Summer – 2017 Examinations

Model Answer **Subject Code: 17415 (DMT)**

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 should assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given 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 should give credit for any equivalent figure/figures drawn.

5) Credits to 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 (as long as the assumptions are not incorrect).

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:**	20
1 a)	State Fleming's right hand rule. **Ans:** **Fleming's Right Hand Rule:** Stretch out the first three fingers of your right hand such that they are mutually perpendicular to each other , *align* first finger in direction of magnetic field, thumb in direction of relative motion of conductor with respect to field *then* the middle finger will indicate the direction of EMF / current.	2 Marks
1 b)	Give the two functions of yoke in DC motor. **Ans:** **Functions of yoke in DC motor:** 1) Provides mechanical support for poles. 2) Acts as protecting cover for machine. 3) Provides path for magnetic flux.	1 Mark for each function (any two) =2 Marks
1 c)	State the principle of operation of a dc motor. **Ans:** **Principle of operation of a dc motor:** When a current carrying conductor is placed in a magnetic field, the conductor experiences the mechanical force. The magnitude of force is given by F = BIL newton where F – Force , B – Maximum flux density , I – Current , L – Active length of conductor	2 Marks
1 d)	Write voltage equation & power equation of DC motor. Ans: **Voltage equation:** 1) $V = E_B + I_A.R_A$ (for DC shunt motor) V = applied voltage ,volts, E_B = back emf generated (volts), I_A = armature current (Amperes), R_A = armature winding resistance in ohms. 2) $V = E_B + I_A(R_A + R_S)$ (for DC series motor) R_S = series winding resistance in ohms	Any one voltage equation 1 Mark
	Power equation: 1) $VI = E_B I_A + (I_A)^2 R_A + (I_{SH})^2 R_{SH}$ (for DC shunt motor) V = applied voltage (volts), I = current drawn by motor from supply (amperes), E_B = back emf generated (volts), I_A & I_{SH} = armature & shunt field currents respectively (amperes), R_A & R_{SH} = armature & shunt field winding resistances respectively (ohms). 2) $VI = E_B I + I^2(R_A + R_S)$ (for DC series motor) R_S = series winding resistance in ohms (some students may give the relevant equations for the compound motors for which they should be awarded marks)	Any one power equation 1 Mark

1 e) How will you change the direction of rotation of a d.c.motor?

Ans:

(i) By reversing direction of only Armature current.
(ii) By reversing the direction of only field current.

1 Mark for each method = 2 Marks

1 f) A dc motor operating on a supply voltage of 200V dc has armature resistance of 0.5Ω. If armature current is 25A, Calculate the back emf.

Ans:

$E_b = V - I_a R_a$ 1Mark

= 200 – 25× 0.5

= **187.5 volts** 1Mark

1 g) Define:

i) Transformation Ratio ii) Turns Ratio related to 1-ϕ transformer.

Ans:

i)Transformation Ratio:

It is defined as ratio of secondary voltage to primary voltage or secondary turns to primary turns or primary current to secondary current. 1Mark

ii)Turns Ratio:

It is defined as ratio of secondary turns to primary turns or primary turns to secondary turns. 1Mark

1 h) State working principle of a transformer.

Ans:

Working principle of a transformer:

The transformer operates on the principle of mutual induction. 1 Mark

When ac supply is applied to primary it circulates ac flux in core which is going to link with secondary. The changing linking flux with secondary produces emf in secondary . 1 Mark

1 i) Name the two components of no load current I_o of 1-ϕ transformer and also write down their formulae.

Ans:

i) Active or working or iron loss component 1Mark

$I_w = I_o \cos\phi_0$

i) Magnetizing component

$I_\mu = I_o \sin\phi_0$ 1Mark

1 j) State the condition for maximum efficiency for single phase transformer.

Ans:

Condition for maximum efficiency for single phase transformer:

Iron loss = Copper loss **OR** Constant loss = Variable loss 2 Marks

1 k) State any two advantage of three phase transformer over a bank of three single phase transformer.

Ans:

Advantages of three phase transformer over bank of single phase transformers:

For identical magnitudes of power transformation,

i) Saving in copper conductor. 1 Mark for

ii) Saving in electromagnetic core material.
iii) Compact arrangement (Lower space required)
iv) Saving in dielectric material such as insulating oil.
v) Saving in overall cost.
vi) Higher efficiency.

each (any two) = 2 Marks

1 l) Give any two advantages of star-star connection in 3-ϕ transformers.

Ans:

Advantages of star-star connection in 3-ϕ transformers:

1. It is possible to use the transformer for 3-phase, four wire system because of neutral.
2. The phase shift between primary and secondary emfs is zero.
3. As phase current equal line current, windings have to carry large currents; hence can be used for supplying large load currents.
4. As phase voltage is 1/√3 times line voltage, the no.of turns required for primary and secondary are less, hence economical.

1Mark for each of any two advantages

2 **Attempt any FOUR of the following:** 16

2 a) Distinguish between lap and wave winding. (Any four points).

Ans:

Sr. No.	Lap winding	Wave winding
1	No. of parallel paths(A) is equal to No. of poles(P).	No. of parallel paths(A) is equal to two(2).
2	No. of brushes = No. of poles	No. of brushes = 2.
3	Current in each conductor = I_a/A	Current in each conductor = $I_a/2$
4	Coil overlaps hence name is lap winding.	Coil travels in the form of wave hence name is wave winding.
5	Dummy coil is not required.	Dummy coil may be required.
6	Resultant pitch $Y_R=Y_B-Y_F$ (Difference of Y_B and Y_F)	Resultant pitch $Y_R=Y_B+Y_F$ (Sum of Y_B and Y_F)
7	Y_C (Commutator pitch) = ±1	Y_C (Commutator pitch) = $Y_R/2$
8	Used for high current, low voltage applications	Used for low current, high voltage applications

1 Mark for each of any four points

2 b) Determine the flux per pole of a six pole generator required to generate 240V at 500rpm. The armature winding has 1080 conductors and are lap connected.

Ans:

Stepwise solution 4 Marks

$$E_g = \frac{\emptyset ZNP}{60A}$$

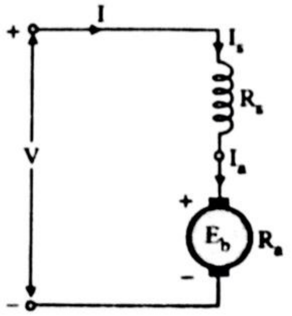
$$\therefore \emptyset = \frac{E_g \times 60A}{ZNP} = \frac{240\times60\times6}{1080\times500\times6} = 0.02667\ Wb$$

2 c) Draw the circuit diagram of

i) DC series motor.
ii) DC long shuntcompound motor.
Also write down the related equation.

Ans:

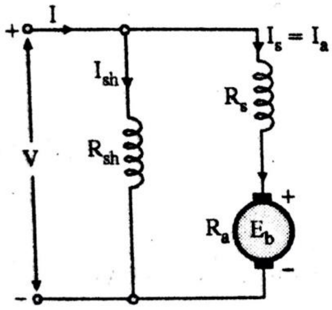
i) DC series motor: 1 Mark for each diagram



1. Total current $I = I_s = I_a$
2. Supply voltage $V = E_b + I_a(R_a + R_s) + V_{brush}$
3. Flux $\phi \propto I_a$ or I_s
4. This is not a constant flux motor
5. Armature voltage $= E_b + I_a R_a + V_{brush}$

1 Mark for any one equation of each motor

ii) DC long shunt compound motor:



Long shunt compound DC motor

1. Total current $I = I_{sh} + I_s = I_{sh} + I_a$
2. Armature current $I_a = I_s$
3. Shunt field current $I_{sh} = V/R_{sh}$
4. Supply voltage $V = I_{sh} R_{sh}$
5. Supply voltage $V = E_b + I_a(R_a + R_s) + V_{brush}$

2 d) What is back emf in DC motor? Explain its significance.

Ans:

Back emf:

When the armature of DC motor rotates under the fixed magnetic field and cuts it, by Faradays law 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 $E_{b.}$ 1 Mark

Significance of back emf:

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

1 Mark

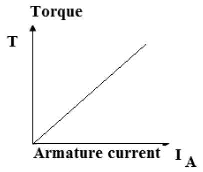
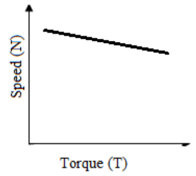
i) If the motor is at standstill or rest E_b is zero. This causes large current flow through armature, which produce high starting torque.
ii) When motor takes speed, the back emf increases, causes armature current to decrease hence decrease in torque.
iii) It follows therefore that back emf in DC motor regulates the flow of armature current i.e. it automatically changes the armature current to meet load requirements.

Significance 2 Marks

2 e) Draw and explain the following characteristics in DC shunt motor:
i) Torque vs Armature current.

ii) Speed vs Torque.

Ans:

Torque Vs Armature current	Speed Vs Torque
 	
$T_a \propto \phi . I_a$ Field current is constant Flux is also constant Therefore $T_a \propto I_a$ Hence the characteristic is straight line passing through zero.	$N \propto \frac{E_b}{\emptyset}$ The flux and back emf E_b are almost constant, hence the speed of shunt motor almost remains constant; however the speed drops with increase in load torque.

1Mark for each characteristic

1Mark for each explanation

2f) A 500V DC shunt motor takes a current of 5amp on no load. The resistances of the armature and field circuits are 0.5Ω and 250Ω. Calculate the efficiency when the motor takes a current of 100amp.

Ans:

$$No\ load\ Motor\ Input\ P_{in} = v \times I_{L0} = 500 \times 5 = 2500W$$

$$Shunt\ field\ current\ I_{sh} = \frac{v}{R_{sh}} = \frac{500}{250} = 2A$$

1 Mark

$$No\ load\ armature\ current\ I_{a0} = I_{L1} - I_{sh} = 5 - 2 = 3A$$

$$No\ load\ armature\ Cu\ loss (P_{cu0}) = I_{a0}^2 \times R_a = 3^2 \times 0.5 = 4.5W$$

$$Field\ Cu\ loss = field\ voltage \times field\ current$$

$$= 500 \times 2 = 1000W$$

$$P_{constant} = No\ load\ Motor\ Input - No\ load\ armature\ Cu\ loss - Field\ Cu\ loss$$

$$P_{constant} = 2500 - 4.5 - 1000 = 1495.5W$$

1 Mark

$$Full\ load\ armature\ current\ I_{a1} = I_{L1} - I_{sh} = 100 - 2 = 98A$$

$$Full\ load\ armature\ Cu\ loss (P_{cu1}) = I_{a1}^2 \times R_a = 98^2 \times 0.5 = 4802\ W$$

$$Total\ full\ load\ losses = armature\ Cu\ loss + fieldCu\ loss + constant\ loss$$

$$Total\ full\ load\ losses = 4802 + 1000 + 1495.5 = 7297.5W$$

1 Mark

$$Full\ load\ input\ power = input\ voltage \times current\ drawn\ by\ motor$$

$$P_{IFL} = 500 \times 100 = 50000W$$

∴Full-load efficiency is given by,

$$\%\eta_{FL} = \frac{motor\ input - losses}{motor\ input} \times 100$$

$$\%\eta_{FL} = \frac{50000 - 7297.5}{50000} \times 100 = 85.4\%$$ 1 Mark

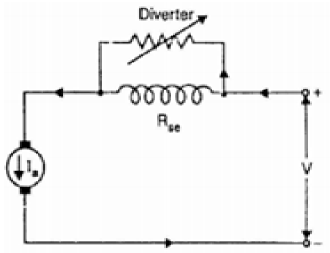
3 **Attempt any FOUR of the following**: 16

3 a) With the help of neat diagrams,explain the following methods of speed control in DC series motor.

i) Field diverter method.
ii) Armature diverter method.

Ans:

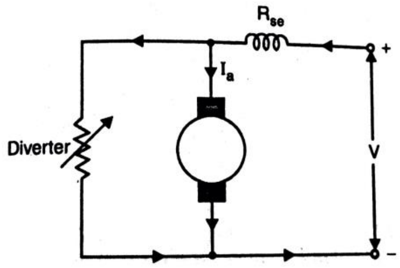
(i) Field diverter method:



- Resistance connected in parallel with field winding
-By adjusting this resistance current can by diverted from field winding
-Thus field current decreases and the speed can be increased above rated speed.

2Marks

(ii) Armature diverter method:



-Resistance is connected in parallel with armature winding.
-This diverter resistance shunts some of the line current, thus reducing armature current.
-Now for a given load if armature current decreased, the flux must increase and hence speed is decreased than the rated speed.

2 Marks

3 b) Give the classification of transformer based on:

i) Construction
ii) Voltage level
iii) Number of phases
iv) Applications

Ans:

Classification of transformer based on:

i) Construction:
Shell type, Core type, Berry type
ii) Voltage level:
Step-Up, Step-Down,
iii) Number of phases:
Single phase, Three phase
iv) Applications:
Power T/F, Distribution T/F

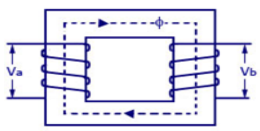
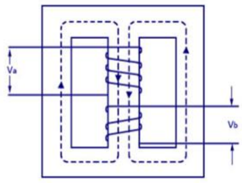
1 Mark for each classification = 4Marks

3 c) Compare core type and shell type transformer on any four parameters.

Ans:

Comparision of core type and shell type transformer:

Sr. No.	Core type	Shell type

1		
2	It has one window	It has two windows
3	It has one magnetic circuit.	It has two magnetic circuits.
4	Core surrounds the winding.	Winding surrounds the core
5	Average length of core is more.	Average length of core is less.
6	Area of cross section is less so more turns are required.	Area of cross section is more so less turns are required.
7	Better cooling for winding	Better cooling for core
8	Mechnical strength is less	Mechnical strength is high
9	Repair and maintenance is easy	Repair and maintenance is difficult
10	Application: Low current, high voltage	Application: High current, low voltage

1 Mark Each for any four differences = 4 marks

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3 d) Derive the emf equation of a transformer.

Ans:

Emf equation of transformer:

N_1 = No. of turns on primary winding

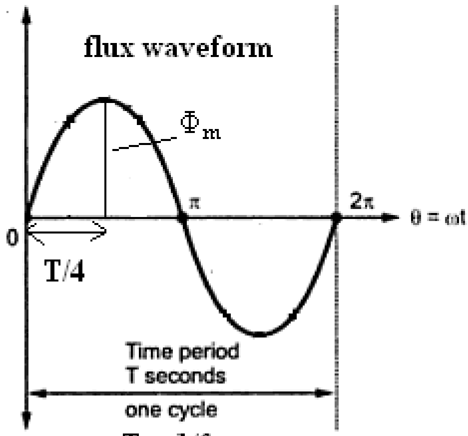
N_2 = No. of turns on secondary winding

Φ_m= maximum value of flux linking both the winding in Wb

F = Frequency of supply in Hz

1 Mark

1st method



T = 1/f

1 Mark

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

Avg. emf induced in each turn = Avg. rate of change of flux = $4\Phi_m f$ — 1 Mark

Form factor = (RMS value)/(Avg. value) = 1.11

R.M.S. emf induced in each turn = 1.11 x Avg. value = 1.11 x $4\Phi_m f$ — 1 Mark

= 4.44 Φm f volts

R.M.S. emf induced in primary winding = (RMS emf / turn) x N_1

$E_1 = 4.44\ \Phi_m f\ N_1$ volts

Similarly, $E_2 = 4.44\ \Phi_m f\ N_2$ volts

OR 2nd method

$\Phi = \Phi_m \sin \omega t$

According to Faraday's laws of electromagnetic induction

Instantaneous value of emf/ turn = - dΦ/dt = -d /dt ($\Phi_m \sin \omega t$)

= $-\omega\Phi_m \cos\omega t$ — 1 Mark

= $\omega\Phi_m \sin(\omega t - \pi/2)$ volts

Maximum value of emf/turn= $\omega\Phi_m$ — 1 Mark

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 — 1 Mark

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

3 e) Draw the connection diagram of Delta-star connection of 3-ϕ Transformer and give any two advantages and disadvantages of this connection.

Ans:

Connection diagram of Delta-star connected 3-ϕ Transformer:

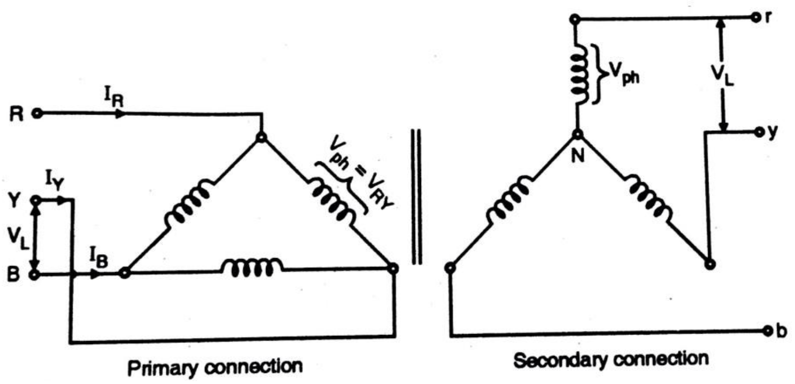


Diagram 2 Marks

Advantages:

i) As primary is connected in delta, distortion due to third harmonic is absent.

ii) Phase shift of 30^0 electrical is present between the primary and secondary line voltages and line currents.

Two Advantages 1 Mark

iii) Small cross section wire can be used on primary side due to delta connection.

iv) Due to availability of neutral on the secondary side, it is possible to use it for 3ph 4wire system.

Disadvantages:

i) In this type of connection, the secondary voltage is not in phase with the primary. Hence it is not possible to operate this connection in parallel with star-star or delta-delta connected transformer. — Two Dis-advantages 1 Mark

ii) One problem associated with this connection is that the secondary voltage is shifted by 30^0 with respect to the primary voltage. This can cause problems when paralleling 3-phase transformers since transformers secondary voltages must be in-phase to be paralleled. Therefore, we must pay attention to these shifts.

iii) If secondary of this transformer should be paralleled with secondary of another transformer without phase shift, there would be a problem.

iv) As line current is equal to phase current the conductor size of winding should be large.

3 f) A 3300/230V, 50Hz single phase transformer is to be operated at a maximum flux density of $1.2 Wb/m^2$ in the core. The effective cross sectional area of the transformer is $150 cm^2$. Calculate suitable values of primary and secondary turns.

Ans:

Cross sectional Area, $A=150 cm^2 = 150\times10^{-4}\ m^2$

Frequency f=50Hz, Max. flux density $B_m = 1.2 wb/m^2$

As $\Phi_m = B_m \times A = 1.2\times150\times10^{-4} = 0.018$Wb. — 1Mark

To find N_1;

$E_1 = 4.44\ \Phi_m f\ N_1$ volt

$3300 = 4.44\times0.018\times50\times N_1$

$N_1 = 826$ turns — 2Mark

$$N_2 = \frac{E_2}{E_1}\times N_1 = \frac{230}{3300}\times 826 = \mathbf{58\ turns}$$ — 1Mark

4 **Attempt any <u>FOUR</u> of the following**: 16

4 a) A 1-Φ Transformer with a ratio of 440/110 V takes a no load current of 5A at 0.2pf lagging. If the secondary supplies a current of 120Amp at a pf of 0.8 lagging, estimate the current taken by the primary.

Ans:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{110}{440} = 0.25$$ — 1Mark

$I_0 = 5A$, $\cos\Phi_0 = 0.2$ hence $\sin\Phi_0 = 0.98 \Phi_0 = 78.463^0$

I_2 = 120A, cos Φ_2= 0.8 hence sin Φ_2= 0.6Φ_2= 36.86^0 1 Mark

Therefore for load component I'_1 of primary current corresponding to I_2,

$I'_1N_1= I_2N_2$, i.e. $I'_1= k \times I_2 = 0.25 \times 120 = 30A$ 1 Mark

Using law of parallelogram;

$I_1^2= I'^2_1+I_0^2+2\times I'_1\times I_0\times \cos(\Phi_0- \Phi_2)$

$=(30)^2+(5)^2+[(2\times30\times5) \times\cos(78.46-36.86)]$

I_1 = 33.9A 1 Mark

OR any equivalent method to find I_1

4 b) 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:

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

$$R'_2 = \frac{R_2}{K^2} = \frac{0.009}{(0.005)^2} = \mathbf{3.6}\Omega$$

$$X'_2 = \frac{X_2}{K^2} = \frac{0.015}{(0.005)^2} = \mathbf{6}\Omega$$ 1Mark

$$R_{1T} = R_1 + R'_2 = 3.45 + 3.6 = \mathbf{7.05}\ \Omega$$

$$X_{1T} = X_1 + X'_2 = 5.2 + 6 = \mathbf{11.2}\ \Omega$$ 1 Mark

Equivalent resistance and reactance as referred to LV side:

$R'_1 = R_1 \times k^2 = 3.45 \times (0.05)^2 = 8.625 \times 10^{-3}\ \Omega$ 1 Mark

$X'_1 = X_1 \times k^2 = 5.2 \times (0.05)^2 = 0.013\ \Omega$

$$R_{2T} = R_{21} + R'_1 = 0.009 + 8.625 \times 10^{-3} = \mathbf{0.0176}\ \Omega$$

$$X_{2T} = X_2 + X'_1 = 0.015 + 0.013 = \mathbf{0.028}\ \Omega$$ 1 Mark

4 c) Efficiency of 400kVA, 1-Φ Transformer is 98.77%, when delivering full load at 0.8pf and it is 99.13% at half load unity pf. Calculate:

i) Iron loss
ii) Full load copper loss.

Ans:

$$Full\ load\ effciency, \eta_{FL} = \frac{KVA \times 1000 \times PF}{(KVA \times 1000 \times PF) + P_i + P_{cu}} \times 100$$

$P_i = Iron\ loss\ which\ is\ constant.$

$P_{cu} = Full\ load\ Cu\ loss$

$\therefore 0.9877 = \frac{400\times1000\times0.8}{(400\times1000\times0.8)+P_i+P_{cuFL}} = \frac{320000}{320000+P_i+P_{cuFL}}$

$\therefore P_i + P_{cuFL} = 3985W \ldots\ldots\ldots\ldots\ldots..(i)$ 1Mark

$$P_{cuHL} = \frac{1}{2}^2 \times P_{cuFL} = \frac{P_{cuFL}}{4}$$

$Effciency\ at\ Half\ load, \eta_{HL}$

$$= \frac{1/2 \times KVA \times 1000 \times PF}{(1/2 \times KVA \times 1000 \times PF) + P_i + P_{cuHL/4}}$$

$$= \frac{1/2 \times 400 \times 1000 \times 1}{(1/2 \times 400 \times 1000 \times 1) + P_i + \frac{P_{cuFL}}{4}}$$

$$P_i + \frac{P_{cuFL}}{4} = 1755.27W \ldots\ldots\ldots\ldots (ii)$$ 1Mark

Subtracting (ii) from (i) and solving we get,

$P_{cuFL} = 2973\ W\ \ and$ 1Mark

$P_i = 1012W$ 1Mark

4 d) Two 1-ϕ transformers with equal turns ratio have impedance of (0.5+j3) Ω and (0.6+j10) Ω with respect to secondary. If they are operated in parallel, determine how they will share a total load of 100kW at pf 0.8 lagging.

Ans:

$Z_A = (0.5 + j3) = 3.04 < 80.6^0$

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

$Z_A + Z_B = (1.1 + j13) = 13.05 < 85.2^0$ 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

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

$= 95.97 < -35.5^0$ 1 Mark

∴ Load shared by Transformer A in kW will be;

$kVA \times pf = 95.97 \times \cos(-35.5^0) = 78.2kW$

Similarly,

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

$= 29.11 < -41.5^0$ 1 Mark

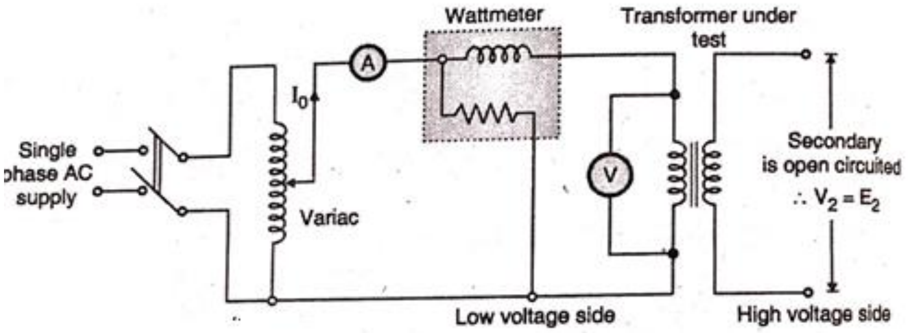
∴ Load shared by Transformer B in kW will be;

$kVA \times pf = 29.11 \times \cos(-41.5^0) = 21.8kW$

4 e) Draw a neat experimental set up to conduct OC test on a single phase transformer. Also give reason why it is preferable to conduct OC test on LV side?

Ans:

Experimental set up to conduct OC test:



Set up for the O.C. test

Diagram 3 Marks

The OC test is always made on the LV side of transformer. Of course iron losses will be the same if measured on either winding. But if measurement is made on HV side, current I_0 is inconveniently small and applied voltage is inconveniently large. 1Mark

4 f) Describe different losses in a transformer. And what measures should be taken to minimize them?

Ans:

Various Losses in Transformer:

i) 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

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

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

ii) 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 = $K_E B_m^2 f^2 T^2$

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. 1 Mark

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

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

Methods to minimize the losses:

i) The copper loss is minimized by using purest conducting material for winding so as to reduce its resistance. 1 Mark

ii) This loss is minimized using laminated core.

iii) This loss is minimized using special magnetic materials like Silicon Steel having small hysteresis loop area.

5 **Attempt any <u>FOUR</u> of the following** 16

5 a) Give any two advantages of parallel operation and any two conditions to be satisfied for parallel operation of 1-Φ transformers.

Ans:

Advantages of parallel operation of transformers:

i) Reliability of the supply system enhances.
ii) Highly varying load demands can be fulfilled.
iii) Loading only the relevant capacity transformer to operate at high efficiency.
iv) Overloading of transformers is avoided and hence of life of transformer increases.

Any two adv 1 mark each= 2 Marks

(Any related advantages should be considered)

Conditions for Parallel operation of 1 phase transformer:

1) Voltage ratings of both the transformers must be identical.
2) Percentage / p.u. impedances should be equal in magnitude.
3) X/R ratio of the transformer windings should be equal.
4) Transformer polarity wise connections must be carried out.

Any two conditions 1 mark each= 2 Marks

5 b) A 1 phase 50kVA, 2400/120V, 50Hz transformer gave following test results:-

OC Test(Instruments on LV side): 120V, 9.85A, 396W

SC Test(Instruments on HV side): 92V, 20.8A, 810W

Calculate:

i) The equivalent circuit constants
ii) Efficiency at rated kVA and 0.8pf lagging.

Ans:

To find R_0 and X_0 from OC test;

$$cos\emptyset_0 = \frac{W_0}{V_2 \times I_0} = \frac{396}{120 \times 9.85} = 0.335 \quad Hence\ \emptyset_0 = 70.42^0$$

$$R_0 = \frac{V_2}{I_0 \times cos\emptyset_0} = \frac{120}{9.85 \times 0.335} = 36.366\Omega$$

1Mark

$$X_0 = \frac{V_2}{I_0 \times sin\emptyset_0} = \frac{120}{9.85 \times 0.9422} = 12.93\Omega$$

To find R_{1T}, X_{1T} and Z_{1T} from SC test;

$$R_{1T} = \frac{W_{sc}}{I_{sc}^2} = \frac{810}{20.8^2} = 1.872\Omega$$

$$Z_{1T} = \frac{V_{sc}}{I_{sc}} = \frac{92}{20.8} = 4.423\Omega$$

2 Marks

$$X_{1T} = \sqrt{Z_{1T}^2 - R_{1T}^2} = \sqrt{4.423^2 - 1.872^2} = \sqrt{16.0585} = 4.0073\Omega$$

To find efficiency;

$\boldsymbol{P_i = 396W}$ $\boldsymbol{P_{cu} = 810W}$

Efficiency at full load;

$$\eta_{FL} = \frac{V \times I \times cos\emptyset_0}{V \times I \times cos\emptyset_0 + P_i + P_{cu}} \times 100$$

$$= \frac{50 \times 10^3 \times 0.8}{50 \times 10^3 \times 0.8 + 396 + 810} \times 100$$

$$= \mathbf{97.07}\%$$ 1Mark

5c) Find all day efficiency of 500kVA distribution transformer whose copper and iron losses at full load are 405kW and 3kW. It is loaded as under per day:

No. of hours	6	6	8	4
Load in kW	450	300	150	0
Power factor	0.9	0.75	1	-

Ans:

Step I: Convert the loading from kW to kVA

i) The loading of 450kW at 0.9 pf is equivalent to (450/0.9) = 500 kVA 1 Mark

ii)The loading of 300 kW at 0.75 pf is equivalent to (300/0.75)= 400 kVA

iii)The loading of 150 kW at 1pf is equivalent to (150/1)= 150 kVA

Step II: Caclulate copper losses at different kVA values:

i) Full load Cu loss i.e. for 500 kVA= 4.5kW is given which is for 6 hours. 1 Mark
ii) For 400 kVA= $(400/500)^2$ x 4.5kW= 2.88kW is for 6 hours
iii) For 150 kVA= $(150/500)^2$ x 4.5kW= 0.405kW is for 8 hours
iv) No Load for 4 hours

Total Energy loss due to Cu losses

E_{cu}= (4.5x6)+(2.88x6)+(0.405x8) = 47.52 kWh

Step III:Calculate Total Energy loss due to Iron Loss

The total energy loss due to iron loss in 24hrs

E_i = 3 x 24 = 72 kWh 1 Mark

Step IV:Output Energy

E_{out}= (450x6) + (300x6) + (150x8)= 5700 kWh

$$All - day\ efficiency\ \eta = \frac{Output\ Energy\ in\ 24\ hrs\ of\ a\ day}{Input\ energy\ in\ 24\ hrs\ of\ the\ day} \times 100$$

$$= \frac{Output\ Energy\ in\ 24\ hrs\ of\ a\ day}{[Output\ energy + Energy\ loss\ due\ to\ copper\ loss\ and\ Iron\ loss]\ in\ 24} \times 100$$

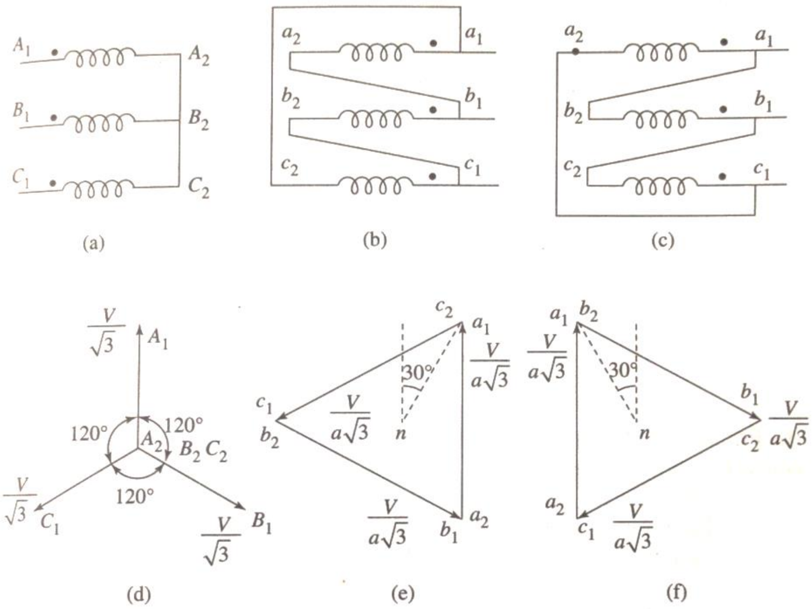
$$= \frac{5700}{[5700 + 47.52 + 72]} \times 100$$

1 Mark

All day efficiency η=**97.946 %**

5d) Draw the connection diagram and phasor diagram of star-delta connection used for 3 phase transformer connection.

Ans:



Star–delta connection with phasor diagrams:
(a) primary winding star connection,
(b) secondary winding delta connection,
(c) secondary winding alternate delta connection,
(d) phasor diagram for primary winding,
(e) phasor diagram for secondary delta connection, –30° phase shift,
(f) phasor diagram for secondary alternate delta connection, +30° phase shift

Connection diagram(a &b or a & c) = 2 Marks

Phasor diagram (d & e or d & f) = 2 Marks

The terminals can be marked as R_1, R_2 for R-phase and so on for HV terminals and r_1-r_2 for R-phase and so on for LV terminals.

5 e) Compare Power and Distribution Transformer on the following parameters:
i)Typical voltages ii) Power Ratings iii)Size .
iv)Load
v)Insulation level
vi)Installation
vii)Maximum efficiency
viii)Type of efficiency

Ans:-

Parameters	Power Transformer	Distribution Transformer
i)Typical Voltages	400kV, 220kV, 110kV,66kV,33kV	11kV,6.6kV, 3.3kV, 440V, 230V
ii)Power Rating	Higher (> 1MVA)	Lower (< 1MVA)
iii)Size	Big	Small
iv)Load	Full load	50-70% of full load
v)Insulation Level	High	Low
vi)Installation	Being large capacity installation is difficult and generally in consumer's premises.	Being small capacity installation is easy and generally in public place.
vii)Maximum efficiency	Obtained near 100% of full load	Obtained near 50% of full load
viii)Type of efficiency	Only power efficiency is sufficient	All day efficiency needs to be defined

½ mark each = 4Marks

5 f) With the help of neat diagram, explain the procedure of phasing out test on 3 phase transformer.

Ans:-

-Short primary & secondary winding of other phases expect the one under test.

-Connect voltmeter to secondary winding.

-A small DC current is circulated through the primary winding through switch.

-Now with the help of switch interrupt the DC supply instantly & repeatedly.

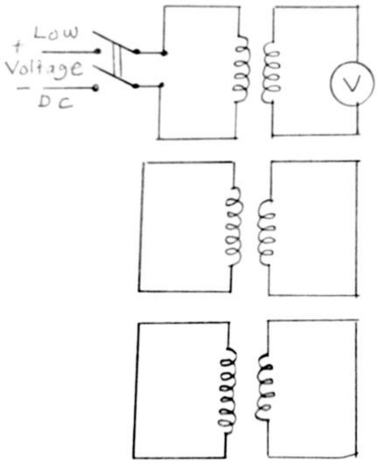


Diagram 2 Marks

-If voltmeter indicator deflects than it indicates the two windings concerned belong to the same phase.

-If not deflect then two windings are not belong to same phase.

-Repeat the procedure by connecting voltmeter to secondary side to next secondary winding till voltmeter gives deflection.

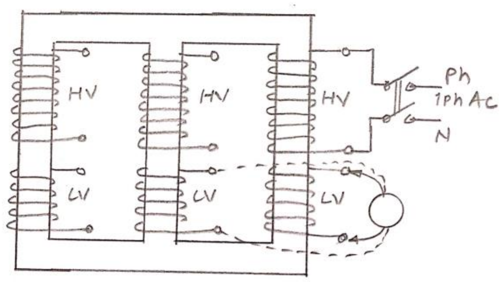
Explanation 2 Marks

-In this way we can search the phasing out.

OR

-This test is carried to find out the corresponding HV and LV phase winding.

-The circuit diagram is as shown in figure. Here normal ac voltage is applied to one of the HV or LV windings. In this case to HV winding and the voltages across all three LV windings are measured.



-The winding across which is much more compared to other two windings represents the secondary of the winding to which supply is connected.

-The test repeated for finding out remaining concerned secondary windings in the same manner.

6 **Attempt any <u>FOUR</u> of the following** 16

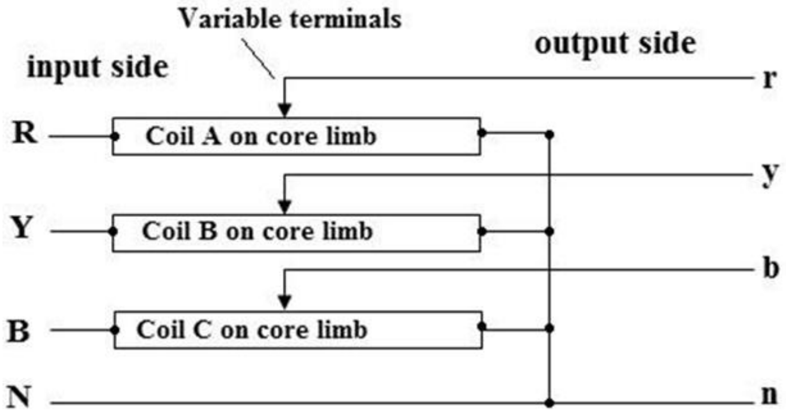
6 a) Describe the construction and operation of three phase autotransformer with the help of neat diagram.

Ans:

Construction and operation of three phase autotransformer:

Diagram 1

Mark



Construction: 1 Mark

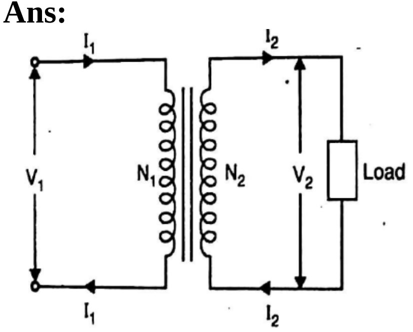
- The coils connected in star are placed on electromagnetic cores, each phase of auto-transformer consists of a single continuous winding common to primary and secondary circuit.
- The limbs (electromagnetic cores) are made of laminations (sheet steel with Silicon).
- The output terminal connections are gang operated to get identical tapings on all phases and are brought out on the insulated plate. The variable voltage may also be obtained by tapings (stepped voltage instead of smooth variations) to which the output terminals are connected as required.

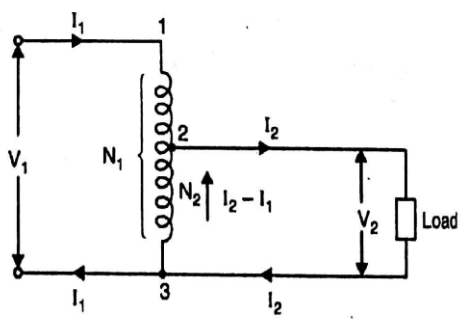
Operation:

- Working principle is based on self-induction.
- When three-phase ac supply is given to star connected three windings, flux is produced and gets linked with each phase winding. The emf is induced in it according to self-induction. 2 Mark
- As only one winding per phase is available, part of it acts as secondary between variable terminal and neutral.
- Depending upon the position of variable terminal, we get variable AC voltage at the output.

6b) Illustrate the saving in copper by using 1-Φ auto transformer instead of two winding transformer of the same rating by deriving proper expressions.

Ans:





1Mark

2-winding transformer **Autotransformer**

i)Two winding transformer

Weight of Cu required α $(I_1N_1 + I_2N_2)$ 1Mark

ii)Autotransformer

Weight of Cu required in section 1-2 α $I_1(N_1-N_2)$

Weight of Cu required in section 2-3 α $(I_2-I_1)N_2$

∴ Total weight of Cu required α $I_1(N_1-N_2)+(I_2-I_1)N_2$

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = \frac{I_1(N_1 - N_2) + (I_2 - I_1)N_2}{(I_1N_1 + I_2N_2)}$$ 1Mark

$$= \frac{I_1N_1 + I_2N_2 - N_2I_1 - N_2I_1}{(I_1N_1 + I_2N_2)}$$

Solving this we get,

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = 1 - \frac{N_2}{N_1} = 1 - K$$ 1Mark

$$\therefore \text{Weight of Cu in autotransformer}(W_a) = \left[(1-K)\left(\text{Weight of Cu in ordinary transformer}(W_o)\right)\right]$$

∴ Saving in Cu= $(W_o-W_a)= W_o- (1-K)W_o=K\ W_o$

6 c) With the help of neat diagram, explain the construction of current transformer.

Ans:

Construction of current transformer:

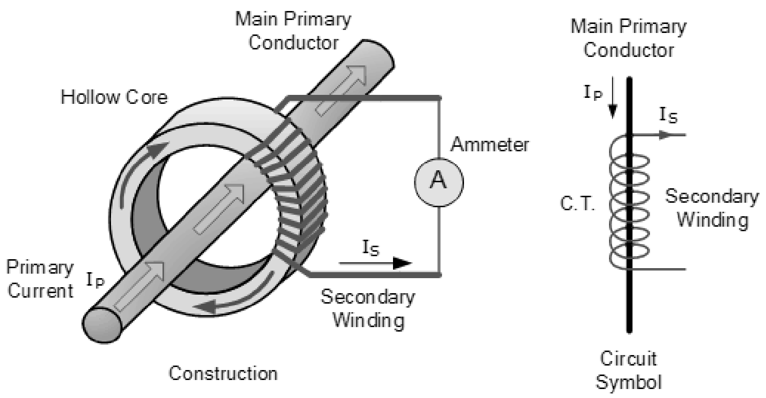


Diagram 2 Marks

- C.T. has bar type conductor, which behaves as primary winding.
- The primary of C.T. carries large current I_p which is to be measured, so the bar is of large cross sectional area.
- The secondary of C.T.is made up of large number of turns. It is wound on core. The secondary winding is a low current winding. Hence its cross sectional area is small. An ammeter of small range is connected across the secondary as shown in figure.

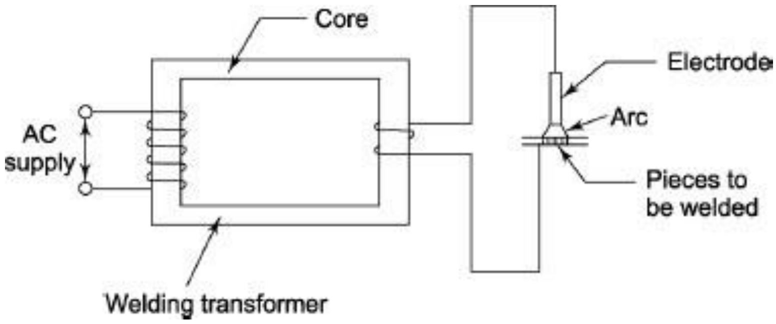
Construction 2 Marks

6 d) Draw schematic diagram of welding transformer showing constructional features of a welding transformer. Also explain its working.

Ans:

Constructional features of welding transformer:

2Marks



Working of welding transformer:

i) It is a step down transformer that reduces the voltage from the source voltage to a voltage desired according to the demands of the welding process.

working 2Marks

ii) Winding used is highly reactive or a separate reactor winding is added in series with the secondary winding.

iii) Having large & thin primary turns and low number but thick secondary turns.

iv) The secondary current is quite high. One end of secondary is connected to welding electrode while other end to the pieces to be welded.

v) Due to the contact resistance 'R' between the electrode and pieces to be welded a very high current flows creating high heat by I^2R that melts the tip of the electrode. The melted tip flows / fills the gap between the pieces to be welded creating a solid weld on cooling.

vi) The secondary has several taps for adjusting the secondary voltage to control the welding current.

vii) The transformer is normally large in size compared to other step down transformers as the windings are of a much larger gauge.

vi) Common ratings:

Primary voltage – 230 V, 415 V
Secondary voltage – 40 to 60 V
Secondary current – 200 to 600 A

6 e) What is an isolation transformer? State any two applications of isolation transformer.

Ans:

i) Isolation transformers are specially designed transformers for providing electrical isolation between primary & secondary windings. The transformer has primary and secondary windings placed on the common core limbs which have equal number of turns so that the voltage fed to the primary is available at the secondary without any change in its magnitude.

ii) These are built with special insulation between primary and secondary.

iii) The construction & working of isolation transformer is same as conventional transformers.

2 Marks

Applications of isolation transformer:

i) Disconnect the load equipment from supply ground:

ii) Reduction of voltage spikes

iii) It acts as a decoupling device.

Two application 1 Mark each= 2Mark

6 f) Draw a neat connection diagram of potential transformer. Also explain the two types of error that are likely to occur in the P.T.

Ans:

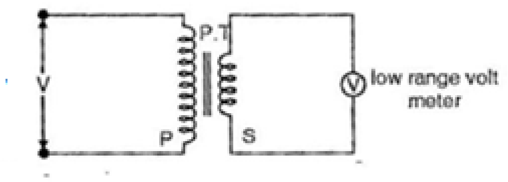


Diagram 2 mark

Errors occur in P.T.:

i) Voltage Ratio Error – The voltage ratio error is expressed in regarding measured voltage, and it is given by the formula as shown below.

$$Ratio\ Error = \frac{K_t I_s - I_p}{I_p}$$

where, K_t is the nominal ratio, i.e., the ratio of the rated primary voltage and the rated secondary voltage.

Two errors 1 mark each= 2 Marks

ii) **Phase Angle Error** – The phase angle error is the error between the secondary terminal voltage which is exactly in phase opposition with the primary terminal voltage. The increases in the number of instruments in the relay connected to the secondary of the potential transformer will increase the errors in the potential transformers.