Important suggestions to examiners:

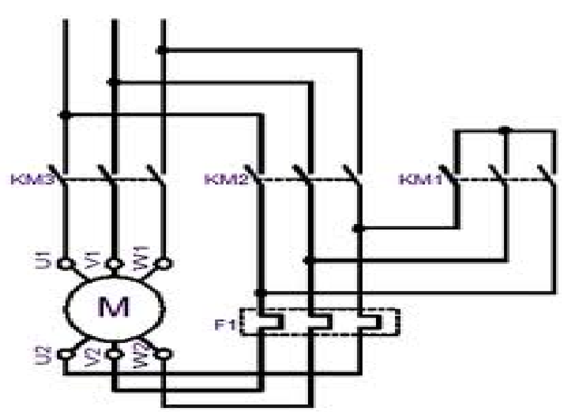
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and communication skills)
4) While assessing figures, examiner may give credit for principle components indicated in a figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case some questions credit may be given by judgment on part of examiner of relevant answer based on candidate understands.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

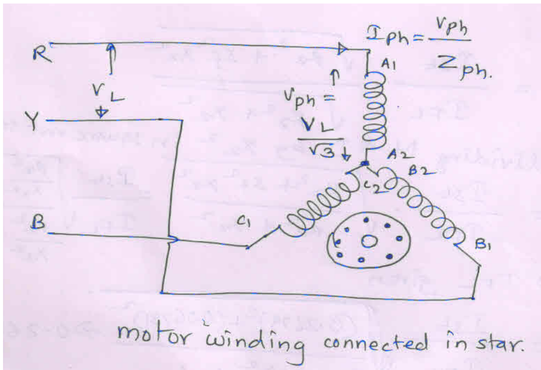
Q.1 (A) Attempt any THREE: 12 Marks

a) Compare squirrel cage induction motor & slip ring induction motor. (Any four points).

Ans: **(Any Four point expected: Each Point -1 Mark)**

S.No.	Squirrel Cage Induction Motor	Slip Ring Induction Motor
1	Rotor is in the form of bars	Rotor is in the form of 3-ph winding
2	No slip-ring and brushes	Slip-ring and brushes are present
3	External resistance cannot be connected	External resistance can be connected
4	Small or moderate starting torque	High Starting torque
5	Starting torque is fixed	Starting torque can be adjust
6	Simple construction	Completed construction
7	High efficiency	Low efficiency
8	Less cost	More cost
9	Less maintenance	Frequent maintenance due to slip-ring and brushes.
10	Starting power factor is poor and power factor on running is better	Starting power factor is adjustable & large but low power factor on full load
11	Size is compact for same HP	Relatively size is larger
12	Speed control by stator control method only	Speed can be control by stator & rotor control method

b)	**State why three phase Induction Motor never run on synchronous speed.**
Ans:	**(4 Marks)** The working principle of three phase induction motor is based on relative motion between rotating magnetic field and rotor conductors i.e. (N_S - N), According to Lenz's law rotor will try to catch the synchronous speed of rotating magnetic field to oppose the 'cause producing it'. But rotor never succeeds due to frictional losses. If rotor catches the synchronous speed of rotating magnetic field, (N_S - N) i.e relative motion will be zero and rotor stops to rotate and therefore three phase induction motor can never run on synchronous speed .
c)	**Explain with diagram how star-delta starters are used for reducing the starting current of 3 phase induction motors.**
Ans:	**Reason for star-delta starters are used for reducing the starting current of 3 phase induction motors.** **(Wiring Diagram-2 Mark & Explaination-2 Mark)** ➢ At Starting, the stator winding is connected in star connection. At the time of starting in star connection, $Iph = \frac{Vph}{Z_{SC}}$ and $Vph = \frac{V_L}{\sqrt{3}}$ Therefore starting current controlled to a safe value because if reduced stator voltage ➢ After the motor has reaches nearly steady state speed, the change over switch is thrown to connect motor in delta **Diagram of Star -Delta starters:**  **OR**



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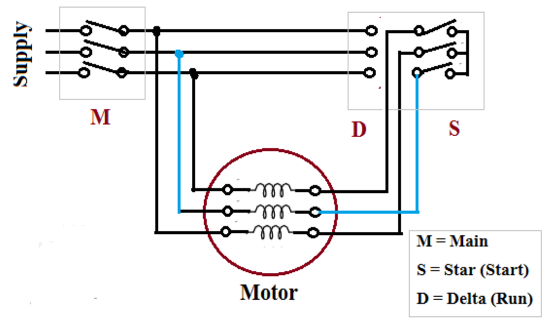


OR Equivalent fig.

d) **Define pitch factor & distribution factor and state the advantages of short pitched coils for an alternator.**

Ans: i) **Distribution factor :** **(Each Definition: 1 Mark)**

It is the ratio of vector sum of the emf in the individual coil to the arithmetical sum if the coils are of concentrated type or all the coil sides are in only one slot.

OR

$$K_d = \frac{Vector\ sum\ of\ coil\ voltages\ per\ phase}{arithmetic\ sum\ of\ coil\ volatges\ per\ phase}$$

ii) Pitch factor:

It is the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil.

OR

$$K_C = \frac{Actual\ voltage\ generated\ in\ the\ short\ pitch\ coil}{Voltage\ generated\ in\ the\ full\ pitch\ coil}$$

Advantages of short pitched coils for an alternator:

(Any Two advantages expected: 1 Mark each)

1. The wave form of induced emf will be improved i.e. the wave form will be very close to pure sinusoid.
2. The harmonic contents of the induced emf reduced.
3. As length required for armature winding decreases, the copper material will be saved, hence it is economical.

	4. As the high frequency harmonics are illuminated, Hysteresis & eddy current losses will be reduced and this increases the efficiency.
Q.1 (B)	**Attempt any ONE: 6 Marks**
a)	**Explain speed control method of 3 phase Induction motor by the following methods. (i) Frequency control (ii) Stator voltage control (iii) Rotor resistance control**

Ans:

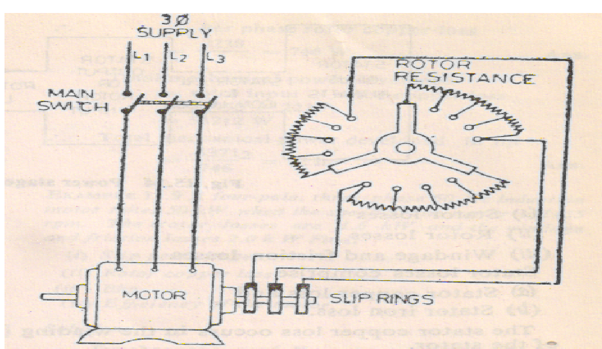
i) By varying applied Frequency (Frequency control): (2 Mark)

- The synchronous speed of an induction motor is given by $N_S = \frac{120 \times f}{P}$.
- It is clear from the equation that the speed of the induction motor can be changed by changing the frequency of the supply.

ii) Stator Voltage Control (by varying applied voltage): (2 Mark)

- This method is very easy but rarely used in commercial practice because a large variation of voltage produces a very small change in speed and much energy is wasted.
- In this method three resistances are inserted in series with the stator winding of the motor and the value of these resistances is varied by a common handle, so that equal resistances come in the stator circuit.
- For a particular load when voltage increases, speed of the motor also increases and vice-versa.

iii) Rotor resistance control (by rotor rheostatic control: (2 Mark)



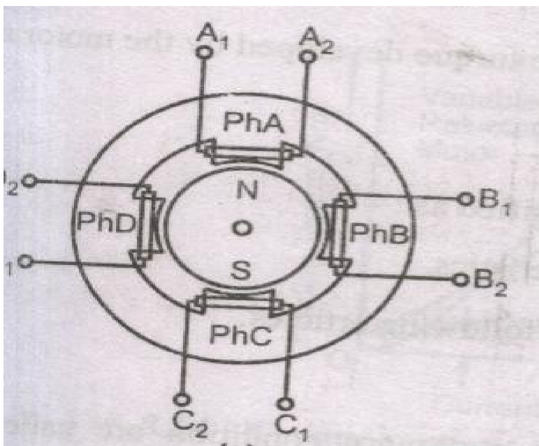
- In this method star connected external resistances (of continuous rating) are connected in the rotor circuit.
- The speed of the motor increases with the decrease of resistance in the rotor circuit.
- The change in speed is approximately inversely proportional to the external

resistance connected in the rotor circuit.

- This method of the speed control is applied where a small variation of speed is required and the power wasted is of no great importance.

b) **Describe with neat sketch the principle of operation of permanent magnet stepper motor.**

Ans: **Permanent Magnet Stepper Motor:-** **(Figure 3 Mark & Working 3 Mark)**



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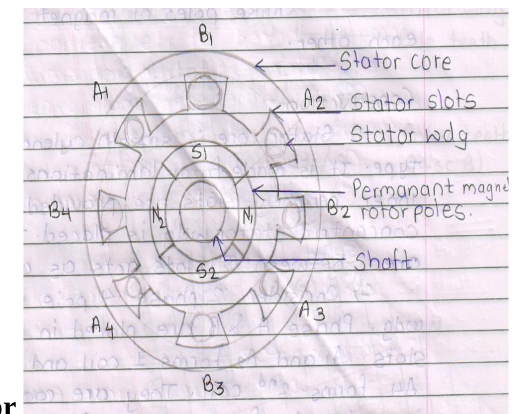
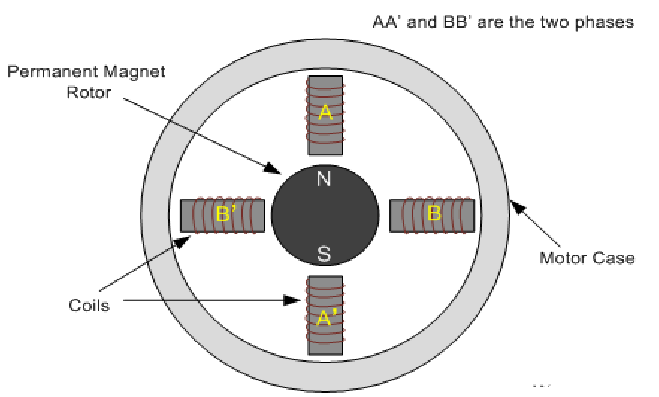


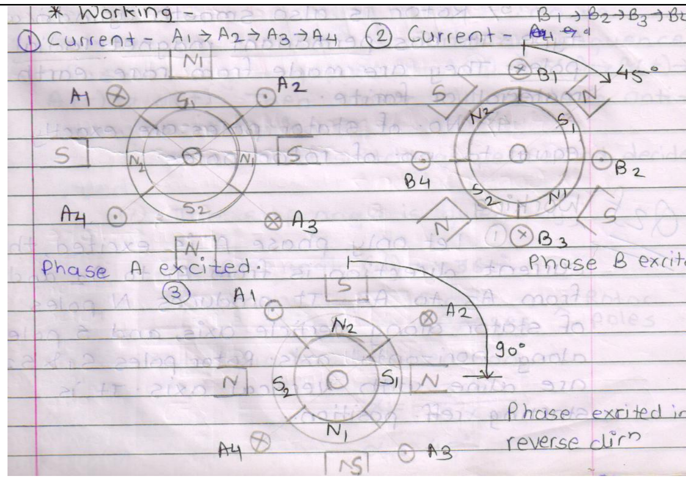


Working :-

When we gives supply to stator's winding. There will be a magnetic field developed in the stator. Now rotor of motor that is made up of permanent magnet, will try to move with the revolving magnetic field of stator. This is the basic principle of working of stepper motor.

OR

If the phase is excited in ABCD, due to electromagnetic torque is developed by interaction between the magnetic field set up by exciting winding and permanent magnet. Rotor will be driven in clockwise direction.



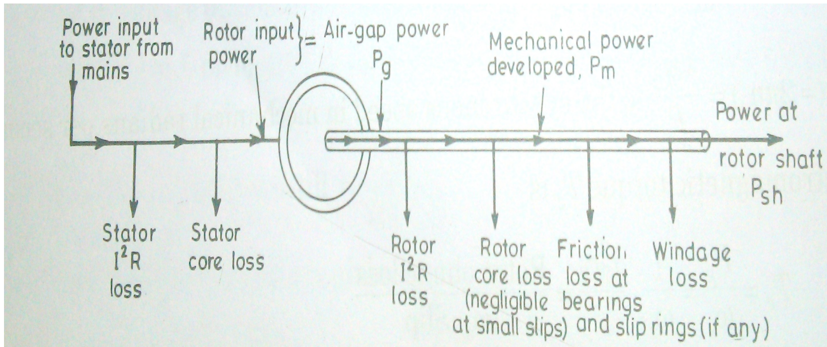
or equivalent figure

Working :

- Let only phase A is ecited, the current direction is form A1 to A2 and from A3 to A4.
- It produces N poles of stator along verticle axis, and S pole along horizontal axis.
- Rotor poles S1 & S2 are aline with vertical axis. It is starting reff.position.
- Now coil · A is switched off & phase B is excited. The current direction is B1 to B2 & B3 to B4. The stator N poles shift in clockwise direction by 45^0. Therefore Rotor poles S1 & S2 also rotate by 45^0 in clockwise direction.
- Now phase B is turned off and Phase A is excited in reverse direction. (A2-A1 & A4-A3) It causes shifted of stator N poles in clockwise direction by 45^0 again. Hence Rotor poles S1 and S2 also rotates further in clockwise direction by 45^0
- If switching sequence is mainted as A(+) → B (+) → A (-) → B (-) → A (+) then motor will continuously rotate in clockwise direction.
- The direction of rotation can be reversed by changing switching sequence. If switching sequence is A(+) → B (-) → B (+) → A (-) → A (+) then motor will rotate in anticlockwise direction.
- The number of switching per second decides speed.

Q.2	**Attempt any FOUR :**	**16 Marks**
a)	**Draw power stages of three phase induction motor. Derive relation for rotor copper loss.**	
Ans:	**Diagram showing power flow stages of a 3 phase induction motor** :	

(Figure: 2 Mark)



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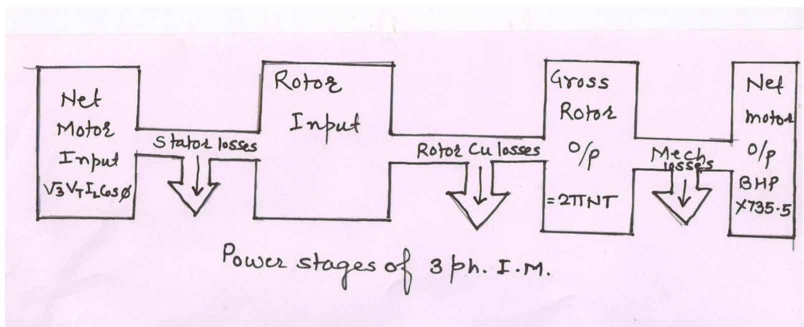

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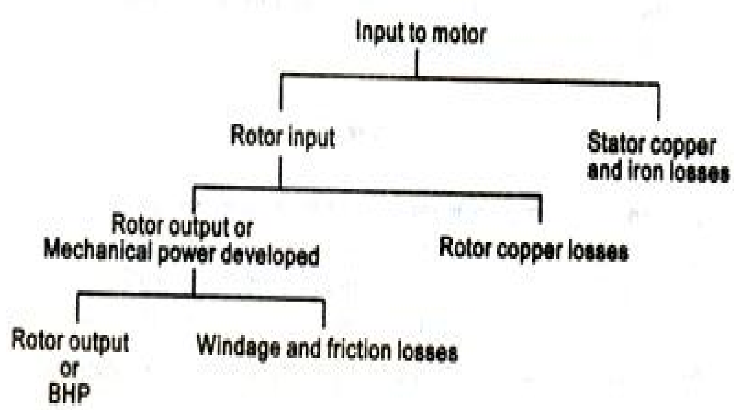


Derive relation for rotor copper loss. Consider 3-ph induction motor: **(2 Mark)**

$Gross\ rotor\ output = 2\pi N Tg$ **Where,** N in rps & T_g in N-m

If rotor rotates with synchronous speed, there will not be copper losses in rotor and hence rotor output will be equal rotor input

$$\therefore Gross\ rotor\ input = 2\,\pi\ N_S\ Tg \quad Where\ \ N_S\ in\ rps$$

$$\therefore Rotor\ copper\ losses = Gross\ rotor\ input - Gross\ rotor\ output$$

$$\therefore Rotor\ copper\ losses = 2\pi\ N_S\ Tg - 2\pi\ N\ Tg$$

$$\therefore Rotor\ copper\ losses = 2\pi\ Tg\ (N_S - N)$$

$$\therefore \frac{Rotor\ Cu\ losses}{Rotor\ input} = \frac{2\pi\ Tg\ (N_S - N)}{2\pi\ Tg \times N_S}$$

$$\therefore \frac{Rotor\ Cu\ losses}{Rotor\ input} = \frac{(N_S - N)}{N_S}$$

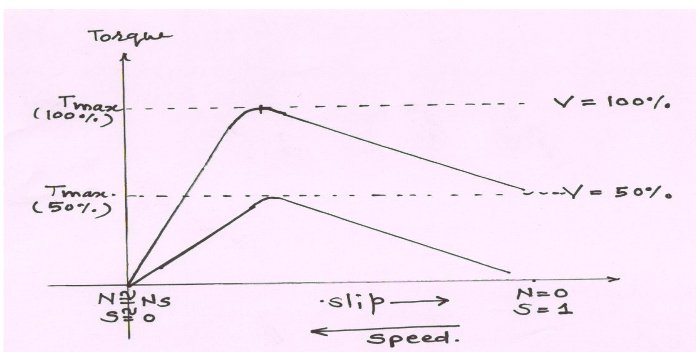
$$\therefore \frac{Rotor\ Cu\ losses}{Rotor\ input} = Slip$$

$$\therefore\ Rotor\ Cu\ \ losses = Slip \times rotor\ input$$

b) **Explain the effect of voltage on torque speed characteristics of 3 phase IM.**

Ans: **Effects of change in supply voltage on torque-Speed characteristics:**

(Figure-2 Marks & Effect- 2 Marks)



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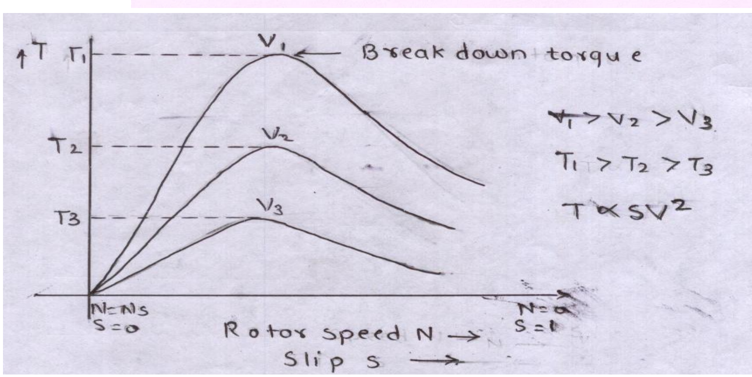
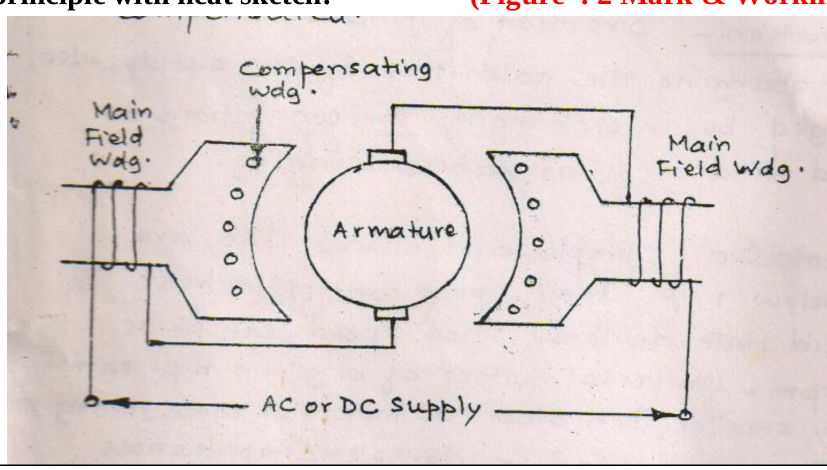
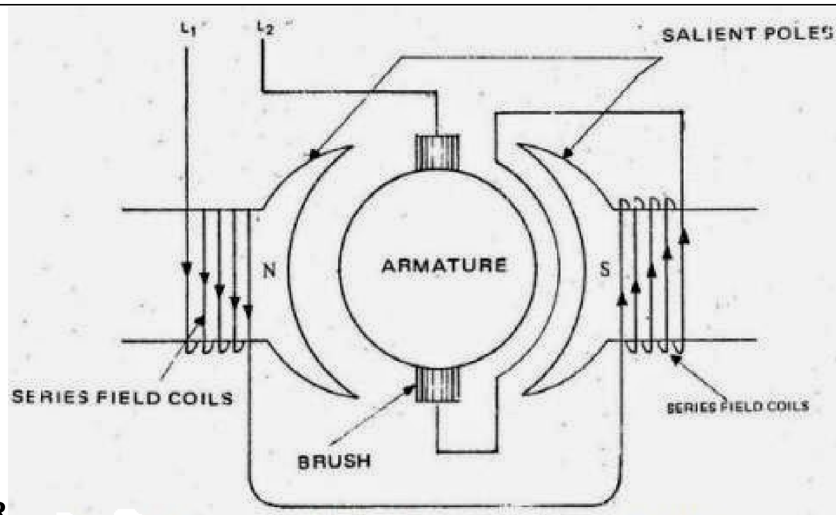


or equivalent figure

Explanation: From the above characteristics:-

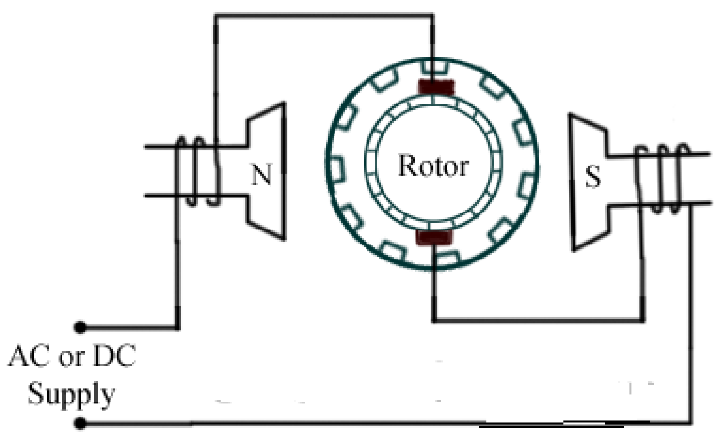
	➢ The torque equation of induction motor is given by: $$T = \frac{K\,\phi\,S\,E_2\,R_2}{R_2^{\,2} + S^2\,X^2}$$ ➢ The simplified form of the above torque equation- $$T\,\alpha\,S \times V^2 \quad (\because\ \phi\,\alpha\,E_1\,,\ and\ \ E_2\,\alpha\,E_1\,, and\ \ E_1\,\alpha\,V\,)$$ ➢ From the above equation it is clear that the torque at any speed is proportional to the square of supply voltage V. ➢ Hence any change in supply voltage will be having great effect on running torque and maximum torque. ➢ As supply voltage decreases up to 50 % of the rated value, maximum torque decreases almost up to 50 % of maximum torque. ➢ This effect is shown in the above torque-speed characteristics
c)	**A 12 pole, 30, alternator is couple to an engine running at 500 rpm. It supplies an induction motor which has full load speed of 1440 rpm. Find the slip and the no. of poles of the induction motor.**
Ans:	The frequency of generated emf of 3-phase alternator: $$f = \frac{N_S \times P}{120}$$ **(1 Mark)** $$f = \frac{(500)\times(12)}{120}$$ $$f = 50\text{Hz}$$ …………………… ………………………….. **(1/2 Mark)** Let, N_S= Synchronous Speed of I.M close to actual Speed of 1440 RPM: $$N_S = 1500\text{ RPM}$$ $$P = \frac{(120)\,(f\,)}{N_S}$$ …………………………………..…….……..**(1 Mark)** $$= \frac{120 \times 50}{1500}$$ $$P = 4 \quad \text{Pole}$$ ……………….…………….…..………….. **(1 /2Mark)** $$\%\ \text{Slip} = \frac{N_S - N}{N_S} \times 100$$ $$= \frac{1500 - 1440}{1500}$$ **(1/2 Mark)** $$\%\ \text{Slip} = 0.04 \text{ or } 4\ \%$$ ………………….……………….…. .**(1/2 Mark)**

d)	**Explain the factors which affect the terminal voltage of alternator.**
Ans:	**The factors affecting terminal voltage of alternator:** **(Any Four Factor expected: 1 Mark each point)** The terminal voltage of alternator depends upon: **(Any four point are expected)** 1) Load current 2) Armature resistance per phase 3) Leakage reactance per phase 4) Armature reaction reactance per phase 5) Excitation (field current) 6) Speed 7) Load power factor **OR** when load power factor is unity or lagging, the terminal voltage drops with increase in load, when the load power factor is leading, the terminal voltage increase with increase in load
e)	**A motor is to be operated from 230 V, 50 Hz single phase AC and 220 V DC supply. Identify above motor and describe its working with neat sketch.**
Ans:	**Name of Motor :** **(1 Mark)** ➢ A motor is operated from 230 V, 50 Hz single phase A.C. and 220 V D.C. supply i.e. motor operates on both AC and DC supply this motor is called as a: **Universal Motor** **Working principle with neat sketch: -** **(Figure : 2 Mark & Working : 1 Mark)** 



OR OR

OR Equivalent figure

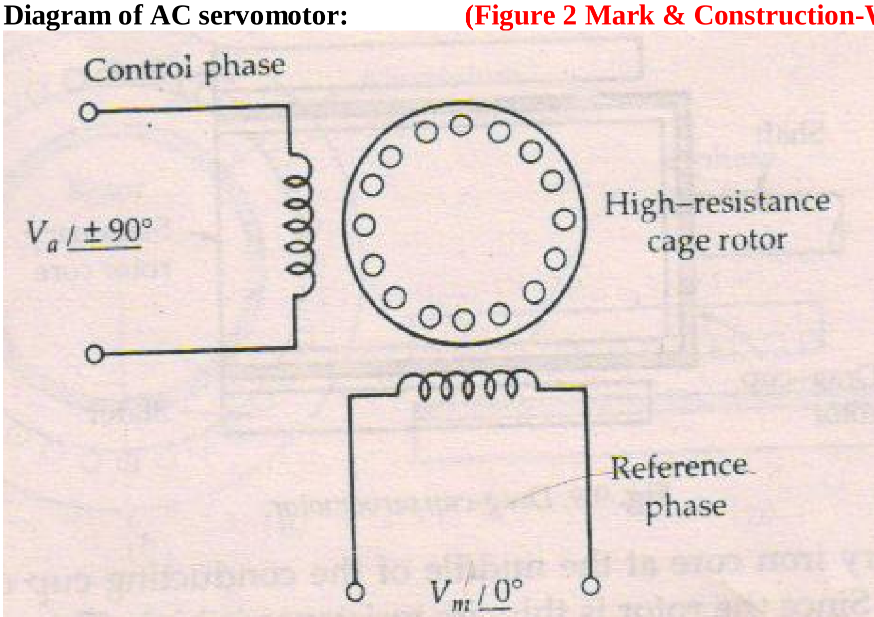


➢ A universal motor works on either DC or single phase AC supply. When the universal motor is fed with a DC supply, it works as a DC series motor. When current flows in the field winding, it produces an electromagnetic field. The same current also flows from the armature conductors. When a current carrying conductor is placed in an electromagnetic field, it experiences a mechanical force. Due to this mechanical force, or torque, the rotor starts to rotate. The direction of this force is given by Fleming's left hand rule.

When fed with AC supply, it still produces unidirectional torque. Because, armature winding and field winding are connected in series, they are in same phase. Hence, as

	polarity of AC changes periodically, the direction of current in armature and field winding reverses at the same time. Thus, direction of magnetic field and the direction of armature current reverses in such a way that the direction of force experienced by armature conductors remains same. Thus, regardless of AC or DC supply, universal motor works on the same principle that DC series motor works.
f)	**Explain construction & working of AC servo motor.**

Ans: **Diagram of AC servomotor:** **(Figure 2 Mark & Construction-Working 2 Mark)**



or Equivalent dia

Construction:

- ➢ The stator has two distributed windings which are displaced from each other by 90^0 electrical degrees.
- ➢ One winding is called the reference or fixed phase, is supplied from a constant voltage source $V_m \langle 0^0$.
- ➢ The other winding, called the control phase, is supplied with a variable voltage of the same frequency as the reference phase, but is phase displaced by 90^0 electrical degrees.

Working of AC Servomotor:

- ➢ The control Phase is usually supplied from a servo amplifier.
- ➢ The speed and torque of the rotor are controlled by the phase difference between the control voltage and the reference phase voltage.

➢ The direction of rotation of the rotor can be reversed by reversing the phase difference, from leading to lagging (or vice versa) between the control phase voltage and the reference phase voltage.

OR

The a.c. servomotor is basically consists of a stator and a rotor. The stator carries two windings, uniformly distributed and displaced by 90° in space, from each other.

One winding is called as **main winding or fixed winding** or **reference winding**. The reference winding is excited by a constant voltage a.c. supply.

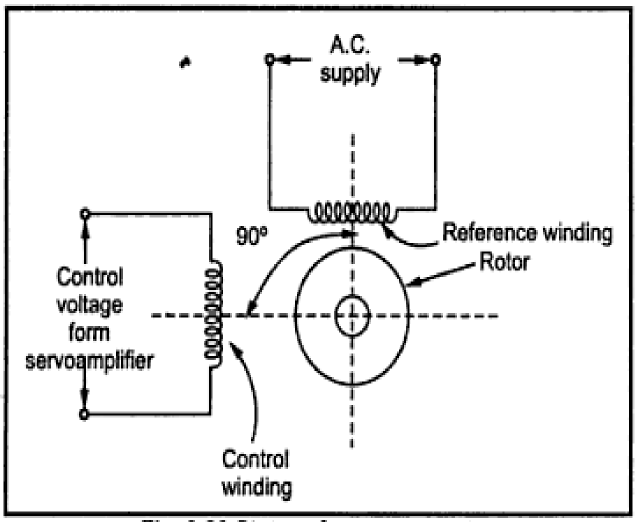


Fig. 9.20 Stator of a.c. servomotor

The other winding is called as **control winding**. It is excited by variable control voltage, which is obtained from a servoamplifier. The windings are 90° away from each other and control voltage is 90° out of phase with respect to the voltage applied to the reference winding. This is necessary to obtain rotating magnetic field.

The schematic stator is shown in the Fig. 9.20.

To reduce the loading on the amplifier, the input impedance i.e. the impedance of the control winding is increased by using a tuning capacitor in parallel with the control winding.

Q.3	**Attempt any Four :**	**16 Marks**
a)	**Derive the condition for T_{max}. of a 3 phase induction motor.**	

Ans: **Note: The student can follow for different method of derivation also**

Let us consider the equation of torque,

$$T = \frac{K\,\phi\,S\,E_2\,R_2}{R_2^{\,2} + S^2\,X^2}$$ --- **(1 Mark)**

Condition of maximum torque can be found out by taking derivative of torque equation w.r.t. Slip and equating it to zero. For the simplicity of derivation, let us put $\frac{1}{T} = M$

$$M = \frac{R_2^{\,2} + S^2\,X_2^{\,2}}{K\,\phi\,S\,E_2\,R_2}$$ --- **(1 Mark)**

$$M = \frac{R_2^2}{K\,\phi\,S\,E_2\,R_2} + \frac{S^2\,X_2{}^2}{K\,\phi\,S\,E_2\,R_2}$$

$$M = \frac{R_2}{K\,\phi\,S\,E_2} + \frac{S\,X^2}{K\,\phi\;E_2\,R_2}$$

$$\frac{d(M)}{dS} = \frac{d}{dS}\left[\frac{R_2}{K\,\phi\,S\,E_2} + \frac{S\,X_2{}^2}{K\,\phi\;E_2\,R_2}\right] = 0$$ ------------------ **(1 Mark)**

$$-\frac{R_2}{K\,\phi\,S^2\,E_2} + \frac{X_2{}^2}{K\,\phi\;E_2\,R_2} = 0$$

$$\frac{X_2{}^2}{K\,\phi\;E_2\,R_2} = \frac{R_2}{K\,\phi\,S^2\,E_2}$$

$$\frac{S^2X_2{}^2}{K\,\phi\;E_2\,R_2} = \frac{R_2^2}{K\,\phi\,S^2\,E_2}$$

$$S^2X_2{}^2 = R_2^2$$

$$\boxed{\therefore R_2 = S\,X_2}$$

------------------ **(1Mark)**

This is the condition for maximum torque of 3-Ph induction motor under running

b)	**A 3 phase, 6 pole 50 Hz induction motor has a slip of 1% at no load, and 3% at full load. Determine (i) synchronous speed (ii) no load speed (iii) full load speed (iv) frequency of rotor at standstill (v) frequency of rotor current at full load**

Ans:

Given Data:

Full load Slip = 3% No load Slip = 1% Pole = 6, F = 50 Hz V= 400 volt

i) Synchronous speed =

$$Ns = \frac{120\ f}{P}$$ ---------------------------------- **(1/2 Mark)**

$$Ns = \frac{120 \times 50}{6}$$

$$Ns = 1000\ RPM$$

----------------------------- **(1/2 Mark)**

ii) No Load Speed N = $(1-S)\,(N_S)$ -- **(1/2 Mark)**

$= (1-0.01)\,(1000)$

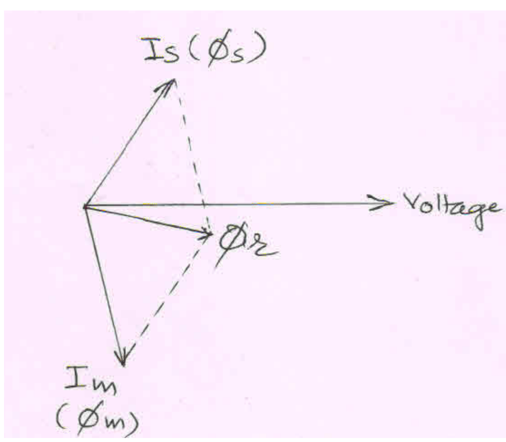
$= 990\ RPM$

-- **(1/2 Mark)**

iii) Full Load Speed N = $(1-S)\,(N_S)$

	$= (1 - 0.03)(1000)$ $= 970\ RPM$ -- (1/2 Mark) **iv) The frequency of rotor at standstill:** Slip at standstill 1 : $f_1 = S f$ -- (1/2 Mark) $f_1 = (1) \times 50$ $f_1 = 50\ Hz$ -- (1/2 Mark) **v) frequency of rotor current at full load:** $f^1 = S\ f$ $f^1 = (0.03) \times 50$ $f^1 = 1.5\ \ Hz$ -- (1/2 Mark)
c)	**Describe the concept of synchronous impedance. Also define the term leakage reactance, armature reaction reactance with respect to an alternator.**
Ans:	**1) Synchronous impedance:** (2 Mark) It is a fictitious impedance employed to account for the voltage effects in armature circuit produced by the actual armature resistance, the actual armature leakage reactance, and the change in air gap flux produced by armature reaction. **OR** $Z_S = R_a + j (X_L + X_a)$ $= R_a + j (X_S)$ Where, Z_S = synchronous impedance, R_a = Armarure resistance, X_L = Leakage reactance, X_a = Armature reaction reactance, X_S = Synchronous reactance **2) Leakage reactance:** (1 Mark) The working flux does not only passes through intended path. Some part of working flux will be lost due to leakage. Hence leakage reactance is defined as the factor or parameters which represents the leakageflux **OR** When armature carries a current, it produces its own flux. Some part of this flux completes its path through the air around the conductors itself. Such a flux is called

	leakage flux. The equivalent reactance due to this leakage flux is called as ;leakage reactance **3) Armature Reaction** reactance: - **(1 Mark)** The effect of armature flux on main flux is called as armature reaction and the parameter which represents the armature reaction at various power factor or load condition, is called armature reaction reactance
d)	**A 3-phase 50 Hz, & pole alternator has a star connected winding with 120 slots and 8 conductors per slot. The flux per pole is 0.05 wb, sinusoidally distributed. Determine the phase and line voltages.**
Ans:	3-Ph, Star connected, **Assuming Pole : 8 Pole**, 50 Hz, alternator **Important Note: The data of pole are not given, So the candidate can assume this data as it is not mentioned, Accordingly the answer will change** $E/ph = 4.44\phi f\ T\ Kc\ Kd$ ---**(1/2 Marks)** m= Number of slots/Pole/phase $m = \frac{120}{8\times 3} = 5$ $\beta = \frac{180^0\ Elec.}{Pole\ pitch}$ $Where\ pole\ pitch = \frac{No.of\ Slots}{Pole} = \frac{12}{8} = 15$ ------------------------- **(1/2 Marks)** $\beta = \frac{180^0\ Elec.}{15}$ $\beta = 12^0\ \ Elect$ Considering Full pitched winding $\therefore K_C = 1$ $K_d = \frac{Sin\ (m\ \beta/2)}{m\ Sin\ (\beta/2)}$ -- **(1/2 Marks)** $K_d = \frac{Sin\,[(5)\ (12/2)]}{(5)\,[\ Sin\,(12/2)]}$ $K_d = \frac{0.5}{0.5226}$

	$K_d = 0.9567$ -- **(1/2 Marks)** $\phi = 0.05\,Wb$ – – *given* $\mathrm{Z/ph} = \dfrac{\text{Total number of conductors in series}}{3}$ -------------------------**(1/2 Marks)** $Z/ph = \dfrac{120 \times 8}{3}$ $Z/ph = 320$ $Number\ of\ turns\ in\ series\ per\ phase: T/ph = \dfrac{Z/ph}{2} = \dfrac{320}{2}$ $T/ph = 160$ $\mathrm{E/ph = 4.44\phi\ f\ \ T\ Kc\ Kd}$ -- **(1/2 Marks)** $E/ph = 4.44(0.05)\ (50)\ (160)\ (1)\ (0.9567)$ $E/ph = 1699.09\ volts$ -- **(1/2 Marks)** $\mathrm{E\ line} = \sqrt{3} \times \mathrm{Eph}$ $E\ line = 2942.93\ volts$ --- **(1 /2Marks)**
e)	**Describe with phasor diagrams phase splitting technique in capacitor start run induction motor.**
Ans:	**Phasor diagrams phase splitting technique in capacitor start run induction motor:** **(Phasor Diagram : 2 Mark & Explanation : 2 Mark)**  **or equivalent figure**

	Explanation: **(2 Mark)** ➢ I_m- the current passing through main winding having inductive nature, lags behind voltage axis by @ 90^0 Elec. This sets up the a.c flux Φ_m ➢ I_S- the current passing through the starting winding circuit consisting capacitors, Leads the voltage axis by some angle. This sets up the a.c flux Φ_S ➢ Both the fluxes Φ_m and Φ_S are of a.c nature, working in same air gap & having a phase difference. The interaction between these two fluxes Φ_m and Φ_S sets up the resultant one flux which is of rotating nature ➢ Rotating magnetic field is the basic requirement of I.M for self-starting, thus by using split phase principle technique in capacitor start run induction motor can be made self-starting characteristics.
Q.4 (A)	**Attempt any TWO:** **12 Marks**
a)	**746 kW, 3 phase 50 Hz, 16 pole induction motor has a rotor impedance of (0.02 + j 0.15) ohm at standstill. Full load torque is obtained at 360 rpm. Calculate. (a) Speed at which maximum torque occurs (b) the ratio of maximum to full load torque. (c) The external resistance per phase to be inserted in the rotor circuit to get maximum torque at starting.**
Ans:	**Given Data:** 3-Ph Pole = 16, F = 50 Hz , 746 K.W I.M , Speed at full load torque = 360 rpm $Z_S\,/Ph = (R_2 + j\,X_2/ph)$ $Z_S\,/Ph = (\,0.02 + j\,0.15)\ \Omega/ph$ **i) Synchronous speed =** $Ns = \frac{120\,f}{P}$ - ---------------------------------- **(1/2 Mark)** $Ns = \frac{120 \times 50}{16}$ $Ns = 375\ RPM$ ------------------------------ **(1/2 Mark)** **ii) The maximum torque occurs at the condition:** $R_2 = S\,(X_2)$ - --------------------------------------- **(1/2 Mark)**

$$S = \frac{R_2}{X_2}$$

$$S = \frac{0.02}{0.15} = 0.133$$

$$S = 0.133$$

-- **(1/2 Mark)**

iii) Speed at Slip = 0.133

N = $N_S\ (1 - S)$

= (375) (1.0.133)

$$N = 325\ RPM$$

--- **(1/2 Mark)**

iv) Full Load Slip S_f = $S_f = \frac{(N_S - N)}{N_S}$

$$S_f = \frac{(375 - 360)}{375}$$

$S_f = 0.04$ ---------------------------- **(1/2 Marks)**

We have ,

$$\frac{T_{max}}{T_{full}} = \frac{a^2 + S_f^{\ 2}}{2\ a\ S_f}$$ -- -- **(1/2 Mark)**

$$Where,\ a = R_2 / X_2 = 0.1333 \quad and \quad S_f = 0.04$$

$$\frac{T_{max}}{T_{full}} = \frac{(0.1333)^2 + (0.04)^2}{2(\ 0.1333)(0.04)}$$

$$\frac{T_{max}}{T_{full}} = \frac{0.01937}{0.010664}$$

$$\frac{T_{max}}{T_{full}} = 1.82$$ - -- **(1 Mark)**

iv) The Maximum torque condition at Starting for Slip ring I.M: :

$$R_2 + r = X_2 \quad When\ \ S = 1$$

-------------------------------- **(1/2 Mark)**

r /ph = resistance per ph to be connected in series to get maximum torque at starting

$$= X_2 - R_2$$

--- **(1/2 Mark)**

	$= 0.15 - 0.02$ $r/ph = 0.13\,\Omega$ -- (1/2 Mark)
b)	**Explain how each of the following can reduce starting current of 3 Ph IM.** **(i) By inserting resistance in rotor winding** **(ii) By connecting auto transformer in stator winding.**
Ans:	**i) By inserting resistance in rotor winding can reduce starting current of 3 phase IM:** **(3 Marks)** This method is only applicable to slip-ring motors. At the instant of starting, the external rotor resistance can be kept at maximum value. Therefore heavy starting current can be controlled. **ii) By connecting autotransformer in stator winding:** **(3 Marks)** ➢ At the instant of starting, the position of the slider/variable tap is kept at zero voltage position. ➢ When the slider moves gradually in clockwise direction, the voltage applied to three phase induction motor will be increased in steps. ➢ At starting reduced voltage can be applied to 3-phase induction motor and hence heavy starting current will be reduced or controlled. ➢ When motor start to rotate and achieve about 70 % of the rated speed, the rated voltage can be applied to 3-phase induction motor. Thus by using 3-phase auto transformer as a starter, starting current can be controlled.
c)	**A 3 ph star connected alternator is rated at 1600 kVA, 13500 V. The armature effective resistance and synchronous reactance are 1.5 ohm and 30 ohm respectively per phase. Calculate percentage regulation for a load of 1280 kW at power factor of** **(i) 0.8 leading (ii) Unity (iii) 0.8 lag**
Ans:	**Solution:-** 3-Ph, star connected alternator, V_T Line = 13.5 x 10^3 KV $\quad R_a/Ph = 1.5\,\Omega \quad \& \quad X_S/Ph = 30\,\Omega$ $V_T/Ph = 13.5 \times 10^3/\sqrt{3} = 7794.23\ Volt$ $I_a\ line\ Current = \frac{KW \times 10^3}{(\sqrt{3}) \times (V_{TLine})\ Cos\phi}$ **(1/2 Marks)**

	$I_a \; line\ Current = \dfrac{(1280)\times 10^3}{(\sqrt{3})\times(13.5)\times 10^3\ (0.8)}$ $I_a \; line\ Current = 68.43\ A$ --------------------- --------------------**(1/2 Marks)** **Now,** **i) % regulation at 0.8 leading Power Factor;** $E/ph = \sqrt{(V_T\ Cos\phi + I_a R_a)^2 + (V_T\ \sin\phi - I_a X_S)^2}$ - ---------------------- **(1/2Mark)** $E_{ph} = \sqrt{(7794.23\times 0.8) + (68.43\times 1.5)^2 + (7794.23\times 0.6 - 68.43\times 30)^2}$ $Eph = \sqrt{6338.25)^2 + (2326.64)^2}$ $Eph = \sqrt{45583814.59}$ $Eph = 6751.5786\ \ Volt$ --- **(1/2Mark)** $\mathrm{Re}\,gulation = \dfrac{6751.5786 - 7794.23}{7794.23}\times 100 = -13.38\,\%$ % Regulation = - 13.38 % --- **(1 Mark)** **ii) % regulation at Unity Power Factor;** $I_a \; line\ Current = \dfrac{KW\times 10^3}{(\sqrt{3})\times(V_{TLine})\ Cos\phi}$ $I_a \; line\ Current = \dfrac{1280\times 10^3}{(\sqrt{3})\times 13500\times 1}$ $I_a \; line\ Current = 54.74\ \ Amp$ $E/ph = \sqrt{(V_T\ Cos\phi + I_a R_a)^2 + (V_T\ \sin\phi + I_a X_S)^2}$ $E_{ph} = \sqrt{(7794.23\times 1 + 54.74\times 1.5)^2 + (7794.23\times 0 + 54.74\times 30)^2}$ $Eph = \sqrt{64733552\ .6}$ $Eph = 8045.72\ \ Volt$ -- **(1/2 Mark)** $\mathrm{Re}\,gulation = \dfrac{8045.72 - 7794.23}{7794.23}\times 100 = 3.23\,\%$ % Regulation = 3.23 % -- **(1/2Mark)**

iii) % Regulation at 0.8 Lagging Power Factor: $\cos\phi = 0.8,\ \sin\phi = 0.6$

$$E/ph = \sqrt{(V_T\ Cos\phi + I_a R_a)^2 + (V_T\ \sin\phi + I_a X_S)^2}$$ ------------------------ **(1/2Mark)**

$$E_{ph} = \sqrt{(7794.23\times0.8)+(68.43\times1.5)^2+(7794.23\times0.6+68.43\times30)^2}$$

$$E_{ph} = \sqrt{(6235.38)+(102.645)^2+(4676.54+2052.9)^2}$$

$$Eph = \sqrt{(6338.025)^2+(6729.44)^2}$$

$$Eph = \sqrt{40170560.9+45285362.71}$$

$$Eph = 9244.2373\,Volt$$ --- **(1/2Mark)**

$$Regulation = \frac{9244.2373-7794.23}{7794.23}\times100 = 18.60\%$$

% Regulation = 18.60 % --- **(1 Mark)**

Q.4 (B)	**Attempt any ONE:** **6 Marks**
a)	**Describe armature reaction with flux distribution waveforms of a three phase alternator when the nature of load on the alternator is resistive, purely inductive and purely capacitive.**

Ans:

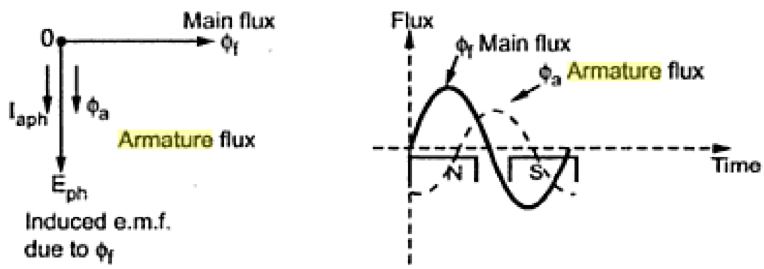
The effect of armature reaction depends upon power factor the load:

1) **For Resistive load or unity P.f.:-** In this case the armature flux crosses the main flux. This Effect is called **'Cross magnetizing effect**. Due to this, the main flux will be distributed and terminal voltage drops ie $V_T \langle E$.------------------**(1 Mark)**
2) **For lagging P.f. or inductive load: -** In this case the armature flux opposes the main flux. This effect is called as **de-magnetizing Effect**. Due to this, the main flux will be weakened and terminal voltage drops ie $V_T \langle E$.---------**(1 Mark)**
3) **For leading P.f. or capacitive load: -** In this case the armature flux assists the main flux. This Effect is called as Strong **magnetizing** and due to this ,the main flux will be stronger & terminal voltage increases ie $V_T \rangle E$.-----------**(1 Mark)**

OR Student May write this way

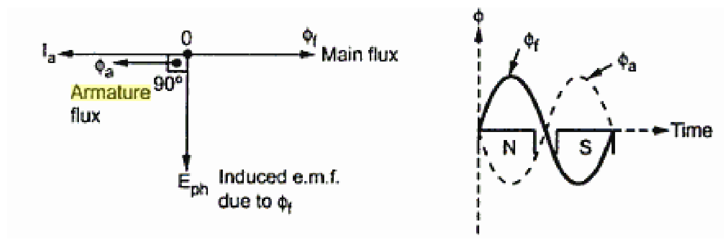
Waveforms showing the effect of armature flux:

1. **Armature reaction in alternators for Unity Power factor: ----------------(1 Mark)**



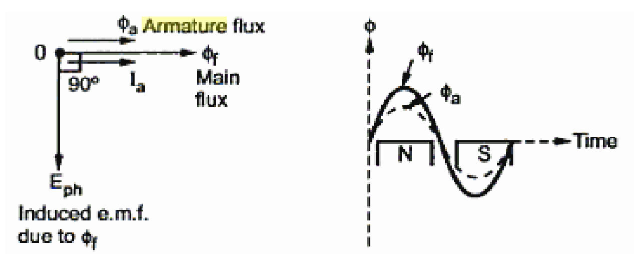
or Equivalent fig

2. **Armature reaction in alternators for Zero Power factor Lagging Load:---(1 Mark)**



or Equivalent fig

3. **Armature reaction in alternators for Zero Power factor Leading Load: --(1 Mark)**



or Equivalent fig

b) **(b) OC and SC test were performed on a 3 phase 0.5 MVA, 3.6 kV, star connected alternator. The result are given below :**
O.C. : If = 10 A, Voc = 3000 V S.C. : If = 10 A, Isc = 150 A
Ra/ph = 1 ohm Calculate the percentage, regulation for full load condition at 0.8 pf lagging.

Ans:

Given Data:

3Ph, 0.5 MVA, 3.6 KV star connected alternator,

V_T Line 3.6 KV (V_T/ph= 2078.46)

$$I_a \text{ line Current} = \frac{MVA \times 10^6}{(\sqrt{3}) \times (V_{TLine})}$$ **(1/2 Marks)**

$$I_a \text{ line Current} = \frac{(0.5)\times 10^6}{(\sqrt{3})\times(3.6)\times 10^3}$$

$$I_a \text{ line Current} = 80.188A$$ --**(1/2 Marks)**

$$Z_S/Ph = \frac{\text{O.C. Voltage}}{\text{S..C.Current}/ph} \text{ at } I_F = 10A$$ -------------------------- **(1/2 Marks)**

$$Z_S/Ph = \frac{3000/\sqrt{3}}{150}$$

$$Z_S/Ph = 11.547\ \Omega$$ -- **(1/2 Marks)**

$$X_S/Ph = \sqrt{(Z_S/ph)^2 - (R_a/ph)^2}$$ **(1/2 Marks)**

$$X_S/Ph = \sqrt{(11.547)^2 - (1)^2}$$

$$X_S/Ph = 11.504\ \Omega$$ --- **(1/2 Marks)**

Now,

% Regulation at full load for 0.8 Lagging P.f :

$$E/ph = \sqrt{(V_T\ \text{Cos}\phi + I_aR_a)^2 + (V_T\ \text{Sin}\phi + I_aX_S)^2}$$ **(1 Marks)**

$$E/ph = \sqrt{[(2078.46)(0.8) + (80.188)\ (1)]^2 + [(2078.46)(0.6) + (80.188)(11.504)]^2}$$

$$E/ph = 2782.96$$ --- **(1/2 Marks)**

% Regulation = $\frac{E_0/ph - V_T/ph}{V_T/ph} \times 100$ --- ----------------------- **(1 Marks)**

% Regulation = $\frac{2782.96 - 2078.46}{2078.46} \times 100$

% Regulation = $33.895\ \%$ --- --------------------------------------- **(1/2 Marks)**

Q.5	Attempt any FOUR : 16 Marks
a)	**A 3 phase induction motor has a starting torque of 100% and a maximum torque of 200% of the full load torque. Determine (i) Slip at which maximum torque occurs. (ii) Full load slip (iii) Rotor current at starting in per unit of full load rotor current.**

Ans: **Given Data:**

$$T_{st} = 1.0 \quad T_{FL} \text{ ------------------------------------- I}$$

$$T_{max} = 2.0 \quad T_{FL} \text{ ----------------------------------- II}$$

Solution:

$$\frac{T_{st}}{T_{max}} = \frac{1}{2} = \frac{2\,a}{1+a^2} \quad (\,Where\ a = \frac{R_2}{X_2})$$

$$\frac{T_{st}}{T_{max}} = 4\,a = 1 + a^2$$

$$\frac{T_{st}}{T_{max}} = a^2 - 4\,a + 1 = 0$$

Solving Quadratic equation :

$$roots = (\frac{-b \pm \sqrt{b^2 - 4\,ac}}{2\,a})$$

$$a = (\frac{-(-4) \pm \sqrt{(-4)^2 - 4 \times (1 \times 1)}}{2 \times (1)})$$

$$a = (\frac{(4) - \sqrt{16 - 4)}}{2})$$

$$a = 0.2679 \quad (a = \frac{R_2}{X_2} \therefore \frac{R_2}{X_2} = 0.2679)$$

i) The Slip at maximum torque (S_m) = $\frac{R_2}{X_2}$

S_m = 0.2679 -------------------- **(1 Mark)**

$$T_{max} = 2.0 \quad T_{FL} \quad given$$

$$\frac{T_{FL}}{T_{max}} = \frac{1}{2} = \frac{2\,a\,S_f}{a^2 + S_F{}^2} \quad Where\ \ S_F = Full\ load\ Slip$$

$$\frac{T_{FL}}{T_{max}} = \frac{2\times 0.2679\times S_f}{(0.2679)^2 + S_f^{\,2}} = \frac{1}{2}$$

$$S_f^{\,2} - 1.0716\ S_f + 0.0676 = 0$$

Solving Quadratic equation :

ii) Full Load Slip :

$$S_f = \left(\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)$$

$$S_f = \left(\frac{1.0716 \pm \sqrt{(1.0716)^2 - 4\times(0.0676)}}{2}\right)$$

$$S_f = \left(\frac{1.0716 \pm 0.93697}{2}\right)$$

$$S_f = 0.06731$$ -------------------- **(1 Mark)**

(iii) Rotor current at starting in per unit of full load rotor current:

$$T_{st}\ \alpha\ K_1 E_2\ I_{st}\ \frac{R_2}{\sqrt{R_2^{\,2} + X_2^{\,2}}}. \quad (Where\ \ S = 1)$$

$$T_{st}\ \alpha\ I_{st}\ \frac{R_2}{\sqrt{R_2^{\,2} + X_2^{\,2}}}$$ ------------------------------ I

$$T_{FL}\ \alpha\ I_{FL}\ \frac{R_2}{\sqrt{R_2^{\,2} + S_f^{\,2} X_2^{\,2}}}.$$ --------------------------- II

Dividing Equation I by equation II :

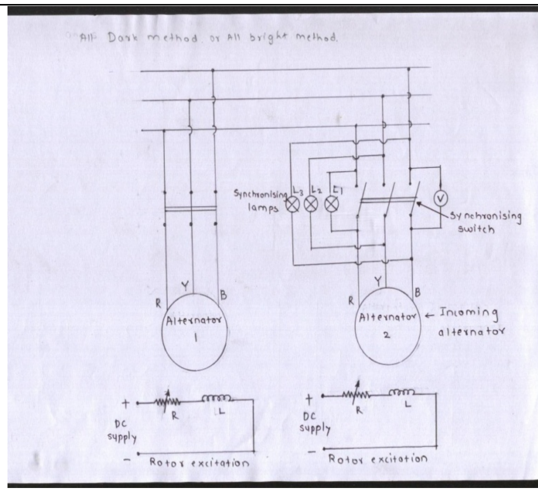
$$\frac{T_{st}}{T_{FL}} = \frac{I_{st}}{I_{FL}} \frac{\dfrac{R_2}{\sqrt{R_2^{\,2} + X_2^{\,2}}}}{\dfrac{R_2}{\sqrt{R_2^{\,2} + S_f^{\,2} X_2^{\,2}}}}$$

$$\frac{T_{st}}{T_{FL}} = \frac{I_{st}}{I_{FL}} \frac{\sqrt{R_2^{\,2} + S_f^{\,2} X_2^{\,2}}}{\sqrt{R_2^{\,2} + X_2^{\,2}}}$$

Dividing Numerator and Denominator in square root terms by X_2^2

	$$\frac{T_{st}}{T_{FL}} = \frac{I_{st}}{I_{FL}} \frac{\sqrt{\frac{R_2^2}{X_2^2} + S_f^2}}{\sqrt{\frac{R_2^2}{X_2^2} + 1}}$$ -------------------- **(1 Mark)** $T_{st} = 1.0 \quad T_{FL} \ given$ **Putting the value of** $\frac{R_2}{X_2} = 0.2669 \ and \ S_f = 0.06731 in \ above \ equation$ $$1.0 = \frac{I_{st}}{I_{FL}} \sqrt{\frac{(0.2679)^2 + (0.06731)^2}{(0.2679)^2 + 1}}$$ $$\frac{I_{st}}{I_{FL}} = \frac{1.0}{0.2669}$$ $$\frac{I_{st}}{I_{FL}} = 3.746 \ I_{FL}$$ -------------------- **(1 Mark)**
b)	**Derive the ratio of full load torque and maximum torque of a 3 phase induction motor.**
Ans:	The Equation of torque: $$T = \frac{S E_2^2 R_2}{R_2^2 + S^2 X_2^2}$$ - -- **(1/2 Mark)** ➢ The torque will be maximum when Slip = R_2 / X_2 ➢ Substituting the value of this slip in above equation we get the maximum value of torque as $$T_{max} = K \frac{E_2^2}{X_2^2} N - m$$ - -- **(1/2 Mark)** **The equation of the full load torque**: $$T_{full} = \frac{S_f E_2^2 R_2}{R_2^2 + (S_f^2 X_2^2)}$$ ---------------------------------- **(1/2 Mark)** **Where, S_f = Slip at full load** **The ratio full load torque to maximum torque:**

	$$\frac{T_{full}}{T_{max}} = \frac{\dfrac{S_f\ E_2^2\ R_2}{R_2^2 + (S_f^2\ X_2^2)}}{K\ \dfrac{E_2^2}{X_2^2}\ N-m}$$ ------------------------------------ **(1/2 Mark)**
	$$\frac{T_{full}}{T_{max}} = \frac{R_2\ (2 \times X_2)\ S_f}{R_2^2 + S_f^2 \times X_2^2}$$ ------------------------------------ **(1/2 Mark)**
	Dividing both numerical & denoted by X_2^2:
	$$\frac{T_{full}}{T_{max}} = \frac{\dfrac{R_2\ (2 \times X_2)}{X_2^2} \times S_f}{\dfrac{R_2^2}{X_2^2} + S_f^2 \times \dfrac{X_2^2}{X_2^2}}$$ ------------------------------------ **(1/2 Mark)**
	$$\frac{T_{full}}{T_{max}} = \frac{2\ (R_2/X_2)\ S_f}{\dfrac{R_2^2}{X_2^2} + S_f^2}$$
	$$Let\quad a = R_2/X_2$$
	$$\frac{T_{full}}{T_{max}} = \frac{2\ a \times S_f}{a^2 + S_f^2}$$ -- -------------------------------------- **(1 Mark)**
c)	**Explain lamp method of synchronizing alternator to the bus bar.**
Ans:	**Following are the ' Three lamp method' of synchronizing an alternator with the bus bar:-** **(Any One Lamp Method are expected: (Figure: 2 Mark & Explanation: 2 Mark)** **1. All Dark lamp method or all bright lamp method:** **Fig: For Three Phase Alternator**



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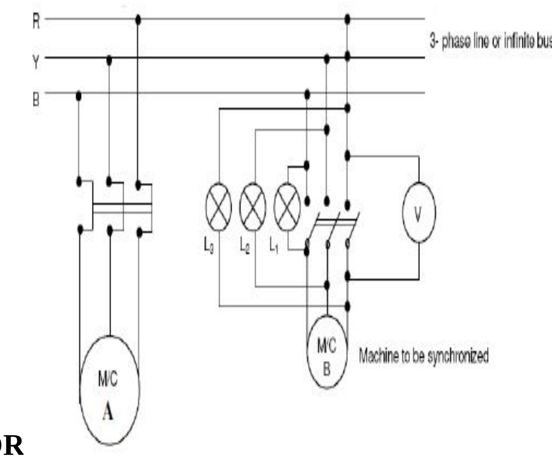
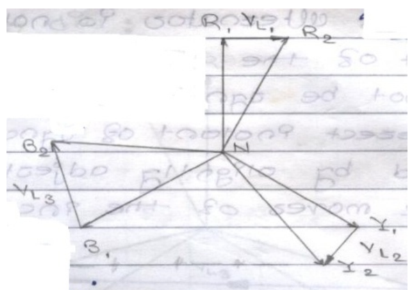




V_{L1} = Voltage across the lamps $L_1 = V_{R2} – V_{R1}$ V_{L2} = Voltage across the lamps $L_2 = V_{Y2} – V_{Y1}$ V_{L3} = Voltage across the lamps $L_3 = V_{B2} – V_{B1}$

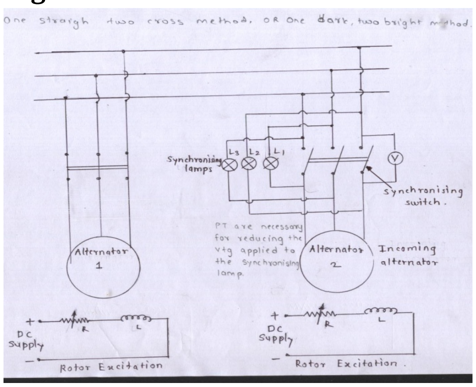
Vector Diagram:

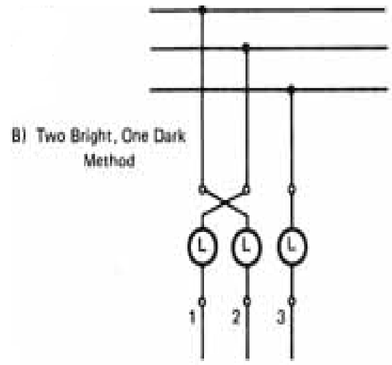
- The 3 lamp pairs L_1 & L_2, and L_2 & L_2, and L_3 & L_3 of equal wattage and voltage rating are connected as shown in figure across the switch and to the bus bar and alternator terminals.
- The Phasor diagram of the bus bar voltages (V_{R1}=V_{Y1}=V_{B1}) and the Phasor diagram of voltage of incoming alternator (V_{R2}=V_{Y2}=V_{B2}) are shown in the figure.
- If the bus bar voltage vector and the alternator voltage vector are in phase with each other then the polarities (phase sequence) of bus bur and alternator are same. At this instant the voltage across each lamp will be zero and thus lamps will be dark. This is the correct instant of synchronizing. The synchronizing switch is closed so that the incoming alternator is connected to the synchronizing satisfactorily.
- If the alternator voltage vectors are not in phase with the bus bar voltage vectors then there will be some voltage across the lamps and the lamps will glow with equal brightness. This shows the polarity of alternator is not the same as that of the bus bars. The alternator should not be synchronized at such instant. The correct instant of synchronizing is obtained by slightly adjusting the speed of the prime mover of the incoming alternator.

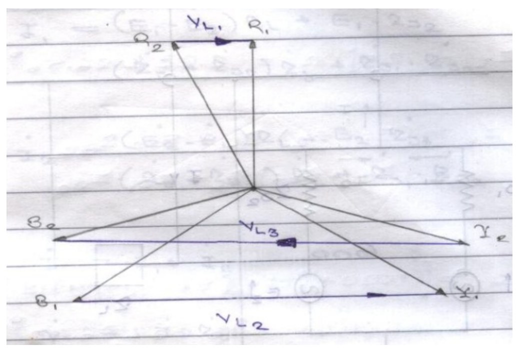
OR other method

2. One Dark, Two bright lamp method (One Straight, two cross method)

Fig: For Three Phase Alternator





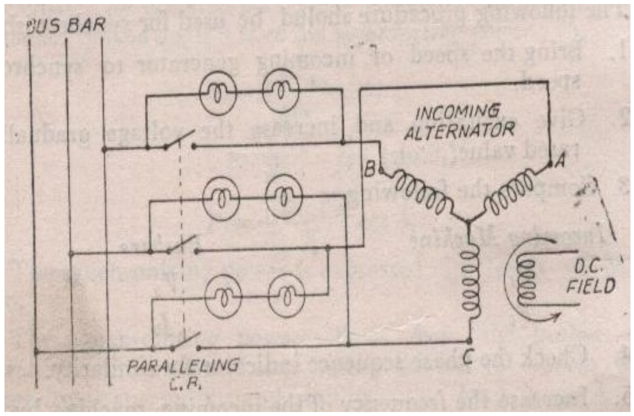


V_{L1} = Voltage across the lamps $L_1 = V_{R1} - V_{R2}$

V_{L2} = Voltage across the lamps $L_2 = V_{Y1} - V_{Y2}$

V_{L3} = Voltage across the lamps $L_3 = V_{B1} - V_{B2}$

- The 3 lamp pairs L_1 & L_2, and L_2 & L_2, and L_3 & L_3 of equal wattage and voltage rating are connected as shown in figure across the switch and to the bus bar and alternator terminals.
- The Phasor diagram of the bus bar voltages ($V_{R1}=V_{Y1}=V_{B1}$) and the Phasor diagram of voltage of incoming alternator ($V_{R2}=V_{Y2}=V_{B2}$) are shown in the figure.
- The lamps will still flickers in this case also and the rate of their flickering will depend on the amount of diff of the frequencies of the two alternators.
- The correctness of the phase sequence is indicated by the lamps blowing bright or dark, one after another and not simultaneously.
- The correct instant of closing the synchronizing switch is when the straight connected

	lamps are dark and the cross connected lamps are equally bright. **OR Student may write this way**  ➢ If the synchroscope is not available, synchronizing lamp method is used. ➢ There are different methods of lamp connection. The method of two bright and one dark lamp indication is illustrated in above figure. ➢ In this connection the lamps become bright and dark as follows for correct phase sequence. "Two lamps bright and one lamp dark at a time". ➢ If all the lamps become simultaneously dark or bright, the phase sequence is wrong. ➢ The switch is closed when the voltage, frequency and the lamps (2 bright and 1 Dark) satisfy the condition of synchronism.
d)	**A total of 1200 kW is shared equally by two identical alternator at 6000 V and 0.866 lagging p.f., the current one alternator is 70 A at lagging p.f. find the p.f. of both the alternators. Both the alternators are 3 phase star connected.**
Ans:	**Solution:** Total load: 1200 kW, Voltage: 6000V, P.f: 0.866 lag current of all = 70 A **Step 1: Total active load (KW_L) =** 1200 kW **Step 2 : Total reactive load :** $\therefore \phi = \cos^{-1}(0.866) = 30^0 \ Elec.$ $\therefore$ Total reactive load $= 1200\ kW \times \tan 30$ $\therefore$ Total reactiv load $= 692.8203$ KVAR ----------------------------- **(1/2 Marks)** **Step 3: Reactive Power shared by alternator 1:** $\therefore = P_1 \tan \phi_1$--- **(1/2 Marks)** $\therefore P_1 = \sqrt{3}\, V_L \times I_L \times Cos\phi$

$$\therefore \ \phi_1 = Cos^{-1}[\frac{P}{\sqrt{3} \times V_L \times I_L}]$$ -------------------------- **(1/2 Marks)**

$$\therefore \ \phi_1 = Cos^{-1}[\frac{600 \times 10^3}{\sqrt{3} \times 6000 \times 70}]$$

$$\therefore \ \phi_1 = Cos - 1(34.431)$$

$$\therefore Cos \ \phi_1 = 0.8247 \quad lag$$ ------------------------------- **(1/2 Marks)**

Reactive power shared by alternator 1 = $600 \times \tan(34.4331)$

$= 411.3379 \ KVAR$ ----------- **(1/2 Marks)**

Step 4: Reactive Power shared by alternator 2 = Total reactive – Reactive power of alt 1

= 692.8203 – 411.3379

Reactive Power shared by alternator 2 = 281.4824 KVAR----- (1/2 Marks)

But,

Reactive power shared by alternator 2 = $P_1 \ \tan \ \phi_2$

$281.4824 = 600 \times \tan \ \phi_2$ ------ **(1/2 Marks)**

$$\tan \ \phi_2 = \frac{281.4824}{600}$$

$$\tan \ \phi_2 = 0.4691$$

$$\phi_2 = \tan^{-1}(0.4691)$$

$$\phi_2 = 25.1331^0$$

$$Cos \ \phi_2 = 0.9053^0$$ ---------------------- **(1/2 Marks)**

OR student may write this way

Step 1: Total active load (KW_L) = 1200 kW is shared equally by two indicate alternators 1 & 2

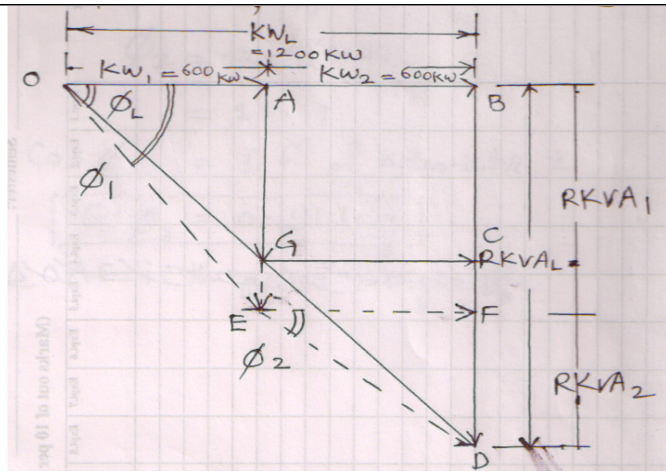


figure is not compulsory

- **The load current shared alternator 1 = I_1= 70 Amp**

$$\therefore \cos\phi_1 = \frac{KW_1}{\sqrt{3}\,V_T\ I_1}$$ -- **(1/2 Marks)**

$$\therefore \cos\phi_1 = \frac{600\times 10^3}{\sqrt{3}\times 6000\times 70}$$

$\therefore$ *Power factor alternator* $\cos\phi_1 = 0.825\ lag$ ----------------------------- **(1/2 Marks)**

$\therefore \phi_1 = \cos^{-1}(0.825) = 34.43^0\ Elec.$ ---------------------- **(1/2 Marks)**

$\therefore length\ (l)\ 'AE' = l\ (BF) = l\ (OA)\ \tan\phi_1$.

$\therefore RKVA_1\ of\ alternator\ 1 = 600\,kW \times \tan 34.43$

$\therefore RKVA_1 = 411.3\ RKVA$ ---------------------------------- **(1 /2Marks)**

$\therefore length\ (l)\ 'BD' = KVA\ of\ load = l\ (OB)\ \tan\phi_L$.

$\therefore \phi_L = \cos^{-1}(0.866) = 30^0\ Elec.$

$\therefore RKVA_L = 1200\ kW \times \tan 30$

$\therefore RKVA_L = 692.82\ RKVA$ -------------------------------------- **(1/2 Marks)**

$\therefore RKVA\ of\ alternator = l\ (FD) = l\ (BD) - l\ (BF) = 692.82 - 411.3$

$\therefore RKVA_2 = 281.52$ ----------------------------------- **(1/2 Marks)**

RA Δ EFD is the power triangle of alternator No.2:

$$\therefore \tan\phi_2 = \frac{l\,(FD)}{l\,(EF)} = 0.47$$ --------------------------------------- **(1/2 Marks)**

$$\therefore \phi_2 = \tan^{-1}(0.47)$$

$$\therefore \phi_2 = 25.17$$

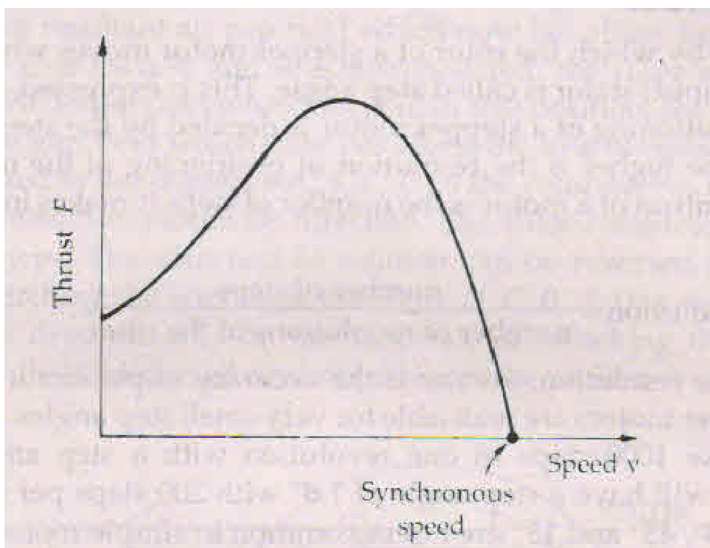
$$\therefore\ Cos\phi_2 = P.f.\ of\ alternator\ 2$$

$$\therefore\ Power\ factor\ alternator\ \cos\phi_2 = 0.91\ lag$$ --------------------------- **(1/2 Marks)**

e) **Draw the torque-speed characteristics of linear induction motor. Write down any two applications of linear induction motor and universal motor.**

Ans:

Torque-speed characteristics of linear induction motor: **(2 Marks)**



or Equivalent fig.

Applications of each of the following: **(Each Motor Application : 1 Mark)**

Sr.No	Types of 1-Ph Induction Motor	Applications (Any Two expected)
1	Linear Induction Motor **(Any One Applications 1Marks)**	• Application for Stationary Field System ▪ Automatic sliding doors in an electrical train, ▪ Metallic belt conveyer, ▪ Mechanical handling equipment, such as propulsion of a train of tubs along a certain route, ▪ Shuttle-propelling application.

		• Applications for the moving field system ▪ High and medium speed applications have been tried with linear motor propulsion of vehicles with air cushion or magnetic suspension. ▪ High speed application as a travelling crane motor where the field system is suspended from loist.
2	Universal Motor **(Any one Applications 1 Marks)**	1) Mixer 2) Food processor 3) Heavy duty machine tools 4) Grinder 5) Vacuum cleaners 6) Refrigerators 7) Driving sewing machines 8) Electric Shavers 9) Hair dryers 10) Small Fans 11) Cloth washing machine 12) portable tools like blowers, drilling machine, polishers etc

f) **What is induction generator? State its applications.**

Ans: **Induction generator:** **(2 Mark)**

When rotor of induction motor runs faster than synchronous speed, induction motor runs as generator and called as induction generator. It converts mechanical energy it receives from the shaft into electrical energy which is released by stator. However, for creating its own magnetic field, it absorbs reactive power Q from the lime to which it is connected. The reactive power is supplied by a capacitor bank connected at the induction generator output terminals.

Applications of Induction Generator: **(Any Two Application expected: 1 Mark each)**

1. It is used in wind mills.

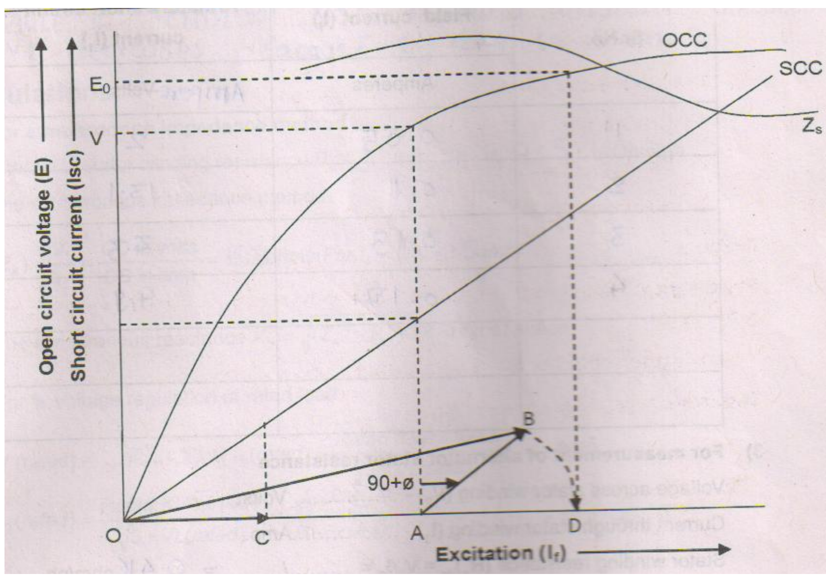
2. It is used to assist the power received from weak transmission lines in the remote areas.
3. To compensate reactive power from the supply.
4. Regenerative breaking of hoists driven by the three phase induction motors
5. With energy recovery systems in industrial processes

Q.6 Attempt any FOUR: 16 Marks

a) Explain the method of finding regulation of alternator by ampere turn methods.

Ans: **NOTE: All the following answer is not expected : only keyword are expected**

(Graph: 2 Mark & Any one method explanation: 2 Mark)



The two components of total field m.m.f. which are' D' and 'A' are indicated in O.C.C. (open circuit characteristics) and S.C.C. (short circuit characteristics) as shown in the

Fig. 1.

- This method of determining the regulation of an alternator is also called Ampere-turn method or Rothert's M.M.F. method.
- The method is based on the results of open circuit test and short circuit test on an alternator.
- For any synchronous generator i.e. alternator, it requires m.m.f. which is product of field current and turns of field winding for two separate purposes.

1. It must have an m.m.f. necessary to induce the rated terminal voltage on open circuit.

2. It must have an m.m.f. equal and opposite to that of armature reaction m.m.f.

Any one Method are expected

1. Ampere Turn Method (MMF Method) at Unity Power factor from graph:

- Draw the line 'OA' to represent if which gives the rated generated voltage (V)
- 'OC' represent field current required for producing full load current on short circuit OC = AB. Draw the line 'AB' at an angle (90) to represent if, which gives rated full load (I_{SC}) on short circuit
- Join the points 'O' and 'B' and find the field current (I_f) by measuring the distance 'OB' the gives the open circuit voltage (E_0) from the open circuit characteristics.
- **% Voltage Regulation =** $\frac{E_0 - V}{V} \times 100$

2. Ampere Turn Method (MMF Method) at Lagging Power factor from graph:

- Draw the line 'OA' to represent if which gives the rated generated voltage (V)
- 'OC' represent field current required for producing full load current on short circuit OC = 'AB'. Draw the line 'AB' at an angle (90+θ) to represent if, which gives rated full load (I_{SC}) on short circuit
- Join the points 'O' and 'B' and find the field current (I_f) by measuring the distance 'OB' the gives the open circuit voltage (E_0) from the open circuit characteristics.
- **% Voltage Regulation =** $\frac{E_0 - V}{V} \times 100$

3. Ampere Turn Method (MMF Method) at Leading Power factor from graph:

- Draw the line 'OA' to represent if which gives the rated generated voltage (V)
- 'OC' represent field current required for producing full load current on short circuit OC = 'AB'. Draw the line 'AB' at an angle (90-θ) to represent if, which gives rated full load (I_{SC}) on short circuit
- Join the points 'O' and 'B' and find the field current (I_f) by measuring the distance 'OB' the gives the open circuit voltage (E_0) from the open circuit characteristics.
- **% Voltage Regulation =** $\frac{E_0 - V}{V} \times 100$

b) **Why single phase induction motor is not self starting ?**

Ans: **Reason for single phase induction motors are not self starting:** **(4 Mark)**

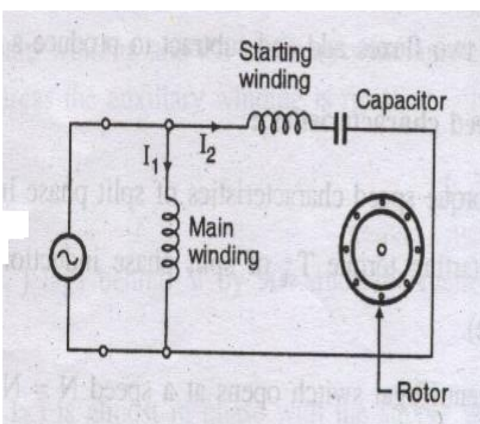
- When single phase AC supply is given to main winding it produces alternating flux.
- According to double field revolving theory, alternating flux can be represented by two opposite rotating flux of half magnitude.
- These oppositely rotating flux induce current in rotor & there interaction produces two opposite torque hence the net torque is Zero and the rotor remains standstill.
- Hence Single-phase induction motor is not self starting.

OR

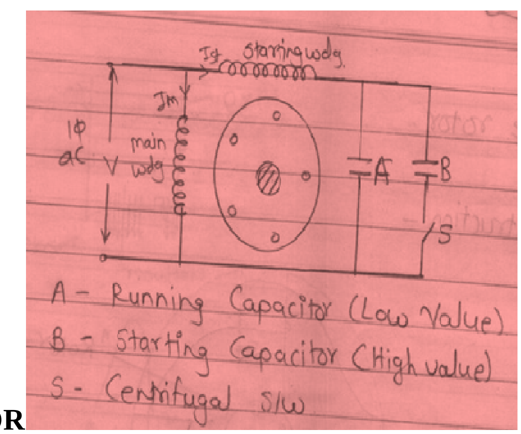
Single phase induction motor has distributed stator winding and a squirrel-cage rotor. When fed from a single-phase supply, its stator winding produces a flux (or field) which is only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving (or rotating) flux as in the case of a two or a three phase stator winding fed from a 2 of 3 phase supply. Now, alternating or pulsating flux acting on a stationary squirrel-cage rotor cannot produce rotation (only a revolving flux can produce rotation). **That is why a single phase motor is not self-starting.**

c) **Explain role of capacitor in a single phase capacitor start capacitor run induction motor.**

Ans: **(Figure -2 Mark & Explanation -2 Mark)**



OR



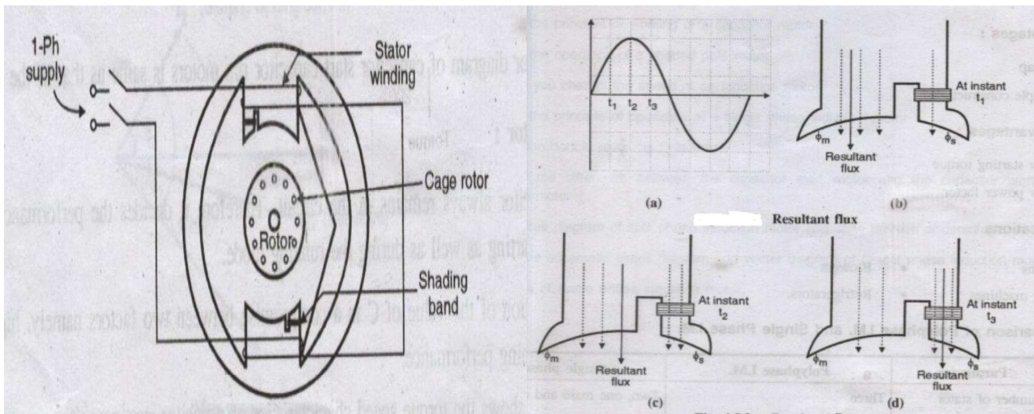
or Equivalent fig

In these motors one capacitor is connected in series with the auxiliary winding. There is no centrifugal switch. Thus this winding along with the capacitor remains energized for both starting and running conditions. **<u>Capacitor serves the purpose of obtaining necessary phase displacement at the time of starting and also improves the power factor of the motor.</u>**

d) Describe with neat sketch the working of shaded pole Induction motor.

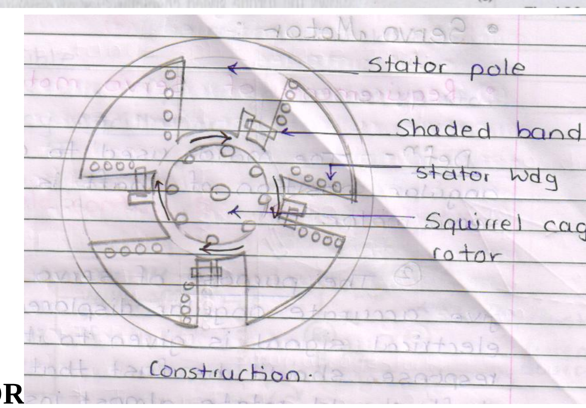
Ans:

i) Shaded Pole Induction Motor : **(Figure-2 Mark & Explanation: 2 Mark)**



or

OR



Equivalent Fig.

Construction & Working:-

When single phase supply is applied across the stator winding an alternating field is created. The flux distribution is non uniform due to shading coils on the poles.

Now consider three different instants of time t_1, t_2, t_3 of the flux wave to examine the effect of shading coil as shown in the fig above. The magnetic neutral axis shifts from left to right in every half cycle, from non shaded area of pole to the shaded area of the pole. This gives to some extent a rotating field effect which may be sufficient to provide starting torque to squirrel cage rotor.

e)	**State applications of the following : (any two)** **(i) DC servo motor (ii) Stepper motor.**
Ans:	**(i) Application of DC servo motor,** It is widely used in **:** **(Any Two Applications expected: 1 Mark each)** 1. Radars 2. Computers 3. Robots 4. Machine Tools 5. Tracking and guidance systems 6. Process controllers **(ii) Application of Stepper motor,** It is widely used in **:** **(Any Two Applications expected: 1 Mark each)** 1. Suitable for use with computer control systems 2. Widely used in numerical control of machine tools 3. Tape Drives 4. Floppy disc Drives 5. Printers 6. X-Y Plotters 7. Robotics 8. Textile Industries 9. Integrated circuit fabrication 10. Electric Watches 11. In Space crafts launched for scientific explorations of planets. 12. In the production of science fiction movies. 13. Varity of commercial, medical and military applications

--END--