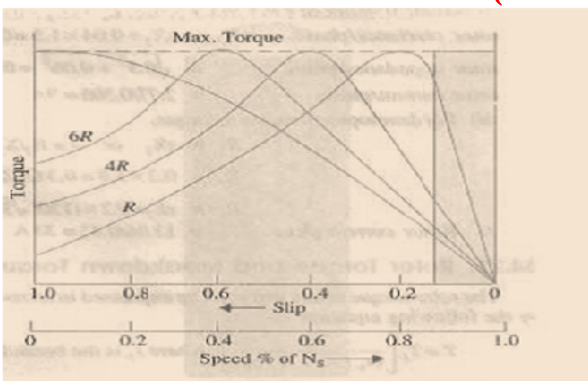
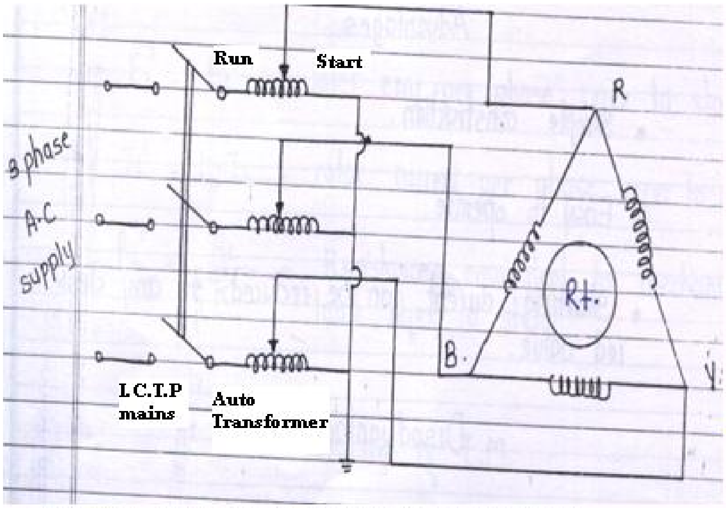
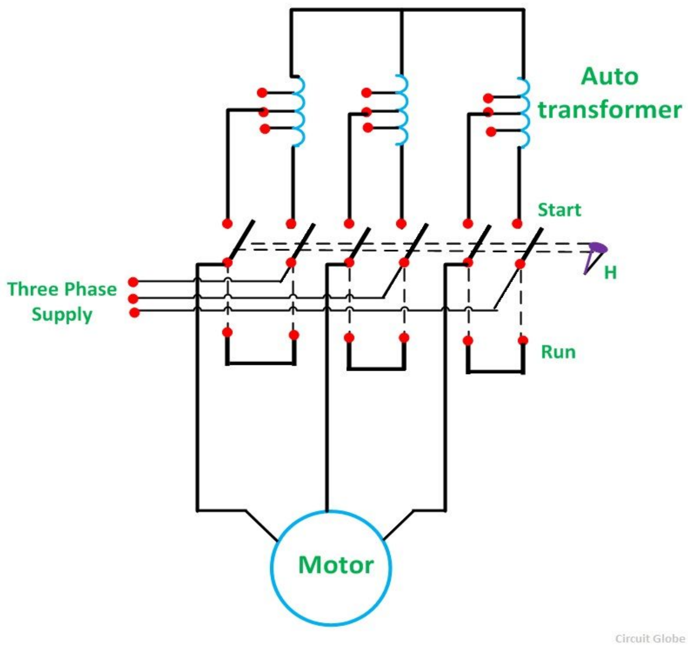
Summer– 2017 Examinations

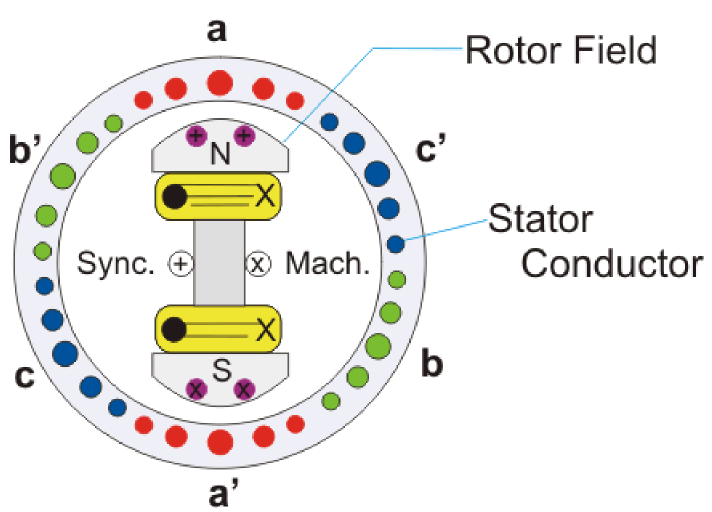
Subject Code: 17511 **Model Answer**

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**
i)	**Explain, why 3-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 .
ii)	**With the help of torque-speed or slip characteristic, explain the effect of rotor circuit resistance on different torques of an induction motor.**
Ans:	**Characteristics:** **(2 Mark Characteristics & 2 Mark Effect)**  **Equivalent Characteristics**

	Effect: ➢ 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.
iii)	**With the help of a neat labelled diagram, explain construction and working of a auto-transformer starter used for starting 3-phase induction motor.**
Ans:	**Diagram for Autotransformer starter :** **(Figure : 2 Marks & Construction & Working:2 Marks)**  OR 

	Construction and working of a auto-transformer starter used for starting 3-phase induction motor : ➢ The **autotransformer** reduced-voltage **starter** places the motor on the secondary of the **autotransformer** while starting. The taps on the **autotransformer** limit the voltage applied to the motor to 50%, 65% or 80% of the nominal voltage. The difference between line and motor current is due to the **transformer** in the circuit. ➢ It is provided with a number of tappings. The starter is connected to one particular tapping to obtain the most suitable starting voltage. A double throw switch S is used to connect the auto transformer in the circuit for starting. When the **handle H** of the switch S in the **START** position. The primary of the auto transformer is connected to the supply line, and the motor is connected to the secondary of the auto transformer. ➢ When the motor picks up the speed of about 80 percent of its rated value, the handle H is quickly moved to the **RUN** position. Thus, the auto transformer is disconnected from the circuit, and the motor is directly connected to the line and achieve its full rated voltage. The handle is held in the **RUN** position by the under voltage relay. ➢ If the supply voltage fails or falls below a certain value, the handle is released and returns to the **OFF** position. Thermal overload relays provide the overload protection.
iv)	**With the help of a neat labelled diagram, explain construction and working principle of a 3-phase alternator.**
Ans:	

	Construction of three phase alternator **(2 Marks)** Construction wise, an alternator generally consists of field poles placed on the rotating fixture of the machine i.e. rotor as shown in the figure above. In most practical construction of alternator, it is installed with a stationary armature winding. There are mainly two types of rotor used in construction of alternator, 1. Salient pole type. 2. Cylindrical rotor type. ***The* working principle of alternator *:*** **(2 Marks)** Principle of alternator depends upon Faraday's law of electromagnetic induction. When the field winding gets excited field current flows through the field winding which produces magnetic flux in the air gap. As the prime mover rotates, the field winding also rotates and hence the magnetic flux also rotates. This rotating magnetic field is cut by the stationary armature conductors. So according to Faraday's law of electromagnetic induction , an EMF is induced in the armature conductors.
Q.1 (B)	**Attempt any ONE:** **6 Marks**
i)	**State different methods used for controlling speed of a 3-phase induction motor and explain any one method of speed control in detail.**
Ans:	**Following methods to control the speed of 3 phase induction motor:** **(3 Mark)** 1. By varying applied voltage (voltage control) 2. By Varying applied frequency (frequency control) 3. By varying number of poles of the stator winding (Pole changing control) 4. By rotor rheostatic control 5. By V/f method **1. by varying applied voltage (voltage control): (Any one explanation expected: 3 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.

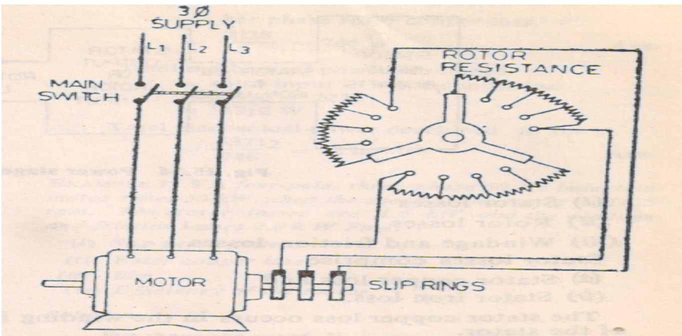
2. By varying applied Frequency (Frequency control):

- 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.
- The speed of the motor will increase if frequency increased and vice vesa.
- Changing the frequency of supply to the motor is not an easy job. Therefore this method is only employed where the variable frequency alternator is available for the above purpose.

3. By varying number of poles of the stator winding (pole changing control):

- The synchronous speed of an induction motor is given by $N_S = \frac{120 \times f}{P}$.
- It is clear from the equation that if the number of poles of the stator is decreased, the speed of the motor will increased.
- When the number of poles are increases, the speed of the motor decreases.
- The poles of the stator winding can be changed by having two or more separate stator windings of different pole combination housed in common stator frame. By selecting proper number of pole combination, Ns can be varied and hence the speed.

4. By rotor rheostatic control:

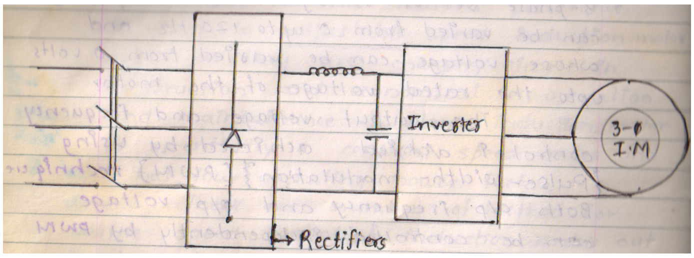


- In this method star connected external resistances (of continuous rating) are connected in the rotor circuit.
- The speed of the motor increases with the decrease of resistance in the rotor

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.

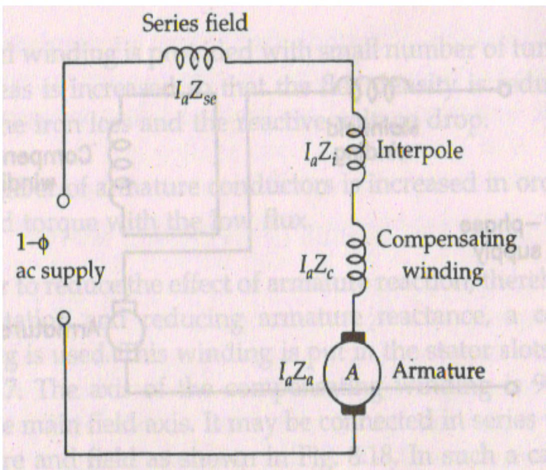
5. By Voltage/ frequency control (V/f) method:



- ➢ If the ratio of voltage to frequency is kept constant, the flux remains constant.
- ➢ The maximum torque which is independent of frequency can be maintained approximately constant.
- ➢ However at a low frequency, the air gap flux is reduced due to drop in the stator impedance and the voltage has to be increased to maintain the torque level.
- ➢ This type of control is usually known as Volts/ Hertz or V/f control.
- ➢ A simple circuit arrangement for obtaining variable voltage and frequency is as shown in the above figure.

ii) **Draw a schematic diagram of an a.c. series motor. How the direction of rotation and speed of this motor can be changed. Give any two applications of this motor.**

Ans: **Schematic diagram of an A.C Series motor:** **(3 Mark)**



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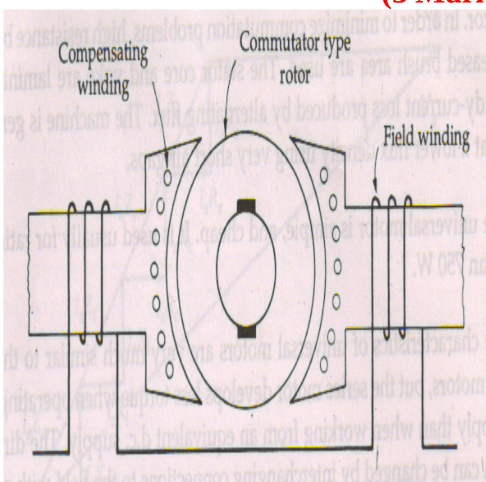
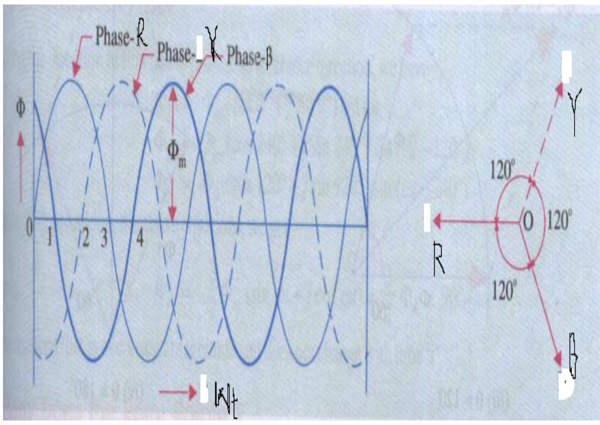
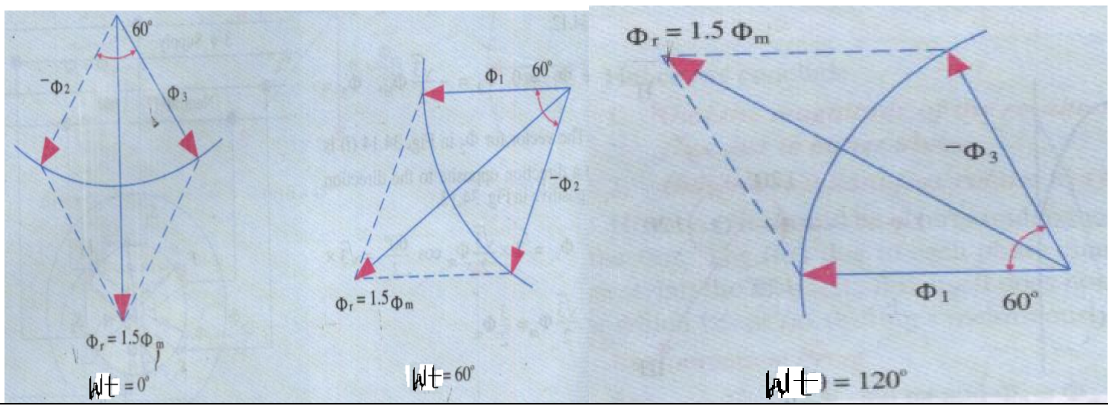


	Change in direction of rotation: **(1 Mark)** ➢ The direction of rotation can be changed by interchanging connection to the field with respect to the armature. **Applications of A.C Series Motor (Any two from following or any similar) (2 Mark)** 1. Where high starting torque is required 2. Stone Crushing Machine 3. Washing Machines. 4. Mixers and grinders 5. Food processors. 6. Small drilling Machines. 7. In Electric Traction
Q.2	**Attempt any FOUR of the following : 16 Marks**
a)	**With neat sketches explain how rotating magnetic field is produced in a 3-phase induction motor.**
Ans:	**Figure: Waveform of 3-ph fluxes: (1 Mark)**



or Equivalent fig

Vector diagram at :
i) wt = 0 **ii) wt = 60^0** **iii) wt = 120^0 --------- (2 Marks)**



	or Equivalent fig. **i) Wt = 0^0, $\phi_r = \frac{3}{2}\phi_m$** **ii) Wt =$60^0$, $\phi_r = \frac{3}{2}\phi_m$** **iii) Wt =$120^0$, $\phi_r = \frac{3}{2}\phi_m$** From the above vector diagrams at different phase angles particularly at 0^0, 60^0 and 120^0 referred in waveform diagram, it is clear that the resultant flux vector is not stationary but it rotates with N_S ----------------------------------- **(1 Mark)**
b)	**A 3- ph, 50 Hz, 4 pole, induction motor operated at a slip of 4%, calculate: (i) Speed of motor (ii) Frequency of rotor emf.** **If the rotor has resistance of 1 ohm and standstill reactance of 4 ohms per phase, calculate rotor power factor at: (i) Stand still (ii) At a speed of 1440 r.p.m.**

Ans: **Given Data:** 3 ph,4-pole, 50Hz

$$N_S = \frac{120\,f}{P}$$ ……………………………………………………..**(1/2 Mark)**

$$= \frac{120 \times 50}{4}$$

$$N_S = \frac{120 \times 50}{4} = 1500\ RPM$$

$$N = (1-S)\ 1500 \qquad N = (1-0.04)\ 1500$$

$$N = 1440\ RPM$$ ……………………………………………….**(1/2 Mark)**

Frequency of Rotor = S . f………………………………………..**(1/2 Mark)**

= 0.04 X 50

Frequency of Rotor = 2.0 Hz ……………………………… (1/2 Mark)

i) Power factor at stand still i.e s=1

$$\mathrm{Cos}\phi_2 = \frac{R_2}{\sqrt{(R_2)^2 + (S)^2 \times X_2^{\ 2}}}$$ ………………………………………...……..**(1/2 Mark)**

$$\mathrm{Cos}\phi_2 = \frac{1}{\sqrt{(1)^2 + (4)^2}}$$

$$\mathrm{Cos}\phi_2 = 0.2425\ \text{lag}$$ ……………………….…… **(1/2 Mark)**

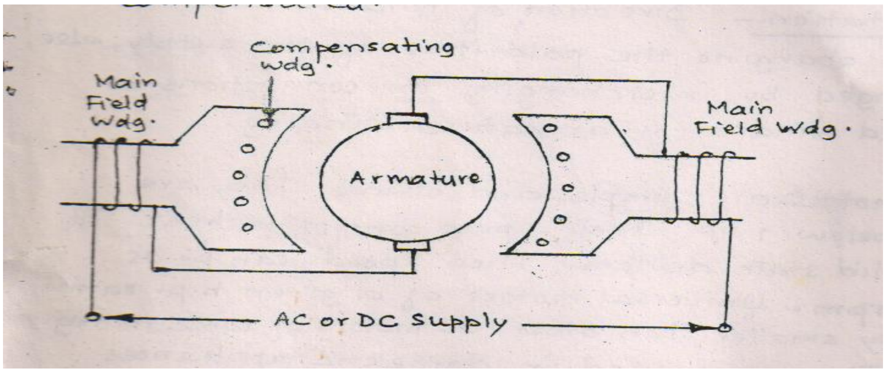
ii) Power factor at speed of 1440 RPM i.e at s= 0.04 :

$$\mathrm{Cos}\phi_2 = \frac{R_2}{\sqrt{(R_2)^2 + (S)^2 \times X^2}}$$ ………………………………..**(1/2 Mark)**

$$\mathrm{Cos}\phi_2 = \frac{1}{\sqrt{(1)^2 + (0.04)^2\ (4)^2}}$$

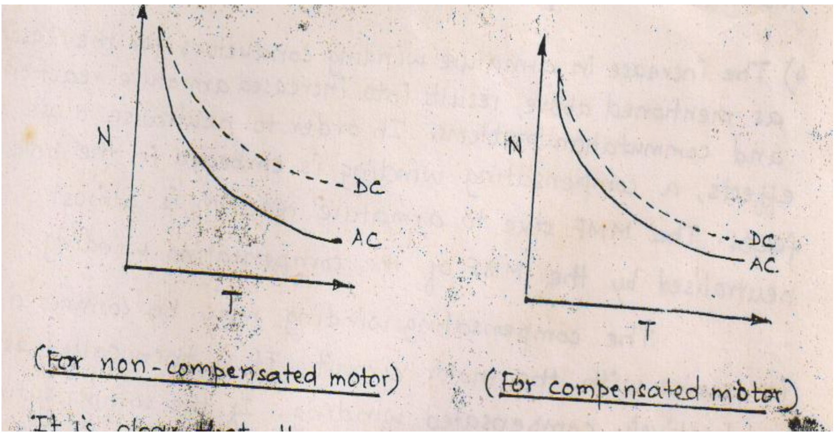
$$\mathrm{Cos}\phi_2 = 0.9874\ \text{lag}$$ ……………………….…… **(1/2 Mark)**

c)	**A 3-phase, 6 pole, star connected alternator revolves at 1000 r.p.m. The stator has 90 slots and 8 conductors per slot. The flux per pole is 0.05 wb (sinusoidally distributed) calculate the value of phase voltage and line voltage generated by the machine, if the winding factor is 0.96.**
Ans:	**Given Data:** $\phi = 0.05$ wb, Pole-6 $N_s = 1000$ rpm $\therefore K_C = 0.96$ $f = \frac{6 \times 1000}{120} = 50\ Hz$ Pole pitch$= \frac{90}{6} = 15$ $\beta(slot \longrightarrow pitch \longrightarrow angle) = \frac{180^0}{15} = 12^0$, $m(No.of slots/pole/phase) = \frac{90}{6 \times 3} = 5$ ------------------- **(1/2 Mark)** $Kd = \frac{Sin\ m \times (\beta/2)}{m\ Sin \times (\beta/2)}$ $\therefore K_d = \frac{Sin\,5 \times (12^0/2)}{5\,Sin \times (12^0/2)} = \frac{0.5}{0.5226} = 0.9567$ ----------------------------- **(1/2 Mark)** $\therefore$ Z/ph $= \frac{No.\ of\ slots \times conductor\ /\ slots}{3} = \frac{90 \times 8}{3} = 240$ ---- **(1/2 Mark)** $\therefore$ T/ph $= \frac{240}{2} = 120$ -- **(1/2 Mark)** $E/Ph = 4.44 \times \phi \times F\ T \times Kc \times Kd$ ------------------------------------- **(1/2 Mark)** $\therefore E_{Ph} = 4.44 \times 0.05 \times 50 \times 120 \times 0.96 \times 0.9567$ -------------------- **(1/2 Mark)** $\therefore E_{Ph} = 1227.18$ volt -- **(1/2 Mark)** $\therefore E_L = \sqrt{3} \times 1227.18$ $\therefore E_L = 2125.55\ volt$ -- **(1/2 Mark)**

d)	**Explain the factors which affects terminal voltage of an 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)	**What is an universal motor? Comment briefly on it's construction features and speed-torque characteristic, state any two applications of this motor.**
Ans:	**Diagram of Universal Motor:** **(Meaning: 1 Mark. Comments of construction feature:1 Mark, Speed torque characteristics :1 Mark and Application: 1 Mark)** **Universal Motor :** ……………………………………………………………..**(1 Mark)** Motors that can be used with a single phase AC source as well as a DC source of supply voltages are called "UNIVERSAL MOTORS" **Comments on Constructional features:** ……………………………………**(1 Mark)**  **OR Equivalent figure** ➢ The field core is to be constructed of a material having low hysteresis loss and it is to be laminated to reduce eddy current loss.

- The field winding is to be designed for smaller number of turns. This helps in reducing the reactance of the field winding.
- The compensating winding may be connected in series with the motor circuit.

Speed-torque characteristics: ……………….……………………………….……….**(1 Mark)**



OR Equivalent figure

Comments:

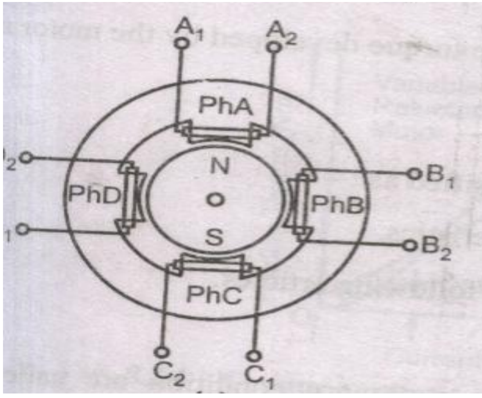
As torque increases speed decreases, the characteristics is similar with DC series motor.

Application of Universal Motor: (Any Two application expected) (1 Mark)

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) **With neat diagram explain working principle of a permanent magnet stepper motor.**

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



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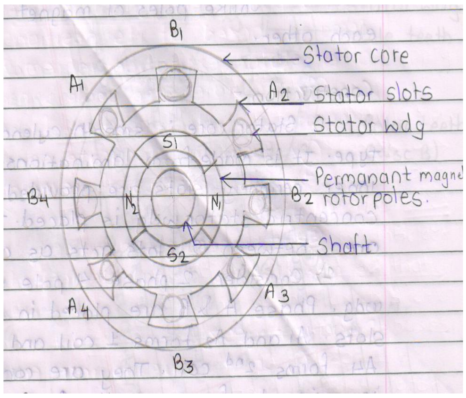
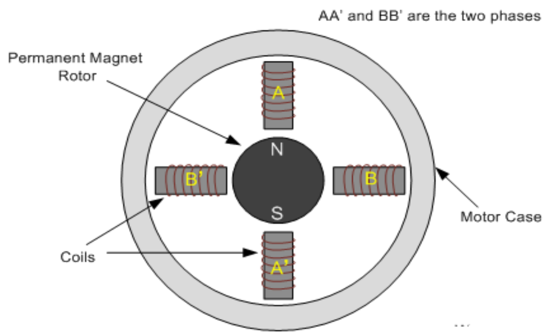


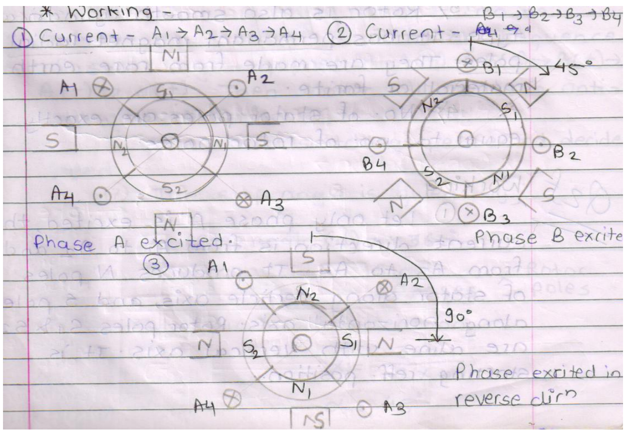


Working :-

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 excited, the current direction is form A1 to A2 and from A3 to A4.
- It produces N poles of stator along vertical 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 $A(+) \rightarrow B(+) \rightarrow A(-) \rightarrow B(-) \rightarrow A(+)$ then motor will continuously rotate in clockwise direction.
- The direction of rotation can be reversed by changing switching sequence. If switching sequence is $A(+) \rightarrow B(-) \rightarrow B(+) \rightarrow A(-) \rightarrow A(+)$ then motor will rotate in anticlockwise direction.
- The number of switching per second decides speed.

Q.3 Attempt any Four of the following : 16 Marks

a) Compare cage and wound rotor type 3-phase induction motor with reference to following: (i) construction (ii) performance (iii) speed control (iv) applications

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

S.No.	Point	Cage Rotor type 3-ph Induction Motor	Wound Rotor type 3-ph Induction Motor
1	Construction	Rotor is in the form of bars. No slip-ring and brushes	Rotor is in the form of 3-ph winding. Slip-ring and brushes are present.
2	Performance	Starting power factor is poor	Starting power factor is adjustable
3	Speed control	Speed control by stator control method only	Speed can be control by stator & rotor control method
4	Applications	For driving somehow constant load e.g Lathe machine, Workshop Machine and water	For driving somehow constant load e.g for driving heavy inertia load & variable speed

			pump	application such as Lift, Crane, Elevator, Cable car, Conveyor belt etc.

b) **b) A 3-phase induction motor has a synchronous speed of 250 r.p.m. and 4% slip at full load. The rotor has resistance of 0.02 ohms per phase and stand still leakage reactance of 0.15 ohms per phase. Calculate:**
(i) The speed at which maximum torque is developed.
(ii) The ratio of maximum to full load torque.
(iii) The ratio of maximum to starting torque.
(iv) What value should the resistance per phase have so that the starting torque is half the maximum torque?

Ans: **Given Data:** **(Stepwise Mark, Total : 4 Mark)**

3-Ph I.M Ns = 250 RPM S = 4 % at full load
R_2/ph = 0.02 ohm and X_2/ph =0.15 ohm

(i) The Slip at which the maximum torque is developed is given by : **(1 Mark)**

$$R_2 = S\ X_2$$
$$\therefore S = \frac{R_2}{X_2} = \frac{0.02}{0.15}$$
$$\therefore S = 0.1333$$

Speed at which maximum torque occurs is

$$N = (1 - S)\ N_S$$
$$= (1 - 0.1333) \times 250$$
$$N = 216.67\ RPM$$

(ii) The ratio of maximum to full load torque: **(1 Mark)**

$$\frac{T_{\max}}{T_{FL}} = \frac{a2 + S_f^{\ 2}}{2a\ S_F}$$
$$a = \frac{R2}{X2} = 0.1333 \quad and \quad S_F = 0.04\ - given$$

$$\frac{T_{\max}}{T_{\ full\ load}} = \frac{(0.1333)^2 + (0.04)^2}{2\,(\,0.1333)\,(0.04)} = \frac{0.01937}{0.01066}$$
$$\frac{T_{\max}}{T_{\ full\ load}} = 1.82$$

(iii) The ratio of maximum to starting torque: **(1 Mark)**

$$\frac{T_{max}}{T_{st}} = \frac{1+a^2}{2\,a} = \frac{1+(0.1333)^2}{2(0.1333)} = \frac{1.0178}{3.751}$$

$$\frac{T_{max}}{T_{st}} = 0.2713$$

(iv) What value should the resistance per phase have so that the starting torque is half the maximum torque: **(1 Mark)**

We have,

$$T_{st} = \frac{C\,R_2}{R_2^{\,2} + X_2^{\,2}} \quad \text{...} (1)$$

$$T_{max} = \frac{C}{2\,X_2} \quad \text{...} (2)$$

$$\frac{T_{st}}{T_{\ max}} = \frac{2\,R_2\,X_2}{R_2^{\,2} + X_2^{\,2}}$$

$$\frac{1}{2} = \frac{2\,R_2\,X_2}{R_2^{\,2} + X_2^{\,2}}$$

$$\therefore\ R_2^{\,2} + X_2^{\,2} = (4)R_2 \times X_2$$

$$\therefore\ R_2^{\,2} - (4)R_2 \times X_2 + X_2^{\,2} = 0$$

$$\therefore\ R_2^{\,2} - (4) \times 0.15\ R_2 + (0.15)^2 = 0$$

$$\therefore\ R_2^{\,2} - 0.6\ R_2 + 0.0225 = 0$$

$$\therefore\ R_2 = \frac{0.6 \pm \sqrt{0.36 - 4 \times 1 \times 0.0225}}{2}$$

$$\therefore\ R_2 = \frac{0.6 \pm \sqrt{0.36 - 0.09}}{2} = \frac{0.6 \pm 0.52}{2}$$

$$\therefore\ R_2 = 0.56\ ohm \quad OR \quad R_2 = 0.04\ ohm$$

$$but\ R_2\ must\ be\ less\ than\ X_2\ \therefore\ We\ select\ R_2 = 0.04\ ohm$$

$$\therefore\ R_2 = r_2 + r_{ext}$$

$$\therefore\ 0.04 = 0.02 + r_{ext}$$

$$\therefore\ r_{ext} = 0.02\ ohm\ /Ph$$

c)	**Derive the emf. equation of a 3-0 alternator.**
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)** $\therefore$ = $4\left(\frac{P\ N}{120}\right)\phi$ $\therefore$ 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)**

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

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

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

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

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

d) Explain the essential difference between cylindrical (smooth) and salient pole rotor used in large alternators. What type of rotor would you expect to find in:
(i) A-2-pole machine (ii) A-12-pole machine

Ans: **(Any Two point expected -1 Mark each)**

S.No	Parameter/Machine	Smooth cylindrical type rotor	Salient pole type rotor
1	**Operating speed**	high	Low medium
2	**Number of poles**	Small & medium	large
3	**Rotor construction**	Cylindrical poles type comparatively moderate weight	Projected type bulky & heavy weight
4	**Axial length**	large	short
5	**Diameter**	small	large
6	**Operation**	Very smooth	noisy
7	**Centrifugal stresses**	uniform	Non uniform
8	**Application**	Thermal power station	In hydro power stations

Type of rotor would expected to find in: **(2 Mark)**

(i) A-2-pole machine:- Cylindrical (smooth) rotor

(ii) A-12-pole machine:- Salient pole rotor

e)	**Why a single phase induction motor doesn't have a self starting torque? Explain with the help of a double field revolting theory.**

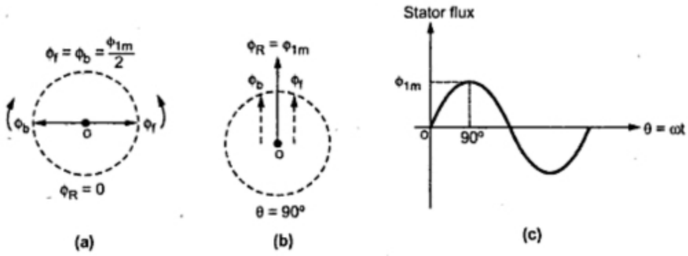
Ans: **Reason for single phase induction motors are not self starting torque:** **(2 Mark)**

- 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 torque.

OR

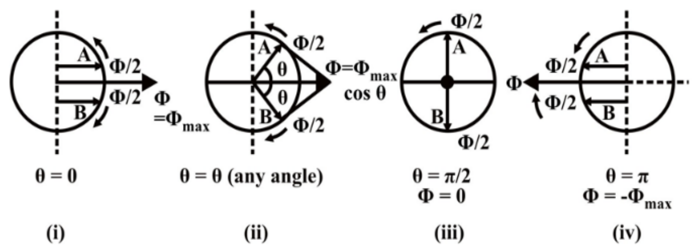
Single phase induction motor has distributed stator winding and a squirrel-cage rotor. When fed from a single-phase supply, its stator winding produces a flux (or field) which is only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving (or rotating) flux 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 torque.**

- **Double field revolving theory:** ------------ **(Figure: 1 Mark & Explantion : 1 Mark)**



OR

Double field revolving theory



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.

	➢ 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 .
Q.4 (a)	**Attempt any THREE of the following: 12 Marks**
i)	**A 500 V, 3-phase, 50 Hz, induction motor develops an out-put of 15 kW at 950 r.p.m. If the input power factor is 0.86 lagging, mechanical losses are 730 W and stator losses are 500 W. Find:** **1) The slip 2) The rotor cu loss 3) The rotor input 4) The line current**
Ans:	**Given Data:** 3Ph, 50 Hz I.M Motor o/p = 15 x 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 +500) Watts

Net Motor input = 17057.92 Watts ---------------------------------- **(1/2 Marks)**

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

4) Line Current of Motor :

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

$= \frac{17057.92}{\sqrt{3} \times 500 \times 0.86}$

$I_L = \frac{17057.92}{744.781}$

$I_L = 22.90A$ --- **(1/2 Marks)**

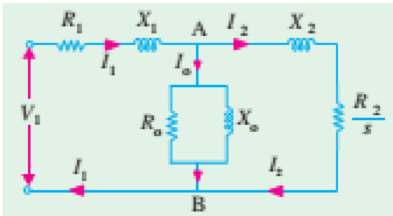
ii) **With the help of mathematical expression state why it is necessary to use starter in 3-phase induction motor.**

Ans: **Mathematical expression it is necessary to use starter in 3-phase induction motor:**

(4 Marks)

If we look at the equivalent circuit of the three phase induction motor at the time of starting, we can see the motor behaves like an electrical transformer with short circuited secondary winding, because at the time of starting, the rotor is stationary and the back emf due to the rotation is not developed yet hence the motor draws the high starting current. So the reason of using the starter is clear here.

The equivalent circuit of three phase induction motor is given below



The stator current is given by following equation

$$\vec{I}_1 = \vec{I}_m + \vec{I}_2$$

$$\vec{I}_m \text{ is CONSTANT}$$

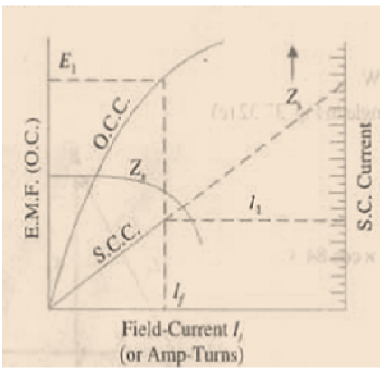
$$\vec{I}_2 = \frac{\vec{V_1}}{\frac{R_2}{s} + jX_2}$$

In above equation, s is the slip. The value of slip is ***1 unity*** at start so value of R_2+jX_2 is smallest which results in large value of I_2 and therefore I_1 i.e. stator current.

As the motor picks up the speed, value of slip reaches near to zero. This results in large value of $R_2/s+jX_2$. Value of I_2 falls to a small value and therefore I_1 i.e. the stator current.

iii) **With the help of a neat circuit diagram, explain the procedure to calculate voltage regulation of a 3-phase alternator by synchronous impedance method.**

Ans: **Necessary graphs and phasor diagram** : **(2 Marks)**



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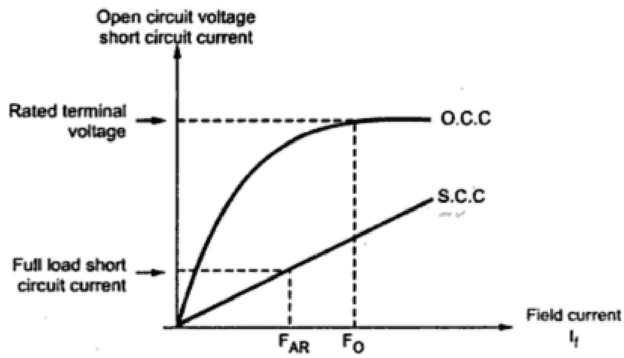

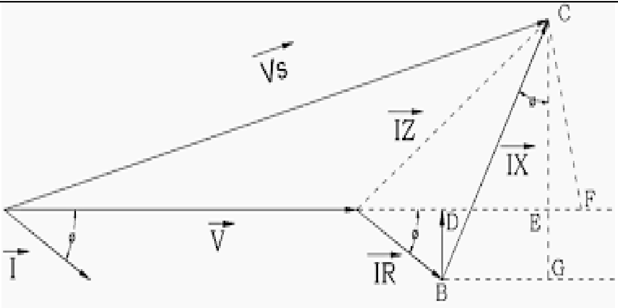

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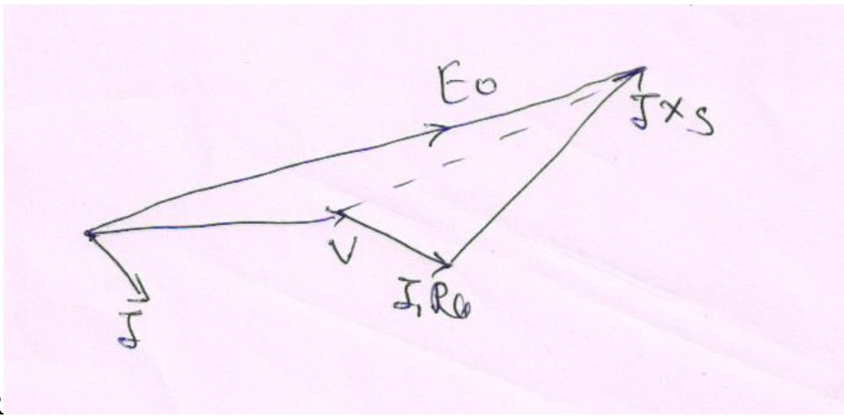


or Equivalent characteristics /Vector dig.

The procedural steps for synchronous impedance method are as follows: **(2 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,

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

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

iv)	**Why it is necessary to run alternators in parallel? Explain.**
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 anyone alternator operates lightly loaded. **OR** **Advantages of parallel operation of alternator:-** 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 of the following:** **6 Marks**
i)	**Define voltage regulation of an alternator. State and explain the factors on which voltage regulation depends.**
Ans:	**Voltage Regulation of Alternator:** **(2 Marks)** It is defined as the rise in voltage when full load is removed, keeping excitation & speed of alternator constant, expressed as percentage of rated terminal voltage is called "Voltage regulation". **OR** It is defined as the ratio of sudden rise or fall in voltage when the load is removed suddenly to the rated terminal voltage, keeping speed & excitation of alternator constant. **Following factors on which voltage regulation depends:** **(Each Point : 1 Mark)** 1. **Armature resistance per phase:** As armature resistance increases I_aR_a drop increases, which make voltage regulation poor. 2. **Armature Leakage flux:** If leakage flux is more, the leakage reactance X_L increases which increases $I_a X_L$ drop. Hence regulation becomes poor. 3. **Magnitude of load current:** If load current increases I_aR_a and $I_a X_L$ drop increases and armature reaction effect also increases. Therefore terminals voltage drops which makes regulation poor. 4. **Load Power factor:** i) For lagging power factor the effect of armature reaction is demagnetizing and therefore the main flux reduces, considerably which causes poor regulation. ii) For unity P.f, the effect of armature reaction is cross magnetizing, therefore distortion in main flux will be resulted & hence regulation is comparatively less. iii) For leading P.f, the effect of armature reaction is strong magnetizing therefore main flux will be more stronger and so terminal voltage actually increases which gives negative regulation.
ii)	**A 3-phase, star connected alternator rated at 1600 kVA 13500 V; The armature resistance and synchronous reactance are 1.5 ohms and 30 ohms respectively per phase - calculate percentage voltage regulation for a load of 1280 kW at a power factor: (i) 0.8 leading (ii) unity**

Ans:	**Solution:-** 3-Ph, star connected alternator, V_T Line = 13.5 x 10^3 KV $R_a/Ph = 1.5\,\Omega$ & $X_S/Ph = 30\,\Omega$ $V_T/Ph = 13.5\times10^3/\sqrt{3} = 7794.23\ Volt$ **(1/2 Marks)** **i)** $I_a\ line\ Current = \dfrac{KW\times10^3}{(\sqrt{3})\times(V_{TLine})\,Cos\phi}$ $I_a\ line\ Current = \dfrac{(1280)\times10^3}{(\sqrt{3})\times(13.5)\times10^3\ (0.8)}$ $I_a\ line\ Current = 68.43\ A$ ----------------------- ---------------------**(1/2 Marks)** **Now,** **% regulation at 0.8 leading Power Factor;** $E/ph = \sqrt{(V_T\ Cos\phi + I_aR_a)^2 + (V_T\ \sin\phi - I_aX_S)^2}$ - ----------------------- **(1/2Mark)** $E_{ph} = \sqrt{(7794.23\times0.8)+(68.43\times1.5)^2+(7794.23\times0.6-68.43\times30)^2}$ $Eph = \sqrt{6338.25)^2+(2623.64)^2}$ $Eph = \sqrt{47056899.91}$ $Eph = 6859.8\ \ Volt$ --- **(1/2Mark)** $\text{Re}\,gulation = \dfrac{6859.8-7794.23}{7794.23}\times100 = -11.99\,\%$ % Regulation = - 11.99 % -- **(1 Mark)** **ii) % regulation at Unity Power Factor;** $I_a\ line\ Current = \dfrac{KW\times10^3}{(\sqrt{3})\times(V_{TLine})\,Cos\phi}$ ---------------------------------**(1/2 Marks)** $I_a\ line\ Current = \dfrac{1280\times10^3}{(\sqrt{3})\times13500\times1}$ $I_a\ line\ Current = 54.74\ \ Amp$ -- **(1/2 Marks)**

	$E/ph = \sqrt{(V_T\ Cos\phi + I_a R_a)^2 + (V_T\ \sin\phi + I_a X_S)^2}$ $E_{ph} = \sqrt{(7794.23\times1 + 54.74\times1.5)^2 + (7794.23\times0 + 54.74\times30)^2}$ $Eph = \sqrt{64733552.6}$ $Eph = 8045.72\ Volt$ -- **(1 Mark)** $\text{Re}\,gulation = \frac{8045.72 - 7794.23}{7794.23}\times100 = 3.23\,\%$ % Regulation = 3.23 % --- **(1 Mark)**
Q.5	**Attempt any FOUR of the following : 16 Marks**
a)	**A 20 H.P., 3-phase, 50 Hz, 4 pole induction motor has a full load slip of 4%. The friction and windages losses are 500 watts. Calculate the rotor copper loss and rotor speed.**
Ans:	Given data: 3-ph, 4 Pole, 50 Hz, 20 HP I.M, S_f = full load slip = 4% Net output of Motor = 20 HP = (20 x 735.5) watts = 14710 watts --- **(1/2 Marks)** Gross Rotor output = Net Motor output + Mechanical Losses----------------**(1/2 Marks)** = 14710 + 500 watts = 15210 watts -- **(1/2 Marks)** **Rotor Copper Losses =** $\frac{S}{(1-S)}$ (Gross Rotor output) ---------------------------- **(1 Marks)** $= \frac{0.04}{(1-0.04)}\times15210$ = 633.75 watts --- **(1 /2Marks)** **Rotor Speed (N) =** $(1\text{-}S)N_S$ **where** $N_S = \frac{120\,f}{P} = \frac{120\times50}{4} = 1500\ \text{RPM}$ **(1/2 Marks)** N = (1-0.04) x 1500 **Motor Speed N = 1440 RPM** --- **(1/2 Marks)**

b)	**State different methods used for measurement slip of a 3-phase induction motor and explain any one method in detail.**

Ans: **Methods used for measurement slip of a 3-phase induction motor:**

(Methods of measurement of Slip:1 Mark each & Explanation any one Method:1 Mark

1. Measurement of actual Speed (Tachometer Method):-
2. Galvanometer Method:-
3. Stroboscopic Method:-

1. Measurement of actual Speed (Tachometer Method):-

In this method speed of rotor (N) is actually measured with the help of digital/ analog tachometer. Than slip is calculated $\%\,Slip = \frac{N_S - N}{N_S} \times 100$ where, N_S is synchronous speed it can be calculated from given data of motor, $N_S = \frac{120 f}{P}$

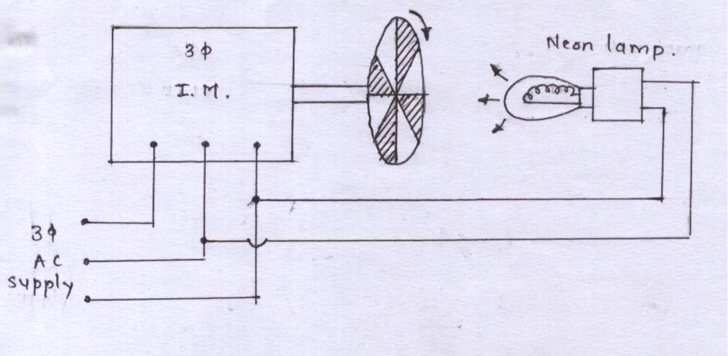
2. Galvanometer Method:-

In case of slip-ring induction motor rotor frequency is measured by inserting a low value centre zero reading DC moving coil voltmeter connected across the slip-rings.

Measure number of oscillations made by pointer of centers zero moving coil voltmeter and time. The slip can be determined from the following relation.

$$Slip = \frac{Number\ of\ oscillations\ counted\ over\ a\ period\ of\ t\ seconds}{50 \times t} = \frac{Rotor\ frequency\,(f^1)}{Supply\ frequency\,(f)}$$

3. Stroboscopic Method:-



In the stroboscopic method a disc with alternate black and white sectors (painted) is attached to the end of the motor shaft. The number of black sector as well as white sectors, each is equal to the number of poles for which the motor is wound. For example for a 6-pole motor there will be 12 sectors, 6 black and 6 white, for testing motor with different numbers of poles, separate disc having different numbers of sectors (painted) is required.

The disc is laminated by means of a neon lamp of stroboscope. The frequency of neon lamp is adjusted till the disc appears stationary; when disc would be appeared stationary at that time the frequency of the stroboscope corresponds to slip frequency. The slip is noted from the calibrated dial or the stroboscope. **OR**

$$Slip = \frac{Apparent\ revolutions\ counted\ in\ the\ given\ time}{Time\ in\ Seconds} \times \frac{pairs\ of\ \ poles}{Supply\ Frequency}$$

c) **State various methods of synchronizing 3-phase alternators and explain any one method in detail.**

Ans:

Following are the ' Three lamp method' of synchronizing an 3-Phase alternator:-

(State : 2 Mark and Any One Lamp Method are expected: 2 Mark)

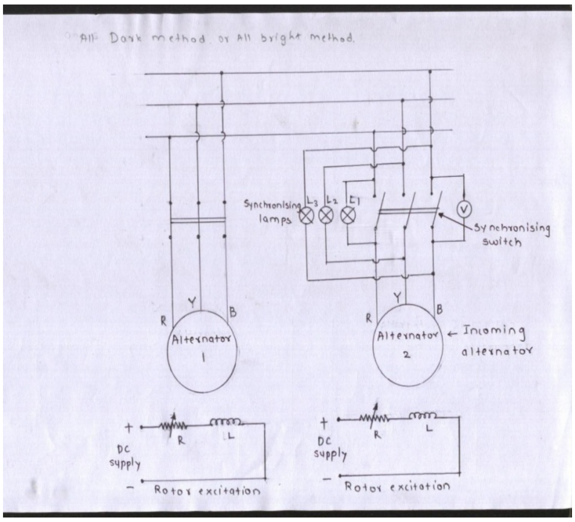
1. All Dark lamp method or all bright lamp method:
2. One Dark, Two bright lamp method (One Straight, two cross method)

Explanation of various methods of synchronizing 3-phase alternators :

(Any One Method expected)

1. All Dark lamp method or all bright lamp method:

Fig: For Three Phase Alternator



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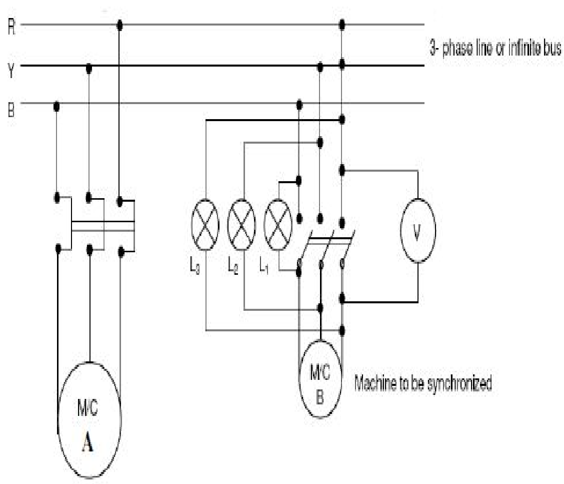
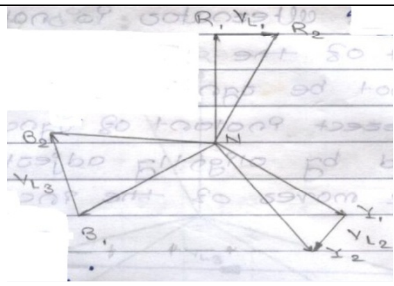




V_{L1} = Voltage across the lamps $L_1 = V_{R2} - V_{R1}$ V_{L2} = Voltage across the lamps $L_2 = V_{Y2} - V_{Y1}$ V_{L3} = Voltage across the lamps $L_3 = V_{B2} - V_{B1}$

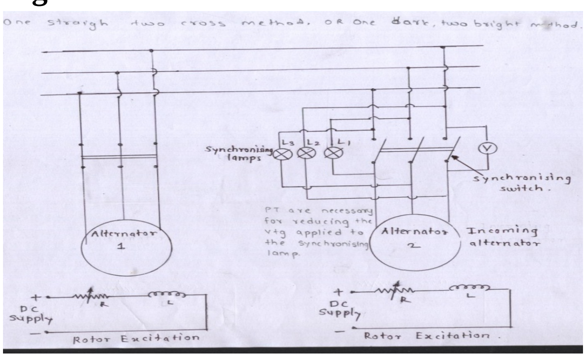
Vector Diagram:

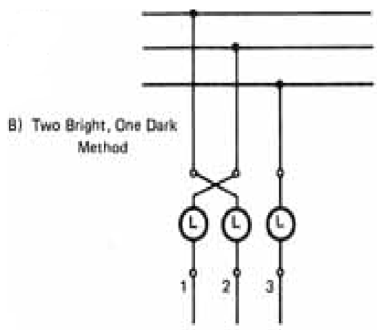
- The 3 lamp pairs L_1 & L_2, and L_2 & L_2, and L_3 & L_3 of equal wattage and voltage rating are connected as shown in figure across the switch and to the bus bar and alternator terminals.
- The Phasor diagram of the bus bar voltages (V_{R1}=V_{Y1}=V_{B1}) and the Phasor diagram of voltage of incoming 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.

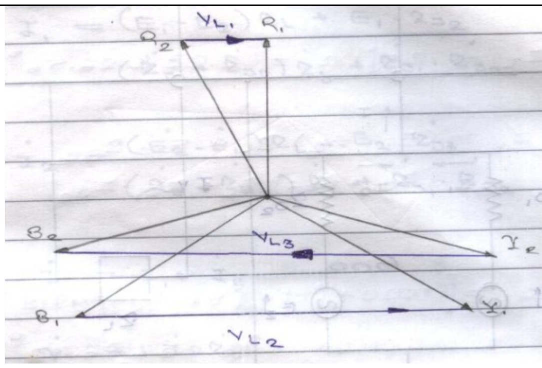
OR other method

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

Fig: For Three Phase Alternator







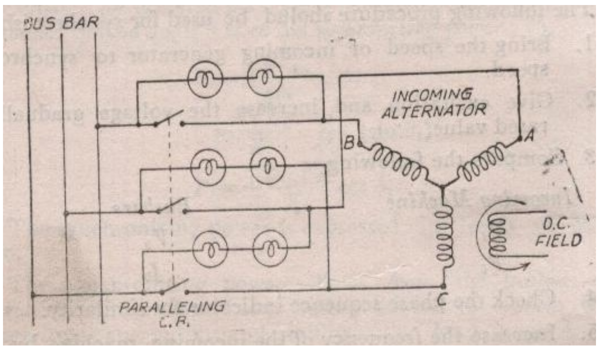
V_{L1} = Voltage across the lamps $L_1 = V_{R1} - V_{R2}$

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



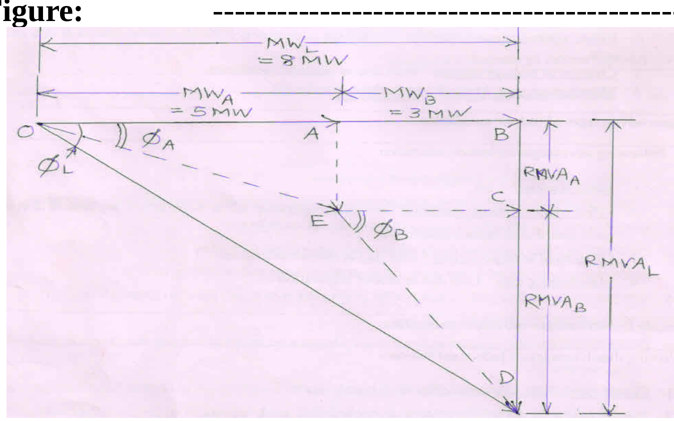
- If the synchroscope is not available, synchronizing lamp method is used.

- 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) **Two alternators A and B operate in parallel and supply a load of 8 MW at 0-8 power factor lagging. The power out put of A is adjusted to 5000 kW by changing its steam supply and its power factor adjusted to 0-9 lagging by changing its excitation. Find power factor of alternator B.**

Ans:

Solution: Figure: -- **(1/2Mark)**



or equivalent fig

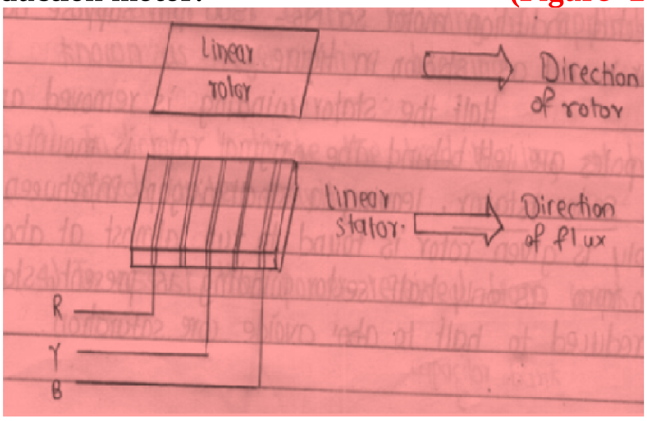
RA Δ OBD is the power triangle of alternator of the load :
RA Δ OAE is the power triangle of alternator of the load A :
RA Δ ECD is the power triangle of alternator of the load B :

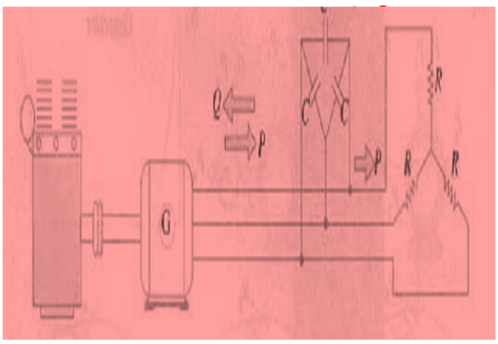
Power factor of alternator A : $\phi_A = Cos^{-1}(0.9) = 25.84^0 \ elect.lag$ ---------- **(1/2Mark)**

Power factor angle of load : $\phi_L = Cos^{-1}(0.8) = 36.86^0 \ elect.lag$ ------------- **(1/2Mark)**

$$l\,(AE) = RMVA\,of\ \ alternator\ \ A = l\,(OA)\,\tan\phi_A$$
$$= (5MW)\ \ \tan 25.84)$$
$$l\,(BC) = 2.421\ RMVA$$ -- **(1/2Mark)**

$$l\,(BD) = RMVA\,of\ \ Load = l\,(OB)\,\tan\phi_L$$
$$= (8MW)\ \ \tan 36.86)$$
$$= 5.998\ RMVA$$ -- **(1/2Mark)**

	$l\,(CD) = l\,(BD) - l\,(BC) = (5.998) - (2.421)$ $l\,(CD) = 3.5766\ RMVA$ -- **(1/2Mark)** In RA ΔECD $\tan\phi_B = \dfrac{l\,(CD)}{l\,(EC)}$ RA ΔECD $\tan\phi_B = \dfrac{3.576}{3}$ RA ΔECD $\tan\phi_B = 1.192$ -- **(1/2Mark)** $\phi_B = Power\ \ factor\ angle\ of\ \ alternator\ \ B$ $\phi_B = \tan^{-1}(1.192)$ $\phi_B = 50^0\ \ Elect.\ lag$ $Cos\ \phi_B = Cos\ 50 = P..f\ \ of\ \ alternator\ at\ B$ $Cos\ \phi_B = 0.64\ lag$ -- **(1/2Mark)**
e)	**Explain the principle of operation of a linear induction motor.**
Ans:	**linear induction motor:** **(Figure- 2 Marks & Principle – 2 Marks)**  **or Equivalent fig.** **Working principle of operation linear induction motor**:- ➢ Linear Induction Motor (LIM) is an asynchronous motor, working on the same principle an Induction motor works, but is designed to produce the linear motion, ➢ When the stator (primary) is excited by applying 3 phase supply in an induction motor, rotating magnetic field is produced.

	➢ Here, after laying down the stator flat, excitation with three phase supply would induce a 'travelling flux', a travelling magnetic field, which would linearly travel along the stator. ➢ This would again induce emfs in the rotor, which produces a forward thrust force, and if the secondary (rotor) is fixed primary is free to move, it would travel across the length of the machine linearly, along the tracks provided so produce the linear motion. **OR** 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) 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)	**What is an induction generator? State it's principle of operation.**
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.  or Equivalent fig.

The principle of operation induction Generator: **(2 Mark)**

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.

Q.6 Attempt any FOUR of the following: 16 Marks

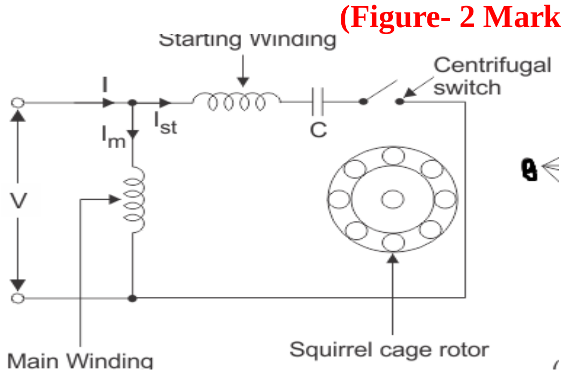
a) State any two applications of the following motors:
(i) Shaded pole induction motor (ii) Capacitor start induction run motor
(iii) Resistance start induction run motor (iv) Capacitor start capacitor run motor

Ans: **Applications of each of the following:**

Sr.No	Types of 1-Ph Induction Motor	Applications (Any Two expected)
i)	Shaded pole motor **(Any Two Applications 1Marks)**	Recording Instruments, Record Player, Gramophones, toy Motors, Hair dryers, Photo copy machine, Advertising display
ii)	Capacitor Start Induction run **(Any Two Applications 1Marks)**	Fans, Blowers, Grinder, Drilling Machine, Washing Machine, Refrigerator, Air conditioner, Domestic Water Pumps, Compressor.
iii)	Resistance Start Induction run **(Any Two Applications 1Marks)**	Washing Machine, Fans, Blowers, Domestic Refrigerator, Centrifugal Pump, Small electrical Tools, Saw machine
iv)	Capacitor Start Capacitor run **(Any Two Applications 1Marks)**	Fans, Blowers, Grinder, Drilling Machine, Washing Machine, Refrigerator, Air conditioner, Domestic Water Pumps, compressors.

b) With a neat circuit diagram, explain construction and working principle of a capacitor start induction run 1-phase induction motor.

Ans: **Working principle of a capacitor start induction run 1-phase induction motor :**
(Figure- 2 Mark & Explanation- 2 Mark)



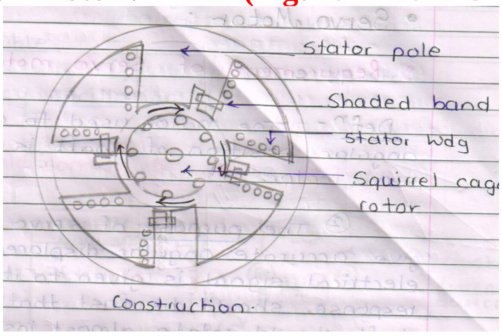
OR Equivalent fig

In these motors one capacitor is connected in series with the auxiliary winding along with centrifugal switch. Thus this winding along with the capacitor remains energized at starting conditions. Capacitor used serves the purpose of obtaining necessary phase displacement at the time of starting. At certain speed the centrifugal switch gets opened due to centrifugal force and the capacitor gets disconnected.

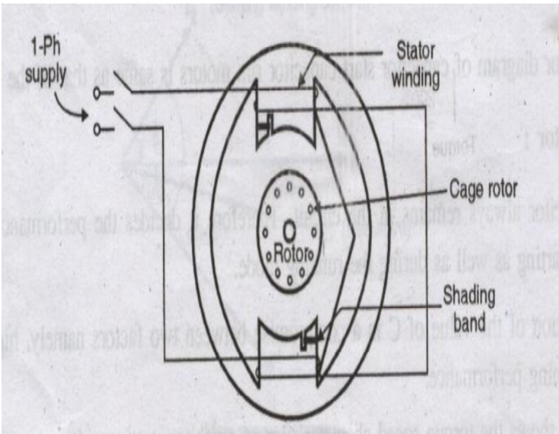
c) **With a neat labelled diagram, explain principle of operation of a shaded pole single phase induction motor.**

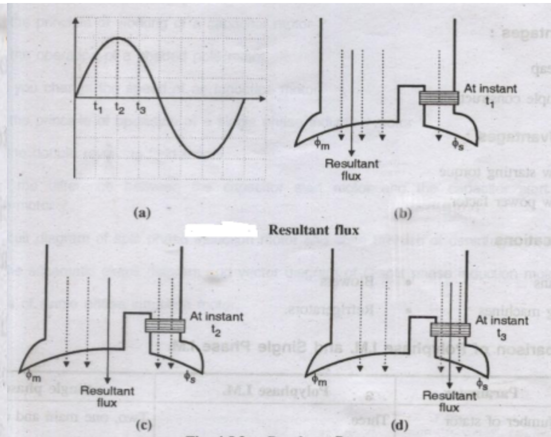
Ans:

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



OR



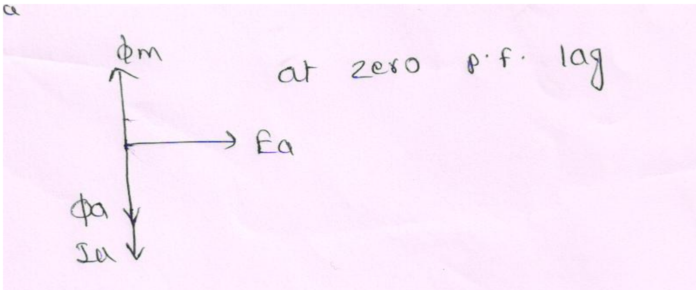
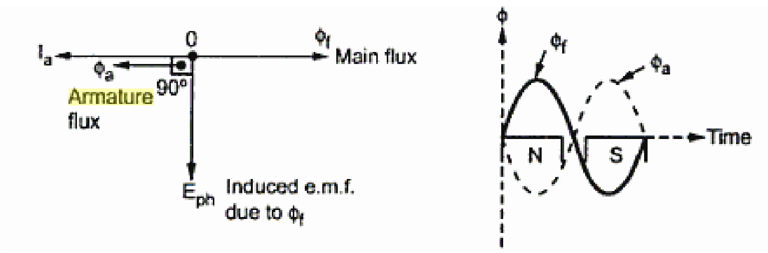


OR Equivalent Fig.

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.

d)	**Define armature reaction in an alternator. Discuss the effect of lagging power factor load on armature reaction.**
Ans:	**Definition of armature reaction in an alternator:** **(2 Mark)** When the armature conductors carry current they produce their own flux this flux affects the main pole flux. Due to the change in flux the terminal voltage available at the load conditions will be different. The effect of armature flux on pole flux is called as armature reaction. **The effect of armature reaction depends upon Lagging power factor the load:**  **OR**  **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 $V_T \langle E$. ---------**(2 Mark)**
e)	**State any two applications of the following motors:** **(i) A.C. servomotor (ii) D.C. servomotor (iii) Variable reluctance stepper motor (iv) Permanent magnet stepper motor**
Ans:	**i) Application of AC servo motor,** It is widely used in **:** **(Any Two Applications expected: 1 Mark each)** 1. Robotics: 2. Conveyor Belts: 3. Camera Auto Focus:. 4. Robotic Vehicle: 5. Solar Tracking System:

6. Metal Cutting & Metal Forming Machines:
7. Antenna Positioning:
8. Woodworking/CNC:
9. Textiles:
10. Printing Presses/Printers:
11. Automatic Door Openers:

(ii) 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

(iii) Application of Variable reluctance 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

	(iv) Permanent magnet 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

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