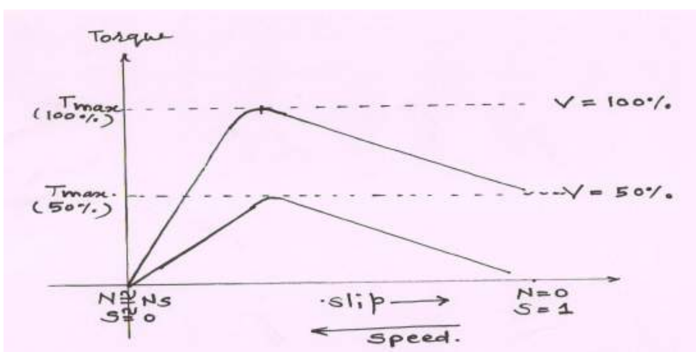
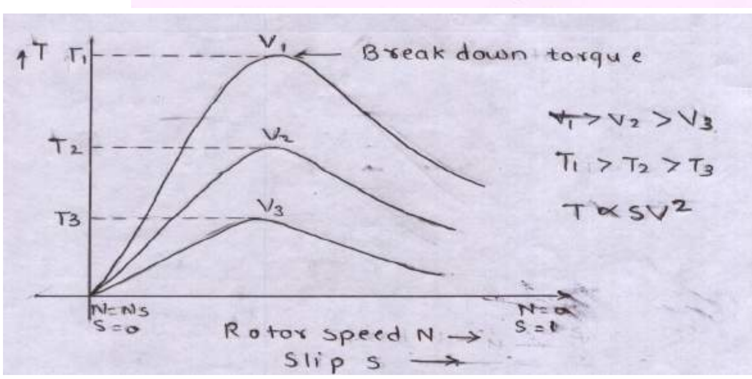
Important suggestions to examiners:

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 of the following: 12 Marks**
a)	**State the effects of change in supply voltage on torque-slip characteristics of 3-phase induction motor.**
Ans:	**effects of change in supply voltage on torque-slip characteristics:** **(Figure-2 Marks & Effect- 2 Marks)**  **OR**  **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
b)	**State the function of following parts of an induction motor (i) Slip-rings, (ii) Fan, (iii) Brushes and (iv) Frame.**
Ans:	**(Each parts of function :1 Mark)**

S.No	**Parts of Induction Motor**	**Function**
i)	Slip-rings	Connect 3-Ph rheostat to the rotor circuit via brushes
ii)	Fan	Air circulation and cooling.
iii)	Brushes	To provide connection between external rheostat to rotor circuit through Slip-ring
iv)	Frame	Supports the stator core, protects inner parts

c)	**(i) State the necessity of starter for three-phase induction motor.** **(ii) Write the names of starters used for 3-phase squirrel cage induction motor.**
Ans:	**i) The necessity of starter for 3-ph induction motor:** ------------------------------- **(2Mark)** If a 3-phase A.C supply is directly given to a 3-phase induction motor, at starting the motor will draw nearly 6-10 times its full load current at very low power factor. Such a huge current is harmful to the motor. Therefore there is necessity of starter for 3-phase induction motor to control the starting current. **OR** The induction motor is similar in action to poly phase transformer with short

	circuited rotating secondary. Therefore if normal supply voltage is applied to such stationary motor than as in case of transformer a very large initial current is taken by the primary for short while. At starting the motor will draw nearly 6-10 times its full load current at very low power factor. Such a huge current is harmful to the motor. And to protect the motors from such heavy currents it is necessary to use starters for 3-phase induction motor. **ii) The names of starters used for 3-phase squirrel cage induction motor.** -------------- **(2Mark)** 1) DOL Starter 2) Star-Delta Starter 3) Stator resistance starter 4) Auto transformer Starter
d)	**Define the following terms and write their mathematical expression :** **(i) Pitch Factor and (ii) Distribution Factor related to the winding of alternators**
Ans:	**i) Pitch factor:** **(1 Mark)** It is the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil. **Mathematical expression:-** **(1 Mark)** $K_C = Cos\ (\frac{\alpha}{2})\ Where\ \alpha = Shorter\ \ angle\ than\ pole\ pitch$ **ii) Distribution factor related to the winding of alternators :** **(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. **Mathematical expression:-** **(1 Mark)** $K_d = \frac{Sin\ (\frac{m\beta}{2})}{m\ .\ Sin\ (\frac{\beta}{2})}\ Where\ \beta = Angular\ distance\ \ between\ two\ adjescent\ armature\ slots$ $m = No.\ of\ \ Slots / Pole / Ph$

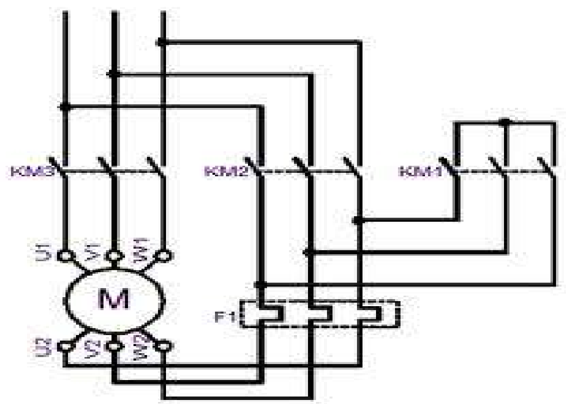
Q.1B)	**Attempt any ONE : 06 Marks**
a)	**Draw and explain how star-delta starter is used for reducing the starting current of a 3-phase induction motor.**

Ans: **(Wiring Diagram-3 Mark & Explanation-3 Mark)**

At Starting, the stator winding is connected in star connection when the triple change over switch is connected to position '1'

After the motor has reaches nearly steady state speed, the change over switch is put in position '2', So that the motor is connected in delta

Diagram of Star -Delta starters:



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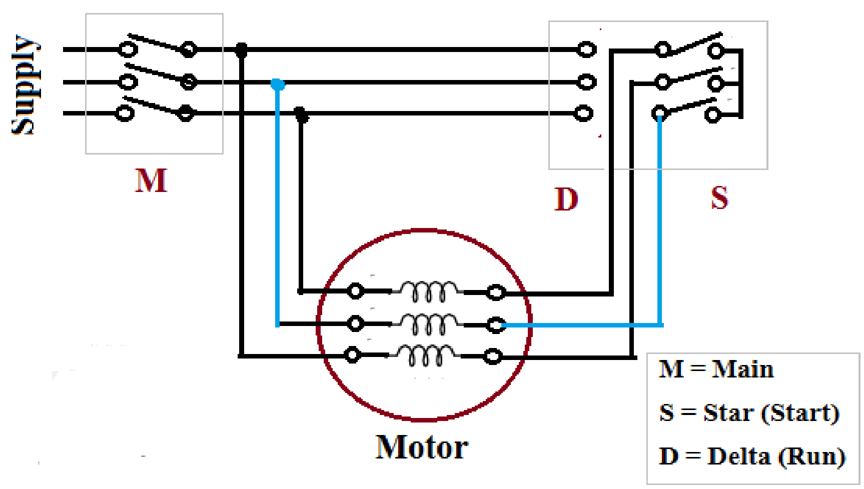


or Equivalent fig.

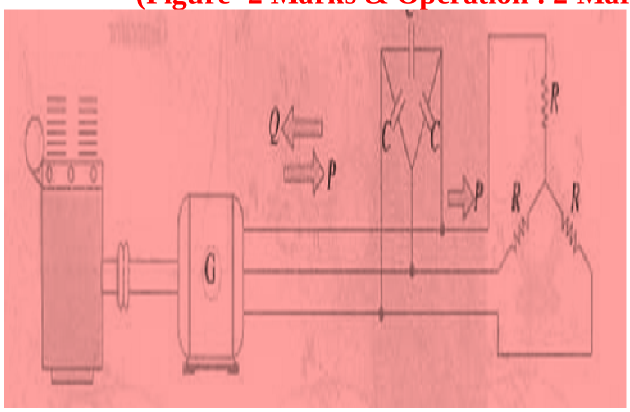
At the time of starting in star connection, $Iph = \frac{Vph}{Z_{SC}}$ But $Vph = \frac{V_L}{\sqrt{3}}$

$$Iph = \frac{V_L}{\sqrt{3}\,Z_{SC}}$$

At the time Starting ,if the winding would have been connected in Delta, the current would have been $Iph = \frac{Vph}{Z_{SC}} = \frac{V_L}{Z_{SC}}$...............$As\ Vph = V_L$

b) **Describe the principle of operation of an induction generator. Draw its torque-speed characteristic.**

Ans: **Figure:-** **(Figure- 2 Marks & Operation : 2 Mark, Characteristics : 2 Mark)**

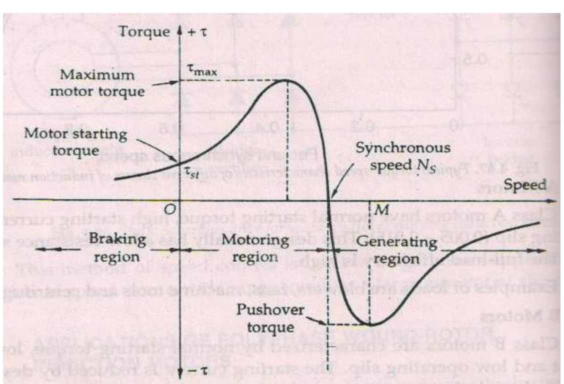


or Equivalent fig.

- **The principle of operation induction Generator:**

When rotor of induction motor runs faster than synchronous speed (N>Ns), 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 line to which it is connected. The reactive power is supplied by a capacitor bank connected at the induction generator output terminals.

- **Torque-speed characteristic:**



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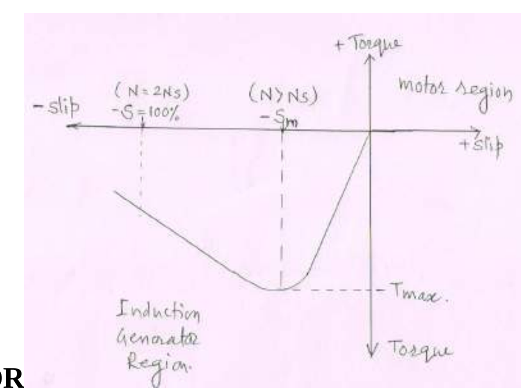

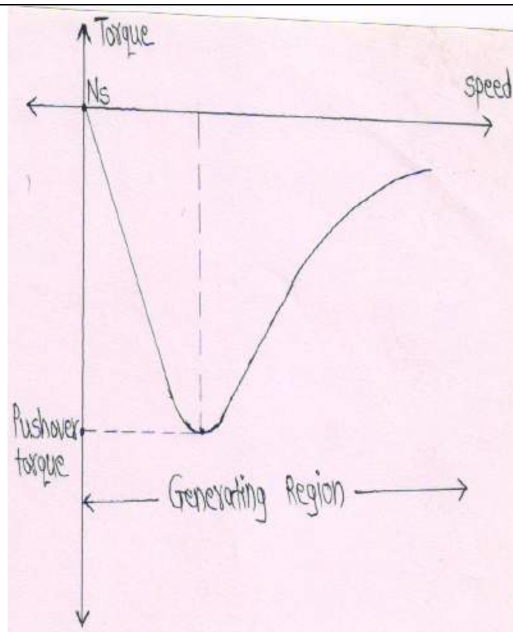

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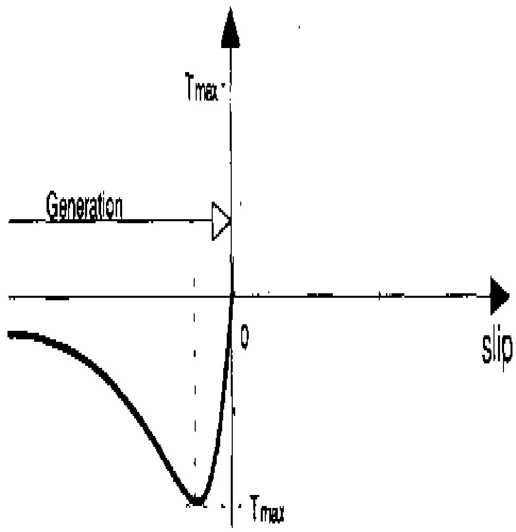


or **equivalent figure**

Q.2	**Attempt any FOUR : 16 Marks**
a)	**Compare squirrel cage and slip-ring induction motor on the basis of :** **(i) Starting torque (ii) Power factor (iii) Speed control and (iv) Applications.**
Ans:	**(Each Point -1 Mark)**

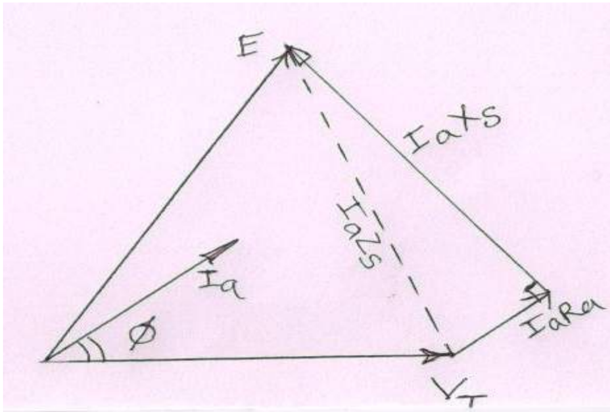
S.No	Points	Squirrel Cage Induction Motor	Slip Ring Induction Motor
i)	Starting torque	Poor	Higher
ii)	Power factor	Poor	Higher
iii)	Speed control	By stator control method only	By stator & rotor control method
iv)	Applications.	For driving somehow constant load e,g. Lathe Machine, Workshop Machine and water pump	For driving heavy load where high starting torque is required eg. Lift, Crane, Elevators, conveyor belts etc

b)	**Explain why three phase induction motor is called as asynchronous motor. Also give the formulae for rotor induced emf and frequency of rotor currents.**
Ans:	**Explanation :** **Reason for three phase induction motor is called as asynchronous motor : (2 Marks)** ➢ Three phase induction motor never runs at synchronous speed hence it is called as asynchronous motor. OR I.M. always runs less than synchronous speed hence it is called as asynchronous motor. ➢ **Formulae for** : rotor induced emf under running condition : **(1 Marks)** $E_r = S\ E_2\ \ Where\ \ S = Slip\ \ \ and\ \ E_2 = rotor\ \ induced\ \ emf\ \ at\ \ standstill$ **OR** $E_r = Ir \times Zr\ \ Where\ Ir = rotor\,current\ under\ runing\ \&\ Zr = rotor\,impedance\ under\ runing$ $E_r = (S\ I_2) \times (\sqrt{R_2^{\ 2} + S^2.X_2^{\ 2}}$ ➢ **Formulae for** : frequency of rotor currents : **(1 Marks)** $f^{'} = S\ f\ \ Where\ \ S = Slip\ \ \ and\ \ f = Supply\ \ frequency$
c)	**Compare salient pole rotor and smooth cylindrical rotor alternator on the basis of : (i) Operating speed (ii) Rotor construction (iii) Ratio of core length to bore diameter and (iv) Applications.**
Ans:	**(Each Point -1 Mark)**

S.No	Points	Salient pole rotor Alternator	Cylindrical rotor Alternator
i)	Operating speed	Low medium	high
ii)	Rotor construction	Projected type bulky & heavy weight	Cylindrical poles type comparatively moderate weight
iii)	Ratio of core length to bore diameter	large	small
iv)	Application	In hydro power stations	Thermal power station

d) **Draw the phasor diagram of loaded alternator when load is capacitive and also write the equation of no load, induced emf.**

Ans: **The phasor diagram of loaded alternator when load is capacitive :** **(2 Mark)**



or Equivalent fig.

The equation of no load, induced emf: **(2 Mark)**

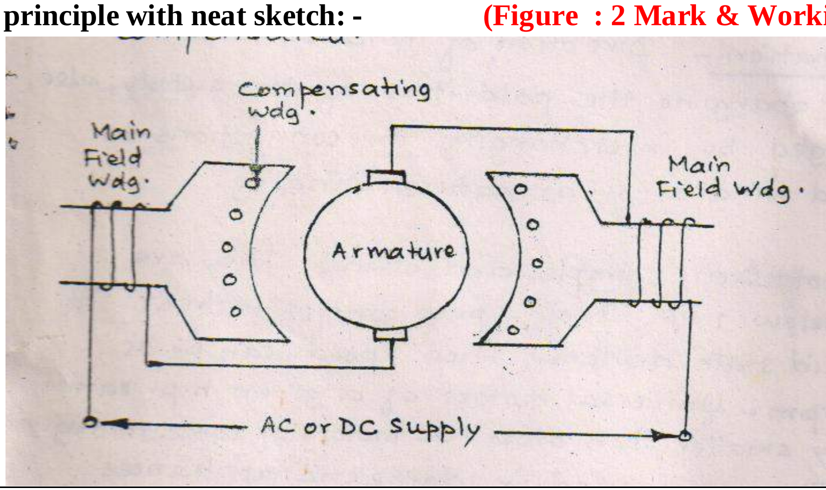
$$No.\,load\ emf\ \ E_0 = \sqrt{(V\,Cos\phi + I_a R_a)^2 + (V\sin\phi - I_a X_S)^2}$$

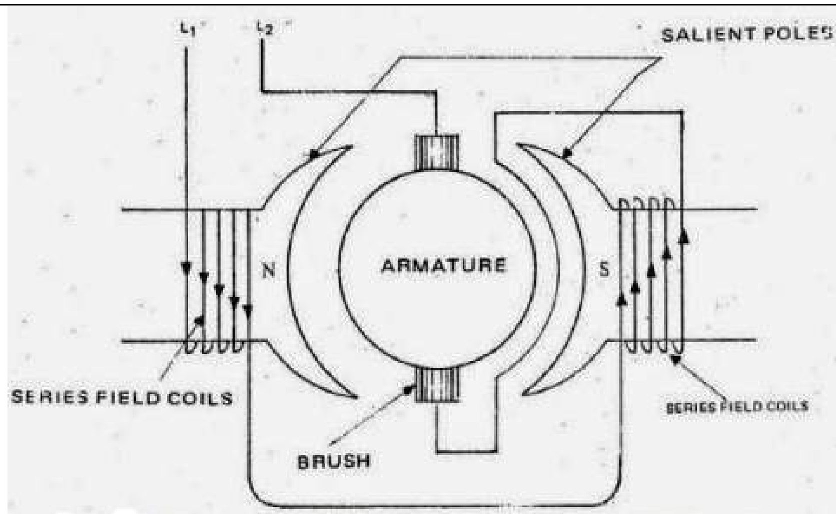
e) **A motor is to be operated from 230 V, 50 Hz single phase A.C. and 220 V D.C. supply. Identify the above motor and describe its working principle with neat sketch.**

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**

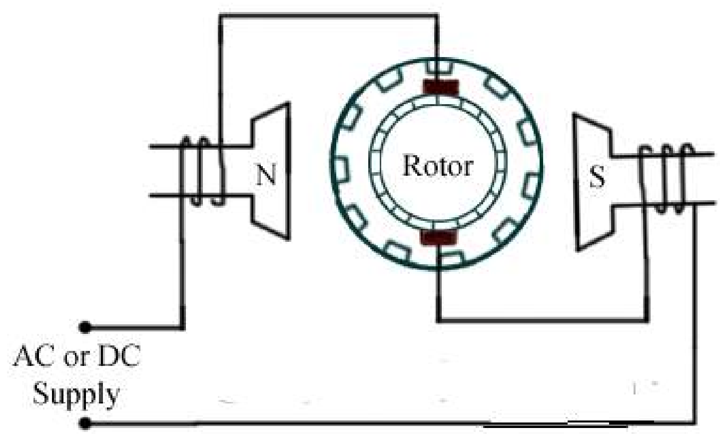
Working principle with neat sketch: - **(Figure : 2 Mark & Working : 1 Mark)**





OR

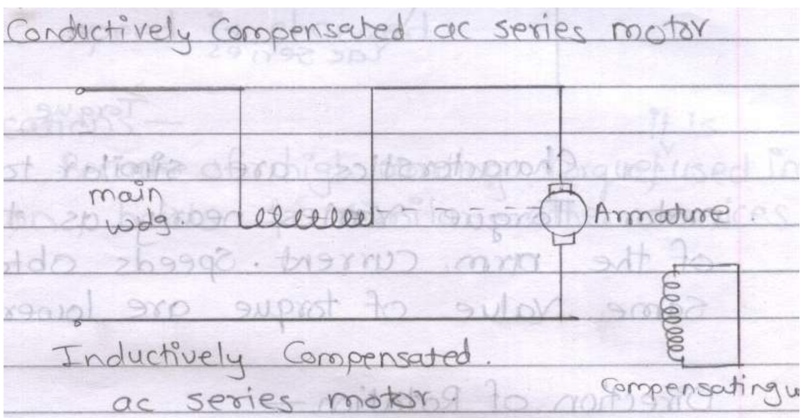
OR Equivalent figure



- 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

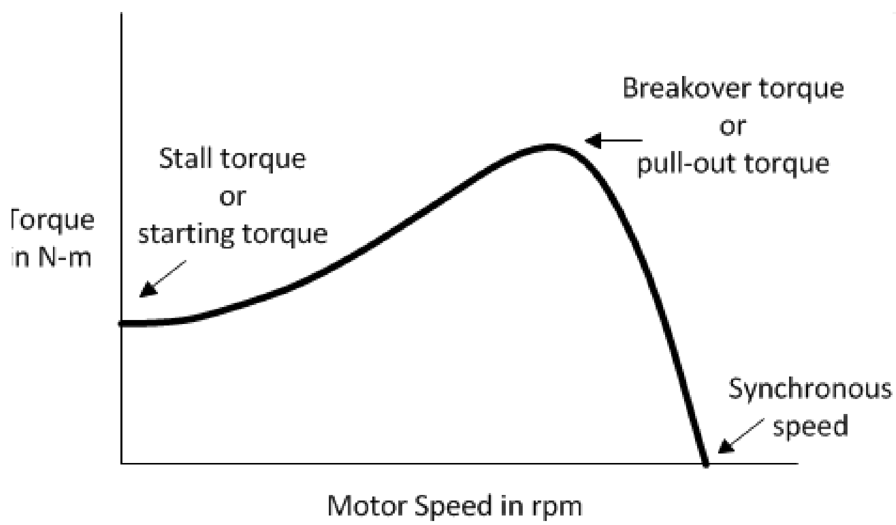
	polarity of AC changes periodically, the direction of current in armature and field winding reverses at the same time. Thus, direction of magnetic field and the direction of armature current reverses in such a way that the direction of force experienced by armature conductors remains same. Thus, regardless of AC or DC supply, universal motor works on the same principle that DC series motor works.
f)	**Practically if D.C. series motor has to be supplied with single phase A.C., what modification and refinements will have to be done on D.C. series motor ?**
Ans:	**(Figure- 2 Marks & Explanation 2 Marks)**

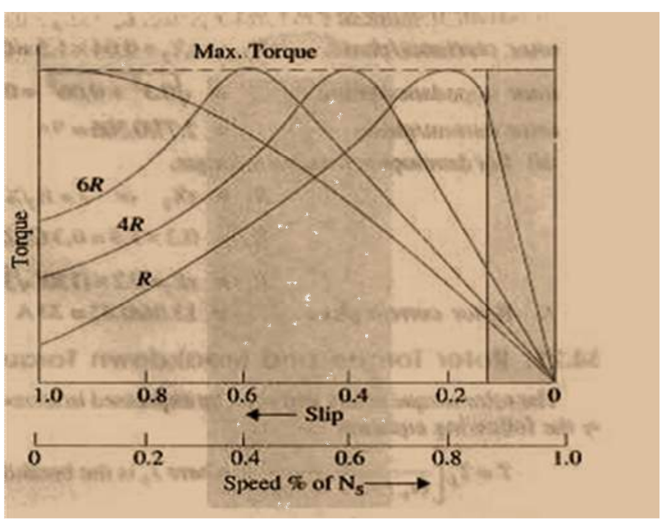


or Equivalent fig

The D.C series motor can be run on A.C supply also, but the following modifications will be done when D.C series motor works on A.C. Supply.

- The field core has to be constructed of a material having low hysteresis loss.
- The rotor and the stator have to be laminated to reduce eddy current losses.
- Also the pulsating nature of AC may cause the commutator segments and brushes to wear out and produce sparking. This can be eliminated by using high resistance leads to connect the coils to the commutator segments.
- The field winding is provided with small number of turns. The field-pole areas is increased so that the flux density is reduced.This reduces the iron loss and the reactive voltage drop.
- The number of armature conductors has to increased in order to get the required torque with the low flux.
- A in order to reduce the effect of armature¬compensation winding is used reaction,

	thereby improving commutation and reducing armature reactance. **OR** 1. The armature & field core are made up of laminated nature to reduce eddy current losses. The Laminations are of silicon steel stampings. 2. The power factor of the motor can be improved by, ➢ If possible motor is run at low frequency **or** ➢ Field is wound with fewer turns than an equivalent DC motor and increase pole area to reduce reluctance. ➢ And operating the iron at low flux density & at high permeability ➢ And by keeping small air gap. 3. The sparking of brushes (Armature reaction) will be minimized by compensating winding which is embedded in the pole faces. 4. If the compensating winding is short circuit on itself as shown in above figure, a motor is said to be inductively compensated.
Q.3	**Attempt any Four : 16 Marks**
a)	**Draw and explain torque-slip characteristics of three phase induction motor.**
Ans:	**Torque-slip characteristics :** **(Figure-2 Marks & Explanation:- 2 Marks)**  Speed-Torque Curve for a Three-Phase Induction Motor **or** **Equivalent fig**

	Explanation: From the above characteristics:- ➢ When Slip (S) ≅ 0 (i.e N ≅ Ns) torque is almost zero at no load, hence characteristics start from origin ➢ As load on motor increases Slip increases and therefore torques increases. ➢ For lower values of load, torque proportional to slip, and characteristics will having linear nature. ➢ At a particular value of Slip, maximum torque conditions will be obtained which is $R_2 = SX_2$ ➢ For higher values of load i.e. for higher values of slip, torque inversely proportional to slip and characteristics will having hyperbolic nature. In short breakdown occurs due to over load. ➢ The maximum torque condition can be obtained at any required slip by changing rotor resistance.
b)	**Describe with the help of curves the effect of variation of a rotor circuit resistance on the torque-slip characteristics of an induction motor.**
Ans:	**(Explanation of Effect- 2 Marks Characteristics -2 Marks)** **Explanation: From the below characteristics:-** ➢ When rotor resistance increases, maximum torque condition occurs at higher values of slip and characteristics shifts towards left hand side. ➢ The maximum torque condition can be obtained at any required slip by changing rotor resistance. **Figure:**  **or characteristics**

c)	**Derive the e.m.f. equation of a three phase alternator from first principle.**
Ans:	**EMF Equation of alternator :** Let, P = No. of rotor poles. ϕ = Flux per pole Z= Number of stator conductors N = Speed in rpm $\therefore turns\ per\ phase\ (Tph) = \frac{Z_{Ph}}{2}$ -- **(1/2 Marks)** $\therefore$ Frequency of induced emf is f = Cycles per rotation x rotation per sec $\therefore = \frac{P}{2} \times \frac{N}{60}$ $\therefore f = \frac{PN}{120}$ -- **(1/2 Marks)** Consider one rotation of rotor then change in flux linkage is, $d\phi = P.\ \phi$ Time required for one rotation is, $\therefore dt = \frac{1}{n} = \frac{1}{(N/60)} = \frac{60}{N} ----------Sec.$ ---------------------- **(1/2 Marks)** By faradays law of Electromagnetic induction $\therefore Average\ emf\ per\ conductor = \frac{d\phi}{dt}$ $\therefore$ E_{ave} / Conductor = $\frac{P.\phi}{(N/60)}$ $\therefore$ E_{ave} / Conductor = $\frac{P \times \phi \times N}{60}$ ---------- Volt ---------------**(1/2 Marks)** $\therefore$ E_{ave} / turn = 2 E_{ave}/ Conductor $\frac{P \times \phi \times N}{60} ---------Volt$ $\therefore$ E_{ave} / turn = 2 $\frac{P \times \phi \times N}{60} ---------Volt$ $\therefore$ = $\frac{4P\phi N}{120} ---------Volt$ -------------------------**(1/2 Marks)** $\therefore$ = $4\ (\frac{P\ N}{120})\ \phi$ $\therefore$ E_{ave} / turn = $4\ f\ \phi$ $\therefore (f = \frac{P\ N}{120})$ $\therefore$ E_{ave} / Phs = E_{ave} / x Number of turns per phase $= 4\ f\ \phi \times T_{Ph}$ -- **(1/2 Marks)** RMS Value per phase is given by, $E_{ph} = E_{ph}$ (ave) x Form Factor

$= 4\ f\ \phi \times T_{Ph} \times 1.11$ ------------------------------------ **(1/2 Marks)**

$E_{ph} = 4.44\ \phi.f\ T_{Ph}$ volts

It is for full pitched concentrated winding. If winding is distributed & short pitched then

$E_{Ph} = 4.44\ \phi.f.\ T_{Ph}.\ kd.kc$ volts

------------------------- **(1/2 Marks)**

Where, Kc = coil span factor or chording factor
Kd = Distribution factor

d) **An 400 V, 125 kVA, 3-phase, star connected alternator has open-circuit characteristics as under :**

Field Current (A)	**0**	**10**	**20**	**30**	**40**	**50**	**60**
Open Circuit emf ('V)	**0**	**140**	**250**	**340**	**400**	**460**	**520**

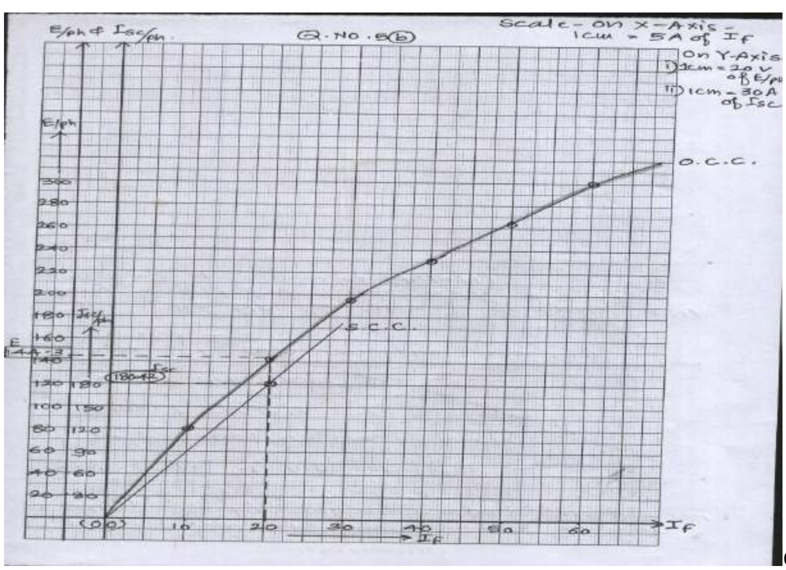
Short circuit characteristics of the alternator is a straight line passing through origin and it is found that the S.C. current is equal to the full load current when If is 20 A. Determine full load regulation of the alternator by Z, method at the following p.f. : (i) 0.8 lagging and (ii) 0.8 leading. Assume Ra is 0.15 O.

Ans: **Given Data:**

3-Ph, 400V, P = 125 KVA Ra = 0.15 ohm

Field current (A)	0	10	20	30	40	50	60
Open circuit emf (V)	0	140	250	340	400	460	520
Open circuit V per Phase		**80.8**	**144.3**	**196.3**	**230.9**	**256.6**	**300**

Note : In Graph Scale may be different : -- **(1/2Mark)**



or equivalent fig

Phase Resistance, R_a = 0.15 ohm

Phase Voltage V= $\frac{400}{\sqrt{3}} = 230.90\, volts$ --------------------------- **(1/2 Mark)**

Full load Line current I = I_a = $\frac{125\times10^3}{\sqrt{3}\times 440}$ =$180.42A$------------ **(1/2 Mark)**

From OCC and SCC:-

$$\therefore Synchronous\ impedance\ per\ phase = Zs = \frac{O.C\ Voltage/ph}{S.C\ Current/ph} = \frac{144.3}{180.42}$$

$\therefore Synchronous\ impedance\ per\ phase = Zs = 0.8\Omega$ -------------------- **(1/2 Mark)**

Synchronous reactance, $X_S = \sqrt{Z_S^2 - R_a^2} = \sqrt{0.8^2 - 0.15^2} = 0.7858\ \Omega$ -- **(1/2 Mark)**

i) 0.8 Lagging Power Factor;

$No.\,load\ emf\ E_0 = \sqrt{(V\ Cos\phi + I_aR_a)^2 + (V\sin\phi + I_aX_S)^2}$ --------------- **(1/2 Mark)**

$$No.\,load\ emf\ E_0 = \sqrt{(230.9\times0.8+180.42\times0.15)^2 + (230.9\times0.6+180.42\times180.42\times0.7858)^2}$$

$$No.\,load\ emf\ E_0 = \sqrt{(211.783)^2 + (280.31)^2}$$

$$No.\,load\ emf\ E_0 = 351.32\ Volt$$

$$\mathrm{Re}gulation = \frac{E_0 - V_T}{V_T}\times100 = 230.9\times100$$

% Regulation = 52.15 %--------------------------------------- **(1/2 Mark)**

ii) 0.8 leading Power Factor;

$$No.\,load\ emf\ E_0 = \sqrt{(V\ Cos\phi + I_aR_a)^2 + (V\sin\phi - I_aX_S)^2}$$

$$No.\,load\ emf\ E_0 = \sqrt{(230.9\times0.8+180.42\times0.15)^2 + (230.9\times0.6-180.42\times0.7858)^2}$$

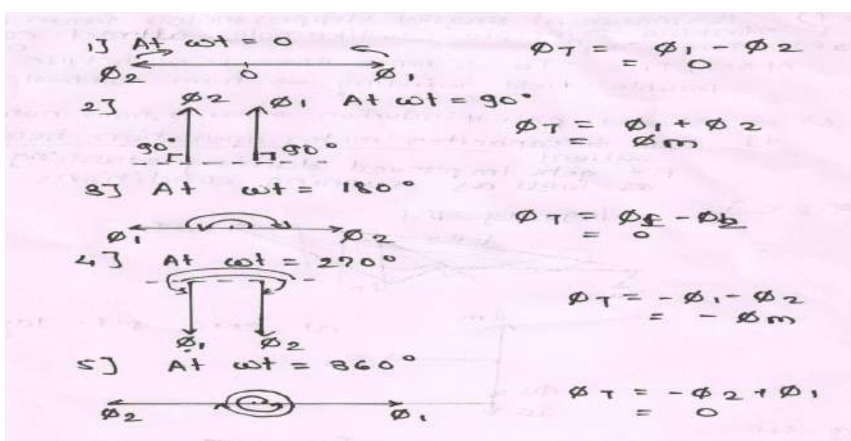
$$No.\,load\ emf\ E_0 = 211.81\ Volt$$

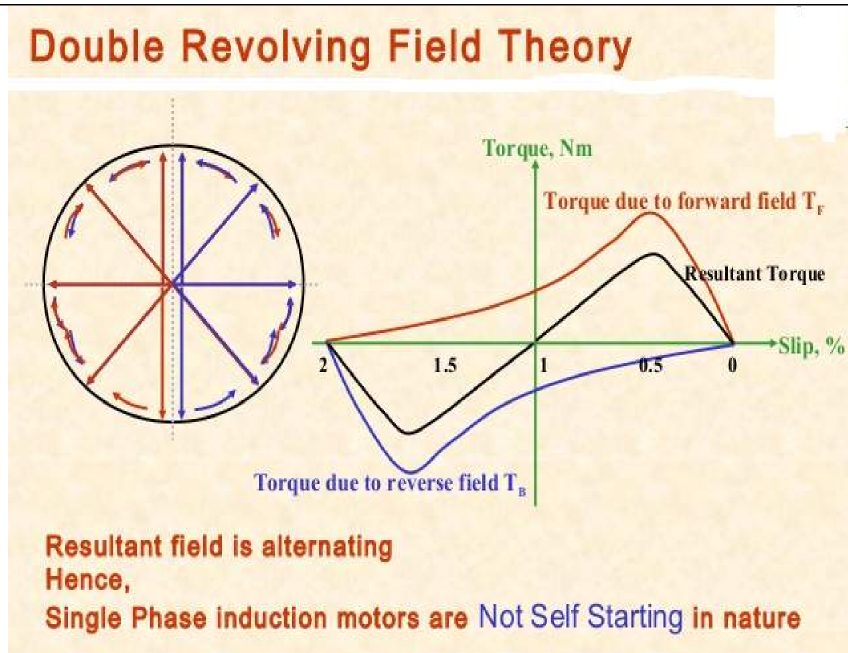
	$$Re\,gulation = \frac{E_0 - V_T}{V_T} \times 100 = \frac{211.81 - 230.9}{230.9} \times 100$$ % Regulation = -8.2674 % ----------------------------- **(1/2 Mark)**
e)	**"Single phase induction motor is not self starting." Justify the statement by double field revolving theory.**
Ans:	**Reason for single phase induction motor doesn't have a self starting torque:** **(2 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**

When single phase A.C supply is applied across the single phase stator winding, an alternating field is produced. The axis of this field is stationary in horizontal direction. The alternating field will induce an emf in the rotor conductors by transformer action. Since the rotor has closed circuit, current will flow through the rotor conductors. Due to induced emf and current in the rotor conductors the force experienced by the upper conductors of the rotor will be downward and the force experienced by the lower conductors of the rotor will be upward .The two sets of force will cancel each other and the rotor will experience no torque .Therefore single phase motors are not self starting.

- **Double field revolving theory:** -- **(2Mark)**





- Consider two components of flux namely ϕ_1 & ϕ_2 each having equal magnitude $\phi_1 = \phi_2 = \phi_M/2$ it is constant.
- Let, at $\phi = 0^0$ two components are at 180^0 displaced from each other. Let ϕ_1 is along +ve X-axis. Therefore total flux is $\phi_1 = \phi_2 = \phi_M = 0$
- Let ϕ_1 is rotation in anticlockwise direction & ϕ_2 in clockwise direction. Both have constant angular speed of ω rad/sec.
- At $\phi = 90^0$, ϕ_1 & ϕ_2 rotate by 90^0 & both aline along +ve y-axis. Therefore, total flux $\phi = \phi_1 = \phi_2 = \phi_M$
- At $\phi = 180^0$, both fluxes rotate by 180^0, ϕ_1 is now along – ve X-axis & ϕ_2 is along +ve X-axis. Therefore, total flux is zero
- At $\phi = 270^0$, ϕ_1 & ϕ_2 aline with –ve axis & therefore, total flux becomes $-\phi_M$
- At $\phi = 360^0$, ϕ_1 is along +ve X-axis & is along –ve X-axis. Therefore, total flux is zero. **OR**

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.

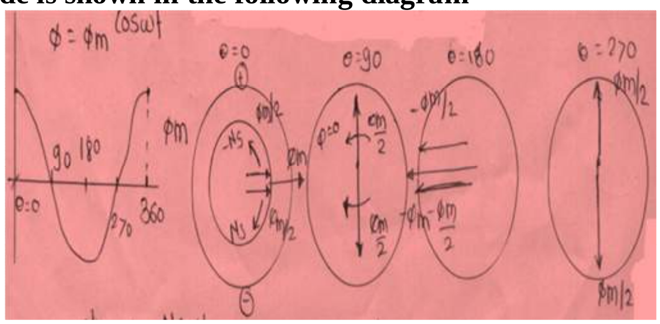
If the rotor rotates in the direction of forward revolving filed then, torque in that direction will increases and torque in opposite direction will decreases this will make rotor to rotate in forward direction.

OR

When single phase supply is applied across the single phase stator winding, an alternating field is produced. The axis of this field is stationary in horizontal direction. The alternating field will induce an emf in the rotor conductors by transformer action. Since the rotor has closed circuit, current will flow through the rotor conductors.

Due to induced emf and current in the rotor conductors the force experienced by the upper conductors of the rotor will be downward and the force experienced by the lower conductors of the rotor will be upward .The two sets of force will cancel each other and the rotor will experience no torque .

Production of rotating field with the help of two oppositely rotating fluxes each of half magnitude is shown in the following diagram



or Equivalent fig.

Q.4 A) Attempt any THREE of the following: 12 Marks

a) A 440 V, 6-pole, 3-phase, 50 Hz induction motor develops an output of 15 kW at 950 r.p.m. If the input power factor is 0.86 lagging, mechanical losses are 730 W and the stator losses 1500 W. Find (i) The Slip (ii) The rotor copper losses (iii) The motor input and (iv) The line current.

Ans:

Given Data:

3Ph, 50 Hz I.M   Motor o/p = 15×10^3 W   N = Actual Speed= 950RPM

Assuming , N_S= 1000 RPM which is very close with N

1) The Slip :

$$\% \text{ Slip} = \frac{N_S - N}{N_S} \times 100 = \frac{1000-950}{1000}$$

$$\% \text{ Slip} = 0.05 \text{ or } 5\ \%$$ ------------------------------------ **(1 /2Marks)**

Now,

Gross Rotor output = Net Motor output + Mechanical Losses

= (15000+730) watt

= 15730 Watts -------------------------------------- **(1/2 Marks)**

2) Rotor Copper Losses = $\frac{S}{(1-S)}$ (Gross Rotor output) **(1/2 Marks)**

$$= \frac{0.05}{(1-0.05)} \times 15730$$

$$= 827.895 \text{ watts}$$

Rotor Copper Lossees $\cong$ 827.9 Watts ---------------------------- **(1/2 Marks)**

3) Net Motor input:

Rotor Input = $\frac{\text{Rotor Copper losses}}{S}$ **(1/2 Marks)**

Rotor Input = $\frac{827.895}{0.05}$

Rotor Input = 16557.92 Watts

Net Motor input = Rotor Input + (Stator Losses)

Net Motor input = (16557.92 +1500) Watts

Net Motor input = 18057.92 Watts ---------------------------------- **(1/2 Marks)**

Net Motor input = $\sqrt{3}\ V_L\ I_L\ \text{Cos}\phi$

4) Line Current of Motor :

$$= \frac{\text{Net motor input}}{\sqrt{3}\ V_L\ \text{Cos}\phi}$$ **(1/2 Marks)**

$$= \frac{18057.92}{\sqrt{3} \times 440 \times 0.86}$$

$$I_L = \frac{18057.92}{655.408}$$

$I_L = 27.552\ A$ -- **(1/2 Marks)**

b)	**Write any four significances of a rotor resistance starter.**
Ans:	**Following the significances of a rotor resistance starter :**

(Any Four point expected : 1 Mark each)

1. It reduces starting current of slip ring I.M.
2. It increases starting torque of slip ring I.M.
3. By changing values of rotor resistance torque of different magnitude are obtain
4. It is also useful for speed control of slip ring I.M.

c)	**Find the no-load line voltage of a star connected 3-phase, 6-pole alternator which runs at 1200 rpm, having flux per pole of 0.1 Wh sinusoidally distributed. Its stator has 54 slots having double layer winding. Each coil has 8 turns and the coil is chorded by one slot.**
Ans:	**Given Data:**

$\phi = 0.1$ wb, Pole-6 N= 1200 rpm

$\therefore$ Since winding is chorded by one slot, it is short pitched by 1/9 or $180^0/9 = 20^0 = \alpha$

$K_C = Cos\,(\frac{\alpha}{2})$ -- **(1/2 Mark)**

$\therefore$ $K_C = Cos\,(\frac{20^0}{2}) = 0.98$ --- **(1/2 Mark)**

$\therefore$ f = $\frac{6 \times 1200}{120} = 60\ Hz$ $\beta = Slot\ pitch\ angle,\ \ m = No.\ of\ slots/pole/phase$

$\therefore$ Pole pitch = $\frac{54}{6} = 9$, $\beta = \frac{180^0}{9} = 20^0$, $m = \frac{54}{6 \times 3} = 3$ ------------------------- **(1/2 Mark)**

$$Kd = \frac{Sin\ m \times (\beta/2)}{m\ Sin \times (\beta/2)}$$

$\therefore K_d = \frac{Sin\,3 \times (20^0/2)}{3\,Sin \times (20^0/2)} = 0.96$ --- **(1/2 Mark)**

$\therefore$ Z = $\frac{54 \times 8 \times 2}{3} = 288$, $\therefore T = \frac{288}{2} = 144$ ------------------- **(1/2 Mark)**

$\therefore$ E_{Ph}= $4.44 \times 0.98 \times 0.96 \times 60 \times 0.1 \times 144$ --------------------- **(1/2 Mark)**

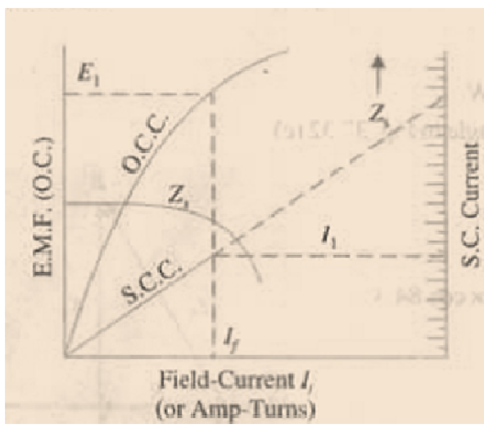
$\therefore$ E_{Ph}= 3610 volt -- **(1/2 Mark)**

$\therefore$ E_L= $\sqrt{3} \times 3610$

$\therefore$ E_L= $6252.7034\ volt$ --- **(1/2 Mark)**

d)	**Explain the need of parallel operation of Alternators.**
Ans:	**The necessity of parallel operation of Alternators :** **(Any Four Point expected: 1 Mark each)** 1. **Continuity in supply system**: Continuity in supply system is we have two or more alternator in parallel and if one is out of order then the power supply can be maintained with the help of another alternator. 2. **More Efficiency:** The alternators can be put ON or cut OFF as per the load demand. The efficiency of alternator is maximum at full load. Therefore we can put ON required number of alternators as per load demand and operate the alternators at full load capacity. 3. **Maintenance and repair:** With more number of alternators in parallel, any one can be taken out of maintenance and repair without disturbing the supply. The smaller units are very easily repairable. 4. **Standby of reserved unit**: In case of number of small alternators in parallel, The standby alternator required is also of small capacity. 5. **Future expansion:** Considering the probable increasing in demand in future, some additional units are installed and can be connected in parallel. 6. **Saving In Fuel**: Since almost all alternators are operated on full load no any one alternator operates lightly loaded. **OR** **Advantages of parallel operation of alternator or transformer:-** 1. Several small units connected in parallel are more reliable than a single large unit. If one of small units is disabled, the entire power supply is not cut –off. 2. The units may be connected in service and taken out of service to correspond with the load on the station. This keeps the units loaded to their full load capacity & increases the efficiency of the operation.

	3) Out of several units if one unit fails, it can be repaired easily without the failure of supply to consumers. 4) Additional units can be connected in parallel with the resent units to correspond with the growth of the load. 5) Cost of the spares if any required for repair, maintenance will be reduced.
Q. 4 B)	**Attempt any ONE :** **06 Marks**
a)	**Describe with the help of necessary graphs and phasor diagram, the procedure to calculate voltage regulation of a 3-phase alternator by synchronous impedance method.**
Ans:	**Necessary graphs and phasor diagram** : **(3 Marks)**



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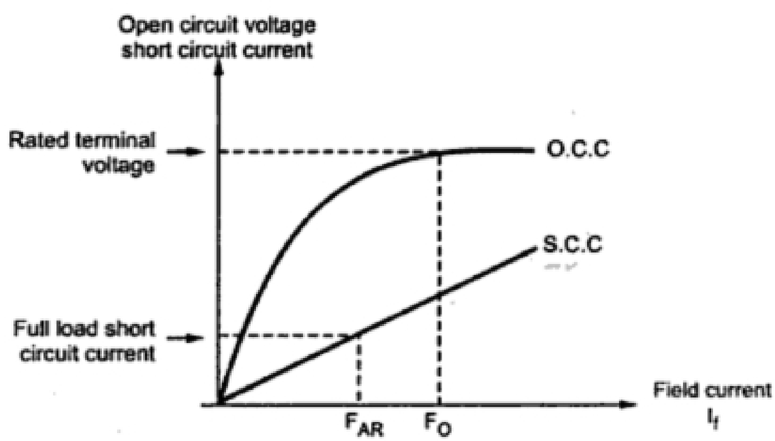

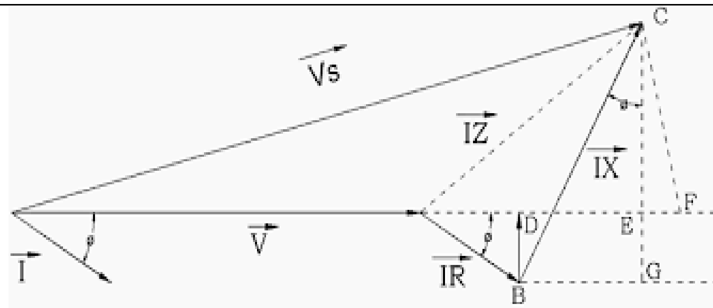

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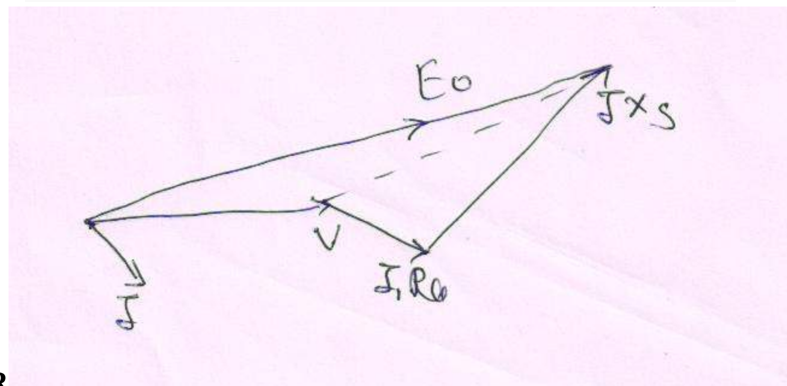


or Equivalent characteristics /Vector dig.

The procedural steps for synchronous impedance method are as follows: (3 Marks)

1) The Open Circuit Characteristics OCC is plotted from open circuit test
2) Short Circuit characteristics is plotted from short circuit test:

   Short circuit characteristics are straight line through origin. Both characteristics plotted for common field current base. Consider field current If and the corresponding OC voltage E_1.During short circuit, at the same field current, the whole E1 is being used to circulate the short circuit current (I_{sc}) in armature.

3) The synchronous impedance Zs can be calculated as,

$$E_1 = I_{SC}\, Z_S \rightarrow Z_S = \frac{E_{1OCC}}{I_{SC}}$$

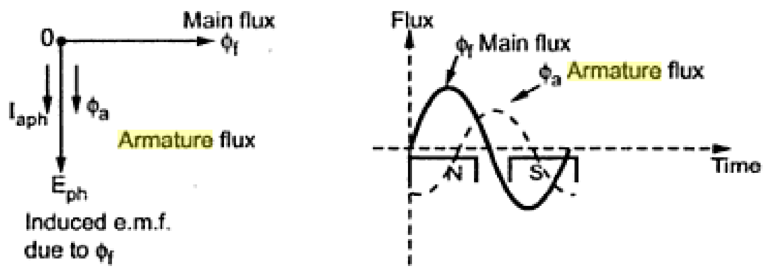
4) By performing resistance test, Effective armature resistance, Ra can be calculated Synchronous reactance can be calculated as

$$X_S = \sqrt{Z_S^2 - R_a^2}$$

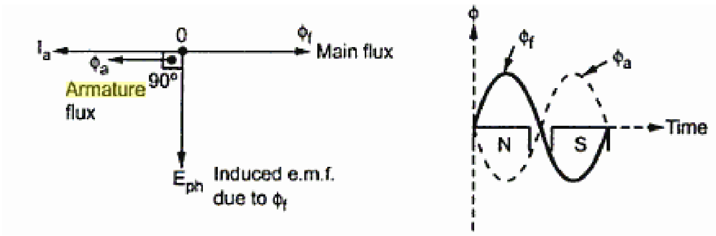
5) The regulation of the alternator at a particular load condition can be calculated as, the generated EMF; E_0 can be calculated as,

$$E_0 = \sqrt{(V\,Cos\phi + I_a R_a)^2 + (V\,Sin\phi + I_a X_S)^2}$$

$$\text{The \% regulation} = \frac{E0 - V}{V} \times 100$$

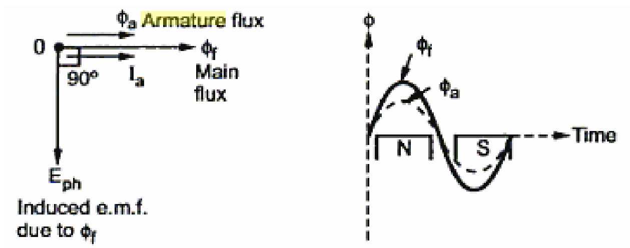
b) i)	**(i) Write the formulae for Xs, Z, of an alternator.**
Ans:	**(3 Marks)** **1.** $Z_S = \frac{E_{O.C}}{I_{S.C}}$ OR $Z_S = \frac{Open\ circuit\ voltage}{Short\ circuit\ current}$ --------- $for\ the\ same\ field\ current$ **2.** $X_S = \sqrt{Z^2{}_S - R_a{}^2}$ $Ra = Armature\ D.C\ resistance$ All the above mentioned quantities are per phase quantities
b) ii)	**(ii) Explain the effect of armature reaction at various p.f. of loads of an alternator. Draw suitable wave-forms showing the effects.**
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)

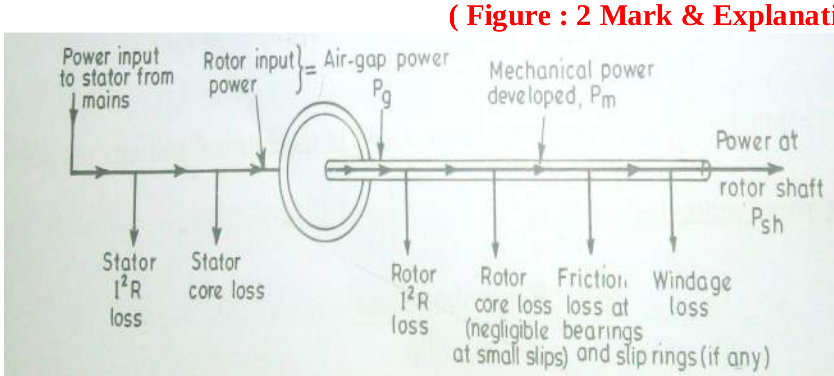


or Equivalent fig

Q.5	**Attempt any FOUR :**	**16 Marks**
a)	**Draw and explain power flow diagram of three phase induction motor.**	

Ans: **Diagram showing power flow stages of a 3 phase induction motor** :

(Figure : 2 Mark & Explanation : 2 Mark)



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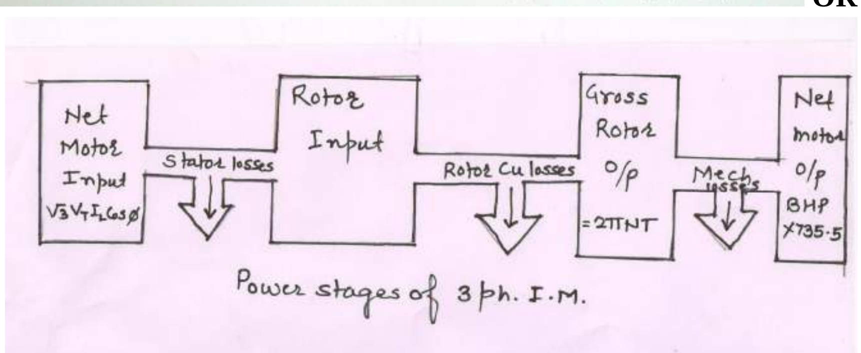
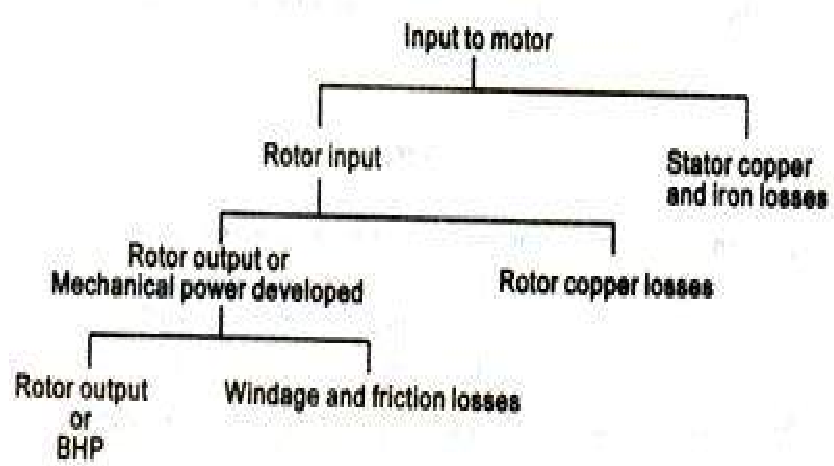


Explanation:

- **The net motor input given to the stator is** $\sqrt{3}\, V_T \;\; I_L \; Cos\phi$
- Rotor input = net motor input - stator losses.
- Gross rotor output = rotor input - rotor copper losses
- Net motor output = Gross rotor output – mechanical losses
- % Efficiency of motor = $\dfrac{Net \;\; Motor\ output}{Net \;\; Motor\ input} \times 100$

OR



b) **Prove that rotor copper loss in induction motor is slip times rotor input.**

Ans: **Consider 3-ph induction motor,** **(4 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

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

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

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

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

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

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

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

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

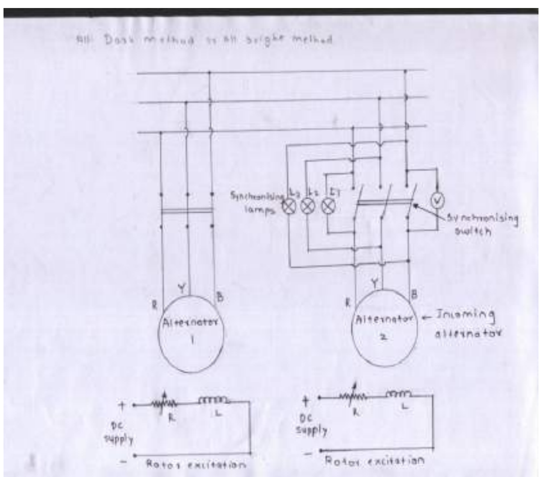
c) Describe three-lamp method of synchronising an alternator with the bus-bar.

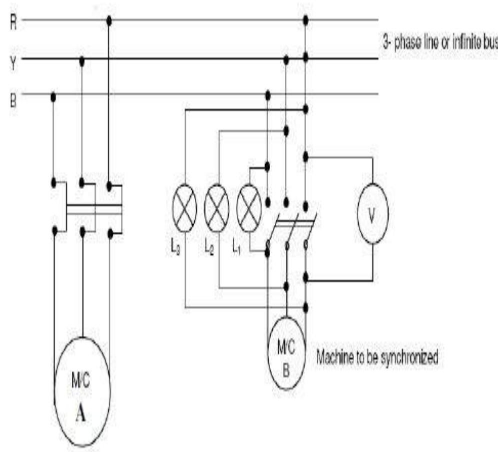
Ans: **Following are the ' Three lamp method' of synchronizing an alternator with the bus bar:-**

(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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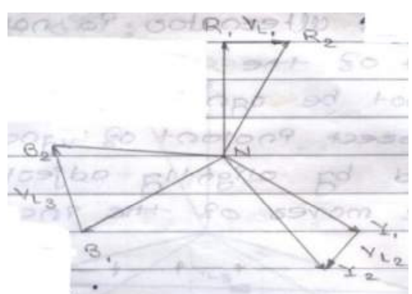


V_{L1} = Voltage across the lamps $L_1 = V_{R2} - V_{R1}$ V_{L2} = Voltage across the lamps $L_2 = V_{Y2} - V_{Y1}$ V_{L3} = Voltage across the lamps $L_3 = V_{B2} - V_{B1}$

Vector Diagram:

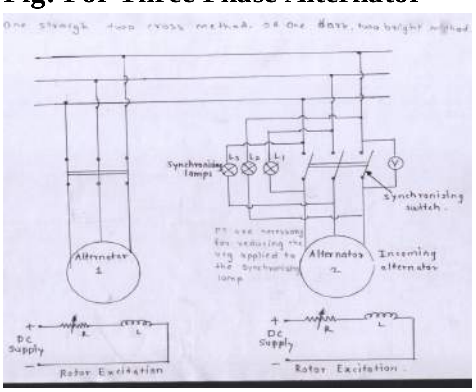
- The 3 lamp pairs L_1 & L_2, and L_2 & L_2, and L_3 & L_3 of equal wattage and voltage rating are connected as shown in figure across the switch and to the bus bar and alternator terminals.

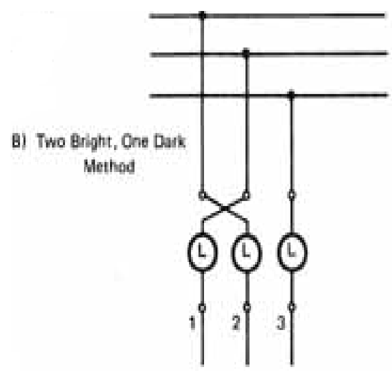
- The Phasor diagram of the bus bar voltages (V_{R1}=V_{Y1}=V_{B1}) and the Phasor diagram of voltage of incoming alternator (V_{R2}=V_{Y2}=V_{B2}) are shown in the figure.
- If the bus bar voltage vector and the alternator voltage vector are in phase with each other then the polarities (phase sequence) 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.

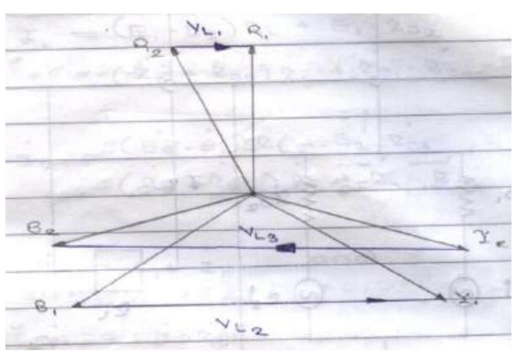
OR other method

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

Fig: For Three Phase Alternator







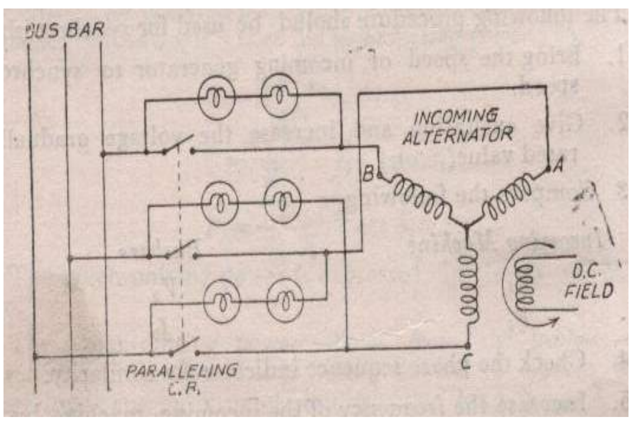
V_{L1} = Voltage across the lamps L_1 = $V_{R1} – V_{R2}$

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)	**What are the conditions to he fulfilled when two alternators are to be connected in parallel?**
Ans:	**The conditions to he fulfilled when two alternators are to be connected in parallel:** 1. **Magnitude of voltage**: **(Any Four Condition expected: 1 Mark each)** They must have the same o/p voltage rating. 2. **Frequency**: The frequency of the alternators must be same. 3. **Type:** The alternator should be of same type so as to generate voltages of the same wave form. They may differ in their KVA ratings. 4. **Prime mover:** The prime mover of the alternators should have same speed-load characteristics, which of course must be dropping ones, so as to load generator in proportion to their o/p rating. 5. **Reactance**: The alternator should same have reactance in their armature, so otherwise they will be not operating in parallel successfully. **OR** **1. Magnitude of voltage**: The terminal voltage of the incoming alternator must be same as that of bus bar voltage. **2. Frequency**: The frequency of the incoming alternator must be same as that of the bus bar frequency. **3. Phase Sequence**: The phase sequence of the incoming alternator must be the same as that of a bus bar. The phase of the incoming machine voltage must be the same as that of the bus-bar voltage relative to the load i.e. the phase voltages of the incoming machine and the bus-bar should be in phase opposition. So that there will be no circulating current between the windings of the alternators already in operation and the incoming machine. **4. The correct instant of synchronizing i.e phase coincidence (Polarity)**: The polarity of the voltage of incoming alternator and the polarity of voltage of bus bar must be same or identical.

e)	**Describe the construction and working principle of Line as Induction Motor. (LIM)**

Ans: **(Construction & Working – 2 Marks & Figure- 2 Marks)**

➢ **Construction & Principle of operation linear induction motor**:-

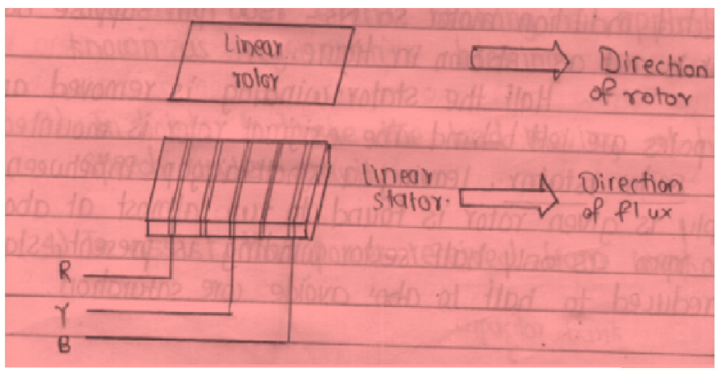
In a sector IM, if sector is made flat and squirrel cage winding is brought to it we get linear I.M. In practice instead of a flat squirrel cage winding, aluminum or copper or iron plate is used as rotor.

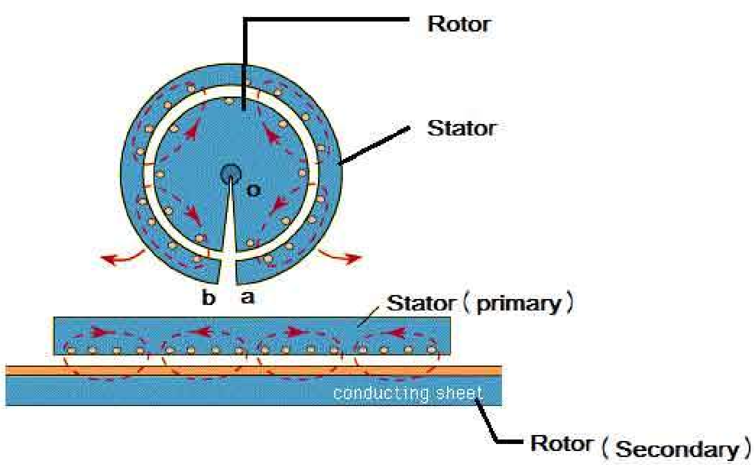
The flat stator produces a flux that moves in a straight line from its one end to other at a linear synchronous speed given by Vs = 2 wf

Where, Vs = linear synchronous speed in m/sec

w = width of one pitch in m.

f = supply frequency (Hz)





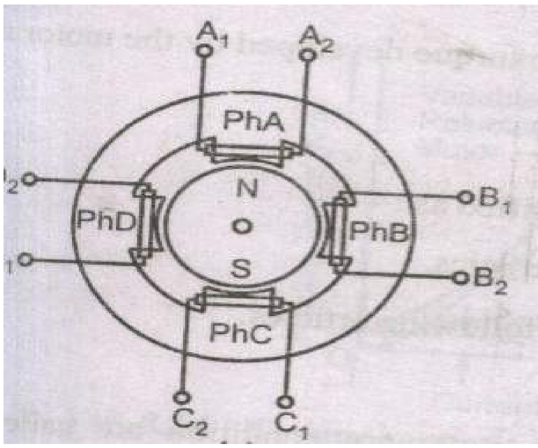
or Equivalent fig.

The speed does not depends on number of poles but only on the poles pitch and supply frequency. As the flux move linearly it drags the rotor plate along with it in same direction. However in much practical application the rotor is stationary while stator moves

f) **Describe the working principle of permanent magnet stepper motor.**

Ans:

Permanent Magnet Stepper Motor:- (Figure 2 Mark & Construction-Working 2 Mark)



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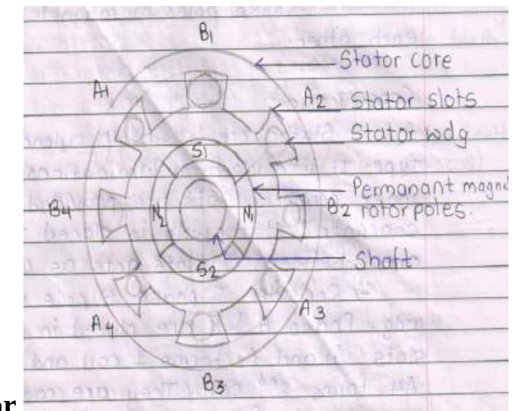
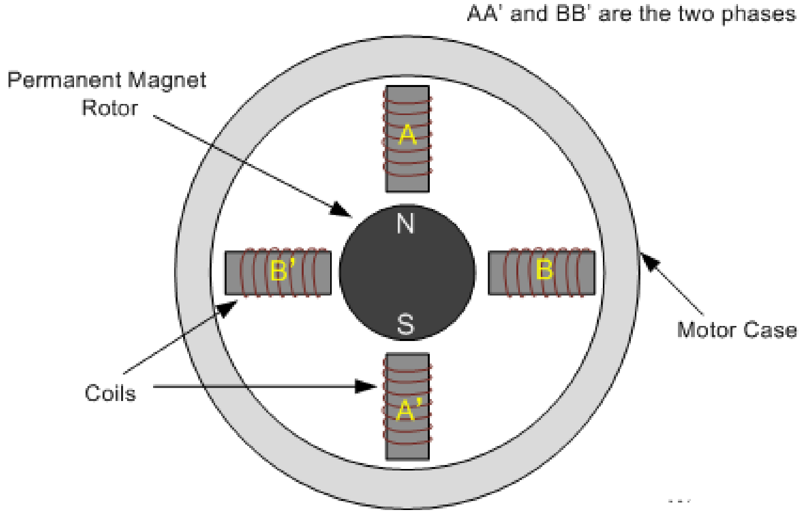


AA' and BB' are the two phases



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

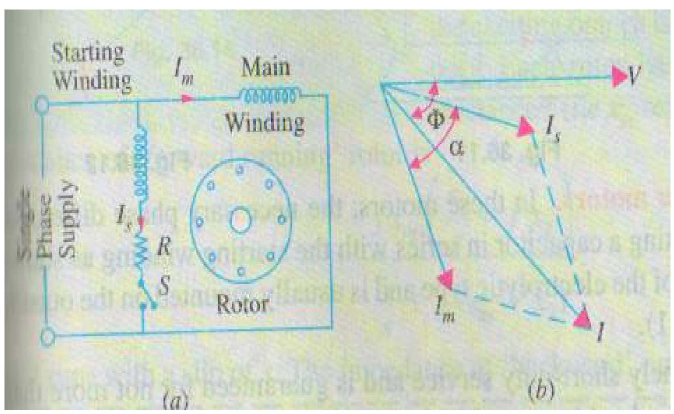
If the phase is excited in ABCD, due to electromagnetic torque is developed by interaction between the magnetic field set up by exciting winding and permanent magnet. Rotor will be driven in clockwise direction.

Q.6	Attempt any Four: 16 Marks
a)	**Discuss about the split-phasing principle used in the starting of single phase induction motor. Explain the construction and working of resistance split phase induction motor in detail.**
Ans:	(Discussion : 1 Mark & Figure : 1.5 Mark & Construction- Working : 1.5 Mark)

Discuss about the split-phasing principle used in the starting of single phase induction motor :

- A single phase induction motor is not self starting motor due to a pulsating torque.
- It has to be run up to about 70 % of synchronous speed by some method.
- The single phase induction can be made self starting by using split phasing principle
- This principle can be implemented by using a capacitor or a resistance in the starting winding circuit.

Diagram of resistance split single phase induction motor:



or equivalent figure

Construction and working of resistors split single phase induction motor:

- The starting winding is having high resistance and main winding is having high reactance.
- Due to this the two winding currents have a phase difference.
- These two currents produce two fluxes having a phase difference.
- These two fluxes are displaced in space by @ 90^0 These two fluxes having time and space displacement produce a resultant rotating magnetic field and rotor starts rotating as per induction principle.
- A centrifugal switch S is connected in series with the starting winding and is located on rotor of the motor.
- It's function is to automatically disconnected the starting winding from the supply when the motor has reached 70 to 80 per cent of its full load speed.

b)	**State one application of the following special machines : (i) Universal motor (ii) Linear Induction motor (iii) Induction Generator and (iv) Stepper motor**
Ans:	**Applications of each of the following: (Each Motor Application : 1 Mark)**

Sr.No	Types of 1-Ph Induction Motor	Applications (Any Two expected)
1	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
2	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.
3	Induction Generator	1. It is used in wind mills.

		(Any One Applications 1Marks)	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
	4	Stepper Motor **(Any One Applications 1Marks)**	1.Suitable for use with computer controlled system 2. Widely used in numerical control of machine tools. 3. Tape drives 4. Floppy disc drives 5. Computer 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 Automotive 14. Food processing 15. Packaging

c) **State four advantages of rotating field over rotating armature of a 3-phase alternator.**

Ans:

(Any four Point Expected each point 1 Marks)

Following Advantages of rotating field over rotating armature of a 3-phase alternator:

Various advantages of rotating field can be stated as,

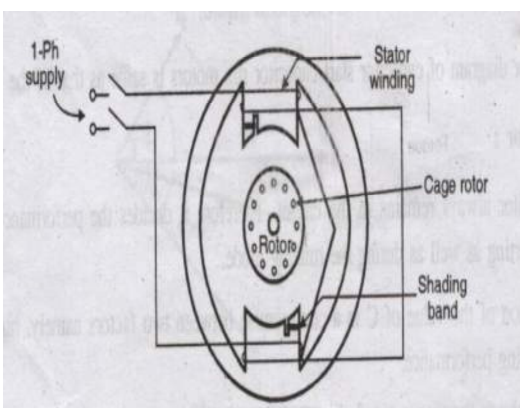
1) The generation level of a.c. voltage may be higher as 11 KV to 33 KV. This gets induced in the armature. For stationary armature large space can be provided to accommodate large number of conductors and the insulations.
2) It is always better to protect high voltage winding from the centrifugal forces caused due to the rotation. So high voltage armature is generally kept stationary. This

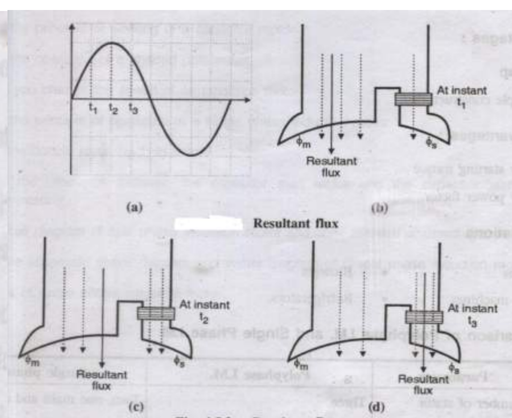
avoids the interaction of mechanical and electrical stresses.

3) It is easier to collect larger currents at very high voltage from a stationary member than from the slip ring and brush assembly. The voltage required to be supplied to the field is very low (110 V to 220 V d.c.) and hence can be easily supplied with the help of slip ring and brush assembly by keeping it rotating.
4) Due to low voltage level on the field side, the insulation required is less and hence field system has very low inertia. It is always better to rotate low inertia system than high inertia, as efforts required to rotate low inertia system are always less.
5) Rotating field makes the overall construction very simple. With simple, robust mechanical construction and low inertia of rotor, it can be driven at high speeds. So greater output can obtain from an alternator of given size.
6) If field is rotating, to excite it be external d.c. supply two slip rings are enough. Once each for positive and negative terminals. As against this, in three phase rotating armature the minimum number of slip rings required are three and can not be easily insulated due to high voltage levels.
7) The ventilation arrangement for high voltage side can be improved if it is kept stationary.
8) Rotating field is comparatively light and can run with high speed.

d) **Describe with neat sketch, the principle of operation of single phase shaded pole induction motor.**

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





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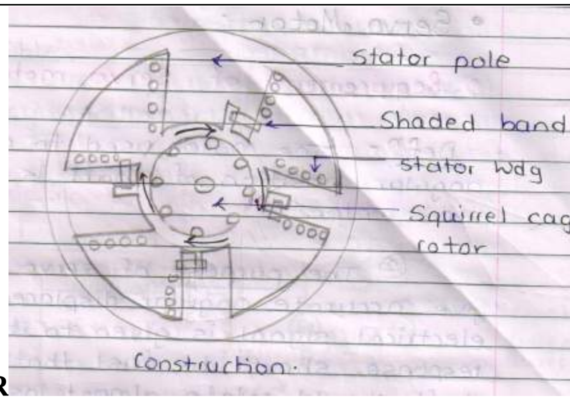
OR 

Equivalent Fig.

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) Compare resistance split phase motor with capacitor split phase motor on the basis of (i) Output, (ii) Starting torque, (iii) Power factor and (iv) Applications.

Ans: **(Each Point -1 Mark)**

S.No	Points	Resistance split phase motor	Capacitor split phase motor
i)	Output	Low	High
ii)	Starting torque	Low	High
iii)	Power factor	Low	High
iv)	Applications	Washing Machine, Fans, Blowers, Centrifugal Pump, Small electrical Tools etc	Grinder, compressors, Refrigerator, Air conditioners, drill machines etc

---**END**---