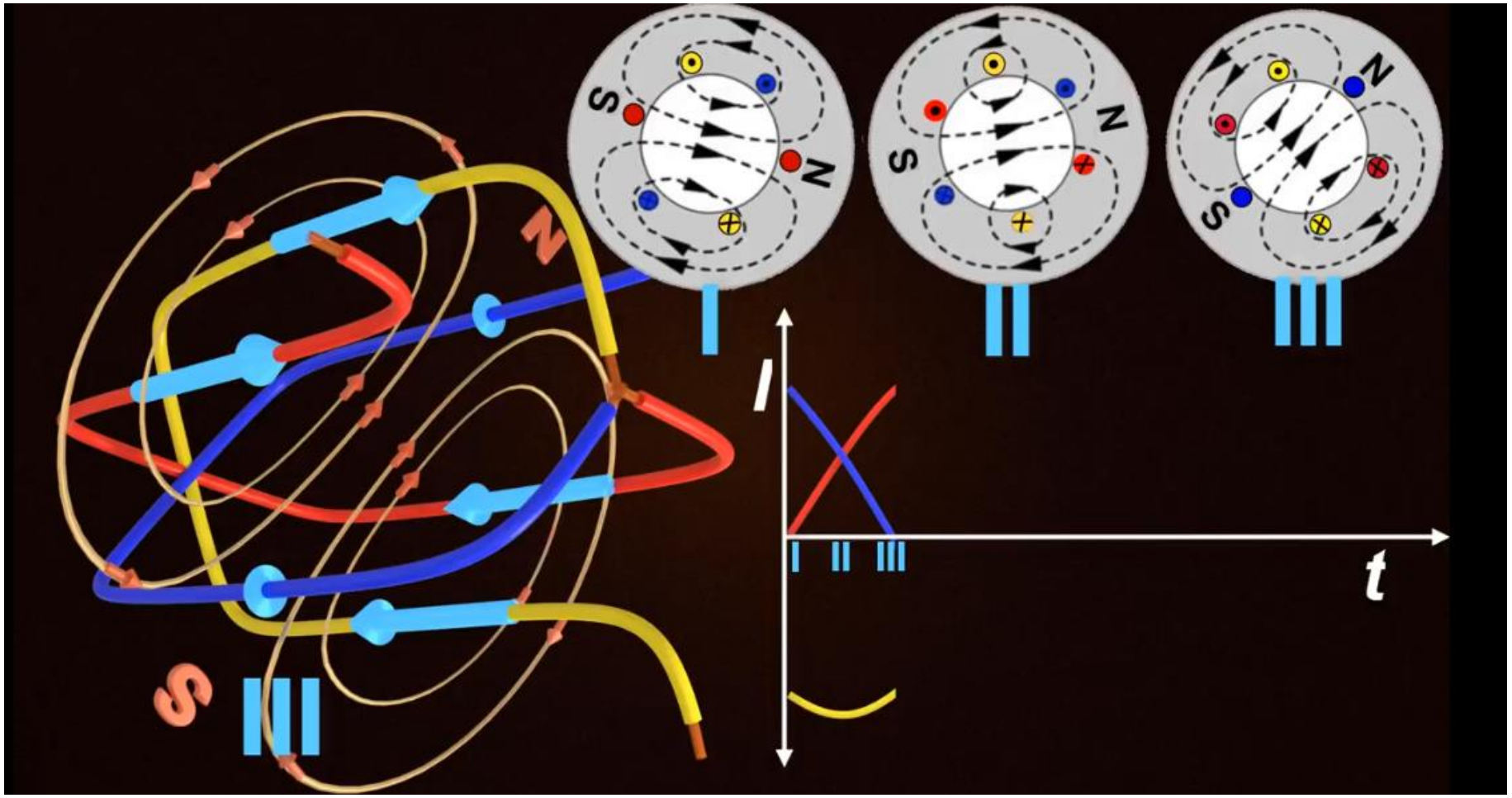
Working Principle of 3 Phase Induction Motor

- https://www.youtube.com/watch?v=AQqyGNOP_3o
- The stator of the motor consists of overlapping winding offset by an electrical angle of 120°. When we connect the primary winding, or the stator to a 3 phase AC source, it establishes rotating magnetic field which rotates at the synchronous speed.
- According to Faraday's law, an e.m.f. would be induced in any circuit whenever there is a rate of change of magnetic flux linkage through the circuit.
- As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, **an emf is induced in the rotor copper bar** and due to this emf a **current flows through the rotor conductor**.
- Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation.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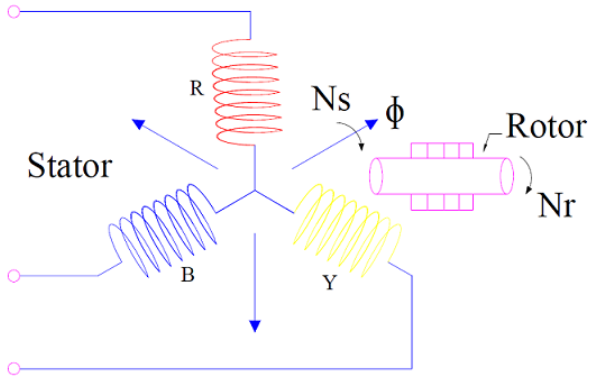
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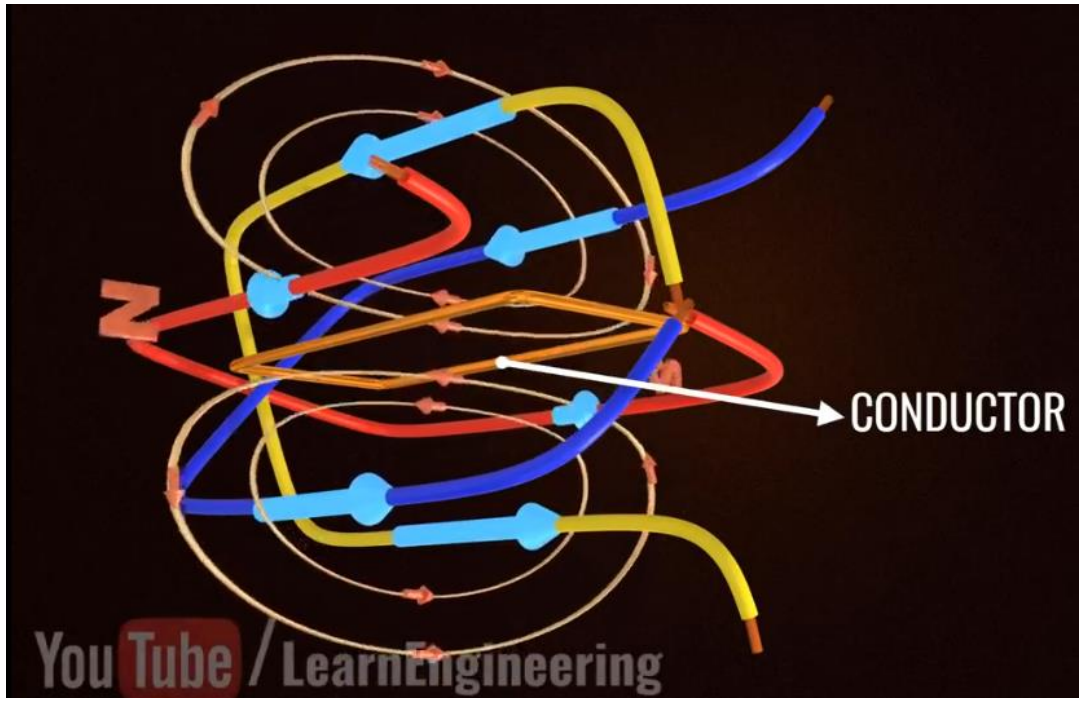
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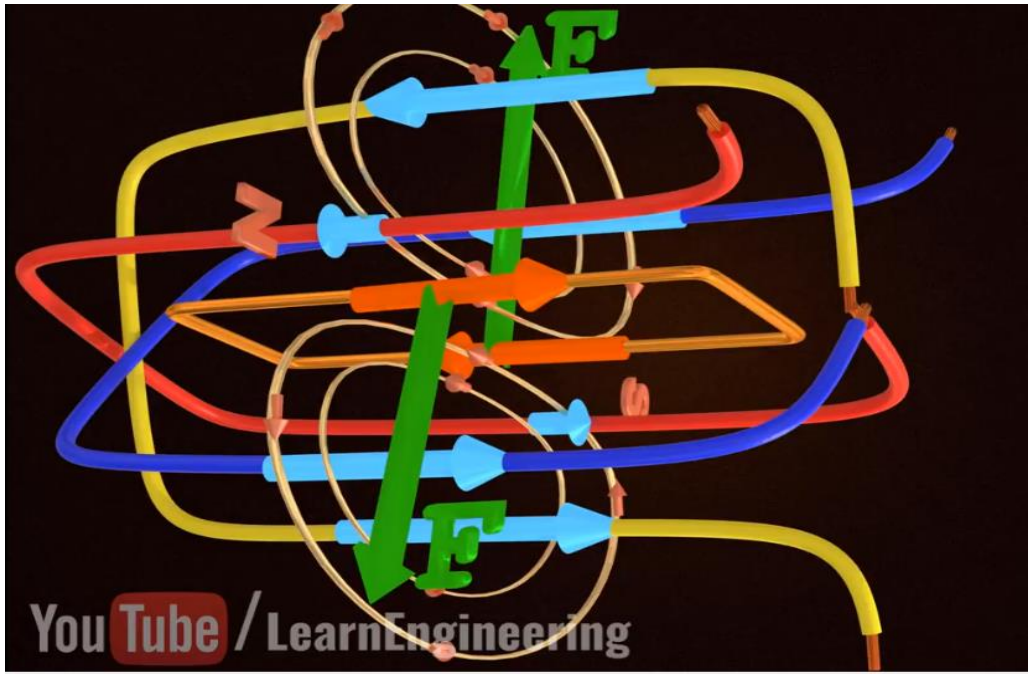
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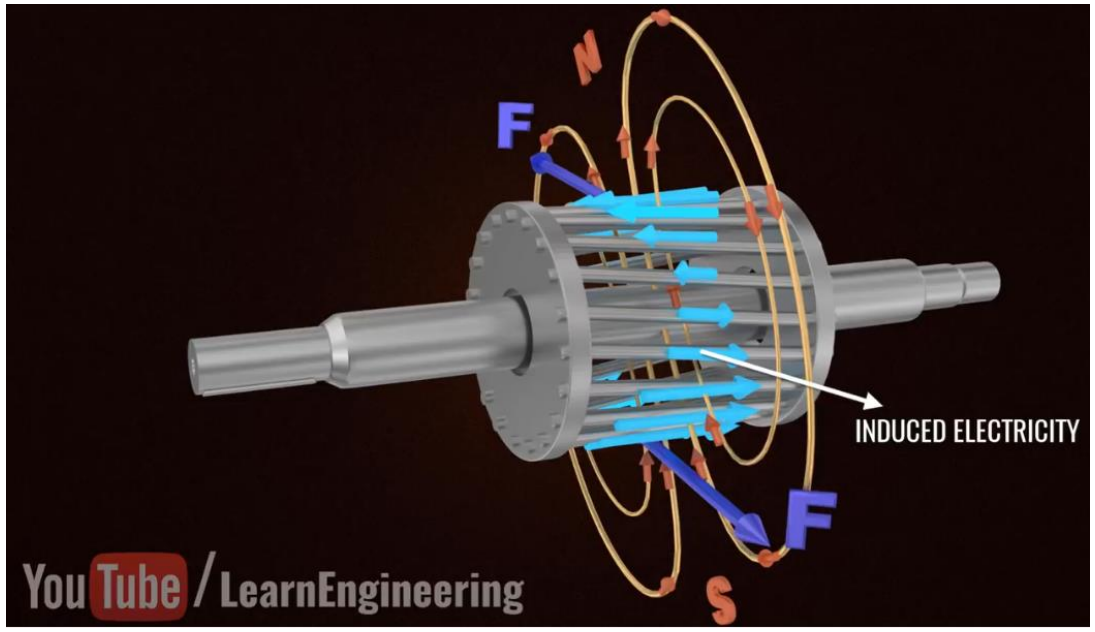
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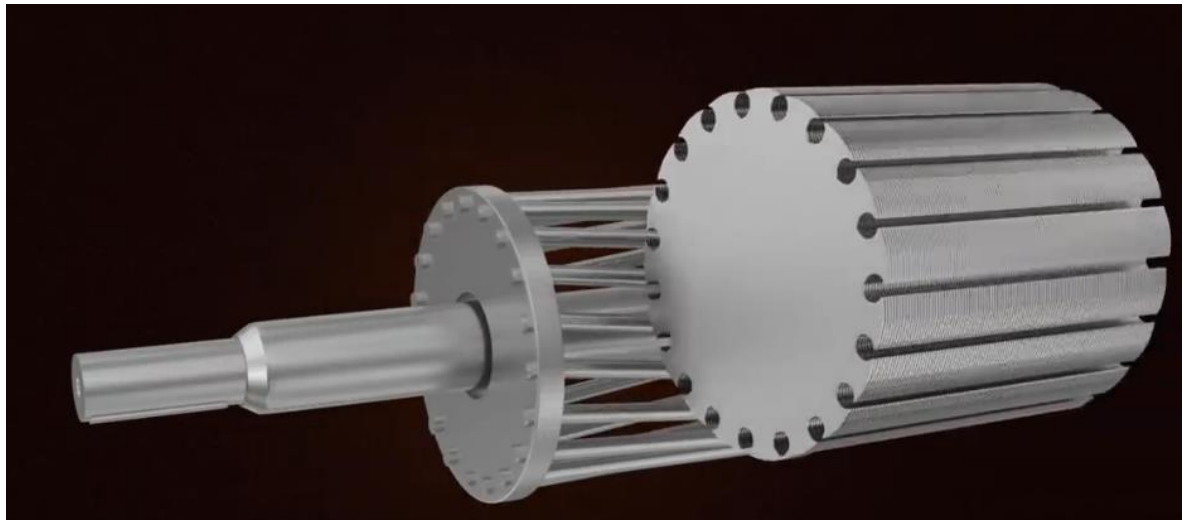


QUICK QUIZ (POLL)

The basic operation of an induction motor is based on

(a) self induction.

(b) mutual induction.

(c) magnetic locking.

(d) Lorentz Force.

Working Principle of 3 Phase Induction Motor

Q: What must be the speed of the rotor?

- From the working principle of three phase induction motor, it may be observed that the **rotor speed should not reach the synchronous speed produced by the stator**.
- If the speeds become equal, there would be no such relative speed, so no emf induced in the rotor, and no current would be flowing, and therefore no torque would be generated.
- Consequently, the rotor cannot reach the synchronous speed. The difference between the stator (synchronous speed) and rotor speeds is called the slip. The rotation of the magnetic field in an induction motor has the **advantage** that no electrical connections need to be made to the rotor.

Slip

Definition: The slip in an induction motor is the difference between the main flux speed and their rotor speed. The symbol S represents the slip. It is expressed by the percentage of synchronous speed. Mathematically, it is written as

$$\%S = \frac{N_s - N}{N_s} \times 100$$

The value of slip at full load varies from 6% in case of small motor and 2% in the large motor.

QUICK QUIZ (POLL)

When the rotor of three phase induction motor run at synchronous speed, the value of slip will be

(a) 0

(b) 0.1

(c) 0.5

(d) 1

Advantages of 3 Phase Induction Motor

1. Self-starting.
2. No Brushes
3. No commutator
4. Rugged in construction.
5. Cheaper.
6. Ease of operation
7. High Starting torque

Applications of 3 Phase Induction Motor

1. Lifts
2. Cranes
3. Hoists
4. Large capacity exhaust fans
5. Driving lathe machines
6. Crushers
7. Oil extracting mills
8. Electric Vehicle
9. Textile and etc.

Single Phase Induction Motor

- We use the single-phase power system more widely than three phase system for domestic purposes, commercial purposes and some extent in industrial uses.
- single-phase system is more economical than a three-phase system and the power requirement in most of the houses, shops, offices are small, which can be easily met by a single phase system.
- single phase motors are simple in construction, cheap in cost, reliable and easy to repair and maintain.
- Due to all these advantages, the single phase motor finds its application in **vacuum cleaners, fans, washing machines, pumps, blowers, etc.**
- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly.
- One is the main and the other is the auxiliary winding or starting winding

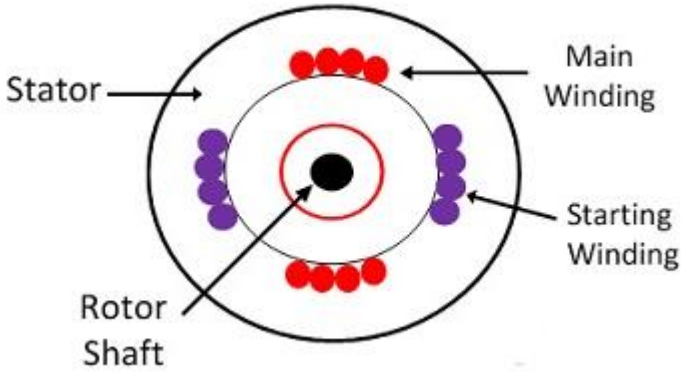
Construction of Single Phase Induction Motor

STATOR

- The construction of the stator of the single-phase induction motor is similar to that of three phase induction motor.
- However, 1-Phase motor has two stator windings namely the main winding and the auxiliary winding.
- These two windings are placed perpendicular to each other.

ROTOR

- The construction of the rotor of the single-phase induction motor is similar to the squirrel cage three-phase induction motor.



Working Principle of Single Phase Induction Motor

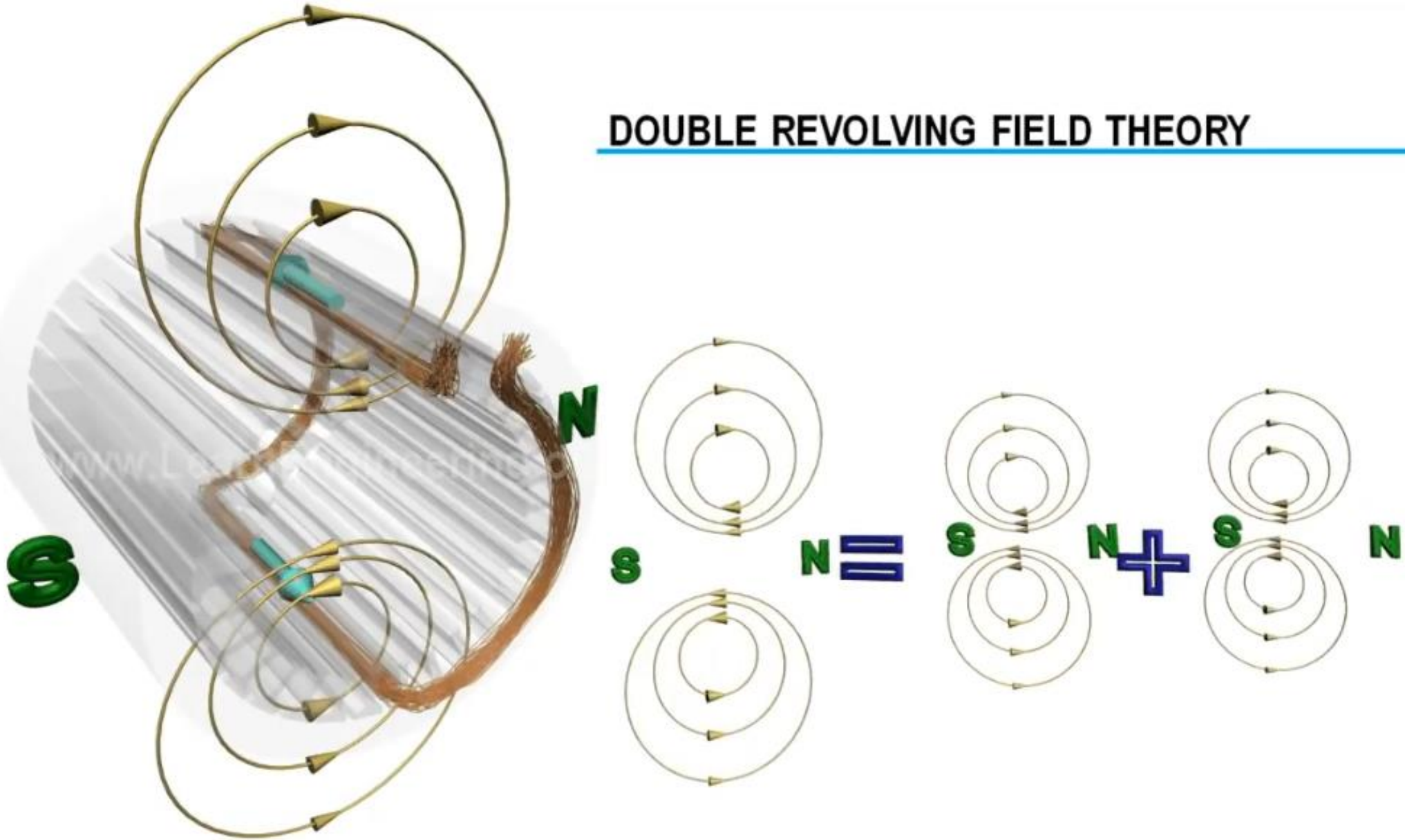
- Link: https://www.youtube.com/watch?v=awrUxv7B-a8
- The working principle of single phase induction motor is explained with **Double Revolving Field Theory.**
- This theory states that:

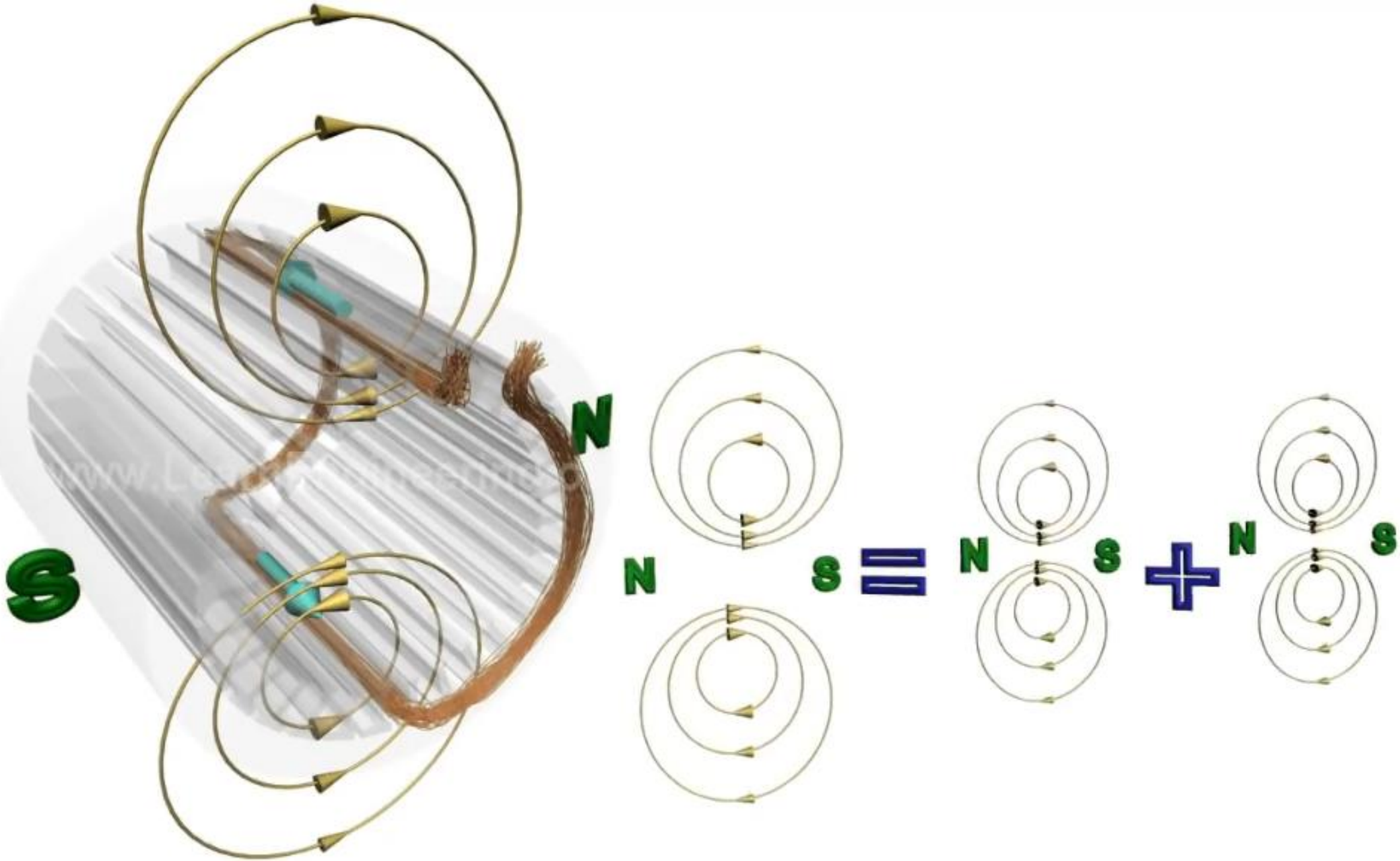
"A pulsating magnetic field is resolved into two rotating magnetic fields. They are equal in magnitude but opposite in directions. The induction motor responds to each of the magnetic fields separately. The net torque in the motor is equal to the sum of the torque due to each of the two magnetic fields".

Working Principle of Single Phase Induction Motor

- A single-phase ac current supplies the main winding that produces a pulsating magnetic field.
- Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.
- The interaction between the fields and the current induced in the rotor bars generates opposing torque.
- Under these conditions, with only the main field energized the motor will NOT start
- However, if an external torque moves the motor in any direction, the motor will begin to rotate.

DOUBLE REVOLVING FIELD THEORY

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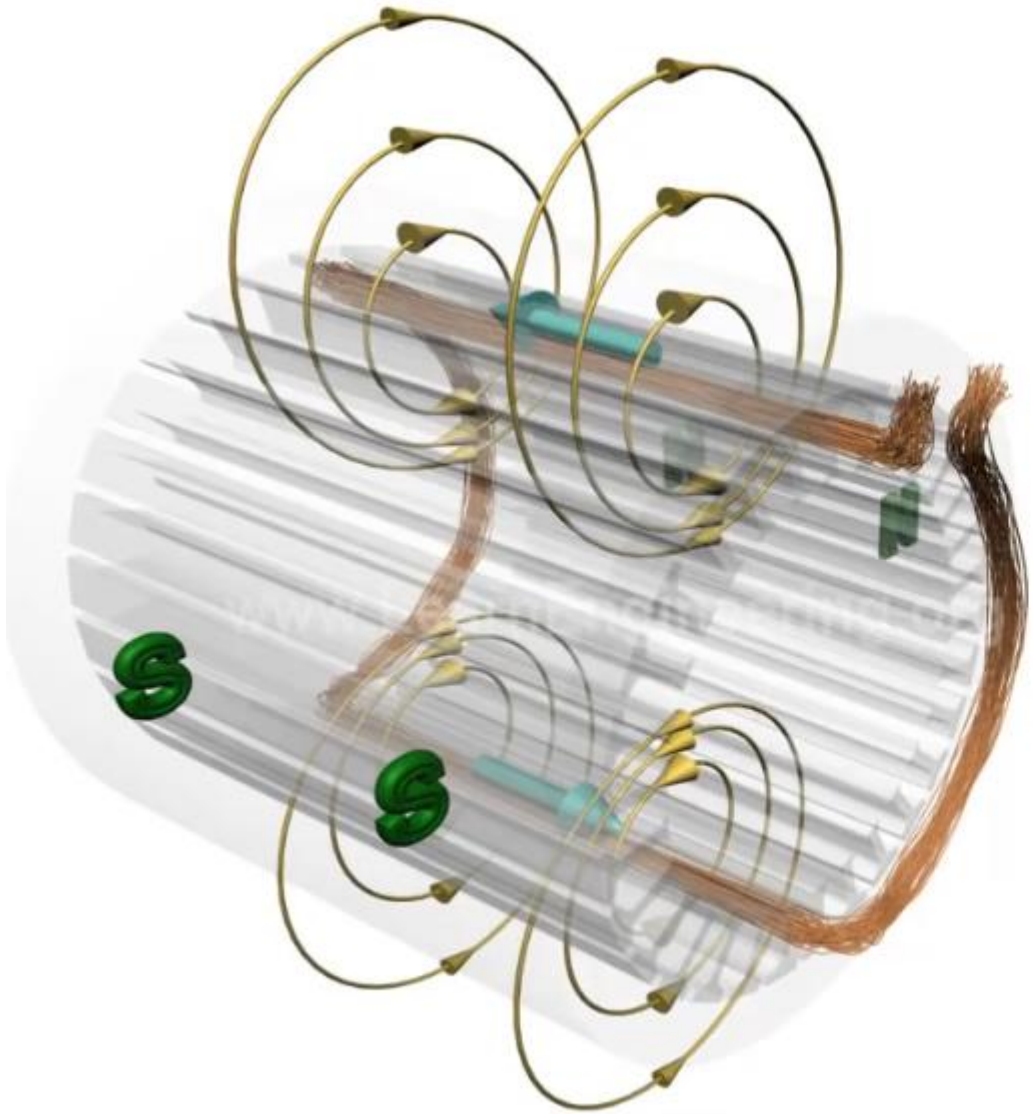
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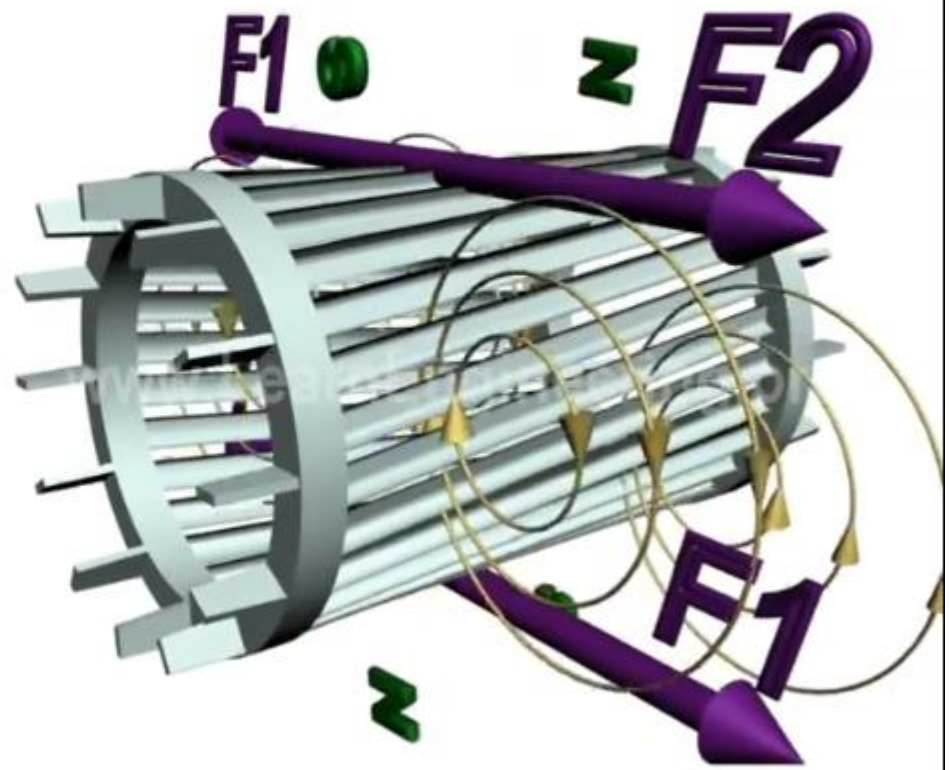
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Why Single Phase Induction Motor is not Self Starting?

- According to double field revolving theory, we can resolve any alternating quantity into two components. Each component has a magnitude equal to the half of the maximum magnitude of the alternating quantity, and both these components rotate in the opposite direction to each other.
- So, they cancel each other and hence the net torque experienced by the rotor at the starting condition is zero. So, the single phase induction motors are not self-starting motors.

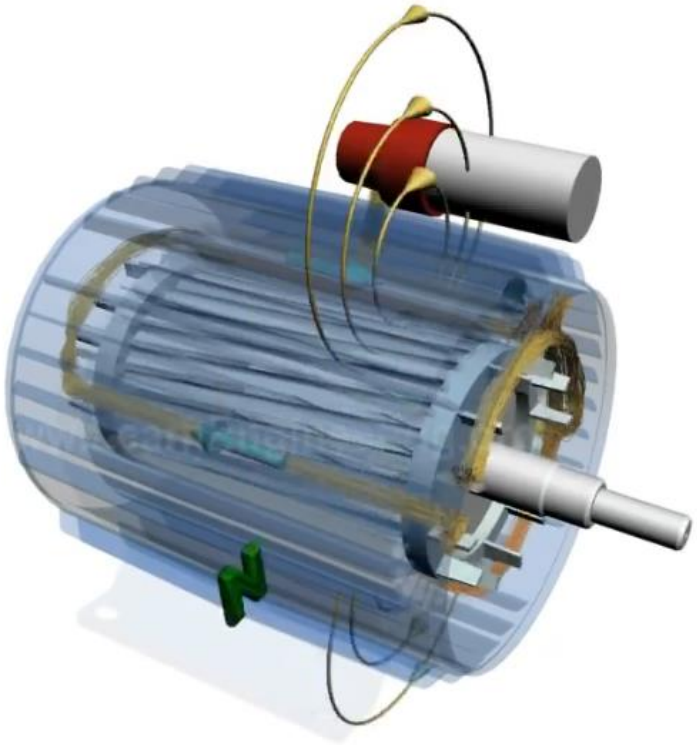
Working Principle of Single Phase Induction Motor

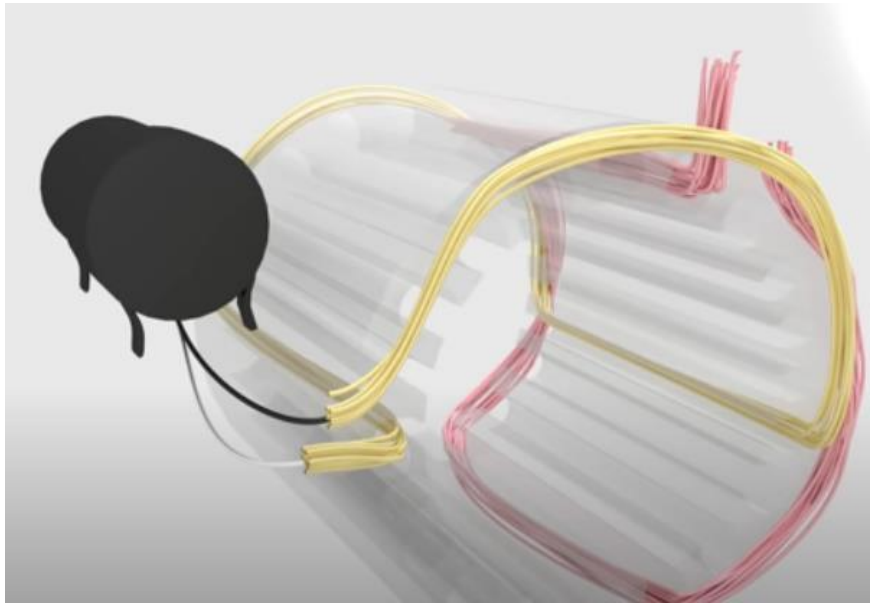
- The solution to this problem is that if we make the stator flux rotating type, rather than alternating type, which rotates in one particular direction only. Then the induction motor will become self-starting.
- Now for producing this rotating magnetic field, we require two alternating flux, having some phase difference angle between them. When these two fluxes interact with each other, they will produce a resultant flux. This resultant flux is rotating in nature and rotates in space in one particular direction only.
- Once the motor starts running, we can remove the additional flux. The motor will continue to run under the influence of the main flux only.
- In single -phase induction motors, Auxiliary windings are used for this purpose.

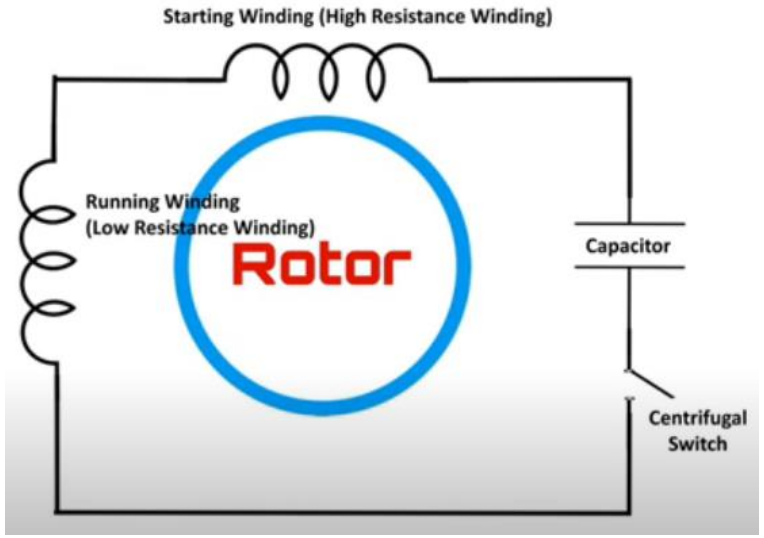
Working Principle of Single Phase Induction Motor

Role of the capacitor:

- The Auxiliary winding is connected through a capacitor. When the capacitor is turned on, similar to main winding, revolving two magnetic fields of the same magnitude but opposite direction are observed on Auxiliary winding.
- From these two magnetic fields of Auxiliary winding, one cancel outs one of the magnetic fields of main winding whereas the other adds up with another magnetic field of main winding. Thus, resulting in a **single revolving magnetic field with high magnitude**. This produces **force** in one direction, hence rotating the rotor.
- Once the rotor starts rotating, it rotates even if the capacitor is turned off.
- The Auxiliary winding is disconnected using a centrifugal switch when the rotor attains 75% of synchronous speed.






Starting Winding (High Resistance Winding)
Running Winding
(Low Resistance Winding)
Rotor
Capacitor
Centrifugal
Switch

QUICK QUIZ (POLL)

If the auxiliary winding is not available in an Induction motor, then:

A. Motor will run with less speed.
B. Motor will run in reverse direction
C. Motor will run with more speed.
D. Motor will not run

Applications of Single Phase Induction Motor

1. Fans
2. Refrigerators
3. Air-conditioners
4. Vacuum cleaners
5. Washing machines
6. Centrifugal pumps
7. Blowers, etc.