**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.

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**Q.1 a) Attempt any THREE of the following: 12 Marks**

**a) Compare squirrel cage induction motor and slip ring induction motor on any four points.**

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

| S.No | Squirrel Cage Induction Motor | Slip Ring Induction Motor |
|---|---|---|
| 1 | **Construction :-** | |
| | Simple and robust | Complicated and bulkily |
| 2 | **Starting Torque :-** | |
| | Poor | Higher |
| 3 | **Operating Efficiency :-** | |
| | Better | Lower |
| 4 | **Applications :-** | |
| | For driving somehow constant load eg. Lathe Machine, Workshop Machine and water pump | For driving heavy load where high starting torque is required eg. Lift, Crane, Elevators, conveyor belts etc |
| 5 | **Limitation :-** | |
| | Low Starting torque external resistance cannot be connected ,speed control is difficult | Frequent maintenance is essential. low efficiency P.f. more costly |

**OR (Any four points expected each point- 1 Mark)**

| S.No. | Squirrel Cage Induction Motor | Slip Ring Induction Motor |
|---|---|---|
| 1 | Rotor is in the form of bars | Rotor is in the form of 3-ph winding |
| 2 | No slip-ring and brushes | Slip-ring and brushes are present |
| 3 | External resistance cannot be | External resistance can be connected |

| | | |
|---|---|---|
| | connected | |
| 4 | Small or moderate starting torque | High Starting torque |
| 5 | Starting torque is fixed | Starting torque can be adjust |
| 6 | Simple construction | Complicated construction |
| 7 | High efficiency | Low efficiency |
| 8 | Less cost | More cost |
| 9 | Less maintenance | Frequent maintenance due to slip-ring and brushes. |
| 10 | Starting power factor is poor and power factor on running is better | Starting power factor is adjustable & large but low power factor on full load |
| 11 | Size is compact for same HP | Relatively size is larger |
| 12 | Speed control by stator control method only | Speed can be control by stator & rotor control method |

**b) Explain the working principle of 3 phase 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. According to 'Lenz Law' the rotor current should oppose the cause which produces it.

Here the cause is relative speed between rotating magnetic field and rotor conductors. Now the rotor conductors will try to catch the rotating magnetic field to minimize the relative speed. But due to inertia and friction of rotor, they never succeed. Hence due to relative speed i.e Ns-N, rotor will be in continuous rotation with speed N, which is always less than Ns.

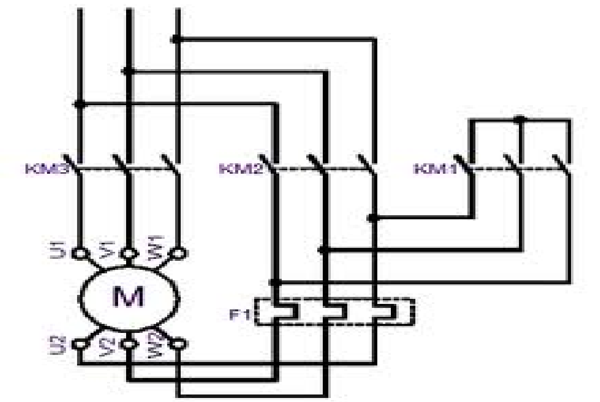
**c) Explain with diagram how star delta starters are used for reducing the starting current of 3 phase induction motors.**

Ans: **(Wiring Diagram-2 Mark & Explanation-2 Mark)**

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

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

**Diagram of Star -Delta starters:**




**or Equivalent fig.**

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

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

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

$$\frac{Starting\ Torque\ with\ stator\ in\ star}{Starting\ Torque\ with\ stator\ in\ delta} = \frac{1}{3}$$

**d)** **Derive the relationship between Ns and f of alternator.**

Ans: **the Relationship between Ns and f of alternator:** **(4 Mark)**

**Let, P = total number of field poles** $p'$ **= pair of field poles**

**$N_S$ = Speed of the field poles in rpm** **$n_s$** = speed of the field poles in rps

f = frequency of the generated voltage in Hz

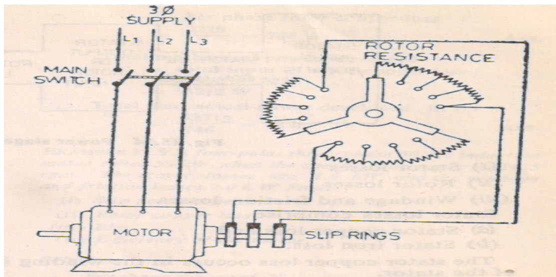
$$n_s = \frac{N_S}{60} \quad and \quad p' = \frac{P}{2}$$

One complete cycle of voltage is generated in an armature coil when a pair of field poles passes over the coil, the number of cycles generated in one revolution of the rotor will be equal to the number of pairs of field poles.

| | |
|---|---|
| | i.e Number of cycles per revolution = $p'$<br>also, Number of revolutions per second = $n_s$<br>Now, $Frequency = number\ of\ cycles\ per\ second = \frac{Number\ of\ cycles}{revolutions} \times \frac{revolutions}{second}$<br>$\therefore f = p' \times n_s$<br>$Since\ n_s = \frac{N_S}{60}\ and\ p' = \frac{P}{2}$<br>$\therefore f = \frac{P \times N_S}{120}\ or\ N_S = \frac{120\ f}{P}$ |
| **Q.1B)** | **Attempt any ONE : 06 Marks** |
| **a)** | **Explain speed control method of 3 phase induction motor by the following methods : i) Frequency control ii) Stator voltage control iii) Rotor resistance control.** |
| Ans: | **Following methods to control the speed of 3 phase induction motor:**<br>i) Frequency control<br>ii) Stator voltage control<br>iii) Rotor resistance control.<br>**1. by varying applied Frequency (Frequency control):---------------------------- (2 Mark)**<br>➢ The synchronous speed of an induction motor is given by $N_S = \frac{120 \times f}{P}$.<br>➢ It is clear from the equation that the speed of the induction motor can be changed by changing the frequency of the supply.<br>➢ The speed of the motor will increase if frequency increases and vice versa.<br>➢ Changing the frequency of supply to the motor is difficult. Therefore this method is only employed where the variable frequency alternator is available for the above purpose.<br>**2. By varying applied voltage ( Stator voltage control): -------------------------- (2 Mark)**<br>➢ 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.<br>➢ 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.<br>➢ For a particular load when voltage increases, speed of the motor also increases and vice-versa. |

**3. By rotor rheostatic control ( Rotor Resistance control): Diagram not expected-----**

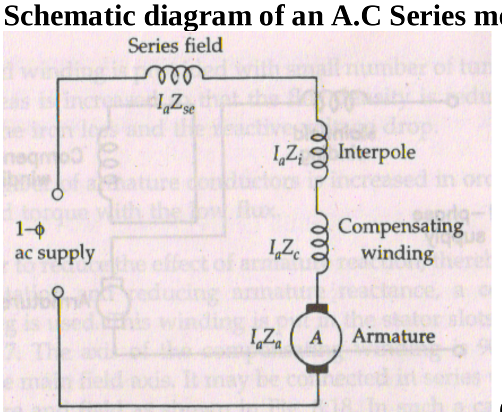
**(2 Mark)**



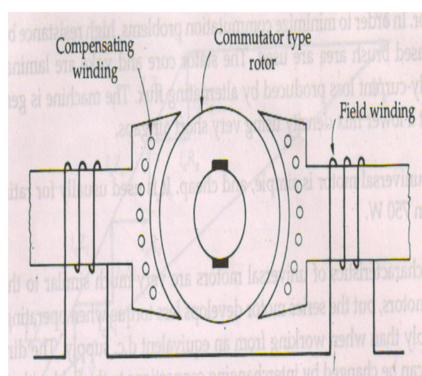

- In this method star connected external resistances (of continuous rating) are connected in the rotor circuit.
- The speed of the motor increases with the decrease of resistance in the rotor circuit.
- The change in speed is approximately inversely proportional to the external resistance connected in the rotor circuit.
- This method of the speed control is applied where a small variation of speed is required and the power wasted is not having great importance.

**b)** **Explain working principle of AC series motor. Draw speed-torque characteristics of AC series motor.**

Ans: **Schematic diagram of an A.C Series motor:** **(2 Mark)**




**OR**



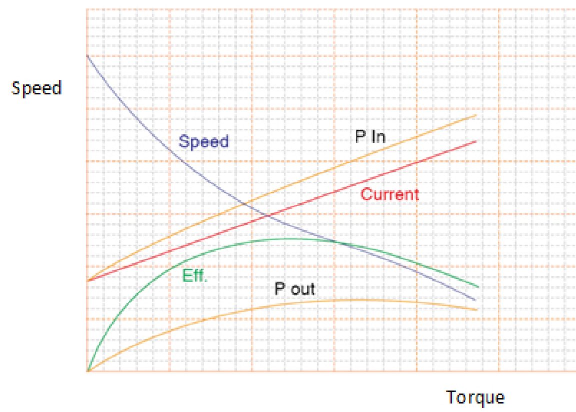

**Working Principle of AC Series Motor: ---------------------------------------------- (2 Mark)**

- **AC series motors** are also known as the modified dc series motor as their construction is very similar to that of the dc series motor.
- An ac supply will produce a unidirectional torque because the direction of both the currents (i.e. armature current and field current) reverses at the same time.
- Due to presence of alternating current, eddy currents are induced in the yoke and field cores which results in excessive heating of the yoke and field cores.
- Due to the high inductance of the field and the armature circuit, the power factor

would become very low.

- ➢ There is sparking at the brushes of the dc series motor.
- ➢ In this type of motor, the compensating winding has no interconnection with the armature circuit of the motor.
- ➢ In this case, a transformer action will take place as the armature winding will act as primary winding of the transformer and the compensation winding will acts as a secondary winding.
- ➢ The current in the compensating winding will be in phase opposition to the current in the armature winding.

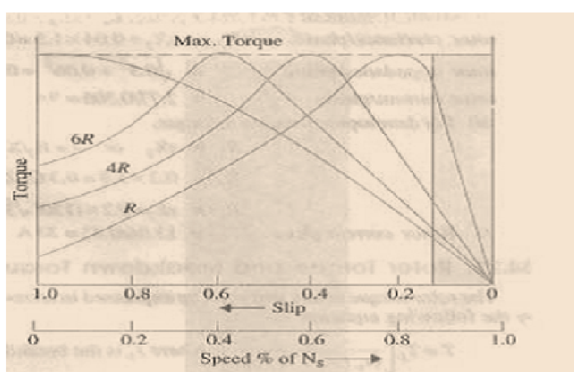
**Speed-torque characteristics of AC series motor: ------------------------------------ (2 Mark)**




**Q.2 Attempt any FOUR : 16 Marks**

**a) Explain the effect of resistance of rotor winding on starting torque of 3 phase IM.**

**Ans: Characteristics:** **(2 Mark Characteristics & 2 Mark Effect)**



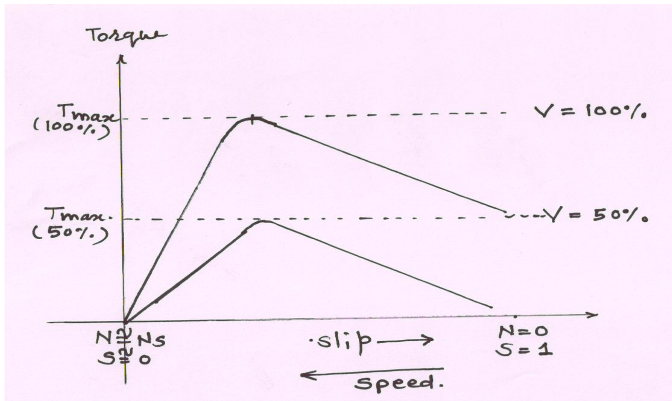

**Equivalent Characteristics**

**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.

| | |
|---|---|
| b) | **Explain effect of voltage on torque speed characteristics of 3 phase IM** |

Ans: **Voltage on torque-speed characteristics:** **(Figure-2 Marks & Effect- 2 Marks)**




**or Equivalent fig**

**Explanation: From the above characteristics:-**

- The torque equation of induction motor is given by:

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

- The simplified form of the above torque equation-

$$T\ \alpha\ S \times V^2\ \ (\because\ \phi\,\alpha\,E_1\ ,\ and\ \ E_2\ \alpha\ E_1, and\ \ E_1\,\alpha\,V)$$

- From the above equation it is clear that the torque at any speed is proportional to the square of supply voltage V.
- Hence any change in supply voltage will be having great effect on running torque and maximum torque.
- As supply voltage decreases up to 50 % of the rated value, maximum torque decreases almost up to 50 % of maximum torque.
- This effect is shown in the above torque-speed characteristics.

| | |
|---|---|
| c) | **Explain why armature winding of an alternator is short pitched and distributed.** |

Ans: **The armature of an alternator is short pitched and Distributed Because of following advantages:** **(Each Point : 1 Mark)**

1. The wave form of induced emf will be improved i.e. the wave form will be very close with perfect (ideal sine wave).
2. The harmonic contents of the induced emf reduces
3. As a length required for armature winding decreases, the copper material will be saved, hence it is economical.
4. As the high frequency harmonics are illuminated, Hysteresis & eddy current losses will be reduced and this increases the efficiency.

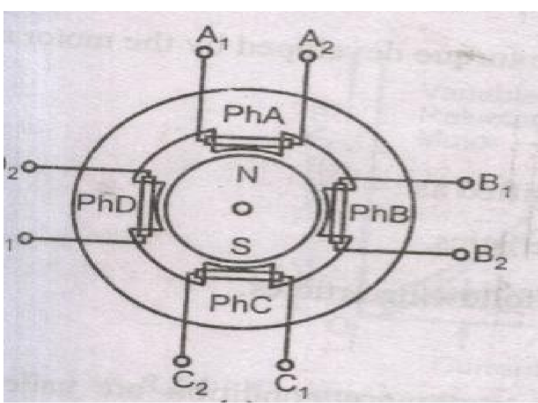
**d)** **Compare salient pole and cylindrical rotor alternator (any four points).**

Ans: **(Any 4 Point expected-1 Mark each)**

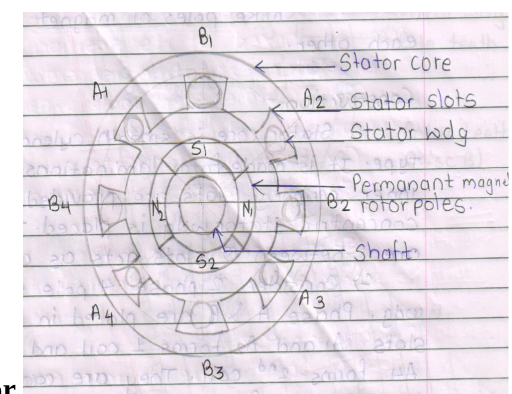
| S.No | Parameter/Machine | Salient pole type rotor Alternator | Cylindrical type rotor Alternator |
|---|---|---|---|
| 1 | **Operating speed** | Low medium | high |
| 2 | **Number of poles** | large | Small & medium |
| 3 | **Rotor construction** | Projected type bulky & heavy weight | Cylindrical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

**e)** **Explain construction and working of permanent magnet stepper motor.**

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




**or**

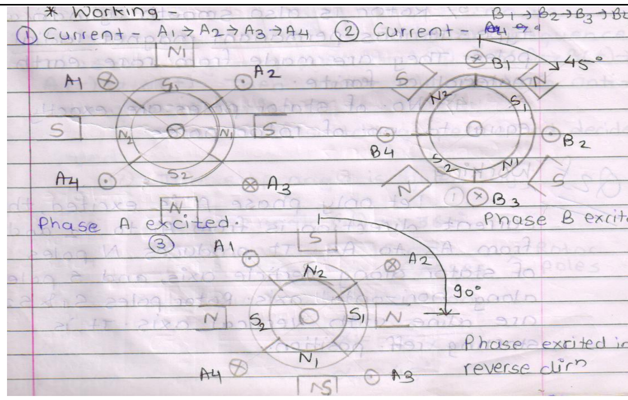



**Working :-**

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**

Working principle: unlike poles attract each other.

**OR**



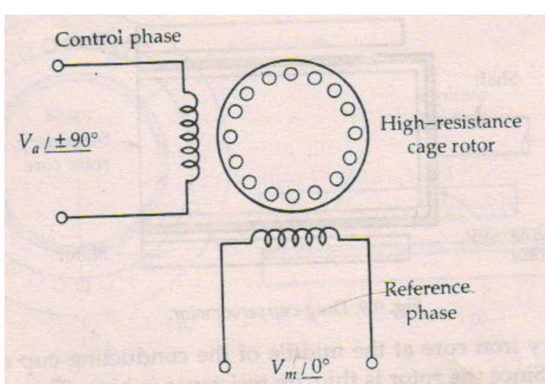

**or Equivalent dia.**

**Working :**

- Let only phase A is ecited, the current direction is form A1 to A2 and from A3 to A4. It produces N poles of stator along verticle axis, and S pole along horizontal axis. Rotor poles S1 & S2 are aline with vertical axis. It is starting reff.position.
- Now coil $\phi$ 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 inclockwise direction by $45^0$
- If switching sequence is mainted as $A(+) \rightarrow B(+) \rightarrow A(-) \rightarrow B(-) \rightarrow A(+)$ then motor will continously 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 swicthing per second decides speed.

**f)** **Explain construction and working of AC servomotor.**

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




**or Equivalent dia**

**Construction:**

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

**Working of AC Servomotor:**

- The control Phase is usually supplied from a servo amplifier.
- The speed and torque of the rotor are controlled by the phase difference between the control voltage and the reference phase voltage.
- The direction of rotation of the rotor can be reversed by reversing the phase difference, from leading to lagging (or vice versa) between the control phase voltage and the reference phase voltage.

**OR**

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

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

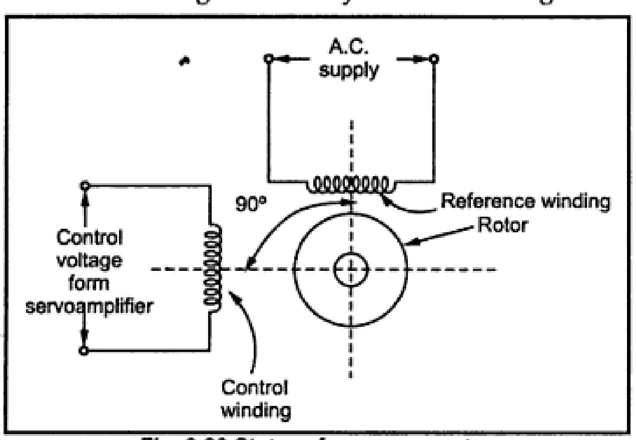


Fig. 9.20 Stator of a.c. servomotor

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

The schematic stator is shown in the Fig. 9.20.

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

| | |
|---|---|
| **Q.3** | **Attempt any Four :** **16 Marks** |
| **a)** | **Derive the condition for Tmax of a 3-phase induction motor.** |
| Ans: | **Note: The student can follow for different method of derivation also**<br>Let us consider the equation of torque,<br>$T = \dfrac{K\,\phi\,S\,E_2\,R_2}{R_2{}^2 + S^2\,X^2}$ ------------------------------------------- **(1 Mark)**<br>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 $\dfrac{1}{T} = M$<br>$M = \dfrac{R_2{}^2 + S^2\,X_2{}^2}{K\,\phi\,S\,E_2\,R_2}$ ------------------------------------------- **(1 Mark)**<br>$M = \dfrac{R_2^2}{K\,\phi\,S\,E_2\,R_2} + \dfrac{S^2\,X_2{}^2}{K\,\phi\,S\,E_2\,R_2}$<br>$M = \dfrac{R_2}{K\,\phi\,S\,E_2} + \dfrac{S\,X^2}{K\,\phi\,E_2\,R_2}$<br>$\dfrac{d(M)}{dS} = \dfrac{d}{dS}[\dfrac{R_2}{K\,\phi\,S\,E_2} + \dfrac{S\,X_2{}^2}{K\,\phi\,E_2\,R_2}] = 0$ ------------------ **(1 Mark)**<br>$-\dfrac{R_2}{K\,\phi\,S^2\,E_2} + \dfrac{X_2{}^2}{K\,\phi\,E_2\,R_2} = 0$<br>$\dfrac{X_2{}^2}{K\,\phi\,E_2\,R_2} = \dfrac{R_2}{K\,\phi\,S^2\,E_2}$<br>$\dfrac{S^2 X_2{}^2}{K\,\phi\,E_2\,R_2} = \dfrac{R_2^2}{K\,\phi\,S^2\,E_2}$<br>$S^2 X_2{}^2 = R_2^2$<br>$\boxed{\therefore R_2 = S\,X_2}$<br>------------------ **(1Mark)**<br>This is the condition for maximum torque of 3-Ph induction motor under running |
| **b)** | **A 3-phase, 6 pole induction motor is connected to a 50 Hz supply. Calculate synchronous speed, rotor speed at 4% slip, frequency of rotor induced voltage at 4% slip, frequency of stator voltage at 10% slip.** |
| Ans: | **Given Data:**<br>Slip = 4% Pole = 6, F = 50 Hz<br>**i) Synchronous speed:** |

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

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

$$Ns = 1000\ \ RPM$$

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

**ii) Rotor Speed N =** $(1-S)\,(N_S)$ ------------------------------------------ **(1/2 Mark)**

$$= (1-0.04)\ (1000)$$

$$= 960\ RPM$$

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

**iii) The frequency of Rotor induced voltage:**

$$f^1 = S\ f$$ ------------------------------------------------ **(1/2 Mark)**

$$f^1 = (0.04) \times 50$$

$$f^1 = 2 \quad Hz$$

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

**iv)** Frequency of stator voltage only depends on supply frequency which is 50 Hz and it is independent of slip. ---------------------------------------------- **(1 Mark)**

| | |
|---|---|
| **c)** | **Calculate the value of pitch factor for a 3 phase winding of a 4 pole alternator having 36 slots and the coil is spread from 1st slot up to 7th slot.** |

**Ans:**

Given Data:

3-ph, 4 Pole, Synchronous alternator, Number of armature Slots = 36

$$Pole\ \ pitch = \frac{Number\ of\ \ Slots}{P}$$ ----------------------------------------- **(1/2 Mark)**

$$Pole\ \ pitch = \frac{36}{4} = 9\ Slots$$ ------------------------------------------------ **(1/2 Mark)**

$$\beta = \frac{180^0\ \ Elec.}{pole\ pitch}$$ -------------------------------------------------- **(1/2 Mark)**

$$\beta = \frac{180.}{20^0} = 20^0\ \ Elect$$ -------------------------------------------- **(1/2 Mark)**

The coil is spread from 1 to 7 th slot. This means that coil pitch is shorter than pole pitch by 2 Number of slots

$$\therefore\ \ \alpha = Shorten\ \ angle = 2 \times 20 = 40^0\ \ Elect$$

$$\therefore\ \ K_C = Coil\ span\ \ factor\ or\ \ pitch\ \ \ factor$$

$$\therefore\ \ K_C = Cos\,\frac{\alpha}{2} = Cos\,\frac{40}{2} = Cos\,20 = 0.9397$$ --------------------------------- **(1 Mark)**

| | |
|---|---|
| **d)** | **Define each of following terms of alternator :**<br>**i) Leakage reactance ii) Synchronous impedance iii) Distribution factor iv) Pitch factor** |
| Ans: | **(Each Definition: 1 Mark)**<br><br>**i) Leakage reactance:**<br>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<br>**OR**<br>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<br>**ii) Synchronous impedance:**<br>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.<br>**OR**<br>$Z_S = R_a + j\ (X_L + X_a)$<br>$= R_a + j\ (X_S)$<br>Where,<br>$Z_S$ = synchronous impedance, $R_a$ = Armarure resistance, $X_L$ = Leakage reactance,<br>$X_a$ = Armature reaction reactance, $X_S$ = Synchronous reactance<br>**iii) Distribution factor**<br>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.<br>**OR**<br>$K_d = \frac{Vector\ sum\ of\ coil\ voltages\ per\ phase}{arithmetic\ sum\ of\ coil\ volatges\ per\ phase}$<br>**iv) Pitch factor:**<br>It is the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil.<br>$K_C = \frac{Actual\ voltage\ generated\ in\ the\ short\ pitch\ coil}{Voltage\ generated\ in\ the\ full\ pitch\ coil}$ |

**e)** **Write any two applications of each of the following :**
**i) Shaded pole IM ii) Capacitor start induction run iii) Resistance start induction run iv) Capacitor start capacitor run.**

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

| Sr.No | Types of 1-Ph Induction Motor | Applications (Any Two expected) |
|---|---|---|
| **1** | Shaded pole motor **(Any Two Applications 1Marks)** | Recording Instruments, Record Player, Gramophones, toy Motors, Hair dryers, Photo copy machine, Advertizing display |
| 2 | Capacitor Start Induction run **(Any Two Applications 1Marks)** | Fans, Blowers, Grinder, Drilling Machine, Washing Machine, Refrigerator, Air conditioner, Domestic Water Pumps, Compressor. |
| 3 | Resistance Start Induction run **(Any Two Applications 1Marks)** | Washing Machine, Fans, Blowers, Domestic Refrigerator, Centrifugal Pump, Small electrical Tools, Saw machine |
| 4 | Capacitor Start Capacitor run **(Any Two Applications 1Marks)** | Fans, Blowers, Grinder, Drilling Machine, Washing Machine, Refrigerator, Air conditioner, Domestic Water Pumps, compressors. |

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

**a)** **A 37 kW (output), 4 pole, 50 Hz 3-ph , induction motor has a friction and windage loss of 20 Nm. The stator losses equal the rotor copper loss. Calculate input power to the stator winding when the 3 phase induction motor is delivering full load output at 1440 rpm.**

Ans: **3-Ph, 4 Pole, f= 50 Hz O/p of Motor = 37 KW Speed N= 1440 RPM at full load**

1) $\therefore Slip\ S_f = \dfrac{N_S - N}{N_S} = \dfrac{1500-1440}{1500}$

$S_f = 0.04\ \ or\ 4\,\%$ ---------------------------------------------------------------- **(1 Mark)**

2. The Mechanical losses = 20 N-m

$= 2\,\pi\,N\,T$

$= 2\,\pi \times 1440/60 \times 20$

$= 3106.32\ watts$

3) $Gross\ Rotor\ Output = Net\ Motor\ o/p + Mechanical\ losses$

$Gross\ Rotor\ Output = 37000 + 3016.32$

$Gross\ Rotor\ Output = 40016.32\ \ Watts$ ---------------------------------- **(1 Mark)**

4) $$Rotor\ Input = \frac{Gross\ \ rotor\ \ output}{(1-S)}$$

$$= \frac{40016.32}{(1-0.04)}$$

$$Rotor\ Input = 41683.67\ \ Watts$$

------------------------- **(1Marks)**

Rotor Copper losses = S (Rotor I/P)
= (0.04) x (41683.67)
= 1667.35 watts

Rotor Copper Losses = Stator Losses ----- given

$$\therefore\ Net\ Motor\ Input = Rotor\ Input + Stator\ losses$$

$$= 41683.67 + 1667.35$$ --- **(1 Mark)**

$$= 43351.02\ \ Watts$$

**b)** **Explain how each of the following can reduce starting current of 3 phase IM :**
**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. Thus for slip ring induction motor external resistance connected in rotor circuit can acts as starter which controls the starting current.

**ii) By connecting autotransformer in stator winding:** **(2 Marks)**

- At the instant of starting, the position of the slider/variable tap is kept at extreme left position or zero voltage position.
- When the slider moves gradually in clockwise direction, the voltage applied to three phase induction motor will be increased in steps.
- At starting reduced voltage can be applied to 3-phase induction motor and hence heavy starting current will be reduced or controlled.
- When motor start to rotate and achieve about 70 % of the rated speed, the rated voltage can be applied to 3-phase induction motor.
- Thus by using 3-phase auto transformer as a starter, starting current can be controlled.

| | |
|---|---|
| c) | **A 3 phase star connected alternator is rated at 1500 kVA, 13.5 kV. The armature resistance and synchronous reactance are 1.4 ohm and 25 ohm respectively per phase. Calculate percentage voltage regulation for a load 1200 kW at 0.8 leading pf.** |

Ans: **Given Data:**

3-Ph, Star connected alternator,

$V_T$ Line = 13.5 x $10^3$ KV

$V_T$/ph= 13.5 x $10^3$ / $\sqrt{3}$ = 7794.23 volts

$R_a$ /ph= 1.4 ohm  $X_S$ /ph= 25ohm

$$I_a\ line\ Current = \frac{KW \times 10^3}{(\sqrt{3}) \times (V_{TLine})\ Cos\phi}$$ ----------------------------------- **(1/2 Marks)**

$$I_a\ line\ Current = \frac{(1200) \times 10^3}{(\sqrt{3}) \times (13.5) \times 10^3\ (0.8)}$$

$$I_a\ line\ Current = 123.17A$$ ---------------------------------------------**(1/2 Marks)**

**Now,**

**% Regulation at full load for 0.8 Leading P.f :**

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

$$E/ph = \sqrt{[(7794.23)(0.8) + (123.17)\ (1.4)]^2 + [(7794.23)(0.6) + (123.14)(25)]^2}$$

$$E/ph = \sqrt{[41060182.78]\ + [2551328.96]}$$

$$E/ph = \sqrt{43611511.73}$$

$$E/ph = 6603.90\ volt$$ ------------------------------------------------------------ **(1/2 Marks)**

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

$$\textbf{\% Regulation} = \frac{6603.90 - 7794.23}{7794.23} \times 100$$

$$\textbf{\% Regulation} = -\ 15.27\ \%$$ --------------------------------------------------- **(1/2 Marks)**

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

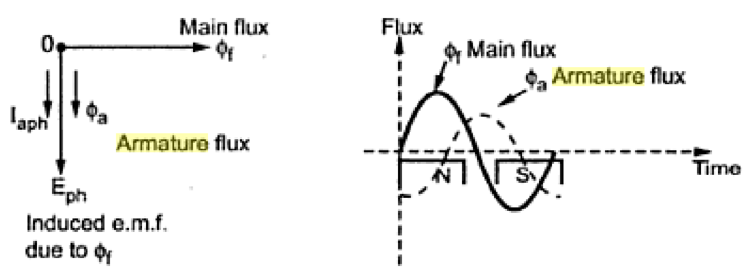
| Q. 4 B) | Attempt any ONE : 06 Marks |
|---|---|
| a) | Explain armature reaction in alternators for unity p.f, zero pf leading, zero p.f lagging load. Draw suitable waveforms showing the effect of armature flux |

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

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

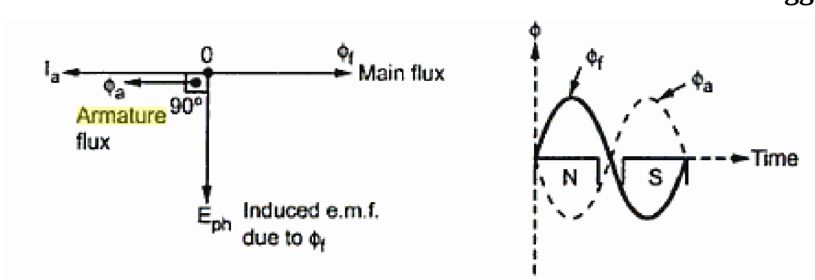
**Waveforms showing the effect of armature flux:**

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

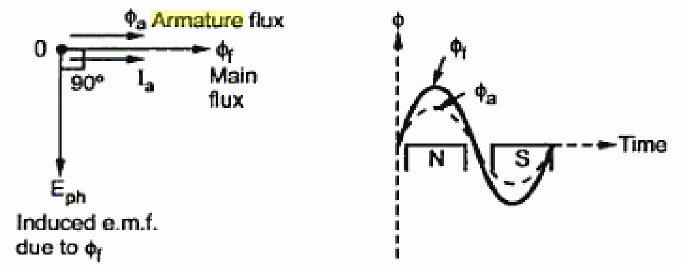



**or Equivalent fig**

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




**or Equivalent fig**

| | |
|---|---|
| | **3. Armature reaction in alternators for Zero Power factor Leading Load: --(1 Mark)**   **or Equivalent fig** |
| **b)** | **Derive the emf equation of an alternator.** |
| **Ans:** | **EMF Equation of alternator:** |

Let, P = No. of rotor poles. $\phi$ = Flux per pole Z= Number of stator conductors

N = Speed in rpm

$$\therefore turns\ per\ phase\ (Tph) = \frac{Z_{Ph}}{2}$$ ------------------------------------------------------- **(1 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 Marks)**

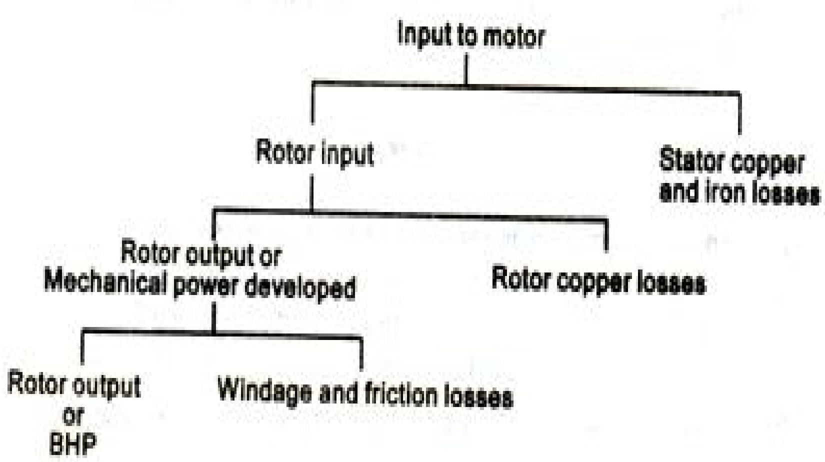
By faradays law of Electromagnetic induction

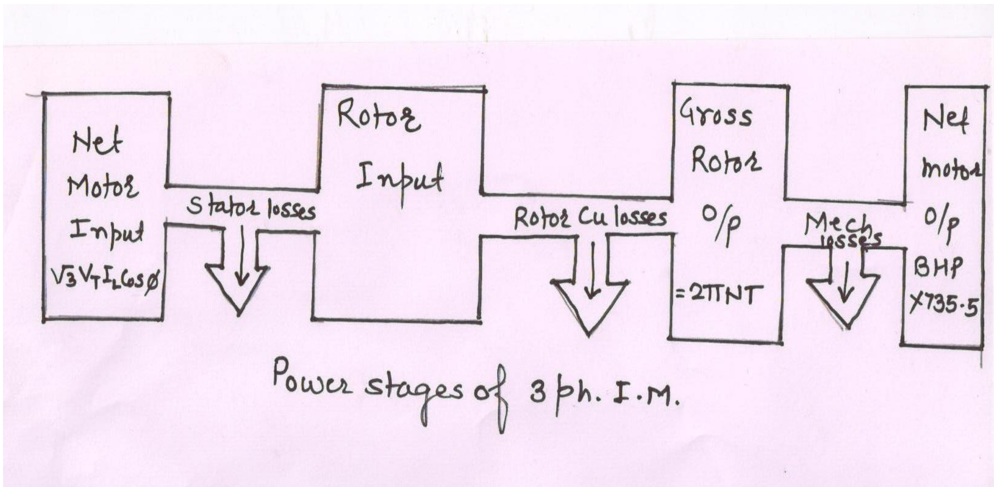
$$\therefore Average\ emf\ per\ conductor = \frac{d\phi}{dt}$$

$$\therefore E_{ave} / Conductor = \frac{P.\phi}{(N/60)}$$

$$\therefore E_{ave} / Conductor = \frac{P \times \phi \times N}{60} --------- Volt$$ ---------------**(1/2 Marks)**

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

| | |
|---|---|
| | $\therefore E_{ave}/\text{turn} = 2\dfrac{P\times\phi\times N}{60}$ – – – – – – – – –*Volt* <br> $\therefore \quad = \dfrac{4P\phi N}{120}$ – – – – – – – – –*Volt* -------------------------**(1/2 Marks)** <br> $\therefore \quad = 4\left(\dfrac{PN}{120}\right)\phi$ <br> $\therefore E_{ave}/\text{turn} = 4f\phi \quad \therefore (f = \dfrac{PN}{120})$ <br> $\therefore E_{ave}/\text{Phs} = E_{ave}$ / x Number of turns per phase <br> $= 4f\phi\times T_{Ph}$ ------------------------------------------------- **(1/2 Marks)** <br> RMS Value per phase is given by, <br> $E_{ph} = E_{ph}$ (ave) x Form Factor <br> $= 4f\phi\times T_{Ph}\times 1.11$ ---------------------------------------- **(1 Marks)** <br> $\boxed{E_{ph} = 4.44\,\phi.f\;T_{Ph}\ \text{volts}}$ <br> It is for full pitched concentrated winding. If winding is distributed & short pitched then <br> $\boxed{E_{Ph} = 4.44\,\phi.f.\,T_{Ph}.\,kd.kc\ \text{volts}}$ <br> --------------------------- **(1 Marks)** <br> Where, Kc = coil span factor or chording factor <br> Kd = Distribution factor |
| **Q.5** | **Attempt any FOUR : 16 Marks** |
| a) | **Draw a block diagram showing power stages of a 3 phase induction motor.** |
| Ans: | **Diagram showing power stages of a 3 phase induction motor** : **(4 Mark)** <br>  <br> **OR** |

| | |
|---|---|
| | **Diagram showing power stages of a 3 phase induction motor** :   |
| **b)** | **Derive the ratio of full load torque and maximum torque of a 3 phase induction motor.** |
| Ans: | **Equation of Maximum Torque:**<br>The equation of torque is<br>$$T = \frac{sE_2^2R_2}{R_2^2 + (sX_2)^2}$$ ------------------------------------------ **(1/2 Marks)**<br>The torque will be maximum when slip s = $R_2$ / $X_2$<br>Substituting the value of this slip in above equation we get the maximum value of torque as,<br>$$T_{max} = K\frac{E_2^2}{2X_2}N-m$$ ----------- (i) ----------------- **(1/2 Marks)**<br>**The equation of the full load torque:**<br>$$T_{full} = K\frac{S_f\ E_2^2\ R_2}{R_2^2 + (S_f\ X_2)^2}$$ ------------------- (ii) --------- **(1/2 Marks)**<br>**Where, Sf = Slip at full load**<br>**The ratio full load torque to maximum torque:**<br>$$\frac{T_{full}}{T_{\max}} = \frac{K\frac{S_f\ E_2^2\ R_2}{R_2^2 + (S_f\ X_2)^2}}{K\frac{E_2^2}{2\ X_2}}$$ ------------------------------------------ **(1/2 Marks)** |

$$\frac{T_{full}}{T_{\max}} = \frac{R_2\,(2\times X_2)\,S_f}{R_2^{\,2} + S_f^{\,2}\times X_2^{\,2}}$$ ---------------------------------------------- **(1/2 Marks)**

**Deviding both numerical & denoted by $X_2^2$ :**

$$\frac{T_{full}}{T_{\max}} = \frac{\dfrac{2\times R_2\times X_2}{X_2^{\,2}}\,S_f}{\dfrac{R_2^{\,2}}{X_2^{\,2}} + S_f^{\,2}\times\left(\dfrac{X_2^{\,2}}{X_2^{\,2}}\right)}$$ ------------------------------------------ **(1 /2Marks)**

$$\frac{T_{full}}{T_{\max}} = \frac{2\,(R_2/X_2)\,S_f}{\dfrac{R_2^{\,2}}{X_2^{\,2}} + S_f^{\,2}}$$

$$Let\ a = R_2/X_2$$

$$\therefore \frac{T_{full}}{T_{\max}} = \frac{2\,a\times S_f}{a^2 + S_f^{\,2}}$$ -------------------------------------------------------- **(1 Marks)**

**c)** **State any four advantages of operating alternators in parallel.**

Ans: **Advantages of operating alternators in parallel:-**

**( Any Four advantages expected: 1 Mark each)**

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

**OR** **( Any Four advantages expected: 1 Mark each)**

1. **Continuity in supply system**:
   Continuity in supply system is we have two or more alternator in parallel and if one is out of order then the power supply can be maintained with the help of another alternator.

2. **More Efficiency:**
   The alternators can be put ON or cut OFF as per the load demand. The efficiency of alternator is maximum at full load. Therefore we can put ON required number of alternators as per load demand and operate the alternators at full load capacity.
3. **Maintenance and repair:**
   With more number of alternators in parallel, any one can be taken out of maintenance and repair without disturbing the supply. The smaller units are very easily repairable.
4. **Standby of reserved unit**:
   In case of number of small alternators in parallel, The standby alternator required is also of small capacity.
5. **Future expansion:**
   Considering the probable increasing in demand in future, some additional units are installed and can be connected in parallel.
6. **Saving In Fuel**:
   Since almost all alternators are operated on full load no any one alternator operates lightly loaded.

**d) Explain 'lamp method' of synchronizing alternator to the bus bar.**

Ans: **Following are the 'lamp method' of synchronizing alternator to the bus bar:-**

**( Any One Lamp Method are expected: (Figure: 2 Mark & Explanation: 2 Mark)**

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

**Fig: For Three Phase Alternator**

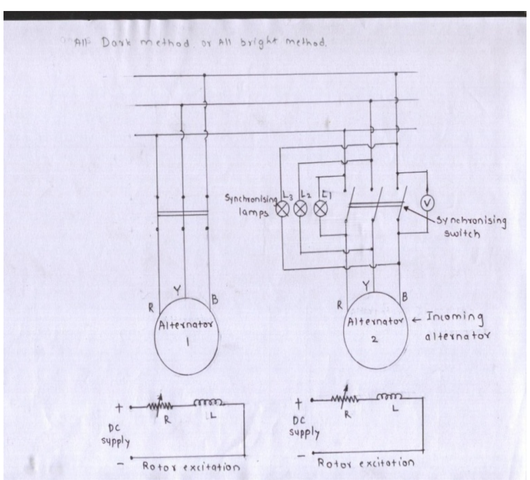
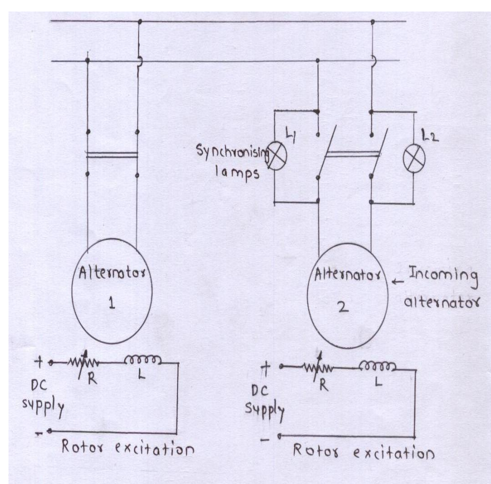
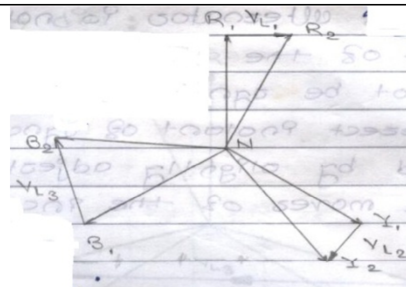



**Fig: For Single Phase Alternator**






$V_{L1}$ = 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**

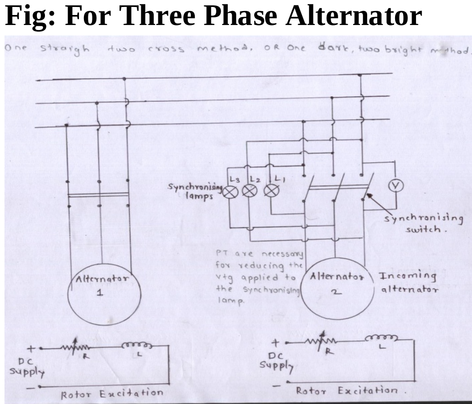
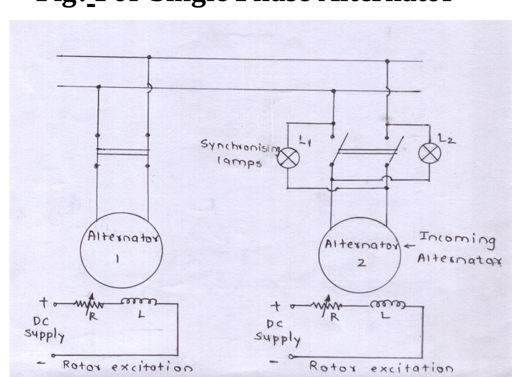
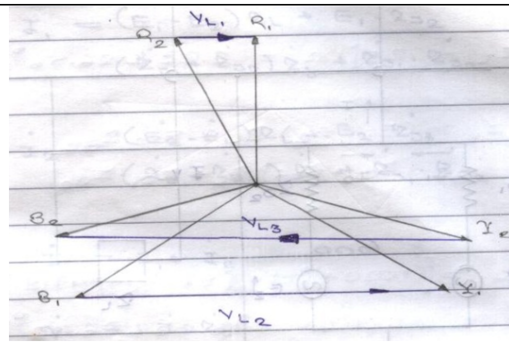



**Fig: For Single Phase Alternator**





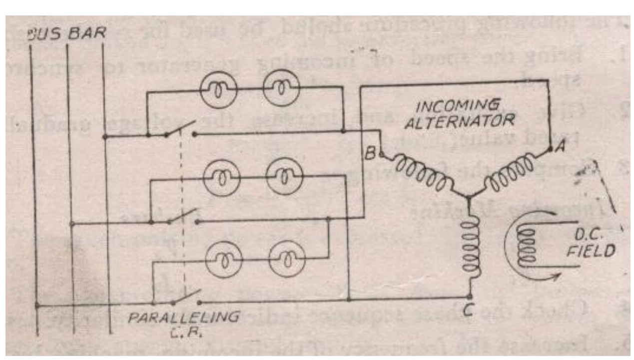
$V_{L1}$ = Voltage across the lamps $L_1 = V_{R1} - V_{R2}$

$V_{L2}$ = 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.

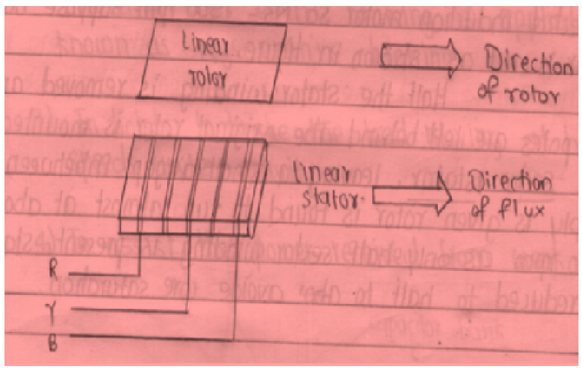
| | |
|---|---|
| | ➢ There are different methods of lamp connection. The method of two bright and one dark lamp indication is illustrated in above figure.<br>➢ In this connection the lamps become bright and dark as follows for correct phase sequence. "Two lamps bright and one lamp dark at a time".<br>➢ If all the lamps become simultaneously dark or bright, the phase sequence is wrong.<br>➢ The switch is closed when the voltage, frequency and the lamps (2 bright and 1 Dark) satisfy the condition of synchronism.<br><br>**OR**<br>The incoming machine should be synchronized with the bus bars. The following steps are for guidance.<br>1. Make sure that the breaker for incoming machine is open.<br>2. Close the isolators of the incoming machine to the connection bar (Use an insulator wrench)<br>3. Bring the speed of incoming generator to synchronous speed.<br>4. Give excitation and increase the voltage gradually to rated value.<br>5. Compare the following: 1) Incoming Machine :- $V_i$ and $F_i$ and 2) Busbar: $V_b$ & $F_b$<br>6. Check the phase sequence indicator for similarity **by phase sequence indicator**.<br>7. Increase the frequency of the incoming machine by 1/10 cycle higher than bus frequency.<br>8. Read synchroscope. It indicates "slow" or "fast".<br>➢ If the frequency of the incoming machine is less than bus frequency, the pointer of synchroscope will indicate " Slow",<br>➢ If the incoming machine is faster, the pointer will indicate " fast"<br>➢ If "slow" increases the speed of the incoming generator till the pointer of the synchroscope comes to middle and towards a little fast.<br>9. Close the generator breaker of synchroscope is at zero angles or at an angle less than $5^0$ **OR**<br>10. Close the circuit breaker at the instant the synchroscope pointer passes into zero (12 o'clock) position. It is good practice to start closing the breaker one or to degrees before the $0^0$ position, thus assuming the actual closing occurs at $0^0$<br>11. Turn the synchroscope switch to "off" |
| **e)** | **Explain with diagram working of Linear Induction Motor.** |
| Ans: | **( Principle – 2 Marks & Figure- 2 Marks)**<br>➢ **Principle of operation linear induction motor**:-<br>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 $V_s = 2\,wf$

Where, $V_s$ = linear synchronous speed in m/sec

w = width of one pitch in m.

f = supply frequency (Hz)




**or Equivalent fig.**

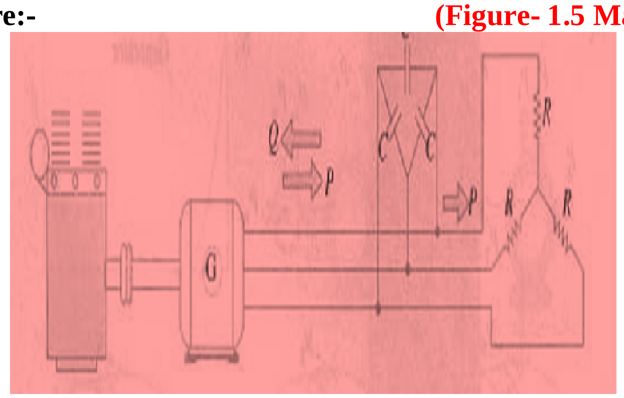
The speed does not depends on number of poles but only on the poles pitch and supply frequency. As the flux move linearly it drags the rotor plate along with it in same direction. However in much practical application the rotor is stationary while stator moves.

**f) Explain working principle of induction generator.**

Ans: **Induction generator:** **(1 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.

**Figure:-** **(Figure- 1.5 Marks & Principle – 1.5 Marks)**




**or Equivalent fig.**

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

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

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

**a) Explain why single phase induction motors are not self starting.**

Ans: **Reason for single phase induction motor doesn't have a self starting torque:**

**(4 Mark)**

- $T_{f} = K.I^2_2. R_2/S$
- $T_B = - K I^2_2 R_2 / (2-S)$ At Start S = 1

$T_f$ = -Tb hence starting torque = 0 hence motor doesn't have a self starting torque

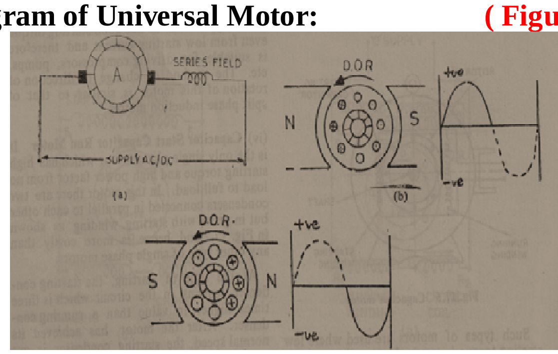
**OR**

- 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.
- Hence Single-phase induction motor is not self starting. **OR**

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

**b) Explain with diagram the working of a universal motor.**

Ans: **Diagram of Universal Motor:** **( Figure : 2 Mark & Explanation : 2 Mark)**




**or equivalent figure**

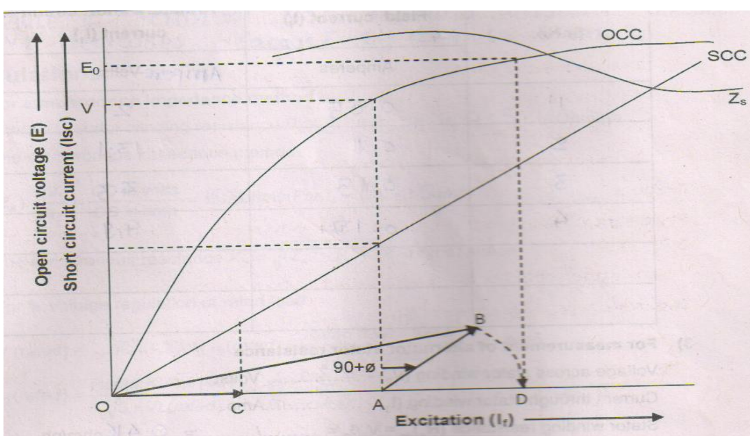
**Explanation of Universal Motor:**

- The motor which operates on both AC and DC supply is called universal motor.
- If through a DC series motor alternating current is passed, it will develop a torque which is always unidirectional because the current in both the armature and filed windings changes simultaneously.
- Consider the case of two pole motor and let the alternating current be in its positive half, then the polarity of the filed poles and the current flowing through the armature conductors be as indicated in above figure.
- By applying Fleming left hand rule it will be seen that the torque developed in the armature will try to rotate in anticlockwise direction.
- During the next instant, the alternating current goes through the negative half cycle. Now current through the field winding and armature will also change as direction in above figure.
- It will again see that the armature will tend to rotate in the anticlockwise direction.

**c) Explain the method of finding regulation of alternator by ampere turn method.**

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

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




The two components of total field m.m.f. which are' D' and 'A' are indicated in O.C.C. (open circuit characteristics) and S.C.C. (short circuit characteristics) as shown in the Fig. 1.

- This method of determining the regulation of an alternator is also called Ampere-turn method or Rothert's M.M.F. method.

- The method is based on the results of open circuit test and short circuit test on an alternator.
- For any synchronous generator i.e. alternator, it requires m.m.f. which is product of field current and turns of field winding for two separate purposes.
  1. It must have an m.m.f. necessary to induce the rated terminal voltage on open circuit.
  2. It must have an m.m.f. equal and opposite to that of armature reaction m.m.f.

## Any one Method are expected

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

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

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

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

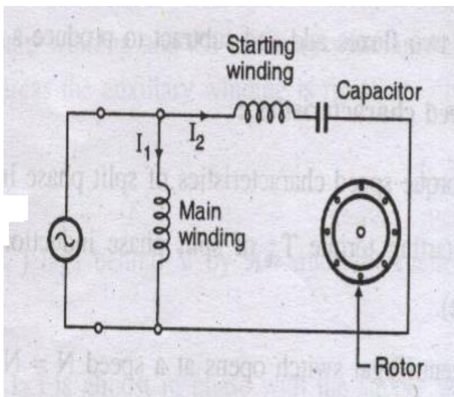
**3. Ampere Turn Method (MMF Method) at Leading Power factor from graph:**

- Draw the line ‘OA’ to represent if which gives the rated generated voltage (V)
- ‘OC’ represent field current required for producing full load current on short circuit OC = ‘AB’. Draw the line ‘AB’ at an angle (90 -$\theta$) to represent if, which gives rated full load ($I_{SC}$) on short circuit

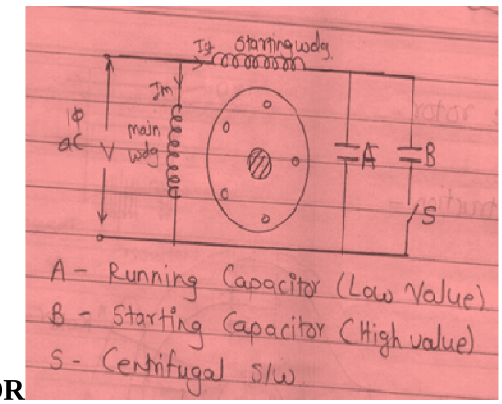
- Join the points 'O' and 'B' and find the field current ($I_f$) by measuring the distance 'OB' the gives the open circuit voltage ($E_0$) from the open circuit characteristics.
- $\% \, Voltage \ \ Regulation = \dfrac{E_0 - V}{V} \times 100$

**d)** **Explain working of capacitor start and capacitor run single phase induction motor.**

Ans: **capacitor start and capacitor run:** **(Figure -2 Mark & Explanation -2 Mark)**




**OR**




**or**

**Equivalent fig**

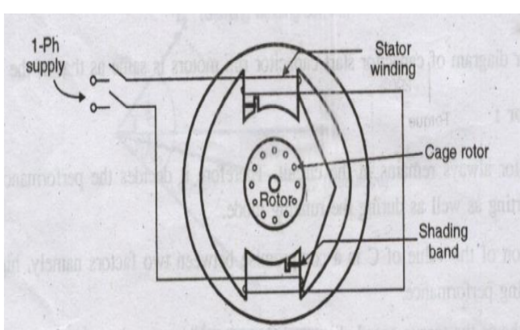
**Working of capacitor start and capacitor run:**

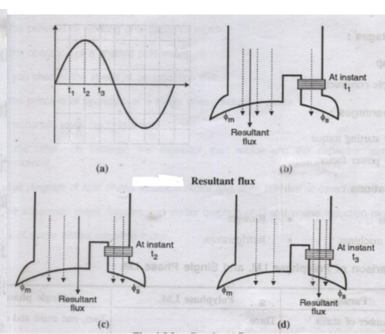
In these motors one capacitor is connected in series with the auxiliary winding. There is no centrifugal switch. Thus this winding along with the capacitor remains energized for both starting and running conditions. **Capacitor used serves the purpose of obtaining necessary phase displacement at the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

**Due to capacitor motor operation becomes salient**

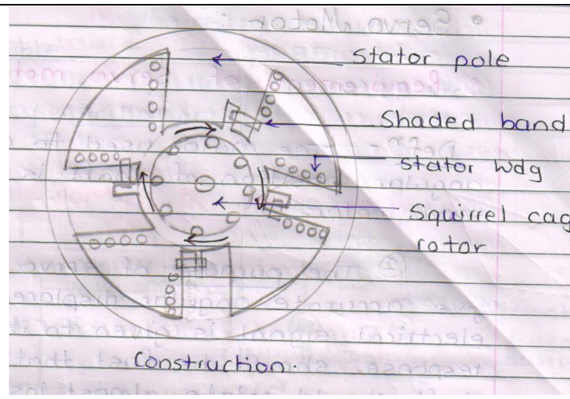
**e)** **Explain working of shaded pole induction motor with suitable sketches.**

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




**or**




**Equivalent Fig.**

**Correct diagram of pole axis shifting from left to right**

**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.

-----------------------------------------------------END-----------------------------------------------------