Important Instructions 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 be supposed 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 principal components indicated in the 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 of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate’s understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.
1 Attempt any TEN of the following. 2 X 10 = 20
1 a Write definition & formula of power factor. 01 mark
Ans-
Power factor:- It is the cosine of the angle between voltage and current, i.e., p.f. = \cos \phi
OR
It is the ratio of resistance to impedance, i.e., p.f. = R/Z
OR
It is the ratio of active power to the Apparent power. Any one formula 01 mark
i.e., Power factor, \cos \phi = (\text{Watts}/\text{VA}) = (VI \cos \phi) / VI.

1 b State any two disadvantages of low power factor in supply system. Any two each 1 mark
Ans-
1) Load current increase.
2) Large copper loss.
3) Poor voltage regulation.
4) Greater conductor size.
5) Large KVA rating.
6) Reduced power handling capacity.

1 c Write formula of 3-phase power and relation between line voltage and phase voltage in 3-phase star connected system. 01 mark
Ans-
3-phase power is given by \[ P = \sqrt{3} V_L I_L \cos \phi = 3V_P I_P \cos \phi. \]
Relation between line voltage and phase voltage in 3-ph star connected system is given as \[ V_L = \sqrt{3} V_P. \]

1 d Define resonance in series R-L-C circuit and write the formula of resonance frequency. 01 mark
Ans-
Resonance is the phenomenon in AC circuit in which circuit exhibits unity power factor or applied voltage and resulting current are in phase with each other.

Resonance frequency \[ f_r = 1/[2\pi \sqrt{LC}] \] 01 mark

1 e Define and write formula of
I) Slip
II) Synchronous speed 0.5 marks
Ans-
I) Slip - The difference between synchronous speed \( N_s \) and actual speed \( N \) of rotor is known as slip.
\[ \% \text{Slip} \quad S = [(N_s - N)/N_s] \times 100 \]
II) Synchronous speed - Speed of rotating magnetic field in air gap is known as synchronous speed(Ns).
\[ N_s = (120f/P) \text{ RPM}. \]
Where, \( f \) = Supply frequency & \( P \) = No. of poles on stator.
1 f  State the E.M.F equation of transformer and write meaning of each term in the formula.
   Ans-
   Induced emf in primary winding- \( E_1 = 4.44 f \Bar{\Omega}_m N_1 \) Volts
   Induced emf in secondary winding\( E_2 = 4.44 f \Bar{\Omega}_m N_2 \) Volts
   Where, \( f = \) Supply frequency
   \( \Bar{\Omega}_m = \) Maximum flux
   \( N_1 \& N_2 = \) No. of Turns on primary & Secondary

1 g  State the Faraday’s law of electromagnetic induction.
   Ans-
   Faraday’s first law of electromagnetic induction:
   When a conductor cuts or is cut by the magnetic flux, an EMF is generated in the Conductor.

   Faraday’s second law of electromagnetic induction:
   The magnitude of EMF induced in the coil depends on rate of change of flux linking with coil.
   \( e = -N \frac{d\Bar{\Omega}}{dt} \) Volts.(where \( e = \) emf induced, \( N = \) no. of turns, \( d\Bar{\Omega}/dt = \) rate of change of flux w.r.t time)

1 h  List any two applications of
   I)   Stepper motor
   II)  Servo motor

   Ans-
   APPLICATIONS OF STEPPER MOTOR
   1)  Wall clocks
   2)  CD drive
   3)  Robotics
   4)  Printer
   5)  Scanners
   6)  CNC machine

   APPLICATIONS OF SERVO MOTOR
   1)  CNC machine
   2)  Precision control
   3)  Process controller
   4)  Robotics
   5)  Sewing machine
   6)  Aeronautical Application
   7)  Conveying
   8)  Tachogenerator

1 i  Define:
   I)  Minimum fusing current
   II)  Fusing factor

   Ans-
I) Minimum fusing current: It is the minimum current at which the fuse element melts and thus disconnects the circuit protected by it.

II) Fusing factor: It is the ratio of minimum fusing current to the current rating of the fuse element i.e.

\[
\text{Fusing factor} = \frac{\text{minimum fusing current}}{\text{current rating of the fuse element}}.
\]

1 j Write the full form of following:
I) ELCB  II) MCB  III) MCCB  IV) HRC (Fuse)

Ans-
I) ELCB – Earth Leakage Circuit Breaker
II) MCB – Miniature Circuit Breaker
III) MCCB – Molded Case Circuit Breaker
IV) HRC – High Rupturing Cartridge Fuse

1 k Define:
I) %regulation
II) %Efficiency of transformer and write formula for it.

Ans-
I) Regulation - The difference between No load voltage $V_o$ and Full load voltage $V_{FL}$ is known as regulation.

\[
\%\text{Regulation} = \left(\frac{V_o - V_{FL}}{V_o}\right) \times 100.
\]

II) Efficiency - It is defined as the ratio of output power to the input power of the transformer.

\[
\%\text{Efficiency} = \left(\frac{\text{output power}}{\text{input power}}\right) \times 100
\]

Or \[
\%\text{Efficiency} = \left(\frac{\text{output power}}{\text{output power + losses}}\right) \times 100
\]

1 l What will happen if transformer is connected to DC supply?

Ans-
When dc current is supplied to the transformer, the primary side will draw a steady current due to which a constant flux is generated. Hence no back emf is produced.

Thus the primary side of the transformer which is a low resistance and zero reactance (\(X_L=0\) due to \(f=0\) Hz) primary side draws excessive current ultimately resulting in burning out of primary winding as the primary winding acts as a short circuit.

1 m How the direction of 3 phase induction motor can be changed?

Ans-
By interchanging any two of the supply phase lines to the motor the direction of stator rotating field is reversed resulting in reversal of the rotor direction.
M1, M2, M3 are the stator three winding terminals of the motor to be connected to the supply lines.

1. Draw only a Circuit diagram and phasor diagram of an ac R-L Series circuit.

   Circuit diagram & phasor diagram of R-L series circuit

2. Attempt any FOUR of the following.

   2a. What are the effects of change in frequency on inductive and capacitive reactance? Also write the formula for $X_L$ and $X_C$.

   Ans-
   
   When frequency increases inductive reactance increases because $X_L \propto f$ & capacitive reactance decreases as $X_C \propto (1/f)$ and vice-versa.

   Formula:
   
   $X_L = 2\pi fL \ \Omega$  
   $X_C = \frac{1}{(2\pi fC)} \ \Omega$.

   2b. Why single phase motor is not self starting? How it is made self starting?

   Ans-
   
   It is necessary to produce RMF to make motor self starting, thus there should be at least two magnetic fields & they are shifted by $90^\circ$ w.r.t. each other in space.
OR

The single-phase ac supply produces alternating flux but which is not revolving in nature. According to double field revolving theory, the flux has two components each equal to half of the alternating flux and each rotating synchronously in opposite direction to each other. These two oppositely revolving fluxes produces equal and opposite torques. Hence they produce no resulting torque at the starting.

Self starting methods -
The single-phase induction motor is not self-starting and it is necessary to mechanical spinning of the shaft or pulling a belt to start it. To make a single-phase induction motor self-starting, we should somehow produce a revolving stator magnetic field. This may be achieved by converting a single-phase supply into two-phase supply through the use of an additional winding. When the motor attains sufficient speed, the starting means (i.e., additional winding) may be removed depending upon the type of the motor.

1. Split – phase Induction Motor
2. Capacitor – Start Mot
3. Permanent – Split Capacitor Motor
4. Capacitor - Start Capacitor – Run
5. Shaded Pole Induction Motor

What is earthing? Draw only schematic diagram of pipe earthing.

Ans-
Earthing or grounding is circuitry which connects parts of the electric circuit with the ground.

Schematic diagram of pipe earthing:-
Define:

i) Cycle
ii) Frequency
iii) Time period
iv) Amplitude of AC Voltage

Ans-

Cycle: One complete set of positive & negative values of alternating quantity is known as Cycle.

Frequency: The number cycles completed in one Second is called frequency of alternating quantity.

Time period: Time taken by an alternating quantity to complete one cycle is called its time period.

Amplitude: The maximum value, positive or negative of an alternating quantities known as Amplitude.
2. e. Three impedance each of 3-ohm resistance and 5-ohm reactance in series are connected in star across 50 Hz, 440 volt line voltage. Find I) Impedance II) Phase current III) Power factor & IV) Total Power.

Ans-
I) Impedance $Z_{ph} = \sqrt{R^2 + X^2} = \sqrt{3^2 + 5^2} = 5.83 \, \text{ohm}$

$V_{ph} = V_L/\sqrt{3} = 254 \, \text{V}.$

Phase current $= V_{ph}/Z_{ph} = 254/5.83 = 43.57 \, \text{A}$

III) Power factor
$\cos \varnothing = R/Z = 3/5.83 = 0.514.$

IV) Total Power $= \sqrt{3} \, V_L I_L \cos \varnothing = \sqrt{3} \times 440 \times 43.57 \times 0.514 = 17067.26 \, \text{watt}$

2. f. Compare 3-phase Slip ring motor and squirrel cage motor based on following point
I) Construction and cost
II) Starting torque
III) Power factor and efficiency
IV) Methods of starting.

Ans-

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Slip ring motor</th>
<th>Squirrel cage motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Construction</td>
<td>Rotor made of windings of copper wires (Coils)</td>
<td>Rotor conductors are not wires they are made by bars of copper, Aluminum or Alloys.</td>
</tr>
<tr>
<td></td>
<td>cost</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>2</td>
<td>Starting torque</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>3</td>
<td>Power factor</td>
<td>Poor</td>
<td>Better</td>
</tr>
<tr>
<td></td>
<td>efficiency</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Methods of starting</td>
<td>Rotor resistance Starter</td>
<td>Stator Resistance starter, Autotransformer starter, Stare delta, DOL.</td>
</tr>
</tbody>
</table>

3. Attempt any FOUR of the following.

3. a. Why the core of the transformer is laminated? Write only the names of losses in transformer and methods to reduce the losses.

Ans -
The core of transformer is laminated to reduce the eddy current loss. There are two types of losses occurs in a transformer;
1) Core loss / Iron loss (Hysteresis and eddy current loss).
2) Copper loss.

Core losses can be reduce by using high permeability & low reluctance.
3 b Write any two applications of

I) Pulse Transformer
II) Auto Transformer
III) Audio Transformer
IV) Intermediate frequency transformer

Ans-

I) Pulse Transformer-
   a) For triggering circuit,
   b) In radar
   c) Particle accelerators
   d) High energy pulse applications.

II) Auto Transformer-
   a) As a dimmerstat
   b) In electrical lab to get variable supply
   c) Interconnect systems operating at different voltage classes
   d) Voltage regulators
   e) Used to provide grounding on three-phase systems

III) Audio Transformer-
   a) Tape recorder
   b) Public Addressing (P.A) system,
   c) Power Amplifier
   d) Impedance matching
   e) Audio amplifier circuits
   f) Isolated external connection for the loudspeakers

IV) Intermediate frequency transformer-
   a) F.M. Circuit,
   b) A.M. Circuit &
   c) Communication Circuit
   d) Valve amplifiers

3 c List out the speed control methods for 3 phase Induction Motor. Explain any one with neat sketches.

Ans:
1) Pole changing method
2) Frequency control method
3) Stator voltage control method
4) Rotor resistance method
5) Injected e.m.f. method

Pole changing method:

a) Speed control using two separate winding-
   An induction motor stator is wound for fixed number of poles. The speed of the induction motor depends upon the number of poles for which stator is wound. If instead of one stator winding two independent windings are wound for a different number of poles then two definite speeds can be obtained. E.g. one winding for 4-pole and another winding for 8-poles them speeds can be achieved. Two windings are insulated from one another when any one of the winding is used, the other should be kept open circuited by the switch or kept star connected.

b) Speed control using consequent pole technique-
   This method is used for obtaining multispeed in squirrel cage induction motor. In this method only one winding is used and it is provided with some simple switching means (device), so that connections of coils with supply are changed and different number of poles are formed. This is explained as below-

   Above fig (a) shows developed winding diagram for one phase of balanced three phase winding. Coil-1 & coil-3 are in series and they form one coil group while coil-2 & coil-4 connected in series to form another coil group. These two coil groups are connected in series such that all coils are magnetized in the same direction. Hence these coils forms 4-North poles and 4-South poles. Thus these arrangement gives total 8-poles.

   Fig (a)
Speed control by changing supply frequency-

The synchronous speed of the induction motor is given by, \( N_s = \frac{120f}{P} \). The synchronous speed of an induction motor can be changed by changing the supply frequency \( f \). Variable frequency can be obtained from solid state equipments or rotary converters (i.e. motor generator set).

A basic block diagram of speed control of induction motor using variable frequency source is shown in above fig. Three phase supply at input is first converted into controlled DC. This DC voltage is applied to inverter circuit whose frequency is controlled by pulses from voltage to frequency controller unit. A smoothing reactor, \( L \) is connected in the circuit to filter the controlled DC.

Stator voltage control Method-

We have relation that, torque is directly proportional to square of the voltage \( (i.e. T \propto V^2) \) e.g. if the applied voltage is reduced from \( V \) to 0.9V, the torque will be reduced from \( T \) to 0.81T. The torque-speed
Slip can be varies by introducing a voltage of slip frequency (rotor current frequency) directly into rotor circuit. Such motors are called slip charge motors. The speed of the motor further decreases.

Since the torque is reduced to to 81%, the rotor starts rotating at speed N2, i.e. its speed will be reduced. This method of speed control is rarely used industrial three phase motors because of requirement of additional costly voltage changing equipment. A large change in voltage is required for a relatively small change in speed.

Control of speed by changing the rotor resistance-
This method of speed control is belongs to speed control by changing slip (s). As in slip ring induction motor slip at a particular load can be changed by changing the rotor circuit resistance. As we increase rotor resistance, the rotor slip increases, thus speed of the rotor decreases as $N = \frac{120f}{p} (1 - s)$, as we further increases the rotor circuit resistance, the speed of the motor further decreases.

Thus speed of the motor can be varied by changing rotor resistance. The arrangement for speed control using variable rotor resistance is shown below.

Injected e.m.f. method-
Slip can be varies by introducing a voltage of slip frequency (rotor current frequency) directly into rotor circuit. Such motors are called scharge motors.
If injected emf is in direct opposition to rotor emf, the motor speed will decrease. If the injected emf is inphase with the rotor emf, then the speed will be above synchronous speed. These motors are rarely used because of bulky construction & high cost.

3 d Draw neat sketch and write working principle of shaded pole single phase motor.

Ans:

Shaded pole motors:

![Diagram](image)

Shaded pole induction motor has squirrel cage rotor and salient pole stator. The stator poles are shaded partially by short circuited conductor band to create the phase difference between the fluxes emerging from shaded and un-shaded portion. These phase differing fluxes produce the required torque on the rotor for motion.

3 e Compare Single phase and three phase system on the basis of following point :

 I) Output  II) Efficiency  
 II) Cost  IV) Power Factor

Ans :

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameter</th>
<th>Single Phase</th>
<th>Three Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Output</td>
<td>Less</td>
<td>more</td>
</tr>
<tr>
<td>2</td>
<td>Efficiency</td>
<td>Low</td>
<td>high</td>
</tr>
<tr>
<td>3</td>
<td>Cost</td>
<td>High cost</td>
<td>Low Cost (economical)</td>
</tr>
<tr>
<td>4</td>
<td>Power Factor</td>
<td>Lower</td>
<td>Greater</td>
</tr>
</tbody>
</table>

Each point carries 01 mark

3 f For a given equation of voltage and current in a circuit v=V_mSinωt, i= I_m Sin (ωt + 90°). State what type of circuit is it. Draw wave form of voltage, current and power in the circuit.

Solution:

For a given equation of voltage & current the type of circuit is Purely Capacitive circuit.
Wave form for Voltage & Current -

Power waveform -

4 Attempt any FOUR of the following.  
4 a What is the principle of 3 phase E.M.F. generation? Draw its waveform.  
Ans:
Principle of three phase EMF generation –

Above fig shows two pole stationary armature, rotating field type three phase alternator. It has three armature coils 'aa', 'bb' and 'cc' displaced 120° apart from one other. With the position and clockwise rotation of the poles as indicated in above fig it is found that the emf induced in conductor-a for coil 'aa' is maximum. The emf in conductor 'b' of coil 'bb' would be maximum when N-pole has turned through 120° i.e. N-S axis lies along 'bb'. It is clear that induced emf in conductor 'b' reaches its maximum value 120° later than that the maximum value in conductor 'a'. Similarly, the maximum emf induced in conductor 'c' would occurs 120° later than that in 'b' or 240° later than that in 'a'.

Three phase waveforms-

An alternating voltage is given as $e = 250 \sin 314.16t$ then find:

I) R.M.S. Value

II) Maximum Value

II) Frequency

IV) Value of voltage at $t = 0.05$ ms

Solution:

I) $R.M.S. = \frac{E_m}{\sqrt{2}} = \frac{250}{\sqrt{2}} = 176.78\text{V}$.  

II) Maximum value = $E_m = 250\text{ V}$
III) Frequency - \( \omega = 2\pi f \)
Therefore, \( f = \frac{\omega}{2\pi} = \frac{314.16}{2\pi} = 50 \text{Hz} \)  
01 mark

IV) value of voltage at \( t=0.5 \text{ms} \)
\( e = 250 \sin 314.06 \times 5 \times 10^{-3} \text{V} = 6.85 \text{Volts} \)  
01 mark

4 c Define dynamically induced EMF and explain principle of mutual induced EMF.

Ans-
Dynamically induced EMF:-
When a moving conductor placed in a uniform magnetic field, an e.m.f. is induced in a conductor which is called as dynamically induced e.m.f.  
01 mark

Mutually induced emf:-

Consider two coils A and B lying close to each other. Coil A joined to a battery, a switch and a variable resistance are whereas coil B is connected to a sensitive voltmeter V. When current through A is established by closing the switch, its magnetic field is set up which partially links with coil B. As current through A is changed, the flux linked with B is also changed. Hence, mutually induced emf is produced in coil B, whose magnitude is given by Faraday's Law and direction by Lenz Law.  
02 mark

4 d Define alternating current and write any three advantages of AC over DC voltage.

Ans-
Alternating current-
The wave form of current which changes its magnitude as well as its direction with respect to time is called as alternating current.  
01 mark

Advantages of AC over DC voltage-
1) AC voltage can be step up or step down easily but DC Voltage cant step up or step down.  
Any three points each
2) Generation of high voltage AC is easier than generation of DC.  
01 mark =
3) Long Distance transmission is possible for AC system.  
03 mark
4) AC Power transmission is economical.  
5) AC machines are simple in construction as compared to DC machines.  
6) Maintenance of AC switchgear & protection system is less and easy.
4 e  What is auto transformer? Write any three applications of auto transformer.

Ans-
Auto transformer: It is a transformer with one winding only, part of this being common to both primary and secondary.

![Diagram of Auto Transformer](image1)

Application of auto transformer:
1) Large three-phase autotransformers are used in electric power distribution systems.
2) Auto transformers are used to get variable output.
3) Auto transformers are used as a dimmer stat.
4) Auto transformers are used as starters for motors.

01 mark

4 f  Draw only circuit diagram of a single phase capacitor start induction run motor. What is the use of centrifugal switch? And write any one application of it.

Ans-
Diagram of capacitor start induction run motor-

![Diagram of Capacitor Start Induction Run Motor](image2)

Use of centrifugal switch –
Centrifugal switch is used to disconnect the series combination of starting winding (Auxiliary winding) and capacitor from the main winding and supply as soon as the motor achieves 75% of its rated speed.

01 mark

Applications-
1) Fans and blowers
2) Centrifugal pumps
5. Attempt any FOUR of the following.

a. What is meant by a three phase balanced load and unbalanced load.

Balanced load:
If all phase impedances of three phase load are exactly identical (Same) in respect of Magnitude and their nature, it is said to be a balanced three phase load. i.e. magnitude of voltages and resulting currents are same & they have same phase angles (they are displaced each other by 120°).

Unbalanced load:
If any one or more than one phase impedances of three phase load are different in respect of Magnitude and their nature, it is said to be a unbalanced three phase load. i.e. magnitude of voltages and resulting currents are also different & do not posses same phase angles (they are not displaced with each other by 120°).
5 b Define following terms as related to AC supplies
   i) Form factor
   ii) Peak factor
   iii) Q-factor
   iv) Impedance

Solution:
   i) Form factor: It is defined as the ratio of RMS value to the Average value of an alternating quantity.
      Each definition 1 mark
   ii) Peak Factor: It is defined as the ratio of Maximum value to the RMS value of an alternating quantity.
   iii) Q-factor: It is defined as the ratio of maximum energy stored to the energy dissipated per cycle.

In mathematical form,
   \[ Q = \frac{2\pi (\text{max. energy stored per cycle})}{(\text{energy dissipated per cycle})} \]
   or
   Voltage magnification in series resonant circuit is also known as Quality factor.
   \[ = \frac{\text{(voltage across L or C)}}{(\text{supply voltage})} \]
   iv) Impedance: It is defined as the combined effect offered by resistance, inductance & capacitance to current in an AC circuit. It is denoted by \( Z \) and is measured in Ohm (\( \Omega \)).

5 c Write any four factors upon which an inductance of a coil depends.
We have,
   \[ L = \frac{N\Phi}{I} = \frac{(N^2A\mu)}{I} \text{ henry} \]

Thus Inductance depends on-
   i) \( N \) = no. of turns of coil
   ii) \( \Phi \) = flux produced in web.
   iii) \( I \) = Current flowing through coil in ampere.
   iv) \( \mu \) = relative permeability of core material
   v) \( l \) = length of the coil
   vi) \( A \) = cross-sectional area of conductor.

5 d Write the property of ideal transformer and also write the formula for transformation ratio.

Properties of ideal transformer:
   i) Ideal transformer has no copper losses i.e. its windings have no ohmic resistance.
   Students should write any 4 properties
   ii) There is no magnetic leakage.
   iii) It has no core losses.
   iv) Ideal transformer consists two purely inductive coils wound on a loss
v) Ideal transformer has 100% efficiency.
vi) Ideal transformer has 0% regulation.

Transformation ratio (K) -
\[ K = \frac{E_1}{E_2} = \frac{N_1}{N_2} \]

Where,
E1 = rms value of induced emf in primary winding.
E2 = rms value of induced emf in primary winding.
N1 = No. of turns in primary.
N2 = No. of turns in secondary.

5 e Explain with neat sketch working principle of universal motor.

Universal Motor -

Working -
A universal motor is defined as the motor which may be operated either DC or single phase AC supply at approximately same speed and output. Such motors develop unidirectional torque, regardless whether they operate on AC or DC supply. Its action is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force whose magnitude is given by,

\[ F = BIL \] Newtons.

i.e. force is exerted between main pole flux and the current carrying armature conductors.

5 f Compare series and parallel resonance circuits (any four points)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Series Resonant Circuit</th>
<th>Parallel Resonant Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonance frequency</td>
<td>( f_0 = \frac{1}{2\pi\sqrt{LC}} ) Hz</td>
<td>( f_0 = \frac{1}{2\pi\sqrt{\left{\sqrt{1/(LC) - R^2/L^2}\right}} ) Hz</td>
</tr>
<tr>
<td>Impedance</td>
<td>Minimum Z=R ohms</td>
<td>Maximum ZD=L/(RC) ohms</td>
</tr>
<tr>
<td>Current</td>
<td>Maximum I0=V/R amp</td>
<td>Minimum I0=V/(L/CR)</td>
</tr>
</tbody>
</table>
6 a) Attempt any FOUR of the following.

Explain in brief the construction and working principle of 3-phase induction motor.

construction-
1) Squirrel cage Induction motor-

- It consist laminated cylindrical core having parallel slots on its outer periphery.
- One copper or aluminum bar is placed in each slot. All the bars are joined at each end by metal rings called end rings.
- Rotor bars are brazed or electrically welded or bolted to the end rings.
- This forms permanently short circuited winding which is non-breakable.
The rotor slots are not parallel to the shaft but they are skewed at certain angle with the shaft.

Or

2) Slip ring Induction motor-

![Diagram 1](image)

- It consist laminated cylindrical core and it carries three phase windings.
- The rotor winding may be single layer or double layer.
- The rotor winding is uniformly distributed in slots and it is always star connected.
- Rotor is wound for same number of poles as that of the stator winding.
- Three phases of rotor winding is are shorted internally to form star point and other three winding terminals are brought out and joined to three insulated slip rings mounted on the rotor shaft.
- One brush is resting on each slip ring. These three brushes are further externally connected to three phase star connected rheostat.

Working-
When 3-Ph AC supply is given to stator, rotating magnetic flux is produced in air gap. It has constant magnitude & constant speed called as 'synchronous speed, (Ns=120 l/P). When the flux rotates over rotor conductors changing flux (dØ/dt) is created & emf is induced in rotor conductor according to faradays laws of electromagnetic induction. As rotor is short circuited, current flows through it. Interaction of rotor current and rotating magnetic field produces torque on rotor and it starts rotating.

According to 'Lenz Law' the rotor current should oppose the cause which produces it. Here the cause is relative speed between flux & rotor therefore to minimize the relative speed rotor starts rotating in the direction of flux.
Write the symbol and unit of following.

i) Magnetic flux density

ii) Magnetic field strength

iii) Reluctance

iv) Coefficient of self inductance

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Term</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Magnetic flux density</td>
<td>B</td>
<td>Tesla or Web/m²</td>
</tr>
<tr>
<td>ii</td>
<td>Magnetic field strength</td>
<td>H</td>
<td>AT/m</td>
</tr>
<tr>
<td>iii</td>
<td>Reluctance</td>
<td>S</td>
<td>AT/Wb</td>
</tr>
<tr>
<td>iv</td>
<td>Coefficient of self inductance</td>
<td>L</td>
<td>Web-Turns/Amp</td>
</tr>
</tbody>
</table>

Draw neat sketch and write working principle of direct on-line starter for small squirrel cage induction motor.

In case of small capacity motors having rating less than 5 h.p., the starting current is not very high and such motors can withstand such starting current without any starter. Thus there is no need to reduce applied voltage, to control the starting current. Such motors use a type of starter which is used to connect stator directly to the supply lines without any reduction in voltage. Hence the starter is known as direct on line starter.

Though this starter does not reduce the applied voltage, it is used because it protects the motor from various severe abnormal conditions like over loading, low voltage, single phasing etc.

Above Fig. shows the arrangement of various components in direct on line starter. The NO contact is normally open and NC is normally closed. At start, NO is pushed for fraction of second due to which coil gets energized and attracts the contactor. So stator directly gets supply. The additional contact provided, ensures that as long as supply is ON, the coil gets supply and keeps contactor in
ON position. When NC is pressed, the coil circuit gets opened due to which coil gets de-energized and motor gets switched OFF from the supply.

Under over load condition, current drawn by the motor increases due to which is an excessive heat produced, which increases temperature beyond limit. Thermal relays get opened due to high temperature, protecting the motor from overload conditions.

6 d Write any four applications of
   i) 3-phase slip ring induction motor
   ii) Squirrel cage induction motor

   i) 3-phase slip ring induction motor applications-
      a) Lifts
      b) Cranes
      c) Hoists
      d) Elevators
      e) Centrifugal pumps
      f) Rolling mills
      g) Propulsion of ships
      h) Winding machines

   ii) Squirrel cage induction motor
      a) Water Pumps
      b) Tube well
      c) Lathes Machine
      d) Line shaft
      e) Grinders
      f) Polishers
      g) Wood Planners / wood cutting equipments
      h) Compressors
      i) Laundry washing machines
      j) Fans
      k) Blowers
      l) Various types of presses
      m) Cement & textile mills

   n) 

6 e Define active, reactive and apparent power in AC circuit. Write the unit of each power and draw the power triangle for an inductive load.

Ans-

Active Power (P):
The average power drawn by the AC circuit is called as Active power.
Or
It is the power which is actually dissipated in the circuit resistance.
It is given by, \[ P = VI \cos \theta \text{ watts (or kilowatts).} \]
6  

Write two general precautions while using electrical energy. Define lagging power factor and leading power factor.

Precautions while using electrical energy-
1) Make all connections tight.
2) Do not leave loose wires.
3) Do not touch live terminals or any open wires in the circuit.
4) Use suitable wire types and sizes while wiring up of electrical circuit.
5) During maintenance work, switch off the supply mains and disconnect the fuse unit.
6) Use insulated hand glows while working with live terminals, electrical apparatus or machine.
7) Understand the equipment to be tested and apparatus to be used from the user point of view before working on it.
8) While working above the ground level, ladder should be hold firmly by subordinate.

Lagging power factor:
If the load current lags the load voltage, which implies lagging power factor and

Neat labeled power diagram
01 mark

Active Power
P = VI \cos \phi

Reactive power
Q = VI \sin \phi

Apparent power
S = VI

01 mark
the load in this case is inductive in nature.

\[ \Phi \]

\[ \text{Power factor} = \cos \Phi \text{ is lagging.} \]

Leading power factor:
If the load current leads the load voltage, which implies leading power factor and
the load in this case is capacitive in nature.

\[ \Phi \]

\[ \text{Power factor} = \cos \Phi \text{ is leading.} \]