Important suggestions to examiners:

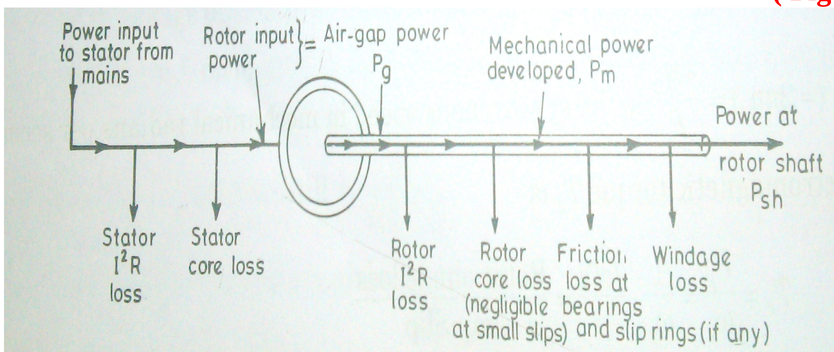
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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	**Attempt any Five:** **(4 x 5 = 20 Marks)**
a)	**State the working principle of 3-ph induction motor.**
Ans:	**Working principle of 3 phase induction motor:** **(4 Marks)** **The principle of working of 3 phase induction motor on the basis of the concept of rotating magnetic field can be explained as follows:** When 3-Ph AC supply is given to stator **of three phase induction motor**, rotating magnetic field is produced in air gap, which starts to rotate around the stator frame with synchronous speed (Ns = 120f/P). There is a relative motion between rotating magnetic field and stationary rotor conductors which is (Ns-N). According to faradays laws of electromagnetic induction, emf will be induced in the rotor conductors. As the rotor conductor **are short circuited on either sides by end rings**, current flows through it. Due to interaction between stator and rotor flux rotor starts rotating .Rotor rotates in the same direction as that of rotating magnetic field. According to 'Lenz Law' the rotor current should oppose the cause which produces it i.e. relative speed Ns-N. So the rotor will try to catch the rotating magnetic field speed Ns to minimize the relative speed. But due to inertia and friction of rotor, they never succeed. Hence rotor will be in continuous rotation with speed N, which is always less than Ns .

b) Draw a block diagram showing power stages of 3-ph induction motor.

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

(Figure : 4 Mark)



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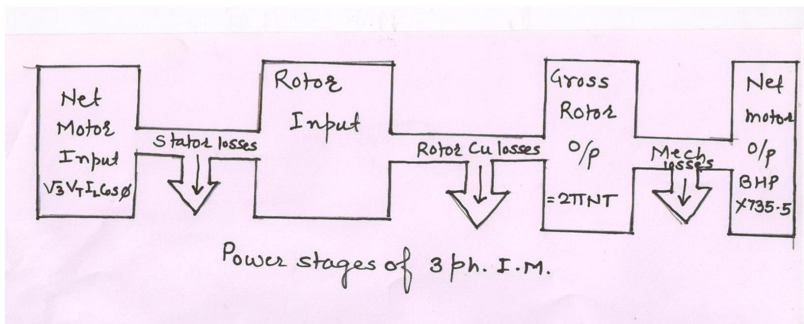

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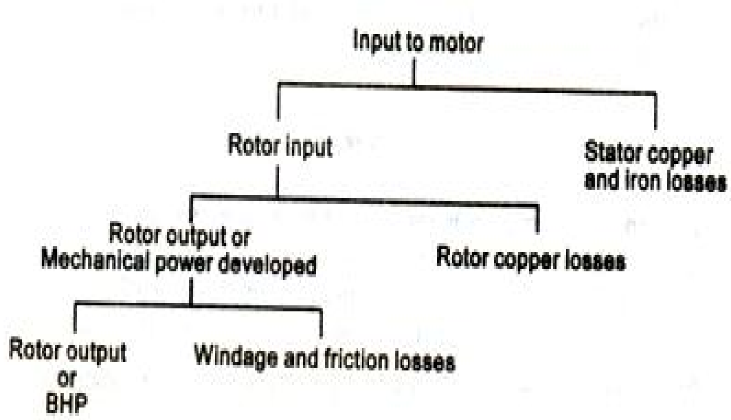


c) State the necessity of starter in 3-ph induction motor. Enlist any four types of starters used in 3-ph induction motor.

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 heavy current because (An induction motor is similar to a poly-phase

	transformer whose secondary is short circuited.) 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. **ii) The names of starters used for 3-phase induction motor.** -------------- **(2 Mark)** 1) DOL Starter 2) Star-Delta Starter 3) Rotor resistance starter 4) Auto transformer Starter
d)	**List out the advantages of having a stationary armature and rotating field of 3-ph alternator.**
Ans:	**(Any four Point Expected each point 1 Marks)** **Following Advantages of stationary armature and rotating field 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. **OR** **Following Advantages of stationary armature and rotating field of a 3-phase alternator:** The field winding of an alternator is placed on the rotor and is connected to d.c. supply through two slip rings. The 3-phase armature winding is placed on the stator. This arrangement has the following advantages: 1. It is easier to insulate stationary winding for high voltages for which the alternators are usually designed. It is because they are not subjected to centrifugal forces and also extra space is available due to the stationary arrangement of the armature. Or It is easier to insulate stationary armature winding for high AC voltage, which may have as high a value as 30KV or more. 2. The stationary 3-phase armature can be directly connected to load without going through large, unreliable slip rings and brushes. 3. Only two slip rings are required for d.c. supply to the field winding on the rotor. Since the exciting current is small, the slip rings and brush gear required are of light construction. Or The sliding contacts i.e. slip rings are transferred to the low voltage, low power DC field current which can, therefore be easily insulated. 4. Due to simple and robust construction of the rotor, higher speed of rotating d.c. field is possible. This increases the output obtainable from a machine of given dimensions.
e)	**State the necessity conditions of parallel operation of 3-ph alternator.**
Ans:	**Conditions of parallel operation of 3-ph alternator:-** **(Any Four Point expected: 1 Mark each)** 1. The phase sequence of both **3-ph alternators** must be same. 2. The AC voltages of both **3-ph alternators** should be equal. 3. The frequencies of both **3-ph alternators** must be equal. 4. Phase voltages of both **3-ph alternators** must be in proper phase relation or polarity of phase voltages of both **3-ph alternators** must be identical.

f)	**Give the reason why single phase induction motors are not self starting.**
Ans:	**Reason for single phase induction motors are not self starting:** **(4 Mark)** ➢ When single phase AC supply is given to main winding it produces alternating flux. ➢ According to double field revolving theory, alternating flux can be represented by two opposite rotating flux of half magnitude. ➢ These oppositely rotating flux induce current in rotor & there interaction produces two opposite torque hence the net torque is Zero and the rotor remains standstill. ➢ Hence Single-phase induction motor is not self starting. **OR** **Single phase induction motor** has distributed stator winding and a squirrel-cage rotor. When fed from a single-phase supply, its stator winding produces a flux (or field) which is only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving (or rotating) flux as in the case of a two or a three phase stator winding fed from a 2 of 3 phase supply. Now, alternating or pulsating flux acting on a stationary squirrel-cage rotor cannot produce rotation (only a revolving flux can produce rotation). **That is why a single phase motor is not self-starting.**
g)	**Give any two advantages and two disadvantages of single phase induction generator.**
Ans:	**Advantages of single phase induction generator:** **(Any Two expected : 1 Mark each)** 1. They are robust and sturdy. 2. Are cheaper in cost. 3. The construction is simple. 4. Low Maintenance. Very little maintenance is required. 5. It does not require any complex circuit for starting. 6. They can be operated in hazardous environments and even under water as they do not produce sparks. **Disadvantages of single phase induction generator:** **(Any Two expected : 1 Mark each)** 1. Speed control is difficult 2. At low loads, the power factor drops to very low values **3.** Efficiency drops at low loads. This is because; the low power factor causes a higher current to be drawn. This results in higher copper losses.

Q.2	Attempt any FOUR : 16 Marks
a)	**Derive the condition for maximum torque at running condition of a 3-ph induction motor.**

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

Let us consider the equation of torque,

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

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

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

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

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

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

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

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

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

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

$$\therefore R_2 = S\,X_2$$

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

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

b)	**How speed of 3-ph induction motor is controlled by using pole changing method ?**

Ans: **by Following reason varying number of poles of the stator winding (pole changing control) :** **(4 Mark)**

1. The synchronous speed of an induction motor is given by $N_S = \frac{120 \times f}{P}$.

	2. It is clear from the equation that if the number of poles of the stator is decreased, the speed of the motor will increased. 3. When the number of poles are increases, the speed of the motor decreases. 4. 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. **OR** From the above equation of synchronous speed, it can be seen that synchronous speed (and hence, running speed) can be changed by changing the number of stator poles. This method is generally used for **squirrel cage induction motors,** as squirrel cage rotor adapts itself for any number of stator poles. Change in stator poles is achieved by two or more independent stator windings wound for different number of poles in same slots. **For example**, a stator is wound with two 3phase windings, one for 4 poles and other for 6 poles. for supply frequency of 50 Hz i) synchronous speed when 4 pole winding is connected, Ns = 120*50/4 = 1500 RPM ii) synchronous speed when 6 pole winding is connected, Ns = 120*50/6 = 1000 RPM
c)	**Define each of the following term of alternator: i) Leakage reactance ii) Synchronous impedance iii) Distribution factor iv) Pitch factor.**
Ans:	**(Each Definition: 1 Mark)** **i) Leakage reactance:** The working flux does not only passes through intended path. Some part of working flux will be lost due to leakage. Hence leakage reactance is defined as the factor or parameters which represents the leakage flux **OR** When armature carries a current, it produces its own flux. Some part of this flux completes its path through the air around the conductors itself. Such a flux is called leakage flux. The equivalent reactance due to this leakage flux is called as ;leakage reactance

	ii) Synchronous impedance: It is a fictitious impedance employed to account for the voltage effects in armature circuit produced by the actual armature resistance, the actual armature leakage reactance, and the change in air gap flux produced by armature reaction. **OR** $Z_S = R_a + j (X_L + X_a)$ $= R_a + j (X_S)$ Where, Z_S = synchronous impedance, R_a = Armarure resistance, X_L = Leakage reactance, X_a = Armature reaction reactance, X_S = Synchronous reactance **iii) Distribution factor** It is the ratio of vector sum of the emf in the individual coil to the arithmetical sum if the coils are of concentrated type or all the coil sides are in only one slot. **OR** $K_d = \frac{Vector\ sum\ of\ coil\ voltages\ per\ phase}{arithmetic\ sum\ of\ coil\ volatges\ per\ phase}$ **iv) Pitch factor:** It is the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil. **OR** $K_C = \frac{Actual\ voltage\ generated\ in\ the\ short\ pitch\ coil}{Voltage\ generated\ in\ the\ full\ pitch\ coil}$
d)	**State the need of parallel operation of 3-ph alternator.**
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.

e) **Give the two applications of each motor : i) A.C. series motor ii) Universal motor iii) Linear induction motor iv) Stepper motor.**

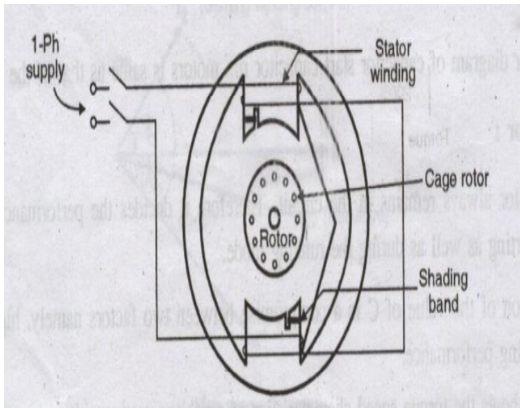
Ans: **Applications of each of the following: (Each Motor Application : 1 Mark)**

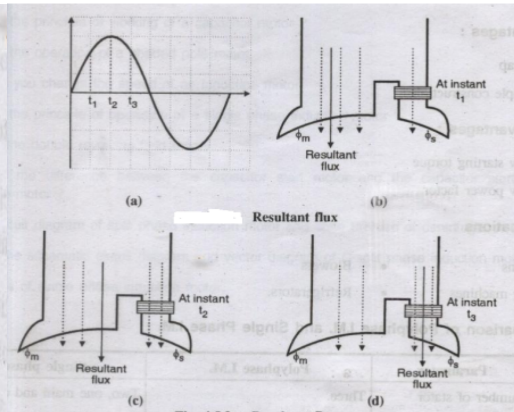
Sr.No	Types of Induction Motor	Applications (Any Two expected)
i)	A.C. series motor (Any Two Applications 1 Marks)	1. Where high starting torque is required e.g. Electric Traction 2. Stone Crushing Machine 3. Washing Machines. 4. Mixers and grinders 5. Food processors. 6. Small drilling Machines. 7. In main line service 8. In Electric Traction

	ii)	Universal Motor **(Any Two 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
	iii)	Linear Induction Motor **(Any Two Applications 1Marks)**	• Application for Stationary Field System 1. Automatic sliding doors in an electrical train, 2. Metallic belt conveyer, 3. Mechanical handling equipment, such as propulsion of a train of tubs along a certain route, 4. Shuttle-propelling application. • Applications for the moving field system. 1. High and medium speed applications have been tried with linear motor propulsion of vehicles with air cushion or magnetic suspension. 2. High speed application as a travelling crane motor where the field system is suspended from loist.
	iv)	Stepper Motor **(Any Two 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

f) **State construction and working of shaded pole single phase induction motor.**

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





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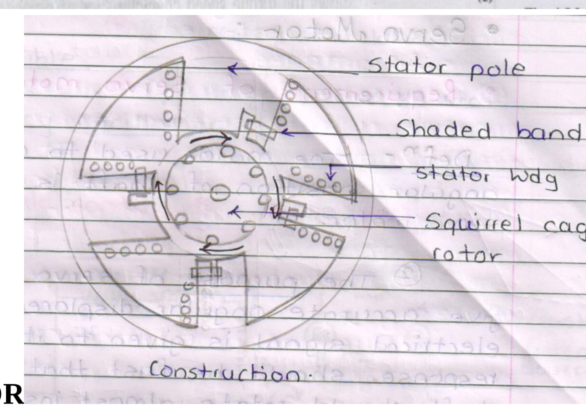
OR 

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.

Q.3 **Attempt any Four :** **16 Marks**

a) **The power input to a 500 V, 50 Hz, 6-pole, 3-ph induction motor running at 975 rpm is 40 kW. The stator losses are 1 kW and the friction and windage losses total 2 kW. Calculate i) The slip ii) The rotor cu-loss iii) Shaft power and iv) The efficiency.**

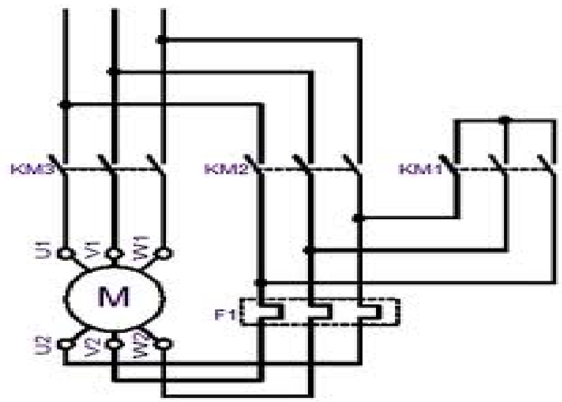
Ans: **Given Data:**

3Ph, 50 Hz I.M P = 6 Motor I/p = 40×10^3 W N = Actual Speed= 975 RPM

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

	1) The Slip : $\% \; Slip = \frac{N_S - N}{N_S} \times 100 = \frac{1000-975}{1000}$ - ---------------- **(1 /2Marks)** $\% \; Slip = 0.025 \; or \; 2.5 \; \%$ ------------------------------------ **(1 /2Marks)** **Now,** **Gross Rotor input =** Net Power input + Stator Losses ----------------- **(1/2 Marks)** = (40 KW+1 KW) watt = 39 KW or 39 x 10^3 Watts ----------------------- **(1/2 Marks)** **2) Rotor Copper Losses:** S (Rotor Input) = (0.025) (39KW) = 975 Watts ---------------------------- **(1/2 Marks)** **3) Shaft Power or Gross Rotor output =** $(1 - S)\,(Rotor\;Input)$ **=** $(1 - 0.025)\,(39 \times 10^3)$ $= 38025 \; watts$ **4) Net Output:** Gross Rotor output – Mechanical Losses = (38025) – (2000) **Net Output** = 36025 Watts **(1/2 Marks)** **5) Efficiency :** **Efficiency** = $\frac{Net\;Output}{Rotor\;Input} \times 100$ - --------------------------- **(1/2 Marks)** = $\frac{36025}{40000} \times 100$ **Efficiency** = 90.06 % ---------------------------- **(1/2 Marks)**
b)	**With neat sketch state the working principle of star-delta starter.**
Ans:	**(Wiring Diagram-2 Mark & Explanation-2 Mark)** ➢ At Starting, the stator winding is connected in star connection. At the time of starting in star connection, $Iph = \frac{Vph}{Z_{SC}}$ and $Vph = \frac{V_L}{\sqrt{3}}$ Therefore starting current controlled to a safe value.

	➢ After the motor has reaches nearly steady state speed, the change over switch is thrown to connect motor in delta **Diagram of Star -Delta starters:**



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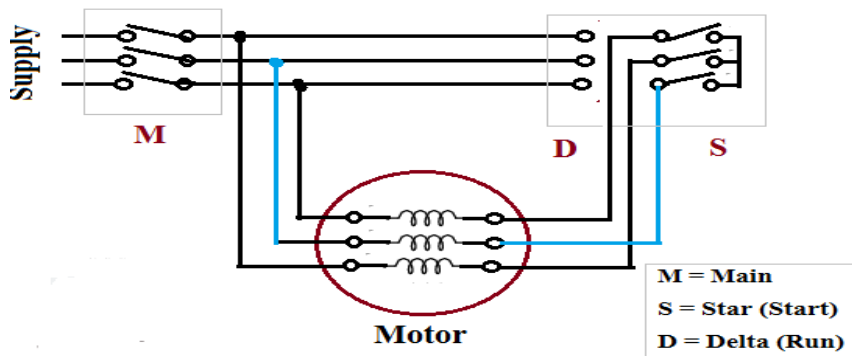


or Equivalent fig.

c) **State any four points of comparison of salient pole type rotor and smooth cylindrical rotor of 3-ph alternator.**

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

S.No	Parameter/Machine	Salient pole type rotor	Smooth cylindrical type rotor
1	**Operating speed**	Low medium	high
2	**Number of poles**	large	Small & medium
3	**Rotor construction**	Projected type bulky & heavy weight	Cylindrical poles type comparatively moderate weight

4	**Axial length**	short	large
5	**Diameter**	large	small
6	**Operation**	noisy	Very smooth
7	**Centrifugal stresses**	Non uniform	uniform
8	**Application**	In hydro power stations	Thermal power station

d) State the effect of change in excitation in case of parallel operation of two, 3-ph alternators.

Ans: **The effect of change in excitation in case of Two 3-ph alternator is as under**, Keeping the total load on the alternator is kept constant. **(4 Mark)**

1. If the excitation of any one alternator increases, it's reactive power component increases, it's power factor decreases and the load current shared by the same alternator increases.
2. The automatic effect on the remaining alternator is that its power factor increases while the load current shared decreases.

e) How the direction of rotation of capacitor start capacitor run motor can be reversed?

Ans: **Reason for capacitor start and capacitor run can be reversed:** **(4 Mark)**

Single phase motors have two windings, the main winding and the auxiliary winding. The auxiliary winding is used to start the motor and may be disconnected once the motor picks up sufficient speed.

Reversing a single phase motors cannot be done by reversing the polarity of the supply to the entire motor. To reverse the single phase motor, the polarity of the supply to only one of the windings needs to be changed.

This can be done by reconfiguring special links which may be provided in the terminal box of the motor.

f) What is the working principle of linear induction motor

Ans: **(Working – 4 Marks)**

- **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.
Q.4	**Attempt any Four: 16 Marks**
a)	**State why three phase induction motor never runs 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 .
b)	**State how each of the following can reduce starting current of 3-ph induction motor : i) By inserting resistance in rotor winding. ii) By connecting autotransformer in stator winding.**
Ans:	**i) By inserting resistance in rotor winding can reduce starting current of 3 phase IM:** **(2 Marks)** This method is only applicable to slip-ring motors. At the instant of starting, the external rotor resistance can be kept at maximum value. Therefore heavy starting current can be controlled. **ii) By connecting autotransformer in stator winding:** **(2 Marks)** ➢ At the instant of starting, the position of the slider/variable tap is kept at zero voltage position. ➢ When the slider moves gradually in clockwise direction, the voltage applied to

	three phase induction motor will be increased in steps. ➢ At starting reduced voltage can be applied to 3-phase induction motor and hence heavy starting current will be reduced or controlled. ➢ When motor start to rotate and achieve about 70 % of the rated speed, the rated voltage can be applied to 3-phase induction motor. ➢ Thus by using 3-phase auto transformer as a starter, starting current can be controlled.
c)	**Derive the emf equation of an 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)**

$$\therefore E_{ave} / turn = 2\ E_{ave} / Conductor\ \frac{P \times \phi \times N}{60} --------- Volt$$

$$\therefore E_{ave} / turn = 2\ \frac{P \times \phi \times N}{60} --------- Volt$$

$$\therefore \quad = \frac{4P\phi N}{120} -------- Volt$$ -------------------------**(1/2 Marks)**

$\therefore \quad = 4\left(\frac{P\,N}{120}\right)\phi$

$\therefore$ E_{ave} / turn = $4\,f\,\phi \quad \therefore \left(f = \frac{P\,N}{120}\right)$

$\therefore$ 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)**

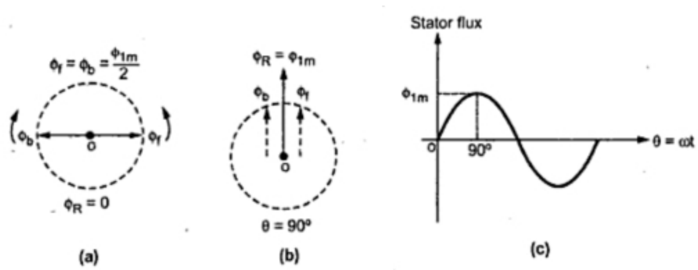
Where, Kc = coil span factor or chording factor

Kd = Distribution factor

d) **State the double field revolving theory of single phase induction motor.**

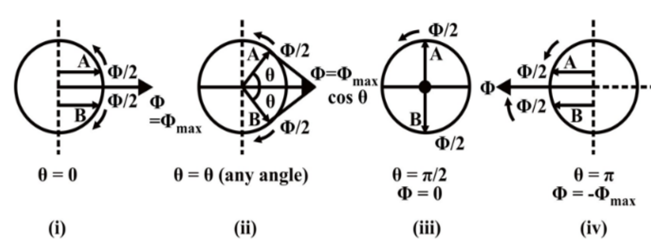
Ans:

- **Double field revolving theory: ------------ (Figure: 2 Mark & Exp[lantion : 2 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.

e)	**Compare resistance split phase and capacitance split phase induction motor (any four points)**

Ans:

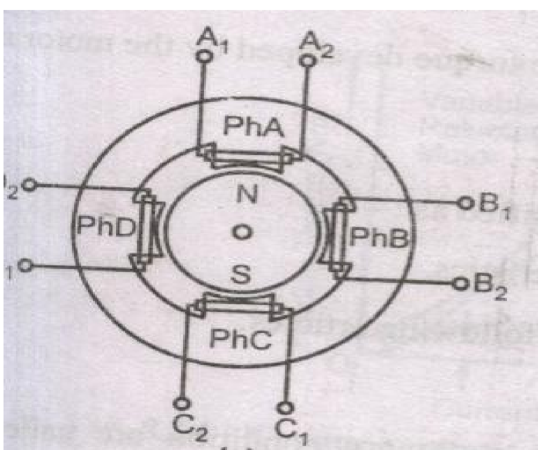
(Each Point -1 Mark)

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

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

Ans:

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



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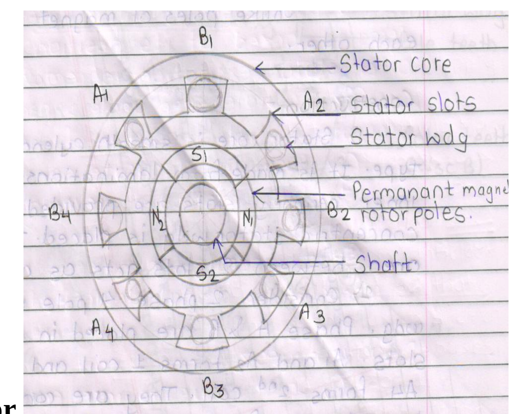
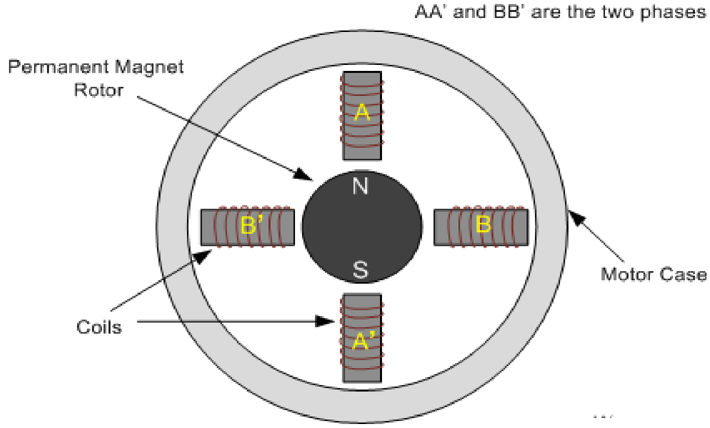


AA' and BB' are the two phases



	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.5	**Attempt any Two :** **16 Marks**
a)	**An 18.65 kW, 4 pole, 50 Hz, 3-phase induction motor has friction and windage losses of 2.5 percent of the output. The full load slip is 4%. Compute for full load a) The rotor cu loss b) The rotor input c) The shaft torque d) The gross torque.**
Ans:	**Given Data:** 3Ph, 4 Pole, 50 Hz I.M Full load Slip = 3.5 % Net motor o/p = 18.65 kW I.M S_f = slip at full load = 0.04 Windage losses = 0.025 Windage & frictional losses (Mech. Losses) = $0.025 \times 18.65 \times 10^3$ $= 466.25\ watts$ ------------------- **(1/2 Marks)** **Gross (Net) Rotor output =** Net motor output + mech. losses--------------- **(1/2 Marks)** $= 18650 + 466.25$ $= 19116.25\ watts$ -- ------------------------------- **(1/2 Marks)** **i) Rotor Input =** $\frac{Gross\ \ Rotor\ \ output}{(1-S)}$ - --- **(1/2 Marks)** Rotor Input = $\frac{19116.25}{(1-0.04)} = 19912.75\ \ Watts$ Rotor Input = $19912.75\ \ Watts$ - --- **(1/2 Marks)** **ii) Rotor Copper Losses =** $S \times Rotor\ \ Input$ --------- ---------------------- **(1/2 Marks)** Rotor Copper Losses = 0.04×19912.75 Rotor Copper Losses **=** $796.51\ \ Watts$ -------------------------------------- **(1 /2Marks)** $N_S = \frac{120\ f}{P} = \frac{120 \times 50}{4} = 1500\ RPM$ ---------------- ---------------------- **(1/2 Marks)**

	Full Load Speed = Ns (1-S), Full Load Speed = 1500 (1-0.04) Full Load Speed = 1440 RPM N in RPS = $N = \frac{1440}{60} = 24\ RPS$ ------ ------------------------- **(1 Marks)** **iii) Gross torque =** $= \frac{Gross\ output}{2\pi N}$ $(Where,\ N\ in\ RPS)$ -------- **(1/2 Marks)** $= \frac{19912.75}{2 \times 3.142 \times 24}$ $T_g = 126.75\ N-m$ -------------------- **(1 Marks)** **iv) The shaft torque or Net torque =** $= \frac{Net\ output}{2\pi N}$ $(Where,\ N\ in\ RPS)$ ----------------- **(1/2 Marks)** $= \frac{18650}{2 \times 3.142 \times 24}$ $T_{sh} = 123.66\ \ N-m$ ----------------- **(1 Marks)**
b)	**A certain 3-ph, star connected, 100 kVA, 11000 V alternator has rated current of 52.5 A. The a.c. resistance of the winding per phase is 0.45 ohm . The test results are given below : O.C. Test — Field current = 12.5 A; Voltage between lines = 422 V** **S.C. Test — Field current = 12.5 A, line current is equal to 52.5 A.** **Determine the full load voltage regulation of the alternator at p.f. 0.8 lagging and 0.8 p.f. leading.**
Ans:	**Given Data:** 3-Ph, 100 KVA, 11 KV star connected alternator, V_T Line 11000 KV (V_T/ph= 6350.85) $I_a\ line\ Current = \frac{KVA \times 10^3}{(\sqrt{3}) \times (V_{TLine})}$ **(1/2 Marks)** $I_a\ line\ Current = \frac{(100) \times 10^3}{(\sqrt{3}) \times (11) \times 10^3}$

$I_a\ line\ Current = 5.25A$--------------------- ---------------------**(1/2 Marks)**

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

$$Z_S/Ph = \frac{422/\sqrt{3}}{52.5}$$

$Z_S/Ph = 4.64\ \Omega$--------------------- ------------------------- **(1/2 Marks)**

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

$$X_S/Ph = \sqrt{(4.64)^2 - (0.45)^2}$$

$X_S/Ph = 4.62\ \Omega$--------------------- ------------------------ **(1/2 Marks)**

Now,

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

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

$$E/ph = \sqrt{[(6350.85)(0.8) + (5.25)\ (0.45)]^2 + [(6350.85)(0.6) + (5.25)(4.62)]^2}$$

$E/ph = 6367.32\ Volt$-- --- **(1/2 Marks)**

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

% Regulation = $\frac{6367.32 - 6350.85}{6350.85} \times 100$

% Regulation = $0.2593\ \%$------------------------- ----------------- **(1/2 Marks)**

ii) % Regulation at full load for 0.8 Lagging P.f;

$No.\ load\ emf\ E_0 = \sqrt{(V_T\ Cos\phi + I_a R_a)^2 + (V_T\ \sin\phi - I_a X_S)^2}$ --------- **(1Mark)**

$$No.\ load\ emf\ E_0 = \sqrt{(6350.85 \times 0.8 + 5.25 \times 0.45)^2 + (6350.85 \times 0.6 - 5.25 \times 4.62^2}$$

$$No.\ load\ emf\ E_0 = \sqrt{(25837321) + (14335689.06)}$$

$$No.\ load\ emf\ E_0 = \sqrt{40173010.12}$$

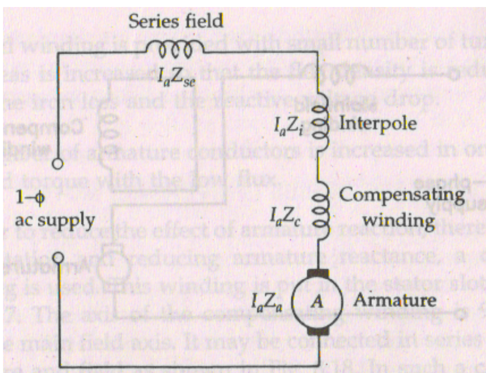
$$No.\ load\ emf\ E_0 = 6338.21\ Volt$$ -- **(1/2 Mark)**

$$\text{Regulation} = \frac{E_0 - V_T}{V_T} \times 100 = \frac{6338.21 - 6350.85}{6350.85} \times 100$$

% Regulation = -1.1988 % -- **(1/2 Mark)**

c) **i) Draw a schematic diagram of an A.C. series motor.**
ii) Draw speed torque characteristics of A.C. series motor.

Ans: **i) Draw a schematic diagram of an A.C. series motor.** **(4 Mark)**



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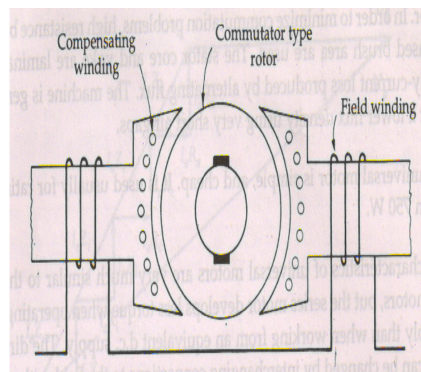
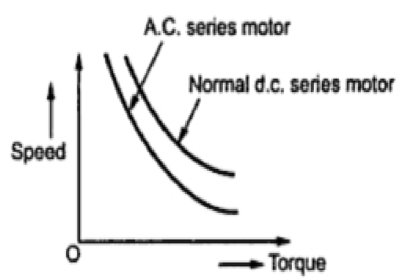


ii) Draw speed torque characteristics of A.C. series motor.

Speed-torque characteristics of AC series motor: ---------------------------- **(4 Mark)**



or equivalent characteristics

Q.6 **Attempt any Two:** **16 Marks**

a) **A 6-pole, 50 Hz, 3 0 , induction motor running on full load with 4% slip develops a torque of 149.3 N-m at its pulley rim. The friction and windage losses are 200 W and the stator copper and iron losses equal to 1620 W. Calculate**
a) Output power b) The rotor copper loss and c) The efficiency at full-load.

Ans: 3Ph, 6 Pole, 50 Hz I.M Full load Slip = 4 % Stator Losses= 1620 watts

Torque at shaft i.e Gross Torque = 149.3 N-m = T_g Mechanical Losses = 200 watt

Where $N_S = \frac{120\ f}{P} = \frac{120 \times 50}{6} = 1000\ RPM$ ---------------------------- **(1 Marks)**

Full Load Speed = Ns (1-S),

Full Load Speed = 1000 (1-0.4)

Full Load Speed = 960 RPM ------ ------------------- **(1/2 Marks)**

1) Gross Rotor Output = $2\ \pi\ N\ T_g$ (Where, N in RPS)

$$= 2 \times 3.142 \times \frac{960}{60} \times 149.3$$

$=15011.22\ \ Watts$ -- **(1/2 Marks)**

Net Motor output = Gross Rotor output – mech. Losses ------------ **(1/2 Marks)**

= 15011.22 - 200

Net Motor output = 14811.22 Watts---------------------------------- **(1/2 Marks)**

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

Rotor Input = $\frac{15011.22}{(1-0.04)} = 15636.69\ Watts$ -- ---------------------------- **(1/2 Marks)**

Rotor Copper Losses = $S \times Rotor\ \ Input$ ------------------------------- **(1/2 Marks)**

Rotor Copper Losses = 0.04×15636.69

Rotor Copper Losses = $625.47\ \ Watts$ ------------------------------- **(1/2 Marks)**

3) Net Motor Input = $Rotor\ Input + Stator\ Losses$

Net Motor Input = $15636.69 + 1620\ \ Watts$

Net Motor Input = $17256.69\ \ Watts$ -- **(1/2 Marks)**

$$\%\ \eta = \frac{Net\ \ Motor\ output}{Net\ Motor\ Input} \times 100$$ ------------------------------ **(1 Marks)**

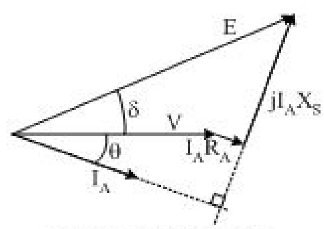
$$\%\ \eta = \frac{14811.22}{17256.69} \times 100$$

$\%\ \eta = 85.82\ \%$ -- **(1 Marks)**

b)	**Describe the factors affecting the regulation of three phase alternator and draw the phasor diagrams of loaded alternator when operating power factor is lagging and leading.**
Ans:	**Factors affecting the regulation**:- **(Any Two point expected : 2 Marks)**

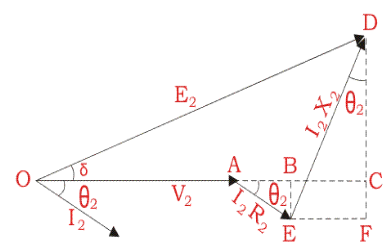
1. It depends on armature resistance(R_a)
2. It depends on leakage reactance (X_L)
3. Magnitude of load current
4. Magnitude of Power factor of load
5. Type of load Power factor (Lagging, leading, Unity)
6. Effect of armature reaction (X_a)

i) Lagging Phasor diagrams of loaded alternator: **(3 Marks)**



Lagging Power Factor
Phasor Diagram

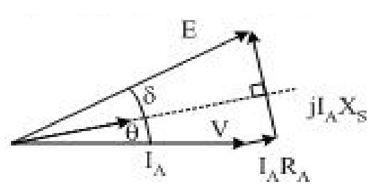
OR



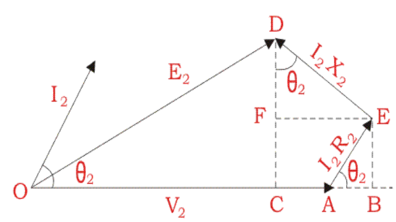
Voltage Regulation at Lagging Power Factor

or equivalent figure

ii) Leading Phasor diagrams of loaded alternator: **(3 Marks)**



Leading Power Factor
Phasor Diagram



OR

Voltage Regulation at Leading Power Factor

or equivalent figure

c)	**A certain 3-ph alternator is rated at 5 kVA, 110 V, 26.3 A, 50 Hz and 1200 rpm. The stator resistance between terminals as measured with d.c. is 0.2 ohm . With no load and rated speed, the stator line voltage is 160V for a field current of 4A. At rated speed, the short circuit stator current per terminal is 60A for a field current of 4A. Calculate: i) Synchronous impedance per phase ii) The voltage regulation of alternator at 0.8 p.f. lagging. The alternator is star connected.**
Ans:	**Given Data:** 3-Ph, 5 KVA, 110 KV star connected alternator, Ra = 0.2 ohm (d.c) 26.3 A 50 Hz and 1200 rpm O.C. Voltage = 160 V (Line) S.C Current = 60A for $I_F = 4$ A 1. $V_{O.C}\ line\ Volatge = 160\ V$ $V_{OC}\ Phase\ voltage = \frac{160}{(\sqrt{3})}$ $V_{OC}\ Phase\ voltage = 92.38\ V$ --(1/2 Marks) 2) **The Synchronous impedance per Phase**: $Z_S/Ph = \frac{O.C.Voltage}{S..C.Current/ph}$ for the same I_F ------------------------ (1/2 Marks) $Z_S/Ph = \frac{92.38}{60}$ $Z_S/Ph = 1.54\ \Omega$------ --- (1 Marks) 3) Armature resistance per Phase : **Given** : = $R_a = 0.2\ ohm\ between\ the\ terminals\ (d.c\ value)$ $\therefore R_a/ph = \frac{0.2}{2} = 0.1\ ohm\ (d.c\ value)$ $\therefore$ *Considering the skin effect, the a.c. value of* R_a/ph *is given by* = $1.5 \times 0.1 = 0.15\ ohm$ 4) Synchronous Reactance per phase: $X_S/Ph = \sqrt{(Z_S/ph)^2 - (R_a/ph)^2}$ (1/2 Marks) $X_S/Ph = \sqrt{(1.54)^2 - (0.15)^2}$ $X_S/Ph = 1.5327\ \Omega$ - -- (1 Marks)

$$V\ line\ Volatge = 110\,V$$ **(1/2 Marks)**

$$V\ \ line\ Volatge = \frac{110}{(\sqrt{3})}$$

$$V\ \ line\ Volatge = 63.51$$ --**(1/2 Marks)**

$$\therefore\ \ Cos\phi = 0.8\ lag\quad Sin\phi = 0.6\quad and\quad Ia = 26.3\ A\ -----\ Assu\min g\ \ full\ \ load\ \ conditio$$

Now,

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

$$E_0 = \sqrt{(V\ Cos\phi + I_a R_a)^2 + (V\ \ Sin\phi + I_a X_S)^2}$$ **(1Marks)**

$$E_0 = \sqrt{[(6.51)(0.8) + (26.3)\ (0.15)]^2 + [63.5)(0.6) + (26.3)(1.5327)]^2}$$

$$E_0 = \sqrt{[(2997.89) + (6148.13)}$$

$$E_0 = 95.63\ \ Volt\ --$$ -- **(1/2 Marks)**

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

% Regulation = $\frac{95.63 - 63.51}{63.51} \times 100$

% Regulation = $50.57\ \ \%$ --- **(1 Marks)**

---**END**---