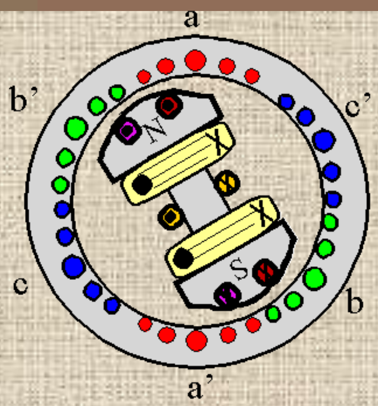
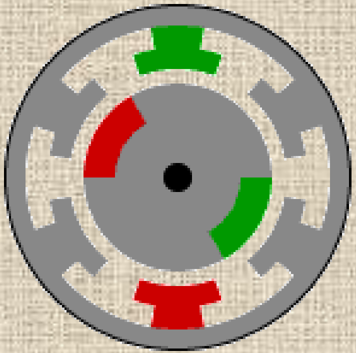
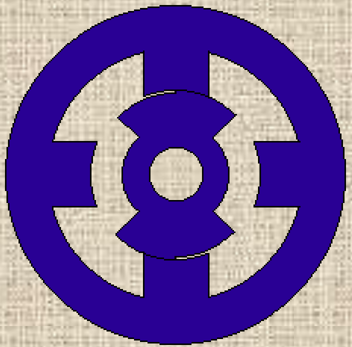
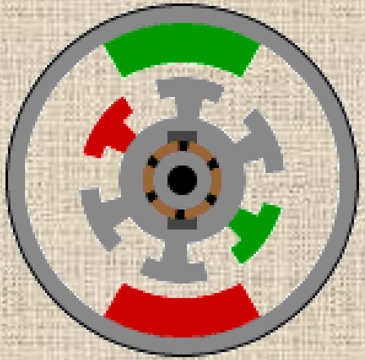
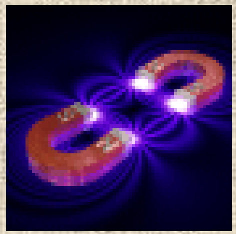
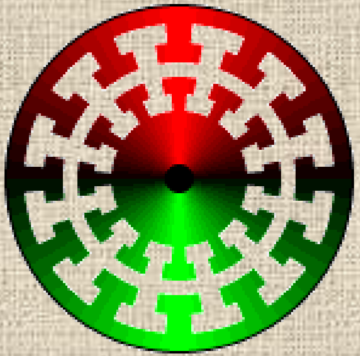


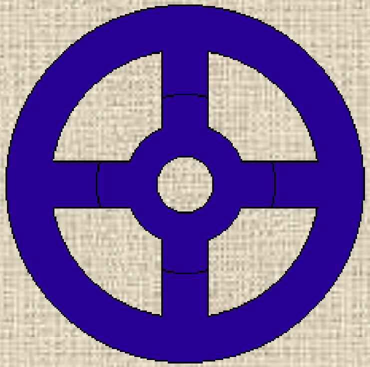
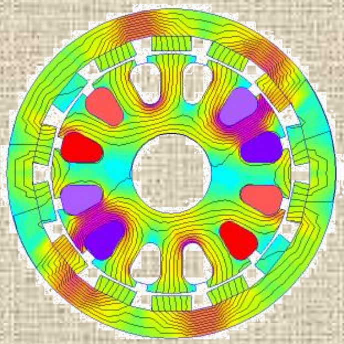
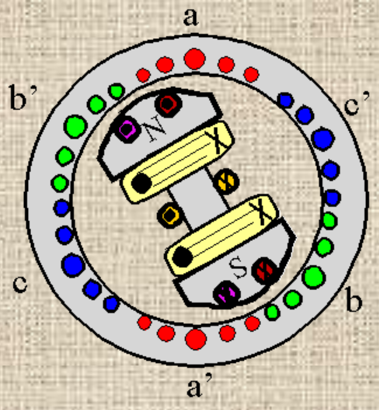




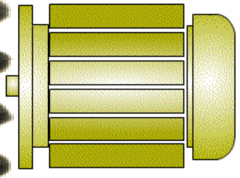
EE552 ELECTRICAL MACHINES III

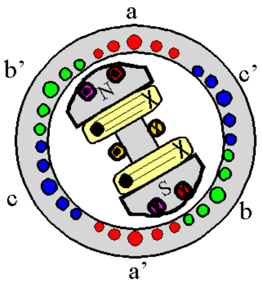
LECTURE 7





LECTURE NOTES

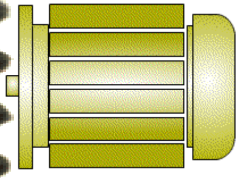


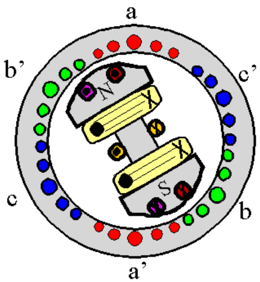
ELECTRICAL MACHINES III

EE552

SPRING 2018

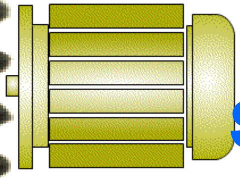
Dr : MUSTAFA AL-REFAI



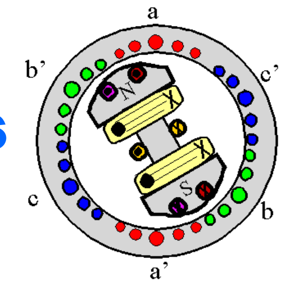


LECTURE 7

SYNCHRONOUS GENERATOR



SYNCHRONOUS GENERATOR
Speed of rotation of synchronous generator



- **synchronous generators are *synchronous, during their operation***

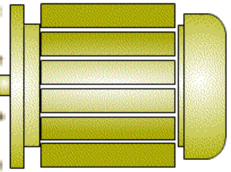
means: electrical frequency is synchronized with mechanical speed of rotor

- **Relation between electrical frequency of stator and mechanical speed of rotor as shown before: $f_e = n_m\, p / 120$**

f_e : electrical frequency in Hz

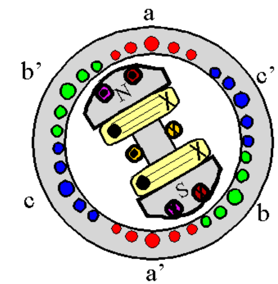
n_m: speed of rotor in r/min

p: number of poles



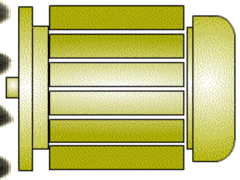
SYNCHRONOUS GENERATOR

Speed of rotation of synchronous generator

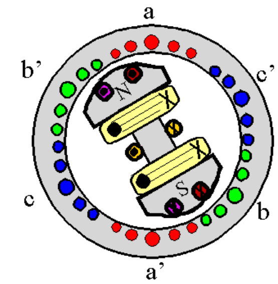


- **Electric power generated at 50 or 60 Hz, so rotor must turn at fixed speed depending on number of poles on machine**

- **To generate 60 Hz in 2 pole machine, rotor must turn at 3600 r/min, and to generate 50 Hz in 4 pole machine, rotor must turn at 1500 r/min**



Synchronous Machines - Stator



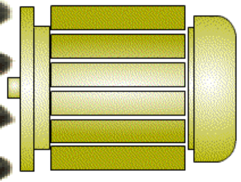
The stator carries the armature windings which have constant magnitude, constant frequency emf's induced in them

• Stator made from laminated material to limit the eddy current losses. the eddy current losses.

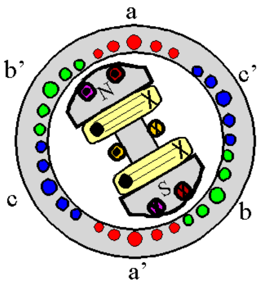
• Fields produced in stator are rotating and time variant

• Stators are cylindrical and house a balanced three phase winding

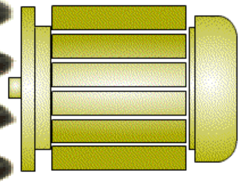
• Small machines may have a single phase winding.



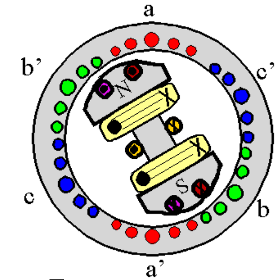
Armature Windings



- Single layer
- Double later (commonly used)
- Full pitch winding
- Fractional pitch winding (used)
- Concentrated winding
- Distributed winding (used)



AC winding design



The windings used in rotating electrical machines can be classified as

- **Concentrated Windings**

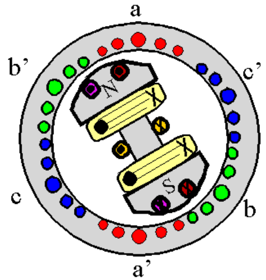
- **All the winding turns are wound together in series to form one multi-turn coil**

- **All the turns have the same magnetic axis**

- **Examples of concentrated winding are**

– field windings for salient-pole synchronous machines
– D.C. machines
– Primary and secondary windings of a transformer

AC winding design



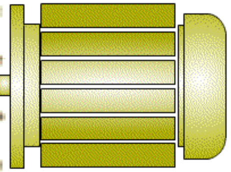
Distributed Windings

- **All the winding turns are arranged in several full-pitch or fractional-pitch coils**

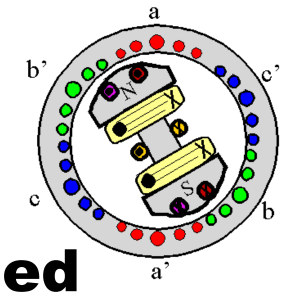
- **These coils are then housed in the slots spread around the air-gap periphery to form phase or commutator winding**

- **Examples of distributed winding are**

– Stator and rotor of induction machines
– The armatures of both synchronous and D.C. machines



AC winding design



Armature windings, in general, are classified under two main heads, namely,

- **Closed Windings**

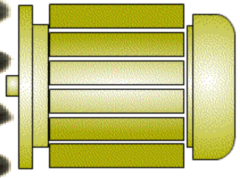
• There is a closed path in the sense that if one starts from any point on the winding and traverses it, one again reaches the starting point from where one had started

• Used only for D.C. machines and A.C. commutator machines

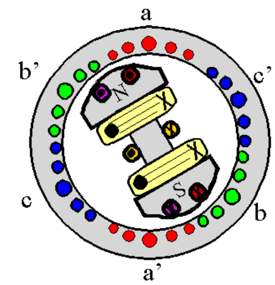
- **Open Windings**

• Open windings terminate at suitable number of slip-rings or terminals

• Used only for A.C. machines, like synchronous machines, induction machines, etc

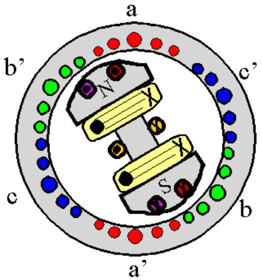


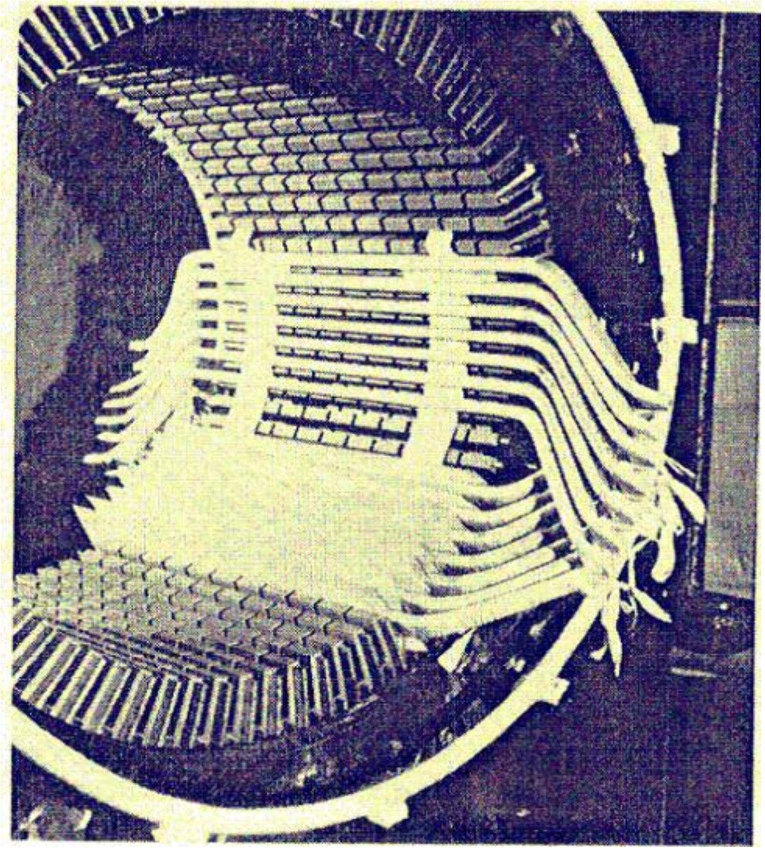
Some Of The Terms Common To Armature Windings Are Described

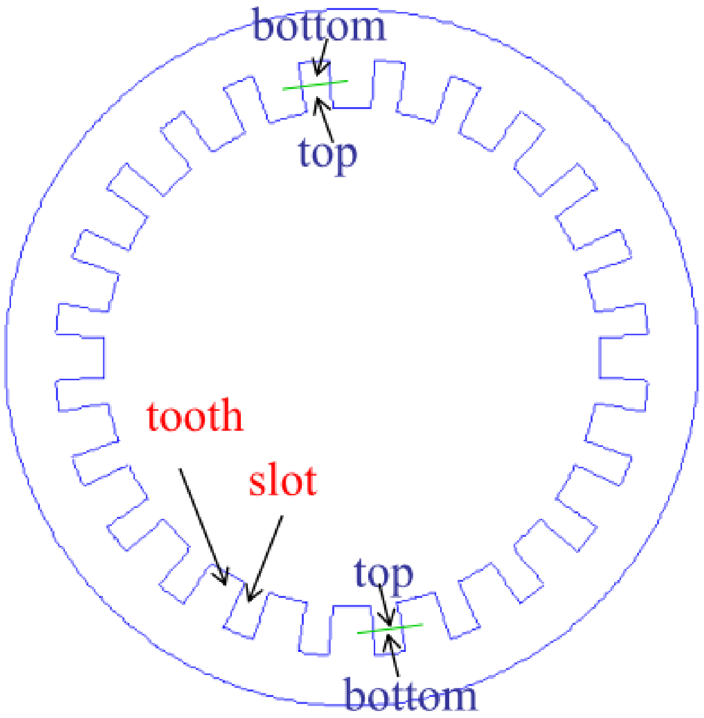


1. **Conductor.** A length of wire which takes active part in the energy conversion Process is A called A conductor.
2. **Turn.** One turn consists of two conductors.
3. **Coil.** One coil may consist of any number of turns.
4. **Coil –side.** One coil with any number of turns has two coil-sides.

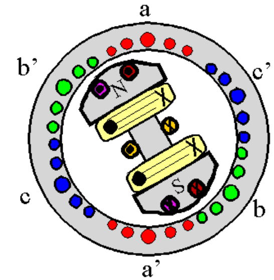
Slots and Coils

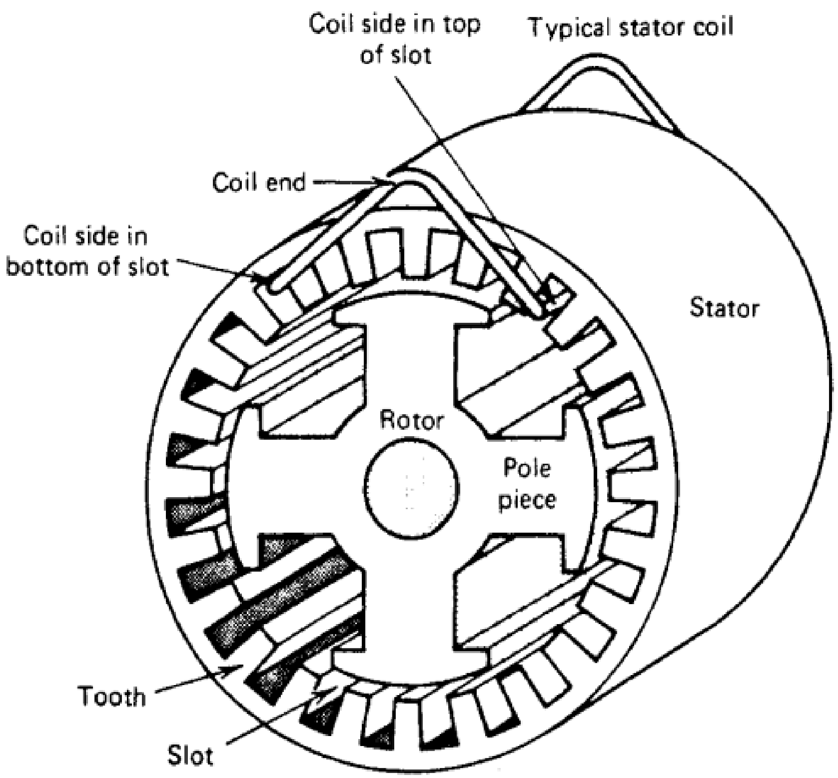


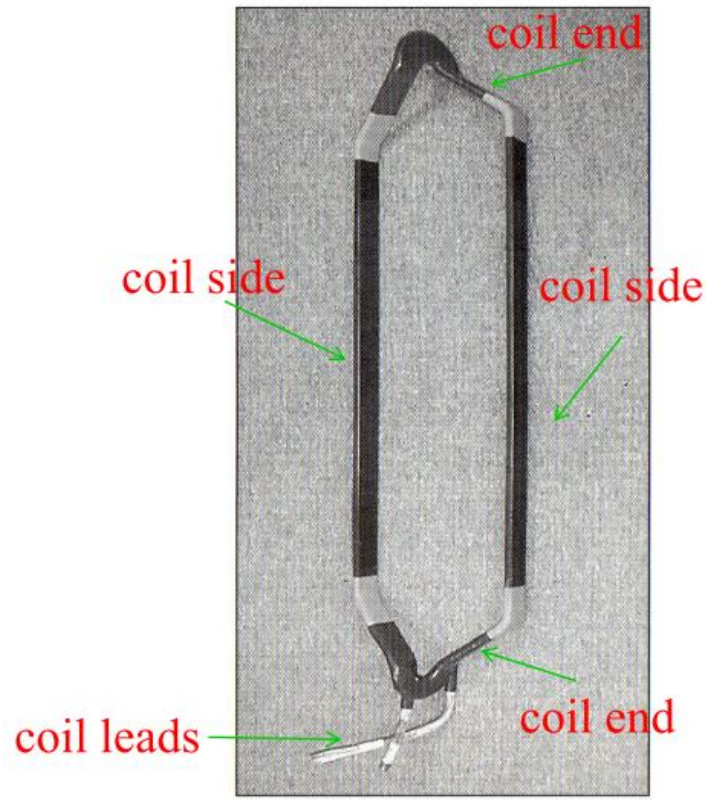




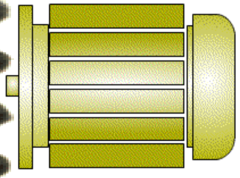
Slots and Coils



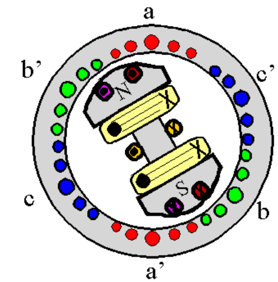




N_c turns, $2N_c$ conductors



Slots And Coilson Armature



- ❑ Each slot has 2 positions: top and bottom (double layer winding)
- ❑ Each coil needs to occupy 2 positions: top position of one slot and bottom position of another slot

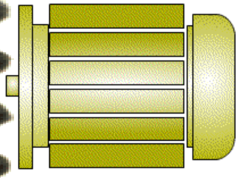
➡ Number of armature coils = Number of armature slots (S)

m phase machine: Number of coils per phase: $S_{ph} = \dfrac{S}{m}$

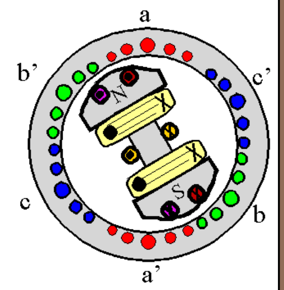
Number of turns per phase: $N_{ph} = \dfrac{S \times N_c}{m}$

Number of conductors per phase: $C_{ph} = \dfrac{S \times N_c \times 2}{m}$

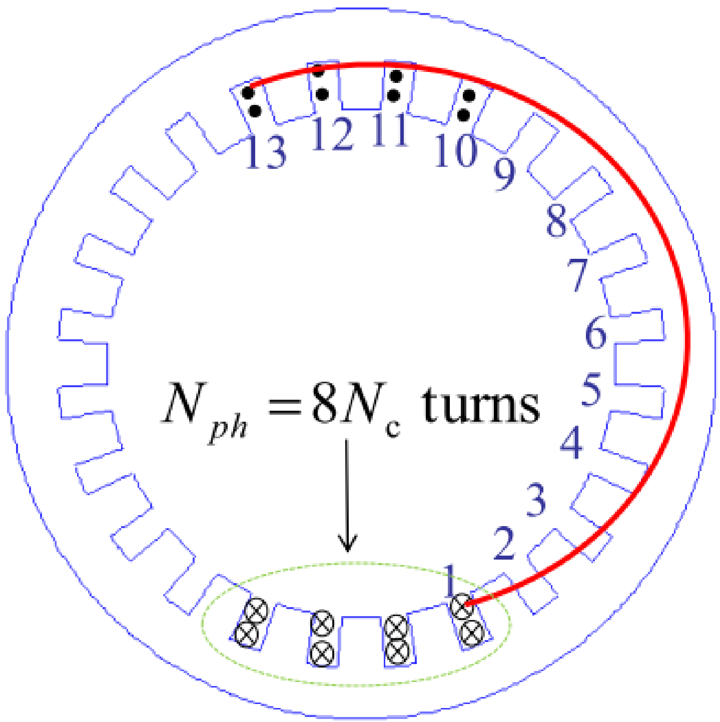
Note: The above three equations are independent of the number of poles (P). For balanced m-phase design, S_{ph} should be an integer.



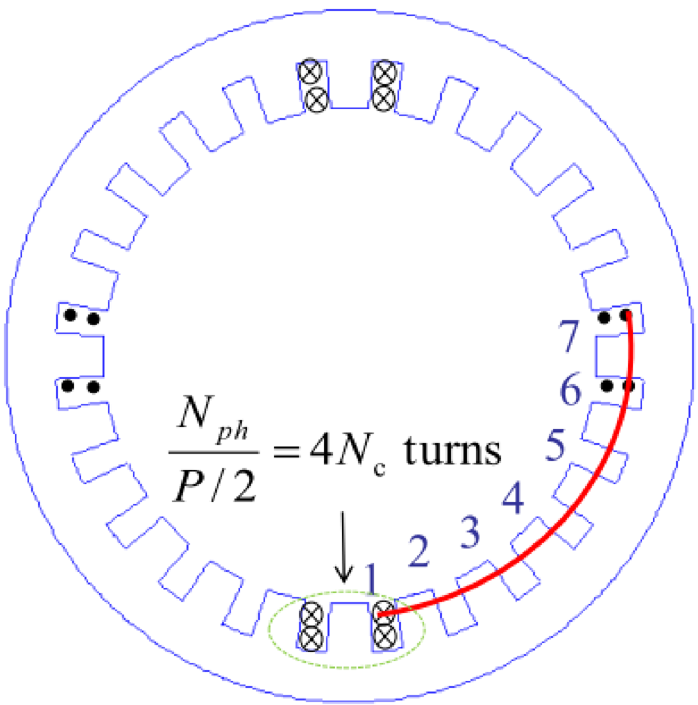
Slots and Coils



8 coils, $8N_c$ turns, $16N_c$ conductors per phase

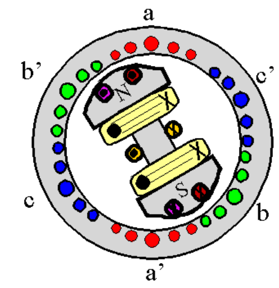


2 pole, Phase A, full-pitch



4 pole, Phase A, full-pitch

Slot Pitch



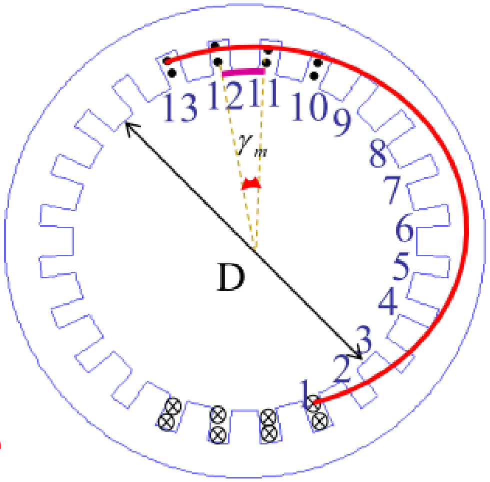
Slot pitch in electrical angle is defined by $\gamma = \frac{P}{2}\gamma_m$

where γ_m is the mechanical angle between two adjacent slots:

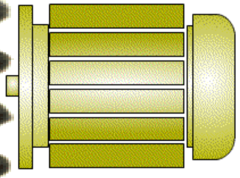
$$\gamma_m = \frac{2\pi}{S} \qquad \Rightarrow \gamma = \frac{\pi P}{S}$$

The slot pitch is also defined as the arc length between two slots on stator inner circle (with diameter D)

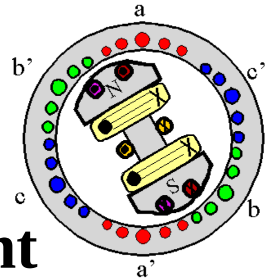
$$\tau_s = \frac{\pi D}{S}$$



3 phase, 24 slots, 2 pole
Phase A, full-pitch



Pole Pitch



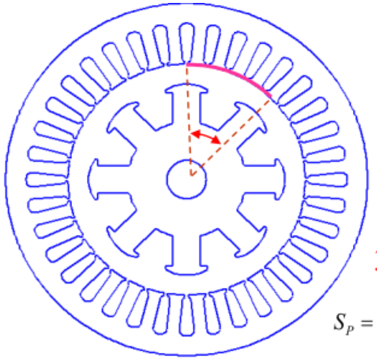
Pole Pitch: angular distance between two adjacent poles on a machine.

$$\rho_P = \frac{360^\circ}{P} = \frac{2\pi}{P}$$ **(in mechanical degree)**

Regardless of the number of poles on the machine, a pole pitch is always 180° or π **in electrical degrees.**

The pole pitch is also defined as the arc length between two adjacent poles on stator inner circle (with diameter D) :

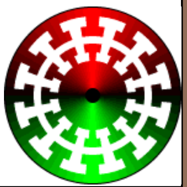
$$\tau_P = \frac{\pi D}{P}$$ (in meter or inch)



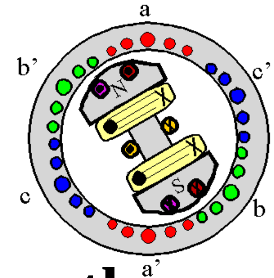
Number of Slots per Pole:

$$S_P = \frac{S}{P}$$

Note: S_P may not be an integer.



Coil Pitch



Full-Pitch Coil: If the armature coil stretches across the same angle as the pole pitch, it is called a full-pitch coil. The coil spans across slots, if S_P is an integer.

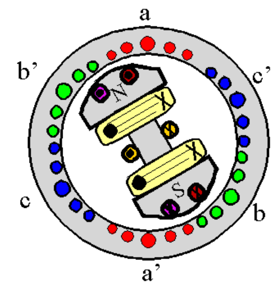
Fractional-Pitch Coil: If the armature coil stretches across an angle smaller than a pole pitch, it is called a fractional-pitch coil (or short-pitched coil, chorded coil) . The coil spans less than S_P slots.

Let S_c be the number of slots that the coil spans.

Let ρ_m be the mechanical angle that the coil spans or $\rho_m = S_c \gamma_m$.

Coil pitch in electrical angle is defined by $\rho = \frac{P}{2}\rho_m$

$$\Rightarrow \frac{\rho}{\pi} = \frac{\rho_m}{\rho_P} = \frac{S_c}{S_P}$$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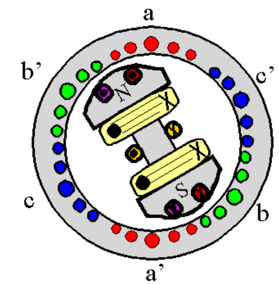
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END OF LECTURE 7