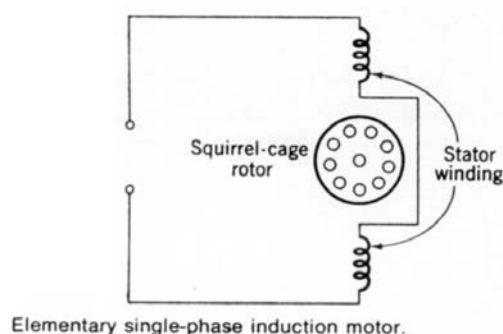
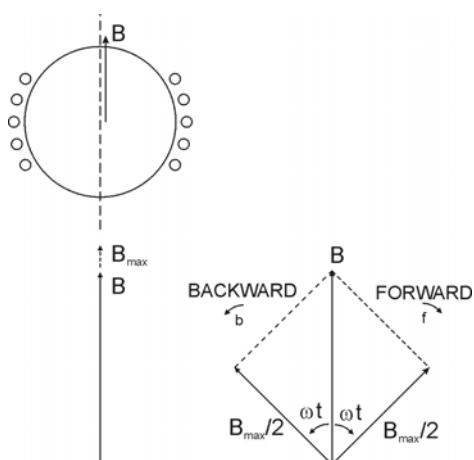


SINGLE-PHASE INDUCTION MOTORS

THEORETICAL CONSIDERATIONS



How such a motor can operate? Let us consider its magnetic field:



1-phase winding creates a pulsating magnetic field:

$$B(x, t) = B_{\max} \cos \frac{\pi}{\tau} x \sin \omega t$$

Pulsating magnetic field B can be substituted by the sum of two rotating fields:

$$\vec{B} = \vec{B}_f + \vec{B}_b$$

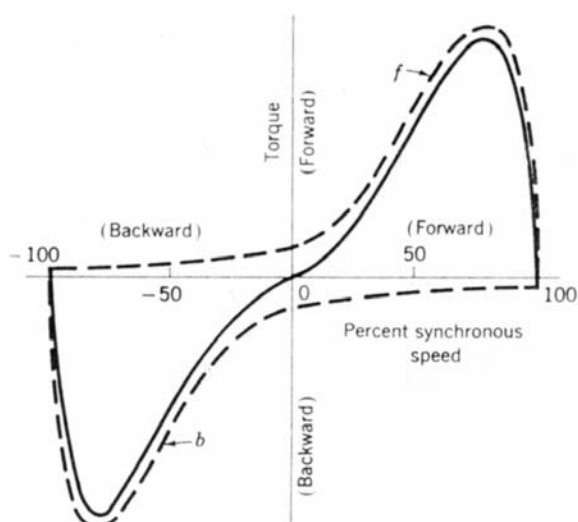
$$B_f = \frac{1}{2} B_{\max} \sin \left(\omega t - \frac{\pi}{\tau} x \right)$$

$$B_b = \frac{1}{2} B_{\max} \sin \left(\omega t + \frac{\pi}{\tau} x \right)$$

It is first spatial harmonic of spatial distribution of the flux density produced by 1-phase winding supplied with sinusoidal current.

INSTEAD OF ONE PULSATING FIELD WE CAN TAKE INTO CONSIDERATION 2 “HALVED” FIELDS ROTATING IN OPPOSITE DIRECTIONS. Each of such rotating fields, while acting at secondary circuit of squirrel-cage rotor, produces an electromagnetic torque.

TOTAL ELECTROMAGNETIC TORQUE ACTING AT SQUIRREL-CAGE ROTOR:



Conclusions:

1. Such a motor doesn't have any starting torque.
2. When rotor is “pushed” from $n=0$ position in any direction it can continue the operation as a “normal” induction motor with rotating magnetic field.
3. The opposing torque, corresponding to another “halved” rotating field, is rather small and doesn't reduce too much a total value of torque, but there are other very bad consequences of the magnetic field rotating in opposite direction.

We can now conclude some questions and answers:

HOW TO ACHIEVE NON-ZERO STARTING TORQUE?

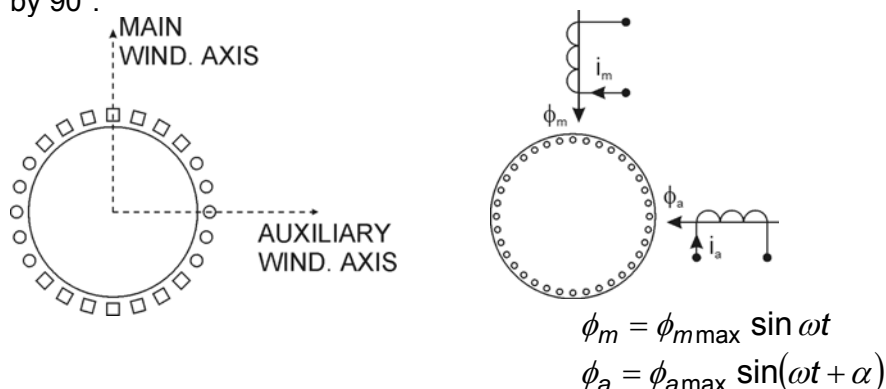
It is necessary to have rotating magnetic field.

HOW TO ACHIEVE ANY ROTATING MAGNETIC FIELD?

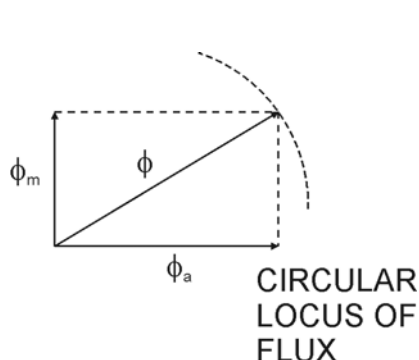
It is necessary to have multi-phase arrangement. For example
3-PHASE SYSTEM: SYMMETRICAL PHASE AND CURRENT
ARRANGEMENT!

What about **2-PHASE SYSTEM?**

Let us consider two 1-phase windings with their axes displaced in space by 90° :



The end of the vector of resultant flux Φ of two pulsating fluxes draws its locus. Can its length be constant?



$$|\Phi| = \sqrt{\phi_a^2 + \phi_m^2} = \text{const}?$$

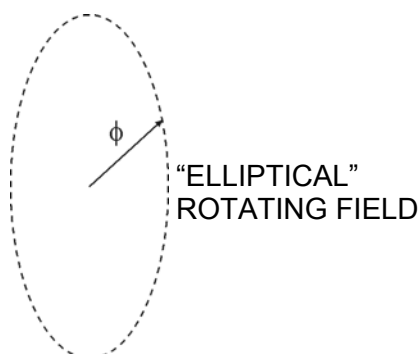
When locus of flux ϕ is circular the resultant magnetic field is ROTATING "CIRCULAR" FIELD, exactly the same as in case of 3 – phase symmetrical arrangement!

This is the most required case!

$|\Phi| = \text{const}$ when two following conditions are fulfilled:

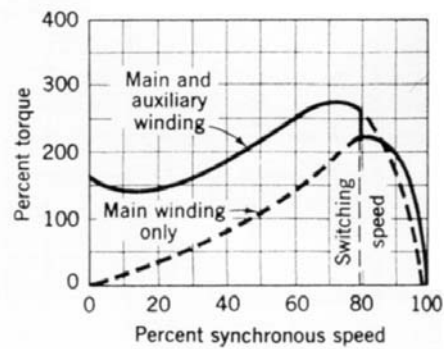
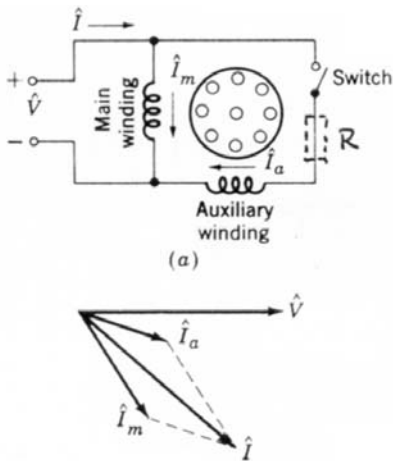
- $\alpha = 90^\circ$ (displacement of fluxes & currents in time) and
- $\phi_{mmax} = \phi_{amax}$ (also $I_{mmax} = I_{amax}$ when $N_m = N_a$)

In other case the locus is elliptical

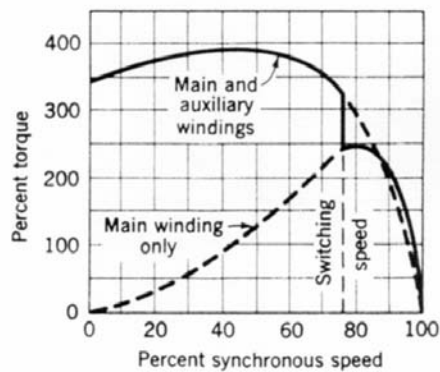
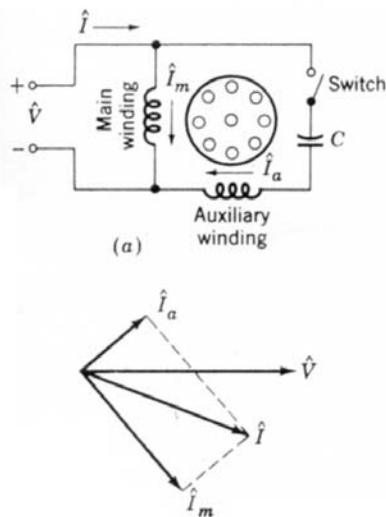


PULSATING FIELD
(one semi-axis of ellipse = 0)
when e.g. :
 $\phi_{amax} = 0$
or
 $\alpha = 0$

POSSIBLE REALIZATIONS OF 1-PHASE MOTORS



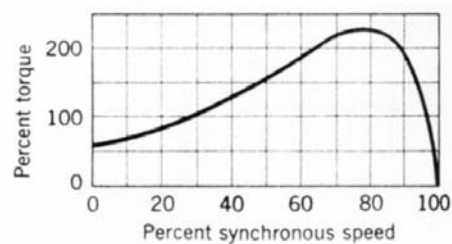
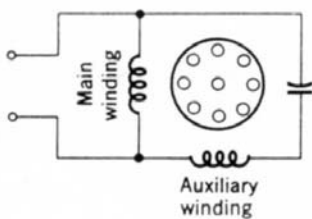
SPLIT-PHASE MOTOR



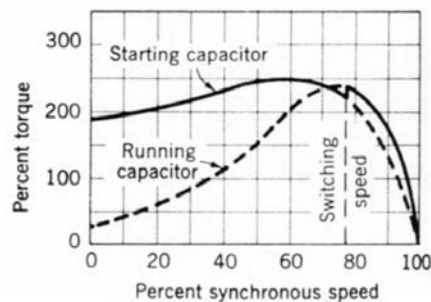
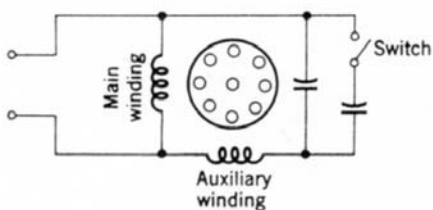
CAPACITOR-START MOTOR

$$C = 20 \div 30 \mu\text{F} \quad 100 \text{ W}$$

$$C = 60 \div 100 \mu\text{F} \quad 750 \text{ W}$$



PERMANENT-SPLIT-CAPACITOR MOTOR (capacitor-run motor)



TWO-VALUE-CAPACITOR MOTOR

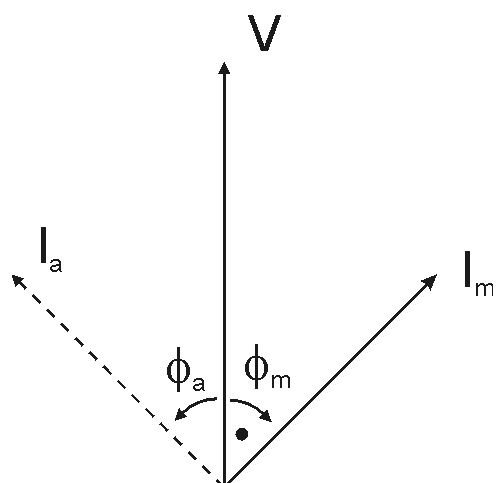
NUMERICAL EXAMPLE

A 250 W, 220 V, 50 Hz capacitor–start motor has the following winding impedances for the main and auxiliary windings at starting:

$$\underline{Z}_m = 18 + j14.8 \, [\Omega]$$

$$\underline{Z}_a = 38 + j14 \, [\Omega]$$

Find the value of starting capacitance that will place the main and auxiliary winding currents in quadrature at starting.



$$\varphi_m = \tan^{-1} \left(\frac{14.8}{18} \right) = 39.42^\circ$$

$$\varphi_a = 39.42^\circ - 90^\circ = -50.58^\circ$$

$$\underline{Z}'_a = 38 + j(14 - X_C)$$

$$\tan^{-1} \left(\frac{14 - X_C}{38} \right) = -50.58^\circ$$

$$\frac{14 - X_C}{38} = -1.217$$

$$X_C = 60.2 \, \Omega$$

$$C = \frac{10^6}{X_C \cdot 2\pi f} = \frac{10^6}{60.2 \cdot 2\pi f} = 52.9 \, \mu\text{F}$$