WINTER – 2022 EXAMINATION

Model Answer

Subject Name: Electric Motors and Transformers

22418: CNE

Important Instructions to examiners:

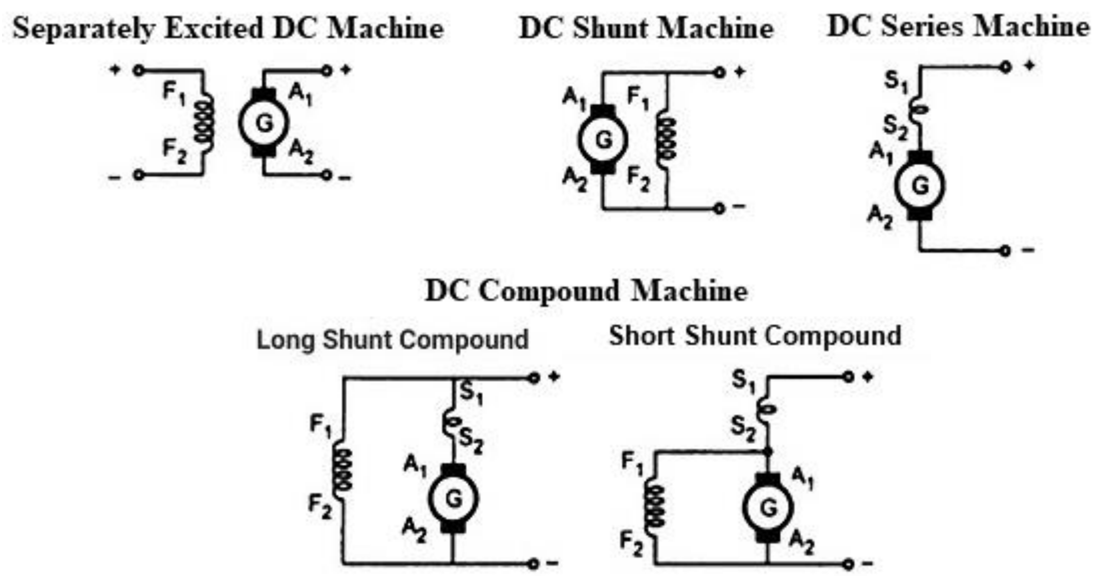
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1.		**Attempt any FIVE of the following:**	**10 Marks**
	a)	State the function of field winding in an electric motor. **Ans:** **Function of Field Winding in an Electric Motor:** Whenever field winding is connected to DC supply, it produces magnetic field in the air gap in which armature rotates.	2 Marks
	b)	State Fleming's left hand rule. **Ans:** **Fleming's Left Hand Rule:** Stretch out the first three fingers of left hand such that they are mutually perpendicular to each other, *align* first finger in direction of magnetic field, middle finger in direction of current flowing through the conductor *then* the thumb will give the direction of force acting on the current carrying conductor.	2 Marks
	c)	Classify transformer based on: i) Construction ii) Voltage level **Ans:** **Classification of Transformer Based On:** **i) Construction:** Shell type, Core type, Berry type **ii) Change in voltage level:** Step-Up, Step-Down	1 Mark for each criterion = 2 Marks
	d)	Write any two characteristics of core type transformer. **Ans:** **Characteristics of Core Type Transformer:** i. It has one window ii. It has one magnetic circuit. iii. Winding surrounds the core.	1 Mark for

		iv. Average length of core is more. v. Area of cross section is less so more turns are required. vi. Better cooling for winding. vii. Mechnical strength is less. viii. Repair and maintenance is easy. ix. Application: Low current, high voltage.	each of any two Characteristics = 2 Marks
	e)	Differentiate between bank of three single phase transformer and single unit of three phase transformer on any two parameters. **Ans:** **Difference Between Bank of Three Single Phase Transformer And Single Unit of Three Phase Transformer:**	Each point 1 Mark (any Two parameters) = 2 Marks

Parameter	Bank of 3 single phase transformers	Single unit Three phase transformer
(i)No. of cores	Three	One
(ii)Space occupied	More	Less
(iii)Weight	More	Less
(iv)If one of the phase is inoperative	Operated as open delta or V-V type transformer with reduced capacity	Inoperative

	f)	Write down any two applications of single Phase auto transformer **Ans:** **Application of Single Phase Auto-Transformer:** 1. Give small boost to distribution cable to correct the voltage drop. 2. As furnace supply transformer to give variable voltage as required 3. As interconnecting transformers in 132 kV/ 33 kV systems. 4. In control equipment for single phase locomotives. 5. As dimmer in lighting circuits.	1 Mark for each of any two Application = 2 Marks
	g)	State any one advantage and any one disadvantage of potential transformer. **Ans:** **Advantages of Potential Transformer:** 1. The capacitive potential transformer is used in measurement of higher voltages. 2. The potential transformer enables the ordinary voltmeter to measure very high voltages. 3. The potential transformer offers electrical isolation between voltmeter and very high voltage power lines. 4. A single potential transformer can be used to control several instruments. 5. Potential transformer facilitates detection of certain faults in power system, hence used in protection circuit. **Disadvantages of Potential Transformer:** 1. The Potential transformer can only be used in measurement of AC voltage. It cannot be used for measurement of DC voltage. 2. The potential transformer is more expensive than the ordinary transformer.	1 Mark each of any one Advantage and one Disadvantage = 2 Marks
2.		**Attempt any <u>THREE</u> of the following:**	**12 Marks**
	a)	Draw a neat schematic diagram of all types of D.C Machine. **Ans:** **Schematic Diagram of All Types Of D.C Machine:**	



1 Mark for Each Type = 4 Marks

b) Give one function and material used for the following parts of D.C motor: -

i). Yoke
ii). Pole Shoe
iii). Armature winding
iv). Brush

Ans:

Part	Function	Material
Yoke	-Provides mechanical support for poles -Acts as protecting cover for machine -Provides path for magnetic flux	Cast Iron OR Cast Steel
Pole shoe	To spread the flux in air gap.	Cast Iron OR Cast Steel
Armature winding	To conduct current and interact with magnetic field to produce torque.	Copper or aluminium
Brushes	To supply and collect current from armature winding.	Carbon

½ Mark for Function and ½ Mark for Material for each of four Parts = 4 Marks

c) State and explain significance of back emf in D.C motor.

Ans:

Back emf:

When the armature of DC machine rotates under the influence of driving torque, the armature conductors move in the magnetic field and cut it. According to Faraday's law of electromagnetic induction, an emf is induced in them. The induced emf acts in opposite direction to the applied voltage as per Lenz's law. Hence known as back or counter emf E_b.

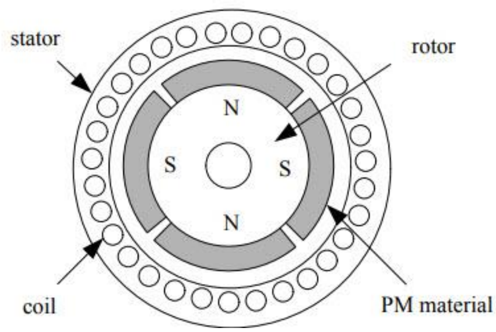
2 Marks

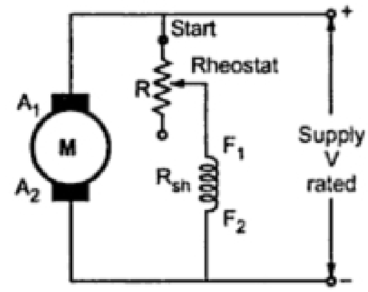
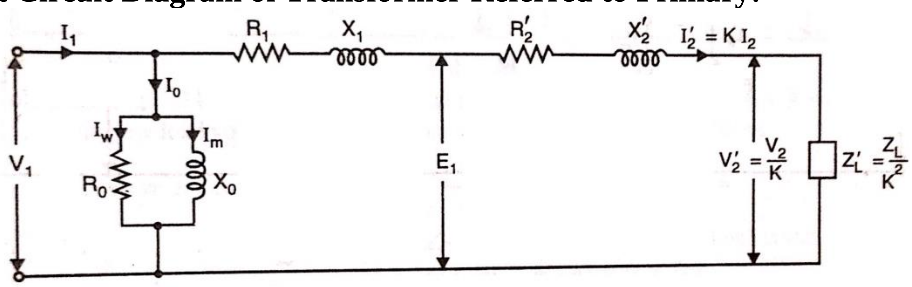
Significance of back emf:

$$\text{Armature current, } I_a = \frac{V - E_b}{R_a}$$

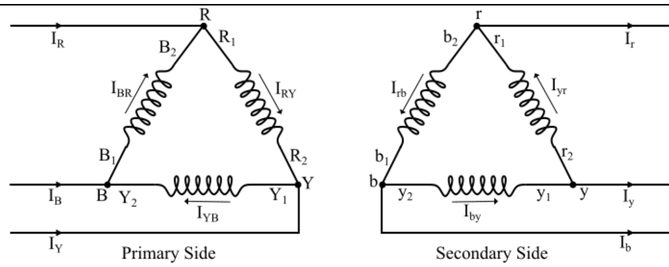
i) If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore the speed of armature is reduced. Hence back emf falls. This allows a larger current flow through armature means increased driving torque, thus the driving torque increases as motor slows down.

2 Marks

		ii) If load on motor is decreased, the driving torque is momentarily in excess so armature is accelerated and armature speed increases, which increases back emf and causes armature current to decrease. It follows therefore that back emf in DC motor regulates the flow of armature current i.e. it automatically changes the armature current to meet load requirements.	
	d)	With the help of neat diagram, explain the construction of the BLDC. **Ans:** **Construction of the BLDC:**  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). **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.	1 Mark for Diagram 3 Marks for Construction
3.		**Attempt any THREE of the following:**	**12 Marks**
	a)	With help of neat circuit diagram, describe the procedure to vary the speed of D.C shunt motor above normal speed. **Ans:**	

		Speed Control of DC Shunt Motor By Field Current Control Method: The back emf induced in the armature winding of DC motor is given by, $E_b = \frac{\emptyset ZN}{60}\frac{P}{A}$ volt Since Z, P, A are constants, $E_b \propto \phi N$ i.e $N \propto E_b/\phi$ Since $E_b \cong$ Supply voltage V, we can write $N \propto 1/\phi$, thus the speed is inversely proportional to the flux.  In this flux control method, speed of the motor is inversely proportional to the flux. Thus, by decreasing flux the speed can be increased. To control the flux, here a rheostat is added in series with the field winding. When the rheostat is increased, the field current and so the magnetic flux decreases. This results in an increase in the speed of the motor. Since the speed is inversely proportional to the flux or field current, the graphical representation curve showing relationship between speed and field current is hyperbola. The field current is relatively small and hence I^2R loss in field winding is less, which makes this method quite efficient. With zero value of rheostat, the motor runs at rated speed and when rheostat is increased, the field current decreases and speed increases. Thus this method controls the speed above normal or rated speed.	2 Marks for circuit diagram 2 Marks for explanation
	b)	Draw neat diagram for equivalent circuit of transformer. **Ans:** **Equivalent Circuit Diagram of Transformer Referred to Primary:**  V_1 -Primary Input voltage I_1 - Input Current I_0- Exciting current/ No load current I_m- Magnetizing component of no load current I_w-Working component of no load current R_0- Core loss resistance X_0- magnetizing reactance R_1 -Primary winding resistance X_1 - Primary winding reactance E_1 –Induced emf in Primary winding R_2' - Secondary winding resistance referred to primary X_2'- Secondary winding reactance referred to primary	2 Marks for Equivalent circuit 2 Marks for terminology

		I_2-Secondary winding current I_2'– Primary equivalent of secondary current K- Transformation ratio V_2- Secondary terminal voltage V_2'- Primary equivalent of secondary terminal voltage Z_L– Load impedance Z_L'- Primary equivalent of load impedance **OR** **Any Other Equivalent Answer**	
	c)	Single phase transformer has 1000 turns on primary and 200 turns on secondary calculate the primary current when secondary current is 280 amperes at p.f. of 0.8 lag. **Ans:** **Data Given:** $N_1 = 1000, N_2 = 200, I_2 = 280A$ $Transformation\ ratio\ k = \frac{N_2}{N_1} = \frac{I_1}{I_2}$ $k = \frac{200}{1000} = \frac{I_1}{280} = 0.2$ $\therefore I_1 = \mathbf{56\ A}$	2 Marks for k 2 Marks for stepwise calculation
	d)	A 30KVA, 2400/120V, 50 Hz, single phase transformer HV winding resistance 0.1 ohm and leakage reactance 0.22 ohm. The LV winding resistance is 0.035 ohm and reactance 0.012 ohm. Find equivalent resistance, reactance and impedance referred to HV side. **Ans:** **Equivalent resistance, reactance and impedance referred to HV side:** Transformation ratio, $k = \frac{120}{2400} = 0.05$ $R_2' = \frac{R_2}{K^2} = \frac{\mathbf{0.035}}{(\mathbf{0.05})^2} = \mathbf{14}\Omega$ $X_2' = \frac{X_2}{K^2} = \frac{\mathbf{0.012}}{(\mathbf{0.05})^2} = \mathbf{4.8}\ \Omega$ $R_{1T} = R_1 + R_2' = 0.1 + 14 = \mathbf{14.1}\ \Omega$ $X_{1T} = X_1 + X_2' = 0.22 + 4.8 = \mathbf{5.02}\Omega$ $Z_{1T} = \sqrt{{R_{1T}}^2 + {X_{1T}}^2} = \sqrt{14.1^2 + 5.02^2} = \mathbf{14.97}\ \Omega$	1 Mark for R_2' 1 Mark for X_2' 1 Mark for R_{1T} & X_{1T} 1 Mark for Z_{1T}
4.		**Attempt any THREE of the following:**	**12 Marks**
	a)	Draw a neat winding connection of Delta Delta for three phase transformers. Also give any two advantages of the same. **Ans:** **Winding connection of Delta Delta Three phase transformer:**	



2 Marks for winding diagram

Advantages of Delta Delta connection of three phase transformer:

i) The delta-delta connection can be used for both balanced and unbalanced loads.

ii) If the third harmonic is present, it circulates in the closed path of the delta loop and does not appear in the output voltage.

iii) In order to get secondary voltage as sinusoidal, the magnetizing current of transformer must contain a third harmonic component. The delta connection provides a closed path for circulation of third harmonic component of current. The flux remains sinusoidal which results in sinusoidal voltages.

iv) Even if the load is unbalanced the three phase voltages remains constant. Thus it allows unbalanced loading also.

v) The important advantage with this type of connection is that if there is bank of single phase transformers connected in delta-delta fashion and if one of the transformers is disabled (failed) then the supply can be continued with remaining two transformers of course with reduced capacity and efficiency.

vi) There is no distortion in the secondary voltages.

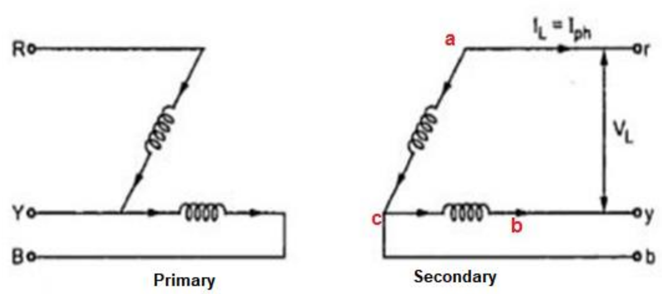
vii) Due to delta connection, phase voltage is same as line voltage hence winding have more number of turns. But phase current is (1/√3) times the line current. Hence the cross-section of the windings is very less. This makes the connection economical for low voltages transformers.

1 Mark for each of any two advantages = 2 Marks

b) Draw a neat connection diagram of open delta three phase transformer and give any two disadvantages of this connection.

Ans:

Open delta Three phase transformer connection:



2 Marks for winding connection diagram

Disadvantages:

1. While the line to line voltages are equal, the line to neutral (phase) voltages are not symmetrical, two phase voltages are equal but remaining phase voltage is 1.732 times larger.
2. Unbalanced single phase loads can cause voltage fluctuations and additional, uneven transformer heating.
3. An open delta connection only has 58% of the capacity of a full set of three transformers, that is a 42% decrease in actual capacity event though the installed capacity only drops

1 Mark for each of any two disadvantages = 2 Marks

by 33%.

c) Compare the distribution transformer and power transformer on the following parameters:-

i) Typical voltages
ii) Power rating
iii) Maximum efficiency
iv) Type of efficiency

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)
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 = 4 Marks

d) A 10 kVA, 1 phase, 50Hz, 500/250 V transformer gave following result.

OC test- (LV side)- 250 V, 3 A, 200 W (HV open)

SC test- (HV side)- 25 V, 20 A, 300 W (LV shorted)

Calculate efficiency and regulation at full load 0.8 pf lagging.

Ans:

Data Given:

Transformer rating S = 10 kVA, Voltage rating: 500/250V

From O.C. test: Iron loss P_i = 200W

From S.C. test: Full-load Cu loss P_{cu} = 300 W

Efficiency at Full load at 0.8 pf lagging:

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

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

$$= \frac{8000}{8500} = 0.9412$$

$$= \mathbf{94.12\%}$$

2Marks for stepwise solution for efficiency

Regulation at Full load at 0.8 pf lagging:

$K = V_2/V_1 = 250/500 = 0.5$

Full load primary current $I_{1\ F.L.} = (10 \times 1000)/500 = 20$ A

From S.C.test: $Z_{T1} = V_{SC}/I_{SC} = 25/20 = 1.25\ \Omega$

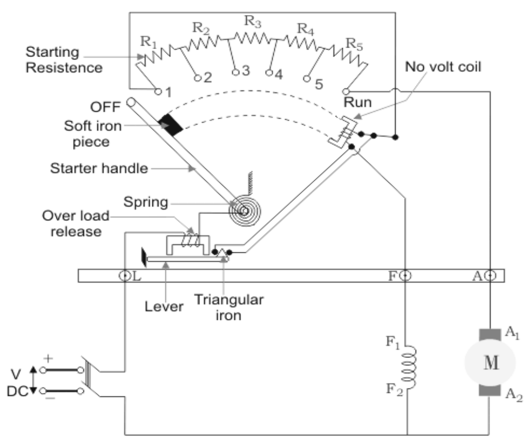
$R_{T1} = W_{SC}/(I_{SC})^2 = 300/(20)^2 = 0.75\ \Omega$

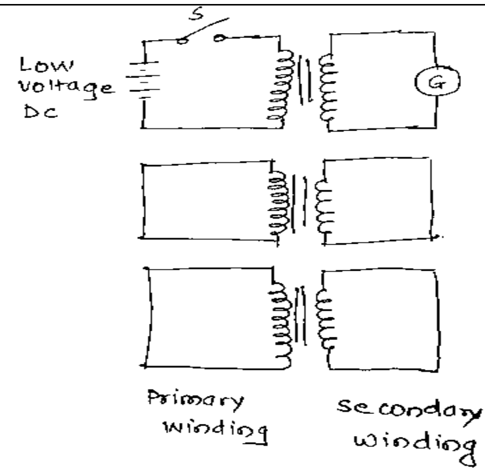
$X_{T1} = \sqrt{(1.25^2 - 0.75^2)} = 1\ \Omega$

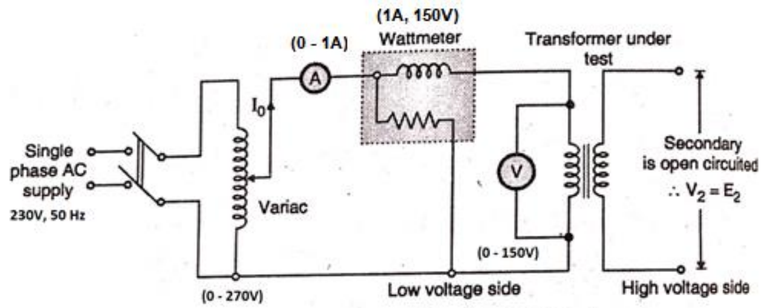
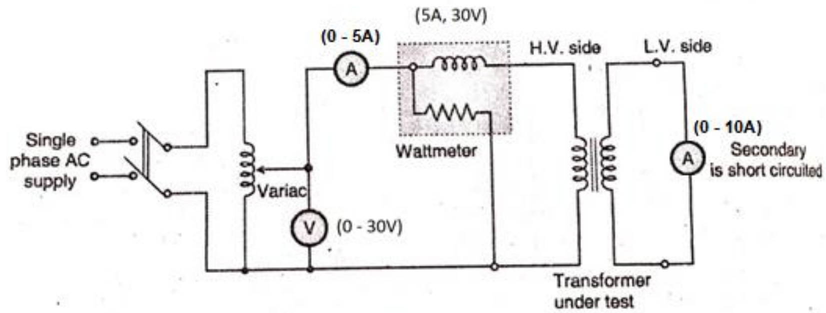
% Regulation = $100 \times I_{1FL}(R_{T1}\cos\varphi + X_{T1}\sin\varphi)/V_1$

$= 100 \times 20(0.75 \times 0.8 + 1 \times 0.6)/500$

2 Marks for stepwise solution for regulation

		= **4.8%**	
	e)	Why secondary of a CT should never be kept open? Explain the reason in detail. **Ans:** 1. The secondary winding of C.T. has a large no. of turns of thin wire. 2. The secondary winding of C.T. should never be open circuited, otherwise there will be no secondary current and no secondary mmf. 3. The secondary mmf opposes primary mmf and as there is no secondary mmf, the opposition is zero. Primary mmf will produce a large flux in core. 4. It would produce high eddy current and hysteresis losses. 5. It would increase the temperature of the core which may result in damage of insulation & core. 6. High voltage will be induced in open circuited secondary and this may be dangerous to the equipment and personnel.	1 Mark for no sec mmf 1 Mark for large prim mmf 1 Mark for high iron losses 1 Mark for high voltage in open sec
5		**Attempt any <u>TWO</u> of the following:**	**12 Marks**
5	a)	Draw a neat labeled diagram of three-point starter and state the function of no volt coil present in it. **Ans:** **Three Point Starter:**  Three Point Starter **Function of No-volt Coil:** When supply fails, the no-volt coil current becomes zero, its magnetism is lost and it releases the starter handle so that by spring tension it goes to off position and motor is disconnected from the supply. On recovery of supply, one has to restart the motor using the starter. Thus the dc motor is prevented from restarting automatically on recovery of supply without starter and protected.	4 Marks for labelled diagram (Marks may be reduced appropriately for unlabeled diagram) 2 Marks for function of No-volt coil
5	b)	State the necessity of phasing out test on a three phase transformer and describe its procedure with the help of neat diagram. **Ans:** **Necessity of phasing out test :** To identify the respective primary & secondary winding of a particular phase in 3-ph transformer. **Phasing out Test:** i) This test is carried out on 3-ph transformer to identify primary & secondary winding belonging to the same phase.	1 Mark for necessity 2 Marks for diagram

		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.	3 Marks for procedure
5	c)	Explain need of parallel operation of transformer. **Ans:** **Need of parallel operation of transformer:** **i) To maximize electrical power system efficiency:** Generally electrical power transformer gives the maximum efficiency at full load. If we run numbers of transformers in parallel, we can switch on only those transformers which will give the total demand by running nearer to its full load rating for that time. When load increases, we can switch on another transformer connected in parallel to fulfill the total demand. In this way we can run the system with maximum efficiency. **ii) To maximize electrical power system availability:** If numbers of transformers run in parallel, we can shut-down any one of them for maintenance purpose. Other parallel transformers in system will serve the load without total interruption of power. **iii) To maximize power system reliability:** If any one of the transformers run in parallel, is tripped due to fault of other parallel transformers is the system will share the load, hence power supply may not be interrupted if the shared loads do not make other transformers over loaded. iv) **To maximize electrical power system flexibility:** There is always a chance of increasing or decreasing future demand of power system. If it is predicted that power demand will be increased in future, there must be a provision of connecting transformers in system in parallel to fulfill the extra demand because, it is not economical from business point of view to install a bigger rated single transformer by forecasting the increased future demand as it is unnecessary investment of money. Again if future demand is decreased, transformers running in parallel can be removed from system to balance the capital investment and its return.	2 Marks for each of any three points = 6 Marks
6		**Attempt any <u>TWO</u> of the following:**	**12 Marks**
6	a)	Draw circuit diagram to conduct OC and SC test on a 1 kVA, 230/115V, 50 Hz single phase transformer. Justify the meter ranges also.	

		Ans:  **Set up for the O.C. test**  **Experimental set up for S.C. test** **Selection of Ranges of Meters:** **1) OC Test:** In OC test, Low Voltage (LV) side is operated as primary and high voltage side is kept open. The no-load current of transformer is less than 10% of full-load current. The full-load current on LV side is $\frac{1\times1000}{115} = 8.69A$. Under no-load condition, LV side current will be less than 10% of 8.69A i.e 0.869A. To measure this current the ammeter of range (0 – 1A) can be used. Since rated voltage is supplied to winding under OC test, the supply voltage will be 115V. To measure this voltage, the voltmeter of range (0 - 150V) can be used. To measure the input power, depending upon the current and voltage, the low power factor (LPF) wattmeter of the range (1A, 150V) can be used. Since under OC test, the circuit is only magnetizing type i.e highly inductive, the low-power-factor (LPF) wattmeter is used. **2) SC Test:** In SC test, the High Voltage side is operated as primary and LV side is short-circuited. The windings carry full-load currents. The current on HV side will be $\frac{1\times1000}{230} = 4.34A$. To measure this current, an ammeter of range (0 – 5A) can be used. Under SC condition, supply voltage required to circulate full-load currents through the windings are @ 10% of rated voltage. Thus the voltage supplied on HV side will be @ 22V. To measure this voltage, the voltmeter of range (0 – 30V) can be used. To measure input power, the wattmeter of range (5A, 30V) can be used. If secondary (LV) is short circuited through ammeter, since its full-load current rating is $\frac{1\times1000}{115} = 7.68A$, the ammeter range should be (0 – 10A).	1½ Mark for OC test circuit diagram 1½ Mark for SC test circuit diagram 1½ Mark for justification of OC test meters 1½ Mark for justification of SC test meters
6	b)	Explain in detail any four cooling methods of three phase transformer. **Ans:** **Methods of cooling of transformer:** **1. Air Natural (A.N):-**	

		• This type of cooling is used for small dry type transformers. • The air in the surrounding vicinity of the transformer is used for cooling. • This type is suitable for transformers upto a rating of 25KVA. **2. Air Forced (A.F):-** • This type of cooling is suitable for dry type transformers of slightly higher ratings. • The air is forced upon the bank surface to increase the rate of heat dissipation. **3. Oil Natural Air Natural (O.N.A.N):-** • This type of cooling is used for transformer upto rating of 30MVA. • The basic structure of transformer is immersed completely in the oil kept in transformer tank. • When transformer gets loaded, the windings & core gets heated, the generated heat absorbed by the oil as per the principle of convection. • The heated oil is being cooled by the natural air. Effective cooling of oil is made by providing cooling tubes to transformer tank. **4. Oil Natural Air Forced (O.N.A.F):-** • In this method the transfer of heat from the various parts of transformer takes place naturally like O.N.A.N, however the cooling fans are used which are mounted below or near the transformer, the forced airs from these fans are directed to the cooling tubes of transformer tanks. These improve the rate of cooling. **5. Oil Forced Air Forced(O.F.A.F):-** • This type of cooling is used for the transformers of ratings above 60MVA. • A separate cooler is mounted away from the transformer tank which is connected through pipes at the bottom & top • The oil is circulated from transformer to the cooler with the help of an oil pump. This oil is then subjected to forced air cooling with the help of fans installed inside the cooler. • It is used for transformers having high rating used in substation & power station. **6. Oil Forced Water Forced Cooling(O.F.W.F):-** • This type of cooling is used for the large transformers and cooling needs a heat exchanger. • Inside heat exchanger the heat from the oil is transferred to the cooling water. • The cooling water is taken away & cooled in separate coolers. The oil is forced to circulate through the heat exchanger by using a pump. • It is used for transformers having higher rating which is in MVA. (e.g. in Generating station)	1½ Mark for each of any four methods = 6 Marks
6	c)	i) Define all day efficiency. **Ans:** **All day efficiency:** It is the ratio of output energy in kWh to the input energy in kWh in the 24 hours of the day. $\text{All Day Efficiency} = \dfrac{\text{Output energy in kWh in 24 hrs}}{\text{Input energy in kWh in 24 hrs}}$	1 Mark
	c)	ii) The 10 kVA transformer has full load efficiency of 96 percentage. The copper and iron losses at full load are equal. Loading schedule of the transformer is given below. Calculate the all day efficiency.	

Loading	No load	Full load	Half load	Quarter load

Number of hours	10	2	5	7

Ans:

Data Given: Rating of T/F = 10 kVA Full load efficiency = 0.96 = 96%

Considering unity power factor, Efficiency at Full load at unity pf

$$\text{Efficiency}_{FL} = \frac{\text{Output}}{\text{Input}}$$

$$\therefore \text{Input} = \frac{\text{Output}}{\text{Efficiency}_{FL}} = \frac{10\text{x}1}{0.96} = 10.41kW$$

$$\text{Total losses in transformer} = \text{Input} - \text{Output} = 10.41 - 10 = \mathbf{0.41kW}$$

Full load Cu loss Pcu = Iron loss P_i = $\frac{\text{Total losses}}{2} = \frac{0.41}{2}$ = **0.205 kW**

1 Mark for P_{cu} & P_i

No of Hrs	Load in KW	Copper Losses/hr = Losses at FL $\times\left(\frac{Actual\ KVA}{Rated\ KVA}\right)^2$	Total cu Losses in kwh	Total Iron losses
10	0	$0.205\ kw \times \left(\frac{0}{10}\right)^2$ = 0 kw	0×10 hr = 0	0.205kW× 24hr = 4.92 kWh
2	10	0.205	0.41	
5	5	0.051	0.256	
7	2.5	0.0128	0.0896	
			0.7556 Kwh	

2 Marks for P_{cu} in kWh

1 Mark for P_i in kWh

Total energy in 24 Hr = (10×0)+(2× 10)+(5×5)+(7×2.5) = **62.5 kWh**

$$\text{Efficiency}_{\text{All day}} = \frac{\text{Output Energy in 24 hrs}}{\text{Output Energy in 24 Hrs} + \text{Losses in 24 Hrs}}$$

$$= \frac{62.5}{62.5+0.7556+4.92} = \frac{62.5}{68.18} = 0.9167 = \mathbf{91.67}\%$$

1 Mark for all-day efficiency