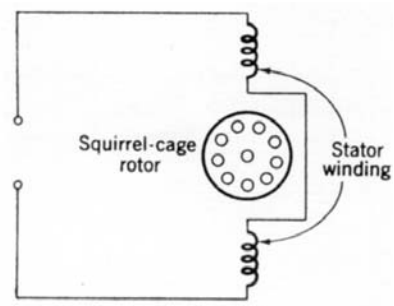
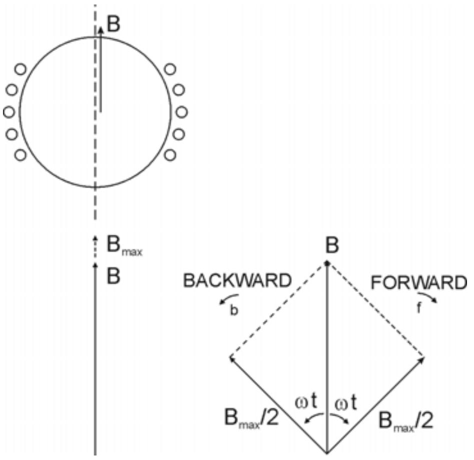
SINGLE–PHASE INDUCTION MOTORS

THEORETICAL CONSIDERATIONS



Elementary single-phase induction motor.

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:

$$\overrightarrow{B} = \overrightarrow{B_f} + \overrightarrow{B_b}$$

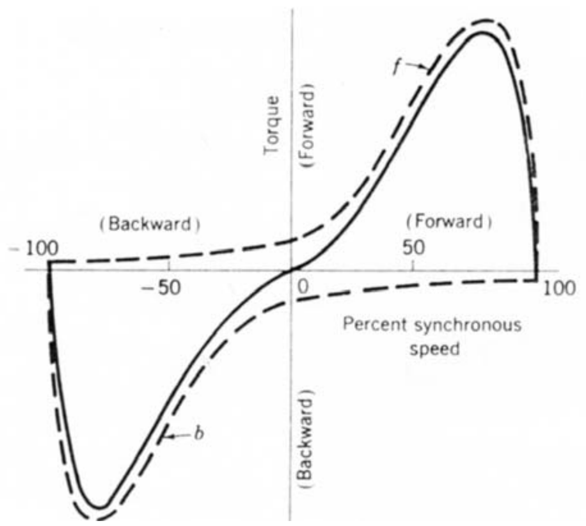
$$B_f = \frac{1}{2}B_{\max}\sin\left(\omega t - \frac{\pi}{\tau}x\right)$$

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

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.*

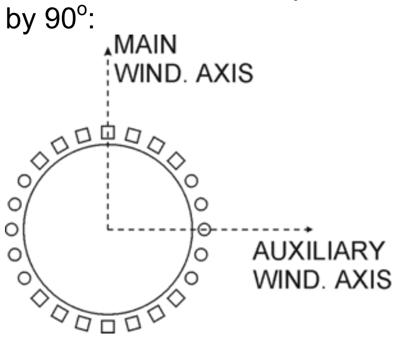
We can now conclude some questions and answers:

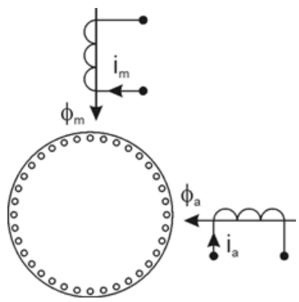
HOW TO ACHIEVE NON-ZER0 STARTING TORQUE?
It is necessary to have rotating magnetic field.

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**?

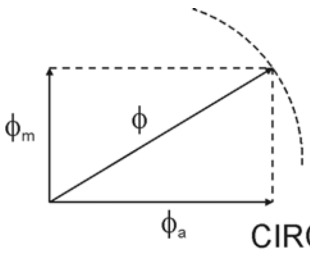
Let us consider two 1-phase windings with their axes displaced in space by 90°:





$$\phi_m = \phi_{m\max} \sin \omega t$$
$$\phi_a = \phi_{a\max} \sin(\omega t + \alpha)$$

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



CIRCULAR LOCUS OF FLUX

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

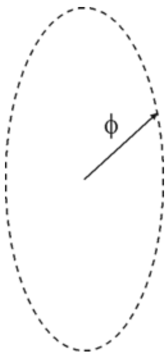
When locus of flux ϕ is circular the resultant magnetic field is ROTATING "CIRCULAR" FIELD, exactly the same as in case of 3 – phase symmetrical arrangement!

This is the most required case!

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

a) $\underline{\alpha = 90^o}$ (displacement of fluxes & currents in time) and
b) $\phi_{m\max} = \phi_{a\max}$ (also $I_{m\max} = I_{a\max}$ when $N_m = N_a$)

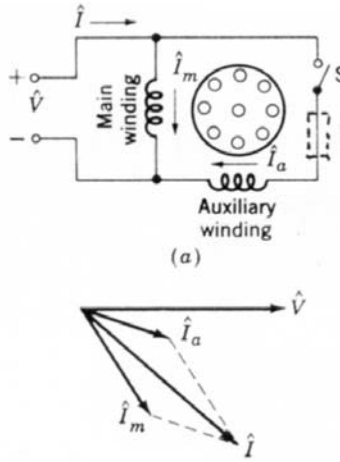
In other case the locus is elliptical

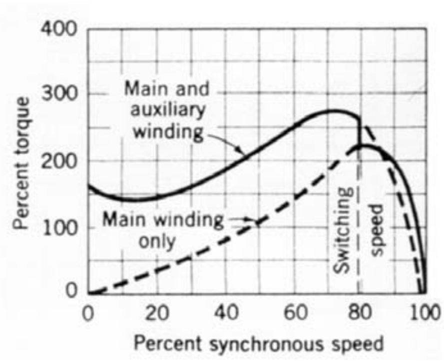


"ELLIPTICAL" ROTATING FIELD

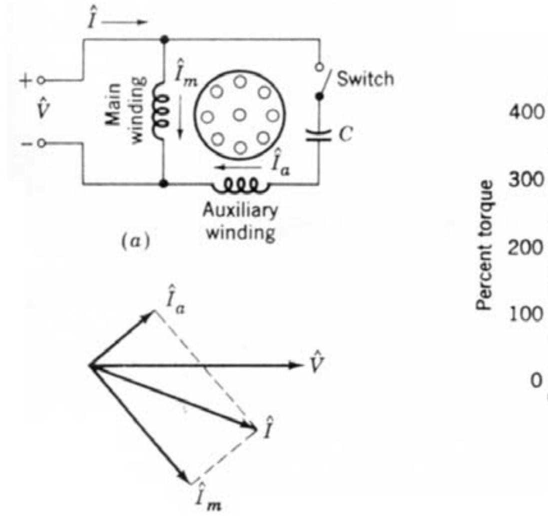
PULSATING FIELD (one semi-axis of ellipse = 0) when e.g. :
$\phi_{a\max} = 0$
or
$\alpha = 0$

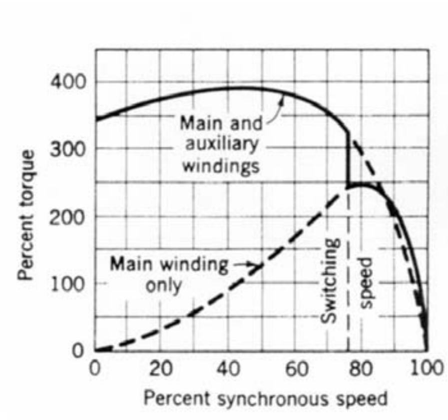
POSSIBLE REALIZATIONS OF 1-PHASE MOTORS





SPLIT-PHASE MOTOR

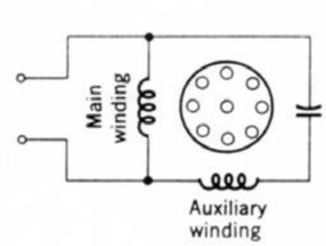


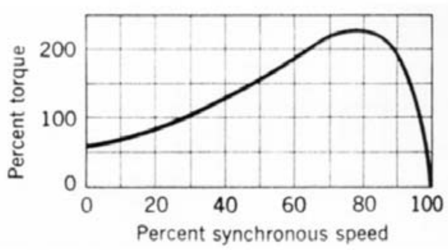


CAPACITOR-START MOTOR

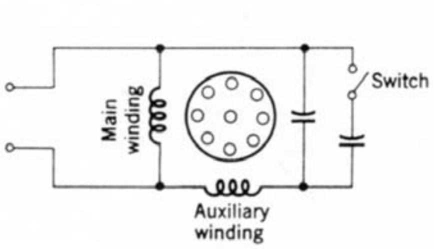
$C = 20 \div 30$ μF 100 W

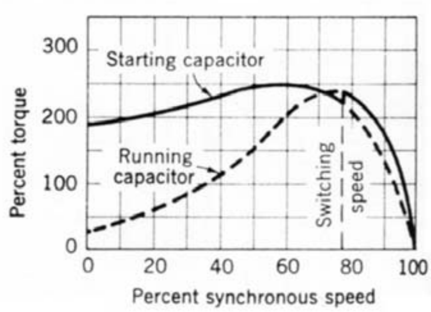
$C = 60 \div 100$ μF 750 W





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





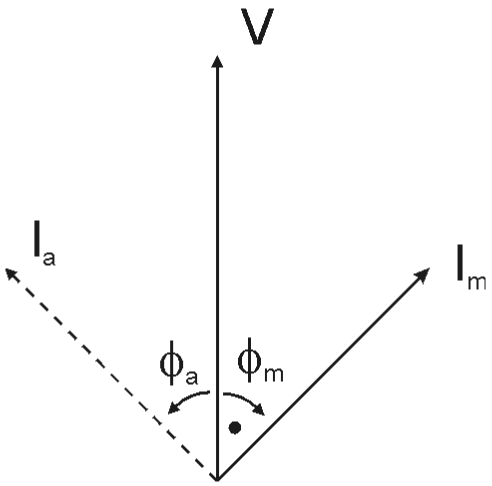
TWO-VALUE-CAPACITOR MOTOR

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.



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

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

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

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

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

$$X_C = 60.2 \ \Omega$$

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