SUMMER – 2022 EXAMINATION

Subject Name: Electric Motors & Transformers **Model Answer:** **22418:CNE**

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 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 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 judgement 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 FIVE of the following: **10**

1 a) Classify the different types of motors.

Ans:

Classification of motors:

A) AC Motors

i. Three-phase AC Motors
   1. Synchronous Motors
   2. Asynchronous Motors (Induction Motors)

ii. Single-phase AC Motors
   1. Synchronous Motors
   2. Asynchronous Motors (Induction Motors)

1 Mark for AC motors

B) DC Motors

(i) DC series motor
(ii) DC shunt motor
(iii) DC Compound motor : short shunt and long shunt

1 Mark for DC motors

1 b) State the rule used for calculating direction of e. m. f. induced in armature winding of DC Generator.

Ans:

Fleming's Right Hand Rule:

Stretch out first three fingers of right hand such that they are mutually perpendicular to each other. If fore finger points the direction of Magnetic field, thumb points the direction of motion of the conductor with respect to magnetic field, then the middle finger points the direction of induced EMF in the conductor.

1 Mark for identifying rule

1 Mark for statement

1 c) Define voltage transformation ratio of transformer.

Ans:

Voltage transformation ratio of transformer:

It is defined as the ratio of secondary voltage to primary voltage of transformer.

1 Mark for definition

1 d) Classify various losses of transformer.

Ans:

Various Losses in Transformer:

1) Copper losses (P_{cu}):

These are also known as Variable losses. The total power loss taking place in the winding resistances of a transformer is known as the copper loss. — 1 Mark

Cu loss = Primary Cu loss + Secondary Cu loss

$P_{cu} = I_1^2R_1 + I_2^2R_2$

where, R_1 & R_2 are resistances of primary & secondary winding respectively.

2) Iron losses (P_i):

These are also known as Fixed losses. These are further divided into eddy current loss and hysteresis loss. — 1 Mark

i) **Eddy current loss** = $K_E B_m^2 f^2 T^2$ watt

where, K_E is eddy current constant, B_m is the maximum value of the flux density, f is the frequency of magnetic reversals; T is thickness of core in m.

ii) **Hysteresis loss** = $K_H B_m^{1.67} f V$ watt

where K_H is Hysteresis constant, B_m is the maximum flux density
f is the frequency of magnetic reversals and V is the volume of the core in m^3

1 e) State ant two conditions of parallel operation of three phase transformer.

Ans:

Conditions for Parallel operation of 3 phase transformer

1) Voltage ratings of both the transformers must be identical.
2) Phase sequence on both sides must be same.
3) Transformer polarity must be same.
4) Phase displacement between primary & secondary voltages must be same.
5) Percentage or p.u. impedance should be equal.
6) X/R ratio of the transformer winding should be equal.

1 Mark for each of any two conditions = 2 Marks

1 f) State the importance of "K" factor of transformer.

Ans:

Importance of "K" factor of transformer:

The K-factor number of the transformer (1, 4, 9, 13, 20) is an indication of the amount of harmonic current the transformer is capable of handling in terms of its heating effects. It is the value that determines how effectively a transformer can handle harmonic currents while maintaining the temperature rise well within the limits. It ranges from 1 to 50. Transformers having K-factor of 1 can handle linear loads only and those rated 50 can withstand harsh harmonics. — 2 Marks

For better K-factor ratings, transformers should be specially designed to make it capable of withstanding extra heats caused due to harmonics. There are many different loads such as computers, solid state devices and motors which cause a nonlinear load. These types of loads generate harmonic currents that cause transformers to overheat, which can destroy the transformer. When a non-linear load is supplied from a transformer, K-factor transformers withstand the heating effects of harmonic currents created by these types of loads due to their larger winding coil diameters and special design.

1 g) State any two applications of pulse transformer.

Ans:

Applications of pulse transformer:

i) Pulse Generating Circuits
ii) Analog Switching Applications
iii) SCR firing circuit
iv) Power Electronics circuits
v) Data Handling Circuits
vi) Radar systems
vii) Switching Transistor circuits
viii) Communication circuits
ix) Microwave Tube Circuits
x) Control Circuit for Firing Control
xi) Cathode Ray Tube (CRO) Circuits
xii) Digital Electronics

1 Mark for each of any two applications = 2 Marks

2 Attempt any THREE of the following: **12**

2 a) Suggest the material for the following part of motor.

i) Armature winding
ii) Commutator
iii) Brushes
iv) Frame

Ans:

Sr. No.	Part	Material used
1	Armature winding	Copper or aluminium
2	Commutator	Copper for segments and mica for separators
3	Brushes	Carbon
4	Frame	Cast iron, Cast steel

1 Mark for each bit = 4 Marks

2 b) Explain the principle of working of an induction motor.

Ans:

- When the motor is excited with three-phase supply, three-phase stator winding produces a rotating magnetic field of constant magnitude which rotates at synchronous speed.
- This rotating magnetic field is cut by the rotor conductors and induces emf in them according to the Faraday's laws of electromagnetic induction. As these rotor conductors are shorted, the current starts to flow through these conductors.
- The situation gets changed such that the current carrying rotor conductors are now placed in rotating magnetic field produced by stator. Consequently, mechanical force acts on rotor conductors as per basic motor principle. The sum of the mechanical forces on all the rotor conductors produces a torque, which tend to move the rotor in same direction as the rotating magnetic field.
- The direction of force acting on the conductor is given by Fleming's Left hand rule.

Step-wise explanation = 3 Marks

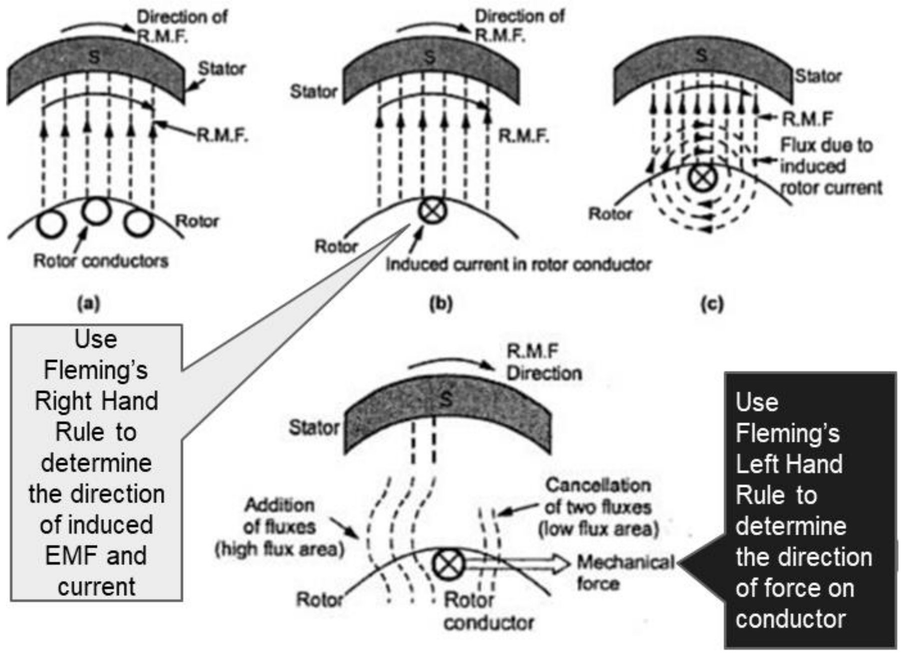
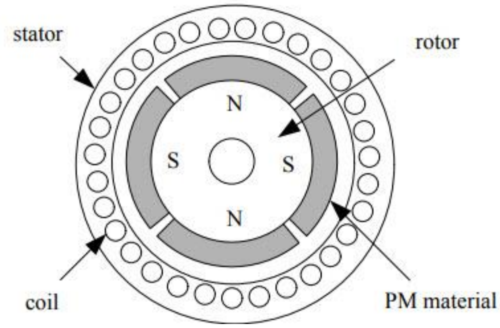


Figure = 1 Mark

2 c) Explain construction and working of Brusless D. C. motor.

Ans:



OR
Any equivalent Diagram

Construction of Brushless DC (BLDC) Motor:

A BLDC Motor consists of two main parts: a stator and a rotor.

Stator: The structure of the stator of a BLDC Motor is similar to that of three-phase induction motor or synchronous motor. It is made up of stacked steel laminations with axially cut slots for winding. The winding in BLDC are slightly different than that of the traditional induction motor. BLDC motors consist of three stator windings that are connected in star or 'Y' fashion (without a neutral point). — 2 Marks for construction

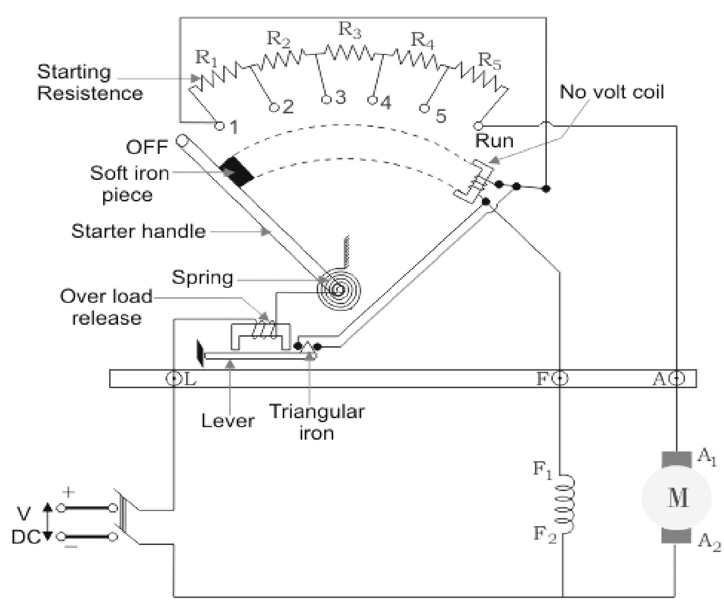
Rotor: The rotor part of the BLDC Motor is made up of permanent magnets, usually, rare earth alloy magnets like Neodymium (Nd), Samarium Cobalt (SmCo) and alloy of Neodymium, Ferrite and Boron (NdFeB). Based on the application, the number of poles can vary between two and eight with North (N) and South (S) poles placed alternately. The magnets are placed on the outer periphery of the rotor.

Position Sensors (Hall Sensors): Since there are no brushes in a BLDC Motor, the commutation is controlled electronically. In order to rotate the motor, the windings of the

stator must be energized in a sequence and the position of the rotor (i.e. the North and South poles of the rotor) must be known to precisely energize a particular set of stator windings.
A Position Sensor, which is usually a Hall Sensor (that works on the principle of Hall Effect) is generally used to detect the position of the rotor and transform it into an electrical signal. Most BLDC Motors use three Hall Sensors that are embedded into the stator to sense the rotor's position.
The output of the Hall Sensor will be either HIGH or LOW depending on whether the North or South pole of the rotor passes near it. By combining the results from the three sensors, the exact sequence of energizing can be determined.

Working of BLDC motor:
In case BLDC motor, the current carrying conductor is stationary while the permanent magnet rotor moves. When the stator coils are electrically switched to a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Separate power electronic switching circuit is used to produce and supply three-phase voltage generated from DC supply to three-phase stator winding. The three-phase stator winding produces rotating magnetic field to which the rotor poles are locked and then rotate with the rotating magnetic field produced by stator. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate. 2 Marks for working

2 d) Draw a neat labeled diagram of three-point starter.
Ans:
Three Point Starter:



Three Point Starter

4 Marks for labeled diagram

3 Marks for partially labeled diagram

2 Marks for unlabeled diagram

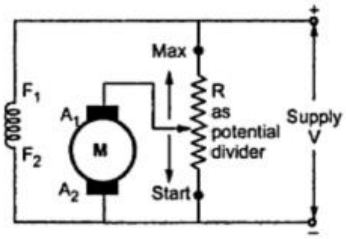
3 Attempt any <u>THREE</u> of the following: 12

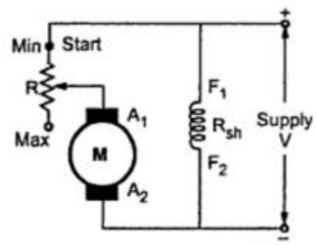
3 a) Describe with sketches, speed control method used for getting speed below normal speed in case of D. C. shunt motor.

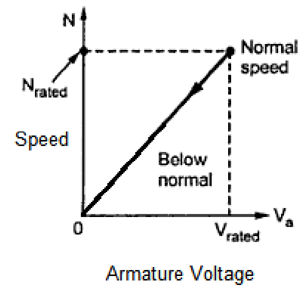
Ans:

DC Shunt Motor Speed Control Below Normal:

Armature Voltage Control method:







1 Mark for any one circuit diagram

Back EMF equation of DC Motor is given by,

$E_b = \frac{\phi Z N}{60}\frac{P}{A}$ volt $\qquad E_b \ \alpha \ \phi N$

$N \ \alpha \ \frac{Eb}{\phi}$ Or $N \ \alpha \ \frac{(V - I_a R_a)}{\phi}$

1 Mark for N Versus V_a plot

Thus, speed of DC motor is –

i) directly proportional to armature voltage V

ii) inversely proportional to magnetic flux ϕ.

In case of DC shunt motor, if the shunt field winding is connected across input DC supply, the field current and hence magnetic flux remains constant. Then the speed becomes directkly proportional to back emf only. Since back emf $E_b = (V_a - I_a R_a)$, by controlling the armature voltage V_a, the speed can be controlled linearly, as shown in the figure. To control the armature voltage i.e the voltage supplied to armature winding, either the armature is supplied from potential divider arrangement or connected in series with external resistance. By changing the position of variable tap of potential divider or external rheostat, the armature voltage can be varied below the rated voltage value and therefore speed can be controlled below normal only.

2 Marks for explanation

3 b) Derive EMF equation for the single phase transformer.

Ans:

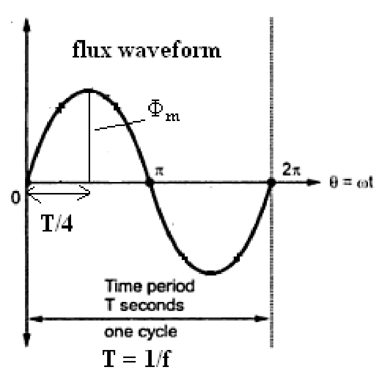
Emf equation of transformer:

N_1 = No. of turns on primary winding

N_2 = No. of turns on secondary winding

Φ_m= Maximum value of flux linking both the windings in Wb

f = Frequency of supply in Hz



1 Mark for waveform

1st method:

Maximum value of flux is reached in time

t = 1/ 4f

Avg. rate of change of flux = $\Phi_m/t = \Phi_m/(1/ 4f)$

= $4\Phi_m f$ Wb/sec

From Faraday's laws of electromagnetic induction

1 Mark

Avg. emf induced in each turn = Avg. rate of change of flux = $4\Phi_m f$ volt
Form factor = (RMS value)/(Avg. value) = 1.11for sinusoidal voltage
R.M.S. emf induced in each turn = 1.11 x Avg. value = 1.11 x $4\Phi_m f$
= 4.44 Φm f volt
R.M.S. emf induced in primary winding = (RMS emf / turn) x N_1 — 1 Mark
$E_1 = 4.44\ \Phi_m f\ N_1$ volts
Similarly, $E_2 = 4.44\ \Phi_m f\ N_2$ volts — 1 Mark

OR

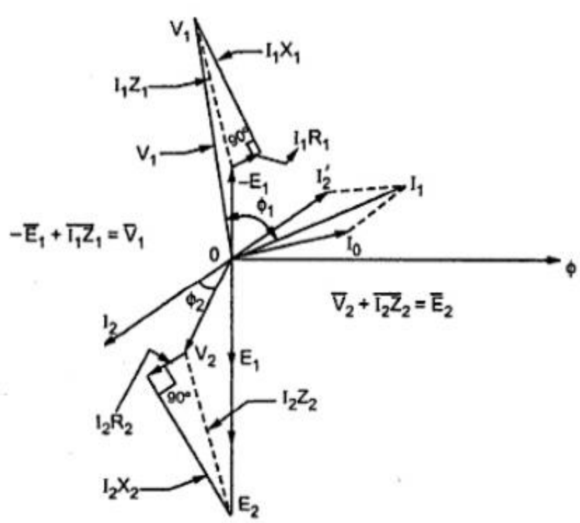
2nd method:

$\Phi = \Phi_m \sin \omega t$
According to Faraday's laws of electromagnetic induction
Instantaneous value of emf/ turn = - $d\Phi/dt$ $= -\frac{d}{dt}(\Phi_m \sin \omega t)$ — 1 Mark
$= -\omega\Phi_m \cos\omega t$
$= \omega\Phi_m \sin(\omega t - \pi/2)$ volts — 1 Mark
Maximum value of emf/turn = $\omega\Phi_m$
But $\omega = 2\pi f$
Max. value of emf /turn $= 2\pi f\ \Phi_m$
RMS value of emf /turn = 0.707 x $2\pi f\ \Phi_m = 4.44\Phi_m f$ volts
RMS value of emf in primary winding $E_1 = 4.44\Phi_m\ f\ N_1$ volts — 1 Mark
$E_2 = 4.44\ \Phi_m f\ N_2$ volts — 1 Mark

3 c) Draw the labelled phasor diagram of single phase transformer supplying load at lagging power factor.

Ans:

Phasor diagram of single phase transformer supplying load at lagging power factor:



For Lagging pf condition

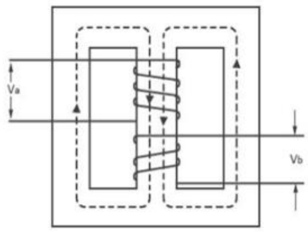
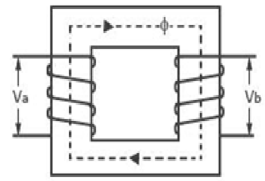
4 Marks for labelled diagram

2 Marks for partially labelled diagram

3 d) Compare shell type and core type single phase transformer (any four points).

Ans:

Comparision of Shell Type and Core Type single phase Transformer:

Sr. No.	Shell type	Core type
1		
2	It has two windows	It has one window
3	It has two magnetic circuits.	It has one magnetic circuit.
4	Winding surrounds the core	Core surrounds the winding.
5	Average length of core is less.	Average length of core is more.
6	Area of cross section is more so less turns are required.	Area of cross section is less so more turns are required.
7	Better cooling for core	Better cooling for winding
8	Mechnical strength is high	Mechnical strength is less
9	Repair and maintenance is difficult	Repair and maintenance is easy
10	Application: High current, low voltage	Application: Low current, high voltage

1 Mark for each of any 4 points = 4 Marks

4 Attempt any THREE of the following: **12**

4 a) Compare the distribution transformer and power transformer on any four points.

Ans:

Comparision of distribution transformer and power transformer:

Parameters	Distribution Transformer	Power Transformer
Typical Voltages	11kV,6.6kV, 3.3kV, 440V, 230V	400kV, 220kV, 110kV,66kV,33kV
Power Rating	Lower (< 1MVA)	Higher (> 1MVA)
Size	Small	Big
Load	50-70% of full load	Full load
Insulation Level	Low	High
Installation	Pole mounted/ Plinth Mounted.	Compulsory Plinth Mounted
Maximum efficiency	Obtained near 50% of full load	Obtained near 100% of full load
Type of efficiency	All day efficiency needs to be defined	Only power efficiency is sufficient

Each point 1 Mark (any four points) = 4 Marks

4 b) Explain the effects of harmonics on the operation of Transformer.

Ans:

Effect of Harmonics on the Operation of Transformer:

1. Core loss: Harmonics increase the hysteresis and eddy current losses in the lamination. The amount of the core loss depends on harmonics present in the supply voltage.

2. Copper loss: Harmonic current increases copper loss. The loss mainly depends on the harmonics present in the load current and effective ac resistance of the winding. Copper loss increase temperature and create hot spots in that transformer. The effect is prominent in the case of converter transformers. These transformers do not benefit from the presence of filters as filters are normally connected on the AC. system side.

3. Stress: Voltage harmonics increase stresses on the insulation,

4. Core vibration: Current and voltage harmonics increase small core vibrations.

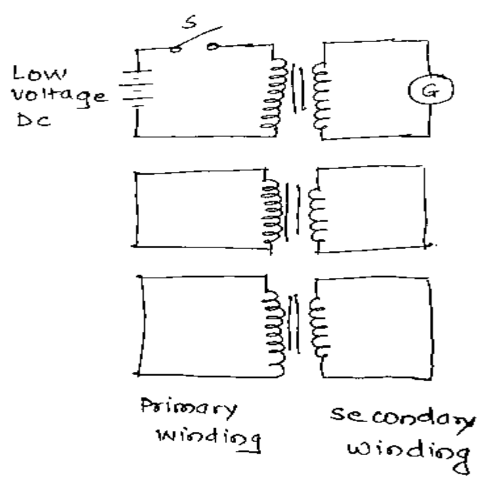
5. Saturation problem: Sometimes additional harmonic voltage causes core saturation.

2 Marks for each of any two effects = 4 Marks

4 c) Describe with neat relevant diagram, the test carried out on three phase transformer to identify the windings corresponding to same phase.

Ans:

Phasing out Test:



1 Mark for circuit diagram

3 Marks for stepwise description

i) This test is carried out on 3-ph transformer to identify primary & secondary winding belonging to the same phase.

ii) As shown in figure, all primary & secondary phases are short-circuited except the phases to be checked.

iii) Low voltage DC supply is given to one primary winding. The galvanometer is connected to terminals of secondary winding which is not short-circuited.

iv) The switch 'S' is connected as shown in figure. When switch is closed, deflection of galvanometer is observed.

v) Similarly galvanometer is connected to other secondary winding terminals and procedure is repeated. The winding across which maximum deflection occurs is the secondary phase winding that corresponds to primary winding to which source is connected.

vi) The procedure is repeated for remaining primary windings.

vii) Phasing out test can be carried out by using AC voltage source also. Voltmeter is connected at secondary terminals to observe deflections.

viii) The purpose of this test is to check the respective phases of primary & secondary windings in 3-ph transformer.

4 d) In a 25KVA, 2000/200V single phase transformer, the iron and full load copper losses are 350 watt and 400 watt respectively. Calculate the efficiency at unity power factor on full load.

Ans:

Full load efficiency at any pf:

$$= \frac{(Full\ load\ kVA) \times 1000 \times pf}{[Full\ load\ kVA \times 1000 \times pf] + Iron\ Loss + Full\ load\ Copper\ Loss} \times 100$$

1 Mark for formula

% full load efficiency at unity pf:

3 Marks for stepwise solution

$$= \frac{25 \times 1000 \times 1}{25 \times 1000 \times 1 + (350 + 400)} \times 100$$

$$= \frac{25000}{25000 + (750)} \times 100$$

= 97.08 %

4 e) List any four special features of isolation transformer with any four applications.

Ans:

Special Features of Isolation Transformer:

i) Number of primary turns are equal to number of secondary turns.
ii) Disconnect the load equipment from supply: Sometimes it is essential to disconnect the load equipment such as the cathode ray oscilloscope (CRO) from the supply ground.
iii) Sensitive and costly equipment need to be disconnected from supply to protect from noisy ground connection. 2 Marks
iv) Reduction of voltage spikes: Voltage spikes are short duration high amplitudes pulses which get superimposed on the ac supply. These are dangerous to delicate equipment. Isolation transformer reduces the amplitude of spike.

Applications of isolation transformer:

i) Disconnect the load equipment from supply ground:
ii) Reduction of voltage spikes 2 Marks
iii) It acts as a decoupling device.
iv) Protects loads from harmonic distortion.

5 Attempt any <u>TWO</u> of the following: 12

5 a) A dc series motor runs at 600 rpm taking 100 A from 230V supply. Armature and series field winding resistances are 0.12Ω and 0.03Ω respectively. Calculate the speed when current has fallen to 50A. Assume flux to be directly proportional to field current.

Ans:

For DC series motor, the voltage equation is:

$E_{B1} = V - I_{A1}(R_A + R_{SE}) = 230 – 100(0.12 + 0.03) = 215$ V

$E_{B2} = V - I_{A2}(R_A + R_{SE}) = 230 – 50(0.12 + 0.03) = 222.5$ V.

2 Marks for back emfs

The back emf is related to flux and speed by, $E_B \propto \phi.N$

$\therefore E_{B1} \propto \phi_1.N_1$ and $E_{B2} \propto \phi_2.N_2$ — 1 Mark

But flux is proportional to current, $\phi \propto I$

$\therefore \phi_1 \propto 100$ and $\phi_2 \propto 50$

$\therefore \phi_2 = 0.5\,\phi_1$ — 1 Mark for flux relation

$\therefore E_{B1} \propto \phi_1.N_1$ and $E_{B2} \propto \phi_2.N_2$

$$\frac{E_{B2}}{E_{B1}} = \frac{\phi_2 N_2}{\phi_1 N_1} = \frac{0.5\,\phi_1 N_2}{\phi_1 N_1} = \frac{0.5 N_2}{N_1}$$

1 Mark for stepwise solution

$$\therefore N_2 = \frac{N_1 E_{B2}}{0.5 E_{B1}} = \frac{(600)(222.5)}{0.5(215)}$$

1 Mark for final answer

$\therefore$ Speed $N_2 = 1241.86$ rpm

5 b) Give the criteria for selection of distribution transformer and power transformer as per IS: 10028 (part-I)

Ans:

Selection Criteria for distribution transformer:

i) **Ratings -** The kVA ratings should comply with IS : 2026 (Part l)-1977*. The no-load secondary voltage should be 433 volts for transformers to be used in 415 V system. Voltage should be normally in accordance with IS: 585-19627 except for special reasons when other values may be used.

ii) **Taps** -The transformers of these ratings are normally provided with off-circuit taps on HV side except in special cases when on-load tap changers are specified. The standard range for off-circuit taps which are provided on HV side should be of 2.5 percent and of 5.0 percent. In case of on-load tap changers, the taps may be in steps of 1.25 percent with 16 steps. The positive and negative taps shall be specified to suit the system conditions in which the transformer is to be operated.

iii) **Connection Symbol** - The two winding transformers should be preferably connected in delta/star in accordance with IS : 2026 (Part 4)-1977s. The exact connection symbol (Dyn11 or Dyn1) is to be specified depending upon requirements of parallel operation.

1 Mark for each of any three = 3 Marks

iv) **Impedance** - Consideration shall be given in the selection of impedance for the standard available rating of the switchgear on the secondary side and associated voltage drops.

v) **Termination Arrangement** - The HV and LV terminals may be bare outdoor bushings, cable boxes or bus trunking depending upon the method of installation. Wherever compound filled cable boxes are used, it is preferable to specify disconnecting chamber between transformer terminals and cable box to facilitate disconnection of transformer terminals without disturbing the cable connections (see also IS: 9147-1979). In case of extruded insulation cables with connections in air, a separate disconnecting chamber is not necessary.

vi) **Cooling** - The transformers covered in this group are generally ONAN, AN

Selection Criteria for Power transformer:

i) Ratings - The kVA ratings should comply with IS: 10028 (Part l)-1985. The no-load secondary voltage should be 5 % more than nominal voltage to compensate the transformer regulation partly. The transformer requiring to be operated in parallel, the voltage ratio should be selected in accordance with guidelines given in 12.0.1 & 12.0.1.1 of IS : 10028 (Part l)-1985 — 1 Mark for each of any three = 3 Marks

ii) Taps –On-Load tap changers on HV side should be specified, wherever system conditions warrant. In case of OLTC, total number of taps should be 16 in steps of 1.25 %. The standard range for off-circuit taps which are provided should be in range of $\pm$ 2.5 percent and $\pm$ 5 percent.

iii) Connection Symbol - The preferred connections for two winding transformers should be preferably connected in delta/star (Dyn) and star/star (YNyn). For higher voltage connections star/star (YNyn) or star/delta (YNd) may be preferred accordance with IS: 10028 (Part l)-1985..

iv) Impedance – The transformer impedance is decided taking into consideration the secondary fault levels and voltage dip. The typical values are given in table 3 of IS:2026.

iv) Termination Arrangement - The HV and LV terminals may be bare outdoor bushings, cable boxes or bus trunking depending upon the method of installation. Wherever compound filled cable boxes are used, it is preferable to specify disconnecting chamber between transformer terminals and cable box to facilitate disconnection of transformer terminals without disturbing the cable connections (see also IS: 9147-1979:). In case of extruded insulation cables with connections in air, a separate disconnecting chamber is not necessary.

v) Cooling - The transformers covered in this group are generally ONAN, ONAN/ONAF, ONAN/ONAF/OFAF.

5 c) Two single-phase transformers with equal turns have impedance of (0.5+j3)Ω and (0.6+j10)Ω respect with secondary. If they operate in parallel. Determine how they will share load of total 100kW pf of 0.8 lagging.

Ans:

$Z_A = (0.5 + j3) = 3.04\angle 80.6^0$ — 1 Mark

$Z_B = (0.6 + j10) = 10.02\angle 86.6^0$

$Z_A + Z_B = (1.1 + j13) = 13.05\angle 85.2^0$ — 1 Mark

Total load= 100kW at 0.8pf lagging.

$\therefore kVA = \frac{kW}{pf} = \frac{100}{0.8} = 125kVA, i.e. S = 125 < -36.9^0\ kVA$ — 1 Mark

$$S_A = S \times \frac{Z_B}{Z_A + Z_B} = 125\angle -36.9^0 \times \frac{10.02\angle 86.6^0}{13.05\angle 85.2^0}$$ — 1 Mark

$= 95.97\angle -35.5^0$

$\therefore$ Load shared by Transformer A in kW will be;

$kVA \times pf = 95.97 \times \cos(-35.5^0) = 78.13kW$

Similarly, — 1 Mark

$$S_B = S \times \frac{Z_A}{Z_A + Z_B} = 125\angle -36.9^0 \times \frac{3.04\angle 80.6^0}{13.05\angle 85.2^0}$$

$= 29.11\angle -41.5^0$

$\therefore$ Load shared by Transformer B in kW will be; — 1 Mark

$kVA \times pf = 29.11 \times \cos(-41.5^0) = 21.80\ kW$

SUMMER – 2022 EXAMINATION

Subject Name: Electric Motors & Transformers **Model Answer:** **22418:CNE**

6 **Attempt any TWO of the following:** **12**

6 a) A 10 kVA, 1 phase, 50Hz, 500/250 V transformer have following result.
OC test- (LV side)- 250 V, 3 A, 200 W
SC test- (HV side)- 15 V, 30 A, 300 W.
Calculate efficiency and regulation at full load 0.8 pf lagging.

Ans:

Efficiency at Full load at 0.8 pf lagging:

3 Marks for stepwise solution for efficiency

$$\text{Efficiency}_{FL} = \frac{\text{Rated output} \times \cos\emptyset}{\text{Rated output} \times \cos\emptyset + \text{Cu. Losses} + \text{Iron Losses}}$$

$$\text{Efficiency}_{0.8\ pf} = \frac{10 \times 10^3 \times 0.8}{10 \times 10^3 \times 0.8 + 200 + 300}$$

$$= \frac{8000}{8500} = 0.9411 = \mathbf{94.11\%}$$

Regulation at Full load at 0.8 pf lagging:

K= V_2/V_1 = 250/500= 0.5

Full load primary current $I_{1\ F.L.}$ = (10x1000)/500 = 20 A

NOTE: The full-load primary current on HV side appears to be 20A, but in short circuit test the current circulated is 30A, which is wrong.

From S.C.test: Z_{T1}= V_{SC}/I_{SC}= 15/30 = 0.5 Ω

3 Marks for stepwise solution for regulation

R_{T1}= $W_{SC}/(I_{SC})^2$ = $300/(30)^2$ = 0.33 Ω

X_{T1}= $\sqrt{(0.5^2 - 0.33^2)}$ = 0.375 Ω

% regulation = 100 x I_{1FL} ($R_{T1}\cos\phi + X_{T1}\sin\phi$)/ V_1

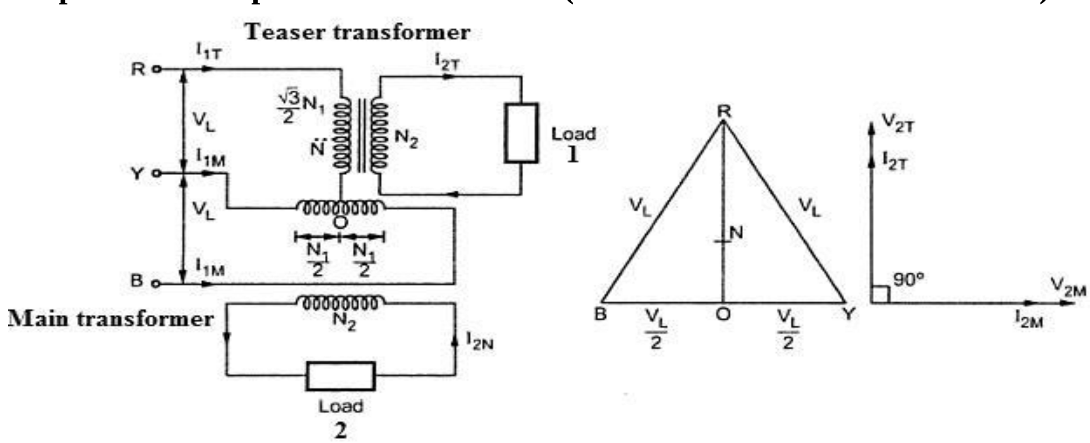
= 100 x 20(0.33 x 0.8 + 0.375 x 0.6)/500

= **1.95%**

6 b) Explain with the neat sketch the Scott connection scheme for conversion of three phase to two phase supply.

Ans:

Three-phase to Two-phase Transformation (Scott Connection of Transformers):



2 Marks for circuit diagram

1 Mark for phasor diagram

3 Marks for explanation

i) Scott connection can be used for three-phase to two-phase conversion using two single-phase transformers.
ii) Scott connection for three-phase to two-phase conversion is as shown in figure.
iii) Point 'O' is exactly at midpoint of winding connected between phases Y & B.

iv) The no. of turns of primary winding will be $\frac{\sqrt{3}}{2}N_1$ for Teaser and N_1 for main transformer. The no. of secondary turns for both the transformers are N_2.

v) When three-phase supply is given to primary, two-phase emfsare induced in secondary windings as per turns ratio & mutual induction action.

vi) It is seen that the voltage appearing across the primary of main transformer is V_{1M} = V_L i.e line voltage. The voltage induced in secondary of main transformer is V_{2M} which is related to V_{1M} by turns ratio N_1:N_2.

vii) From phasor diagram it is clear that the voltage appearing across the primary of Teaser transformer corresponds to phasor RO which is $\frac{\sqrt{3}}{2}$ times the line voltage V_L. Due to this limitation, the turns selected for primary of Teaser transformer are not N_1 but $\frac{\sqrt{3}}{2}N_1$. This makes the volts per turn in teaser transformer same as that in main transformer and results in voltage induced in secondary of teaser transformer same as that in main transformer, i.e $V_{2T} = V_{2M}$.
As seen from the phasor diagram, the output voltages to the two loads are identical.

6 c) A 50KVA, 4400/220V transformer has R_1=3.45Ω, R_2=0.009Ω. The value of reactances are X_1=5.2Ω, X_2=0.015Ω. Calculate for the transformer:
i) Equivalent resistance and reactance as referred to HV side.
ii) Equivalent resistance and reactance as referred to LV side.

Ans:

Equivalent resistance and reactance as referred to HV side:

$k = \frac{220}{4400} = 0.05$

$$R_2' = \frac{R_2}{K^2} = \frac{\mathbf{0.009}}{(\mathbf{0.05})^2} = \mathbf{3.6}\Omega$$

1 Mark for R_2' & X_2'

$$X_2' = \frac{X_2}{K^2} = \frac{\mathbf{0.015}}{(\mathbf{0.05})^2} = \mathbf{6}\Omega$$

1 Mark for R_{1T}

$$R_{1T} = R_1 + R_2' = 3.45 + 3.6 = \mathbf{7.05}\,\Omega$$

1 Mark for X_{1T}

$$X_{1T} = X_1 + X_2' = 5.2 + 6 = \mathbf{11.2}\,\Omega$$

Equivalent resistance and reactance as referred to LV side:

1 Mark for R_1' & X_1'

$R_1' = R_1 \times k^2 = 3.45 \times (0.05)^2 = 8.625 \times 10^{-3}\,\Omega$

$X_1' = X_1 \times k^2 = 5.2 \times (0.05)^2 = 0.013\,\Omega$

1 Mark for R_{2T}

$$R_{2T} = R_{21} + R_1' = 0.009 + 8.625 \times 10^{-3} = \mathbf{0.0176}\,\Omega$$

1 Mark for X_{2T}

$$X_{2T} = X_2 + X_1' = 0.015 + 0.013 = \mathbf{0.028}\,\Omega$$