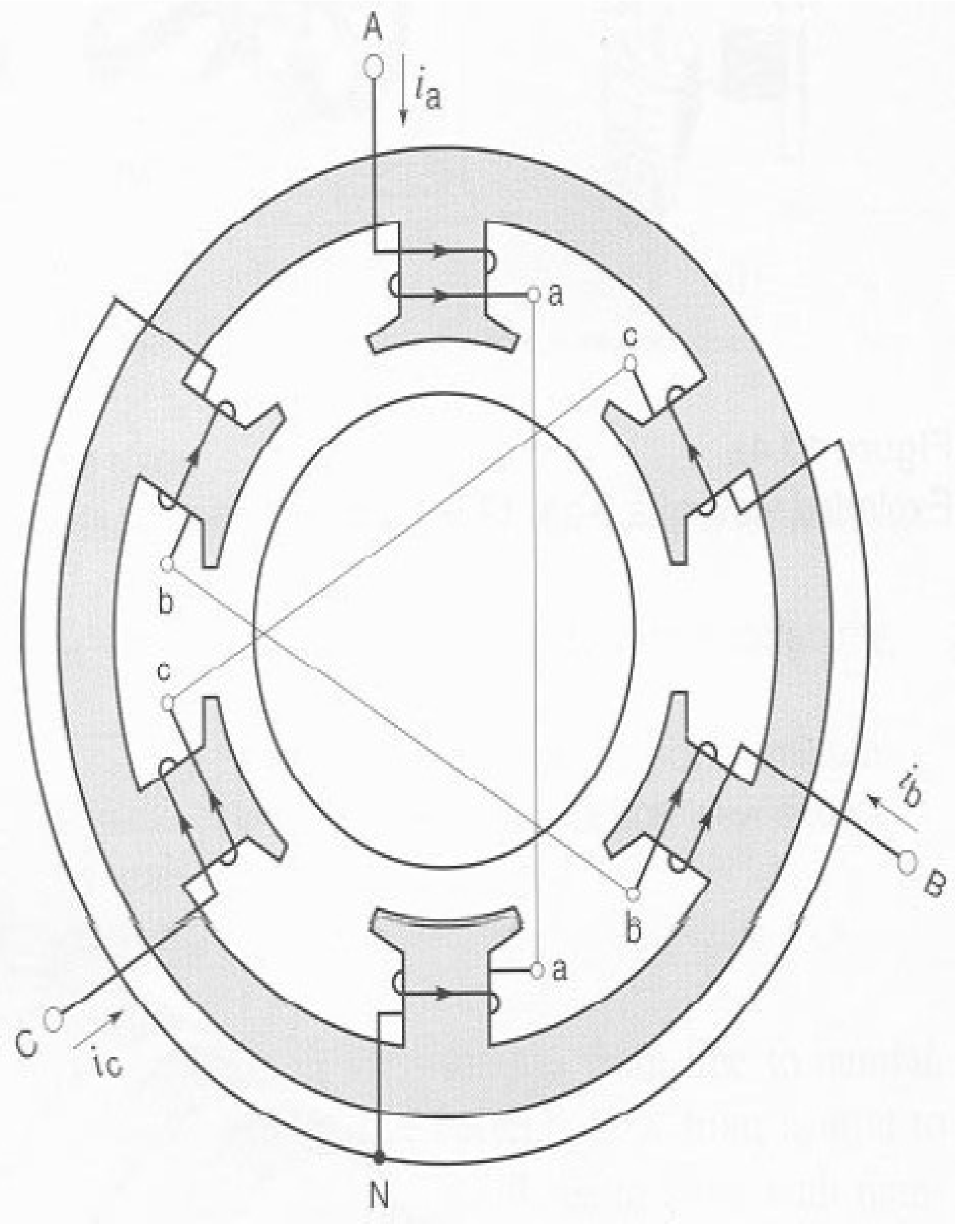
LECTURE 2

Slip and Rotor Speed

1. **Slip *s***
   - The rotor speed of an Induction machine is different from the speed of Rotating magnetic field. The % difference of the speed is called slip.

$$s = \frac{n_s - n_r}{n_s} \quad OR \quad n_r = n_s(1 - s)$$

   - Where;
   - n_s = synchronous speed (rpm)
     n_r = mechanical speed of rotor (rpm)
   - under normal operating conditions,
     s= 0.01 ~ 0.05, which is very small and the actual speed is very close to synchronous speed.
   - Note that : s is not negligible


A
i_a
a
c
b
c
b
a
B
i_b
C
i_c
N

Induction Motor: Rotating Field

- Consider a simple stator with 6 salient poles - windings AN, BN, CN.
- The windings are mechanically spaced at 120° from each other.
- The windings are connected to a 3-phase source.
- AC currents Ia, Ib and Ic will flow in the windings, but will be displaced in time by 120°.
- Each winding produces its own MMF,which creates a flux across the hollow interior of the stator.
- The 3 fluxes combine to produce a magnetic field that rotates at the same frequency as the supply

Slip and Rotor Speed

- **Rotor Speed**
  - When the rotor move at rotor speed, $n_{r\,(rps)}$, the stator flux will circulate the rotor conductor at a speed of (n_s-n_r) per second. Hence, the frequency of the rotor is written as:

$$f_r = (n_s - n_r)p$$
$$= sf$$

- Where; s = slip
  f = supply frequency

Note :

At stator : $n_s = \frac{120f}{p}$

$$\therefore f = \frac{n_s p}{120} \quad .....(i)$$

At Rotor : $n_s - n_r = \frac{120f}{p}$

$$\therefore f_r = \frac{(n_s - n_r)p}{120} \quad .....(ii)$$

$(ii) \div (i)$: $f_r = s.f$

Principle of Operation

Torque producing mechanism

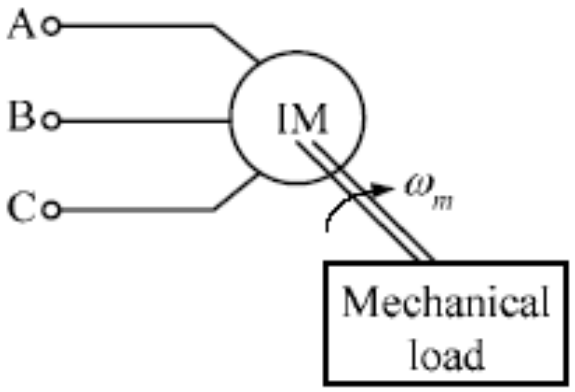
- When a 3 phase stator winding is connected to a 3 phase voltage supply, 3 phase current will flow in the windings, hence the stator is energized.
- A rotating flux Φ is produced in the air gap.The flux Φ induces a voltage E_a in the rotor winding

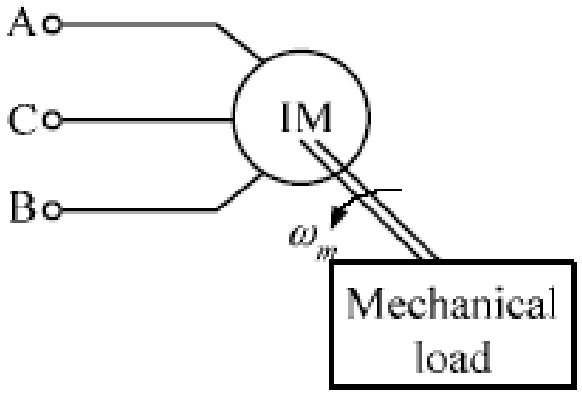
  (like a transformer).
- The induced voltage produces rotor current, if rotor circuit is closed.
- The rotor current interacts with the flux Φ, producing torque.

The rotor rotates in the direction of the rotating flux.

Direction of Rotor Rotates

- Q: How to change the direction of
- rotation?
- • A: Change the phase sequence of the
- power supply.





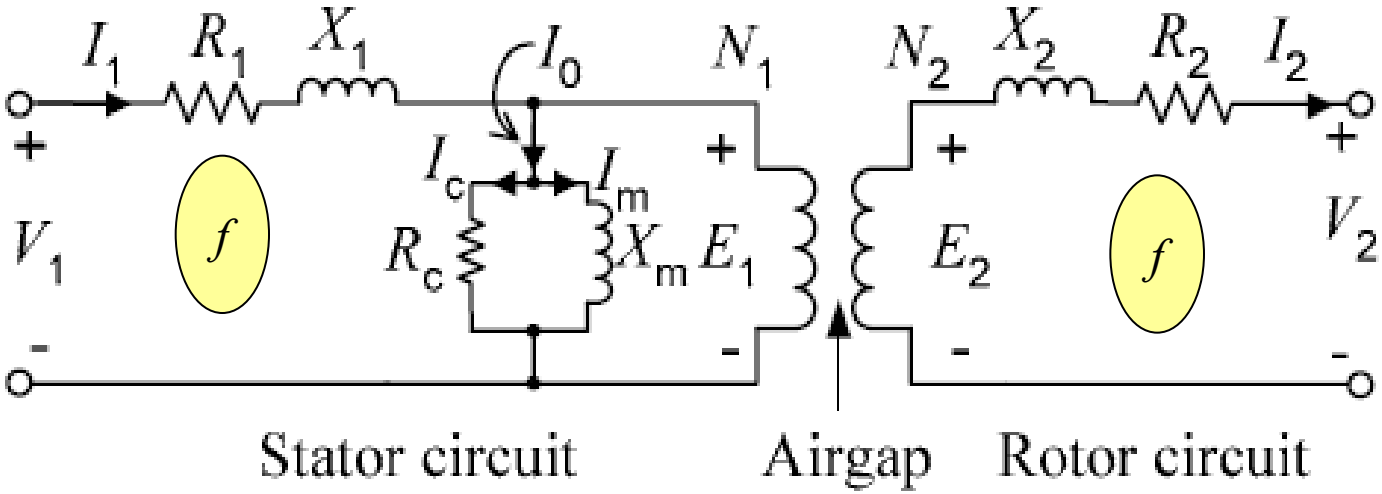
Equivalent Circuit of Induction Machines

- **Conventional equivalent circuit**
  - ❖ *Note:*
    - *Never use three-phase equivalent circuit. Always use per- phase equivalent circuit.*
    - *The equivalent circuit always bases on the Y connection regardless of the actual connection of the motor.*
    - *Induction machine equivalent circuit is very similar to the single-phase equivalent circuit of transformer. It is composed of stator circuit and rotor circuit*

Equivalent Circuit of Induction Machines

- **Step1 Rotor winding is open**

  (The rotor will not rotate)



- Note:
  - the frequency of E_2 is the same as that of E_1 since the rotor is at standstill. At standstill s=1.