Winter – 2016 Examinations

Model Answers **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 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 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) State working principle of DC generator.

Ans:

- Working principle of DC generator is the principle of dynamically (motional emf) induced emf or electromagnetic induction.
- According to this principle, if flux linked with a conductor is changed, then emf is induced in conductor.
- In case of DC generator, when armature winding is rotated by the prime mover, the flux linked with it changes and an emf is dynamically induced into armature winding.

2 marks

1 c) State at least four applications of DC series motor.

Ans:

Applications of DC series motor:

i) Drive Hoists
ii) Drive Cranes
iii) Drive Trains
iv) Drive Fans

Any four each ½ mark = 2 Marks

1 d) DC series motor should never be started at no-load. Justify.

Ans:

- At no load the field current (which is also the armature current) is very small and hence the useful air-gap field flux. Also the torque is very small.
- As $N \propto \frac{1}{\emptyset}$ the speed rises to excessively high values and it is mechanically very harmful for machine.
- At high speeds due to centrifugal forces on the rotating parts they may get damaged.

Hence DC series motor should never be started on no-load.

2 Marks

1 e) Write emf equation of DC short shunt compound motor in the form of their voltage drop.

Ans:

Emf equation of DC short shunt compound motor:

2 marks

The back emf is expressed as,

$E_b = V - I_aR_a - (I_a + I_{sh})R_{se}$

I_a = Armature current

I_{sh} = Shunt field current
R_a = Armature resistance
R_{se} = Series field winding resistance

1 f) State any two applications of Brushless DC motors.

Ans:

1) Synthetic fiber drawing works.
2) Turn table drives in record players.
3) Spindle drives in hard disk circuits.
4) Computer peripheral equipment.
5) Gyroscope motors.
6) Biomedical machines as heart pumps.

1 mark each any two= 2 marks

(other valid answers allowed)

1 g) State four properties of Ideal transformer.

Ans:

Properties of Ideal transformer:

1) No losses (iron and copper), hence no temperature rise.
2) Zero winding resistance and leakage reactance (zero impedance).
3) No voltage drop i.e. $E_1 = V_1$, $E_2 = V_2$.
4) No magnetic leakage.
5) Efficiency 100 %.
6) Regulation 0 %.

OR

1) Zero core power loss [core (hysteresis & eddy current) losses]
2) No ohmic resistance of primary and secondary windings.
3) Zero copper losses [I^2R losses]
4) Zero magnetic leakage (coefficient of coupling between primary and secondary windings is unity).

Any four ½ mark each = 2 Marks

1 h) 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.

$$\text{All-day efficiency} = \frac{\text{Output energy in kWh in 24 hrs}}{\text{Input energy in kWh in 24 hrs}}$$

2 marks

1 i) State why a transformer always have a efficiency of more than 90%.

Ans:

As transformer is static device with no moving parts, the losses due to friction & windage are completely absent. Hence transformer has efficiency of more than 90%.

2 marks

1 j) A 3 kVA, 220/110 V transformer has 500 turns on its primary. Find its transformation ratio and secondary turns.

Ans:

Transformation ratio K = V_2/V_1 = 110/220 = ½.

1 mark

Secondary turns $N_2 = K \times N_1 = (½) \times 500 = 250$ turns. 1 mark

1 k) Give the specification of three phase transformer as per IS 1180(Part-1) 1989. (any four).

Ans:

Specification of 3-phase transformer:

(½ mark each any four = 2 marks)

1) kVA rating of transformer
2) Voltage ratings for the primary and secondary voltages
3) HV and LV currents
4) Operating frequency of the transformer
5) % impedance of transformer
6) Allowable temperature rise.
7) Wiring instructions for HV and LV windings/terminal diagram
8) Model number and serial number of the transformer
9) Weight of the transformer
10) Information related to the tap changer
11) Transformer vector group
12) Winding connection diagrams
13) Type of cooling
14) Insulation class
15) Name of the manufacturer
16) Weight of core
17) Weight of winding
18) Volume of oil in litres.

1 l) Give the criteria for selection of distribution transformer as per IS:10028 (part-I) 1985.

Ans:

Criteria for selection of distribution transformer as per IS:10028 (part-I) 1985:

(½ mark each any four = 2 marks)

1) Total connected load.
2) Load Diversity factor.
3) Expected daily load curve.
4) Type of loads: (1 phase, 3 phase, 3 ph-4 wire system required)
5) Constant Losses.
6) Availability of space for transformer erection (indoor /outdoor).
7) Distance of loads from transformer substation.
8) Times of low loads and maximum loads.
9) Future expansion plans or trends or forecasting.
10) Ambient conditions for deciding insulation class.
11) Tap changing requirement.

2 Attempt any FOUR of the following: 16

2 a) Derive emf equation of DC generator.

Ans:

Let P = no of poles,
Ø = average flux per pole (Wb),
Z = total no of armature conductors.
A = number of parallel paths of armature winding,
N = speed of generator in RPM.
By Faraday's Laws of electromagnetic induction

Induced emf in each conductor $e_c = \frac{d\phi}{dt}$ 1 Mark

In this case, the flux cut by one armature conductor in one revolution = P Ø.

The time for one revolution = (60/N) sec. 1 Mark

Hence e_c = (flux cut in one revolution)/(time for one revolution) volt

$$= \frac{P\phi}{\frac{60}{N}} = \frac{P\phi N}{60} \quad volt$$ 1 Mark

For Z conductors the total emf will be

$$Ez = Z\frac{P\phi N}{60} \quad volt$$

Depending on the number of identical parallel paths the conductors get divided into those many paths (depending on the armature winding type as wave and lap winding)

Hence induced emf $E = E_Z/A = \frac{\phi Z N}{60}\frac{P}{A}$ volt 1 Mark

2 b) A DC generator has an armature emf of 100V when the useful flux per pole is 20mWb and the speed is 800rpm. Calculate the generated emf:
i) With the same flux and speed of 1000 rpm.
ii) With the flux per pole of 24mWb and a speed of 900rpm.

Ans:

$\phi_1 = 0.02$ Wb, E_1=100V, N_1=800rpm,

As

$$E \propto \phi \times N$$
$$\frac{E_1}{E_2} = \frac{\phi_1 \times N_1}{\phi_2 \times N_2}$$

i) $E_2 = \frac{\phi_2 \times N_2}{\phi_1 \times N_1} \times E_1 = \frac{0.02 \times 1000}{0.02 \times 800} \times 100$ =125V 2 Marks

ii) $E_2 = \frac{\phi_2 \times N_2}{\phi_1 \times N_1} \times E_1 = \frac{0.024 \times 900}{0.02 \times 800} \times 100$ =135V 2 Marks

2 c) Explain necessity of starter for DC motor. State various types of starters of DC motor.

Ans:

Necessity of starter for DC motor:

The current drawn by motor $I_a = \frac{V-E_b}{R_a}$

At start speed $N = 0$, $E_b = 0$ and $I_a = \frac{V}{R_a}$

As Ra is very small Ia will be dangerously high at the time of starting. This high starting current may damage the motor armature (& series field winding in case of dc series motors). Hence to limit the starting current, suitable resistance is inserted in series with armature, which is called as starter. This starting resistance is cut-off in steps with increase in speed (as E_b increases). 2 Marks

Types of starters for DC motors:

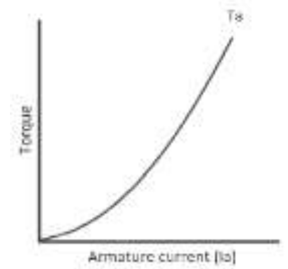
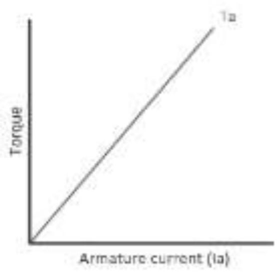
1) Three point starter for DC shunt motors.
2) Four point starter for DC shunt motors.
3) Two point starter for DC series motors.

Any two 1 Mark each = 2 Marks

2 d) Describe T_a-I_a characteristics for DC series and DC shunt motor.

Ans:

Torque-Armature Current Characteristics of DC Motors:

DC Series Motor	**DC Shunt Motor**
	
$T_a \propto \emptyset I_a$ Upto magnetic saturation, $\emptyset \propto I_a$ $\therefore T_a \propto I_a^2$ Hence, the characteristics is parabola passing through origin. Beyond stauration, $\emptyset$ is constant. $\therefore T_a \propto I_a$ at higher current values. Hence, the characteristic is a straight line.	$T_a \propto \emptyset I_a$ Field current is constant. Flux is constant. $\therefore T_a \propto I_a$ Hence, the characteristic is a straight line passing through origin..

2 Marks

2 Marks

2 e) A 250V shunt motor on no load runs at 1000 rpm and takes 5A. The total armature and shunt field resistances are respectively 0.2Ω and 250 Ω. Calculate the speed when loaded and taking a current of 50A, if armature reaction weakens the field by 3%.

Ans:

Motor I/P current , I_{L1} = 5A at no-load

Field current , I_{f1} = (Applied voltage/Field resistance)

= 250/250= 1A

Armature current I_{a1} = Motor I/P current - Field current
= 5 - 1= 4A 1Mark
At a load current of 50A, the armature reaction weakens the field by 3 %,
The back emf E = K Ø N, where K is proportionality constant and E = V- I_aR_a

$$\frac{E_1}{E_2} = \frac{\emptyset_1 N_1}{\emptyset_2 N_2}$$

$$N_2 = \frac{\emptyset_1 N_1 E_2}{\emptyset_2 E_1}$$ 1 Mark

The armature current on load is given by,

$$I_{a2} = I_{L2} - I_{f2}$$ 1 Mark

$$= 50 - 1 = 49A$$

Due to armature reaction, the field is weakened by 3%,
$\therefore\ if\ \emptyset_1 = 1$ then $\emptyset_2 = 0.97$

$$\therefore N_2 = \frac{(1)(1000)(V - I_{a2}R_a)}{(0.97)(V - I_{a1}R_a)}$$

$$\therefore N_2 = \frac{(1)(1000)[250 - 49 \times 0.2]}{(0.97)[250 - 4 \times 0.2]}$$

$$\therefore N_2 = \frac{240200}{241.724}$$

$$\therefore N_2 = 993.69\ rpm$$

1 Mark

2 f) A 230 V shunt motor takes 4 A at no load. The armature and field resistances are 0.8 ohm and 250 ohm respectively. Calculate full load efficiency when current is 22 A.

Ans:

Motor input = 230 x 4 = 920 W.
I_{sh} = Field current at all times = (applied voltage to motor)/field resistance
I_{sh} = 230/250 = 0.92 A.
I_{a0} = Armature current at no load = motor input current -field current
I_{a0} = 4 – 0.92 = 3.08 A.
Field copper loss = (field voltage × field current)
= 230 x 0.92
= 211.6 watt
No-load Armature copper loss =$I_{a0}^2 R_a$ = (3.08) ^{2} x 0.8 = 7.59 watt.
$P_{constant}$ = friction, windage and stray losses
= no load motor input – no load armature copper loss – field copper losses 1 Mark
= 920 – 7.59 – 211.6 = 700.81 watt

Full load efficiency:

I_a = Full load armature current = motor input current – field current
= 22 – 0.92 = 21.08 A.
Full load armature copper losses =$I_a^2 R_a$ = (21.08) ^{2} x 0.8 = 355.49 watt. 1 Mark

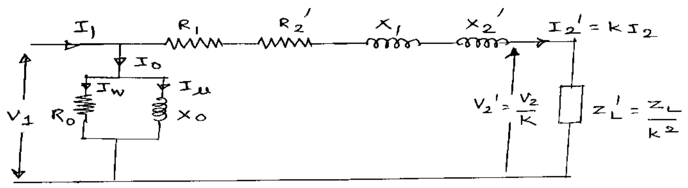
Total full load losses = armature copper losses + field copper losses+ $P_{constant}$
= 355.49 + 211.6 + 700.81 — 1 Mark
=1267.9 watt

Full load input power = input voltage x current drawn by motor
= 230 x 22 = 5060 W.
∴ Full-load efficiency is given by,

$\%\eta_{full\text{-}load}$ = [(motor input – losses)/(motor input)] x 100
= [(5060 – 1267.9)/5060] x100 — 1 Mark
= 74.94%

3 Attempt any FOUR of the following: 16

3 a) Draw the equivalent circuit of transformer referred to primary. State the meaning of each term related to equivalent circuit.
Ans:



2 Marks for eq. circuit

I_o= No load current

$R_o = V_1 / I_w$ Resistance representing core loss

and $X_o = V_1 / I_\mu$ Inductance representing magnetization of core

$K = E_2 / E_1 = N_2 / N_1 = V_2 / V_1$= Transformation ratio of transformer.

$V_2' = V_2 / K$= Secondary voltage of transformer referred to primary

$I_2' = K I_2$= Secondary current of transformer referred to primary

$R_2' = R_2 / K^2$ = Secondary resistance of transformer referred to primary

$X_2' = X_2 / K^2$= Secondary reactance of transformer referred to primary

$R_{01} = R_1 + R_2' = R_1 + (R_2 / K^2)$= Equivalent Resistance referred to primary

$X_{01} = X_1 + X_2' = X_1 + (X_2 / K^2)$ = Equivalent Reactance referred to primary

2 Marks for meaning of any four terms

3 b) List the advantages of OC and SC test (any four).
Ans:
Advantages of OC & SC test:

i) Efficiency can be found for any desired load without actual loading.
ii) Power consuption is less as compared to direct loading.
iii) Losses can be found at any load condition.
iv) Using these tests efficiency at any load condition and power factor can be

1 mark for each Advantage any four = 4

calculated. | marks

v) Using these tests voltage regulation at any load condition and power factor can be calculated.

3 c) A 3300/250V, 50Hz single phase transformer is built on a core having an effective cross sectional area of 125cm^2 and 70 turns on the low voltage winding.
Calculate: i) The value of the maximum flux density.
ii) Number of turns on the high voltage windings

Ans:

Cross sectional Area, A=125cm^2 = 125×10^{-4} m^2

Low voltage Windings turns, N_2= 70 | 1 mark for *Emf equation*

Frequency f = 50Hz

$E_2 = 4.44\ \Phi_m f N_2$ volt

$250 = 4.44\times\Phi_m \times50 \times70$ | 1 Mark for Φ_m

Φ_m = 0.01608 weber

As $\Phi_m = B_m \times A$,

i) $B_m = \Phi_m/A = 0.01608/(125\times 10^{-4}) = 1.2864\ Wb/m^2$ | 1 Mark

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

N_1 = 3300/ (4.44 x 0.01608 x 50) = 924.628 ≅ 925 turns

Or $N_1 = N_2(E_1/E_2)$ = 924 turns. | 1 Mark

3 d) Explain concept of an ideal transformer with its properties.

Ans:

Ideal transformer is the transformer having following properties: | 1 Mark for each of any four properties.

i) The losses are zero (No iron loss, No copper loss). Hence efficiency is 100%.
ii) The primary and secondary winding resistances are zero ($R_1=R_2=0$).
iii) The leakage flux is zero. Therefore, the leakage reactances of primary winding and secondary winding are zero ($X_1 = X_2 = 0$).
iv) The primary induced emf E_1 is same as the external voltage applied to the primary, V_1. This is because primary winding resistance and leakage reactance are zero. Hence $E_1=V_1$
v) Similarly secondary voltage $V_2$is same as the secondary induced emf E_2. This is because secondary winding resistance and leakage reactance are zero. Hence $V_2 = E_2$
vi) The transformation ratio is given by $k = \frac{E_2}{E_1} = \frac{V_2}{V_1}$
vii) The voltage regulation is zero.
viii) All the flux produced by the primary winding is coupled with secondary winding.

3 e) List the conditions for parallel operation of three phase transformer.

Ans:

Conditions for Parallel operation of 3 phase transformer:

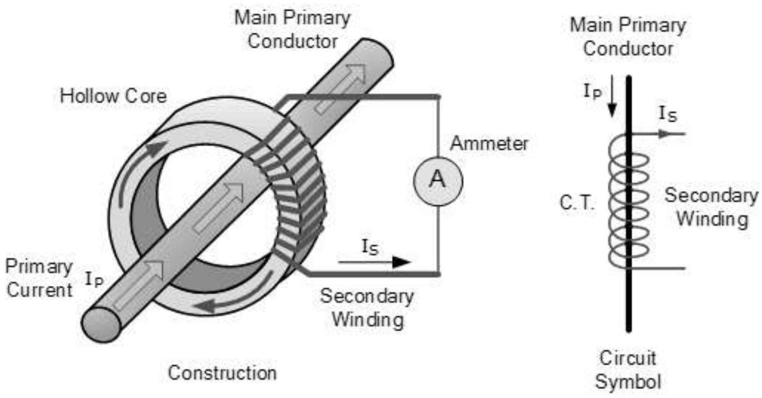
1) Voltage ratings of both the transformers must be identical. | 1 Mark for each of any
2) Percentage / p.u. impedances should be equal in magnitude.

3) X/R ratio of the transformer windings should be equal. four
4) Transformer terminals with identical polarity must be connected to each other on secondary side.
5) Phase displacement between primary & secondary voltages must be same.
6) Phase sequence of both must be same.

3 f) Explain with neat diagram construction and working of a current transformer.

Ans:

Construction:



2 Marks for construction sketch

1 Mark for construction

- Construction of CT is as shown in above figure.
- 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 fig.

1 Mark for working

Working of C.T.

- C.T. is basically a step-up transformer. Hence the secondary is high voltage low current winding.
- The secondary current is given by;
  $I_s = I_p \times \frac{N_1}{N_2}$

$$N_2 \gg N_1$$

- The current I_s is measured by the ammeter. So knowing turns ratio it is possible to measure I_p.
- The primary current is given by;
  $I_p = I_s \times \frac{N_2}{N_1}$

4 Attempt any FOUR· of the following: 16

4 a) Derive the condition for maximum efficiency of transformer.

Ans:

Condition for maximum efficiency of transformer:

The efficiency of transformer is given by,

$$\eta = \frac{V_2 I_2 (\cos\phi_2)}{V_2 I_2 (\cos\phi_2) + P_i + I_2^{\,2} R_{02}}$$ 1 Mark

- In above equation P_i is constant and V_2 is practically constant.

At specified value of load p.f. $\cos\phi_2$, the efficiency is maximum when $\frac{d\eta}{dI_2} = 0$

$$\frac{d\eta}{dI_2} = \frac{d}{dI_2}\left[\frac{V_2 I_2 (\cos\phi_2)}{V_2 I_2 (\cos\phi_2) + P_i + I_2^{\,2} R_{02}}\right] = 0$$ 1 Mark

Solving the above equation, we get

$$Pi - I_2^2 R_{02} = 0$$ 1 Mark

$$I_2^2 R_{02} = Pi$$

∴ Condition for Maximum efficiency is, 1 Mark

Copper loss = Iron loss

4 b) A 500kVA transformer has 2500W iron loss and 7500W copper loss at full load. Calculate its efficiency at full load at unity pf and 0.8pf lagging.

Ans:

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

% full load efficiency at unity pf:

$$= \frac{500 \times 1000 \times 1}{500 \times 1000 \times 1 + (2500 + 7500)} \times 100$$ 1 Mark

= 98.03 % ½ Mark

% full load efficiency at 0.8 lag pf:

$$= \frac{500 \times 1000 \times 0.8}{500 \times 1000 \times 0.8 + (2500 + 7500)} \times 100$$ 1 Mark

= 97.56 % ½ Mark

4 c) Two single phase transformers of 250 kVA each are operated on parallel (both side). Their % drops are (1 + j6) ohm and (1.2 + j4.8) ohm. The load connected across the bus bar is 500 KVA at 0.8 p.f. lag. Calculate load shared by each transformer.

Ans:

As given machines are having equal kVA ratings we may assume the given impedances to be in % or ohmic values (any one)

Given:

Rating of each transformer = 250 kVA
Total Load to be shared S = 500 kVA
Load power factor $\cos\phi = 0.8$ lag

$\phi = \cos^{-1}(0.8) = 36.87°$

$Z_A = 1 + j6 = 6.08\angle 80.53°\ \Omega$,

$Z_B = 1.2 + j4.8 = 4.94\angle 75.96°\ \Omega$

$Z_A + Z_B = 2.2 + j\,10.8 = 11.02\angle 78.48^o\ \Omega$. 1 Mark

The load shared by each transformer is given by,

$S_A = S \times Z_B/(Z_A+Z_B)$

$= [500\angle -36.87^o \times 4.94\angle 75.96^o]/(11.02\angle 78.48°)$ 1 Mark

$= 224.14\angle -39.39°$ kVA ½ Mark

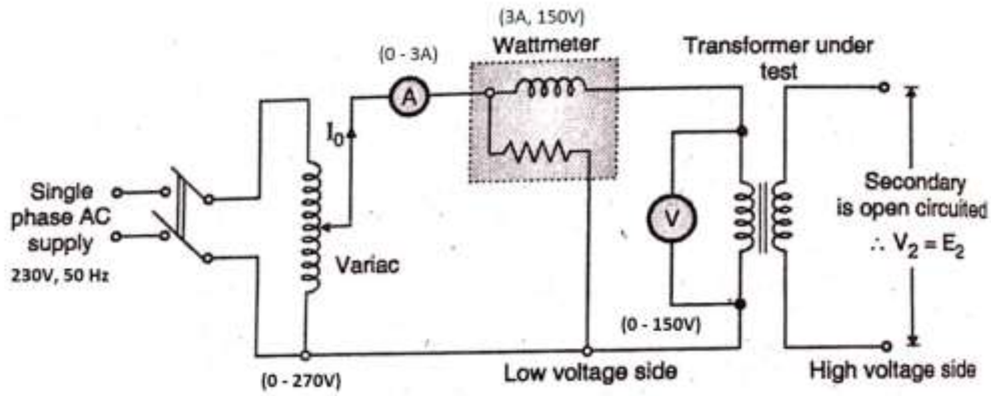
$S_B = S \times Z_A/(Z_A+Z_B)$

$= [500\angle -36.87^o \times 6.08\angle 80.53^o]/(11.02\angle 78.48°)$ 1 Mark

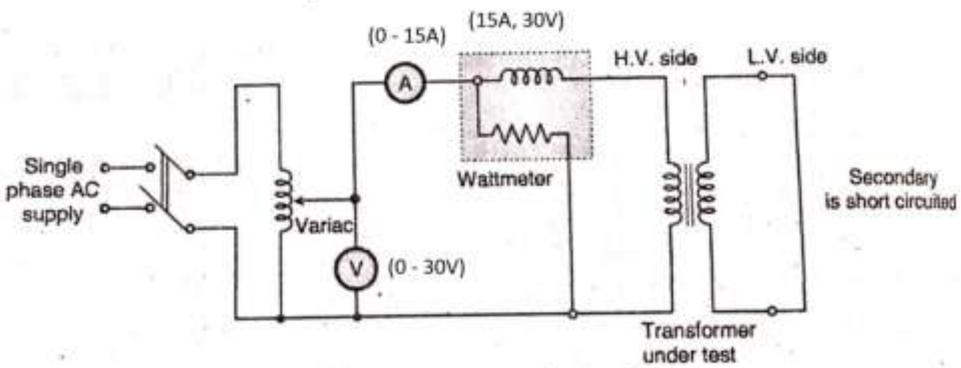
$= 275.86\angle -34.82°$ kVA ½ Mark

4 d) Draw experimental setup to conduct OC and SC test on a 2.5kVA, 220/115V, 50Hz single phase transformer. Select the ranges of meter used for test.

Ans:



Set up for the O.C. test 1 Mark



Experimental set up for S.C. test 1 Mark

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 $\frac{2.5\times1000}{115} = 21.74A$.

Under no=load condition, LV side current will be less than 10% of 21.74A i.e 2.174A. To measure this current the ammeter of range (0 – 3A) or (0 – 5A) 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. 2 Marks for selection of meters

To measure the input power, depending upon the current and voltage, the wattmeter of the range (3A, 150V) or (5A, 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 $\frac{2.5\times1000}{220} = 11.36A$. To measure this current, an ammeter of range (0 – 15A) 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 (15A, 30V) can be used.

4 e) List the various losses in a transformer, the places at which they occur. And list the methods to minimize these losses.

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.

i) Eddy current loss = $K_EB_m^2 f^2T^2$

where, K_E is eddy current constant, ½ Mark

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 = $K_HB_m^{1.67} f V$

where K_H is Hysteresis constant,

B_m is the maximum flux density ½ Mark

F is the frequency of magnetic reversals and
V is the volume of the core in m^3

Place of Losses:

1) The Copper loss takes place in primary and secondary winding of transformer. — 1 Mark
2) The iron loss takes place in the core of transformer.

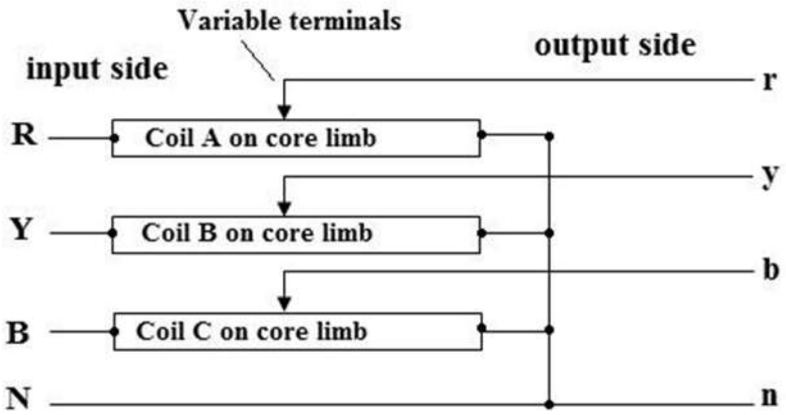
Methods to minimize the losses:

1) The copper loss is minimized by using purest conducting material for winding so as to reduce its resistance. — 1 Mark
2) This loss is minimized using laminated core.
3) This loss is minimized using special magnetic materials like Silicon Steel having small hysteresis loop area.

4 f) Explain construction and operation of 3 phase auto transformer.

Ans:

Three-phase Auto-transformer:



Construction:

- The connections are shown in the diagram. The coils connected in star are placed on electromagnetic cores to increase the magnetizing property of the coils. 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 used in transformers (sheet steel with Silicon).
- The output terminal connections are gang operated to get identical tappings on all phases and are brought out on the insulated plate. The variable voltage may also be obtained by tappings (stepped voltage instead of smooth variations) to which the output terminals are connected as required.

2 Marks for Construction

Operation:

- Working principle of Auto-transformer 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 Marks for Operation

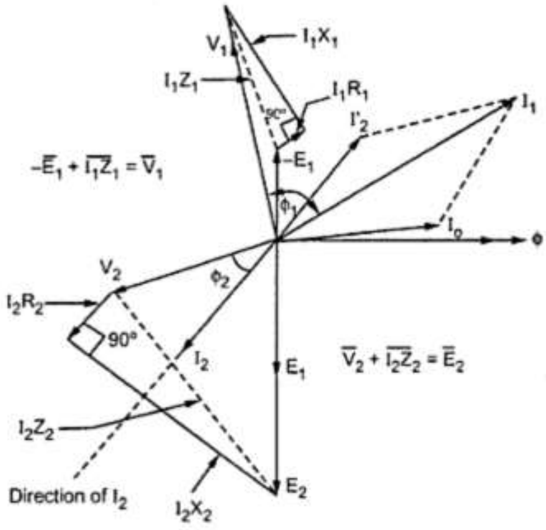
- As only one winding per phase is available, part of it acts as secondary between variable terminal and neutral.
- Depending upon the position of variable terminal, we get variable AC voltage at the output.

5 a) Draw the complete phasor diagram of transformer for lagging pf load condition and leading pf load condition.

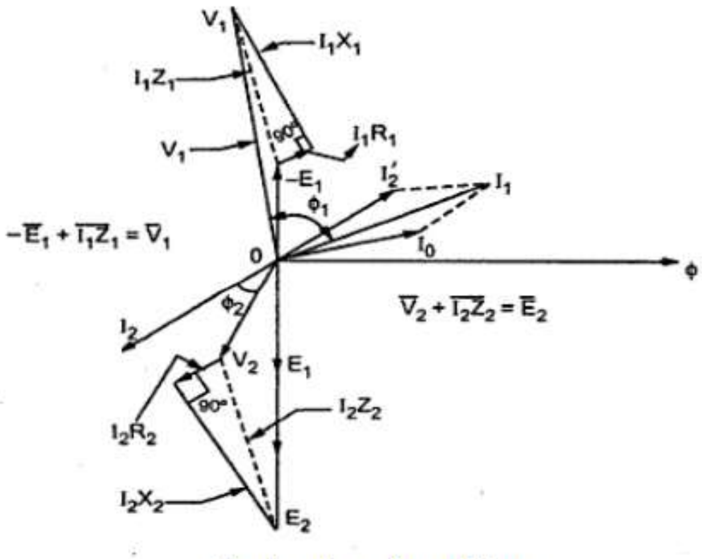
Ans:

Phasor diagram of transformer:

2 Marks for each labelled phasor diagram



For Leading pf condition



For Lagging pf condition

5 b) State the advantages of amorphous core type distribution transformer.

Ans:

Advantages of amorphous core type distribution transformer:

1) Increases efficiency of transformers as constant losses are reduced by 75 % compared to conventional transformers.
2) The material has high electrical resistivity hence low core losses.
3) Amorphous material has lower hysteresis losses, hence less energy wasted in magnetizing & demagnetizing during each cycle of supply current.
4) Amorphous metal have very thin laminations. Result is lower the eddy current losses.
5) Reduced magnetizing current.
6) Better overload capacity.
7) High Reliability.
8) Excellent short circuit capacity.
9) Less maintenance cost

1 Mark for each of any four advantages

5 c) A 500kVA, distribution transformer having copper and iron losses of 5kW and 3kW respectively on full load. The transformer is loaded as shown below

Loading (kW)	Power factor(lag)	No. of hours
400	0.8	06
300	0.75	12
100	0.8	03
No load	--	03

Calculate all day efficiency.

Ans:

Step I: Convert the loading from kW to kVA

i) The loading of 400 kW at 0.8 pf is equivalent to (400/0.8) = 500 kVA
ii) The loading of 300 kW at 0.75 pf is equivalent to (300/0.75) = 400 kVA
iii) The loading of 100 kW at 0.8 pf is equivalent to (100/0.8) = 125 kVA

1Mark

Step II: Caclulate copper losses at different kVA values:

i) Full load Cu loss i.e. for 500 kVA= 5 kW is given which is for 6 hours.
ii) For 400 kVA= $(400/500)^2$ x 5 kW= 3.2 kW is for 12 hours
iii) For 125 kVA= $(125/500)^2$ x 5 kW= 0.3125 kW is for 03 hours
iv) No Load for 3 hours

1 Mark

Total Energy loss due to Cu losses

E_{cu}= (5x6)+(3.2x12)+(0.3125x3) = 69.3375 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} = (400x6) + (300x12) + (100x3)= 6300 kWh

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

$$= \frac{Output\ Energy\ in\ 24\ hrs\ of\ a\ day}{[Output\ energy + Energy\ loss\ due\ to\ copper\ loss\ and\ Iron\ loss]\ in\ 24\ hrs\ of\ the\ day} \times 100$$ 1 Mark

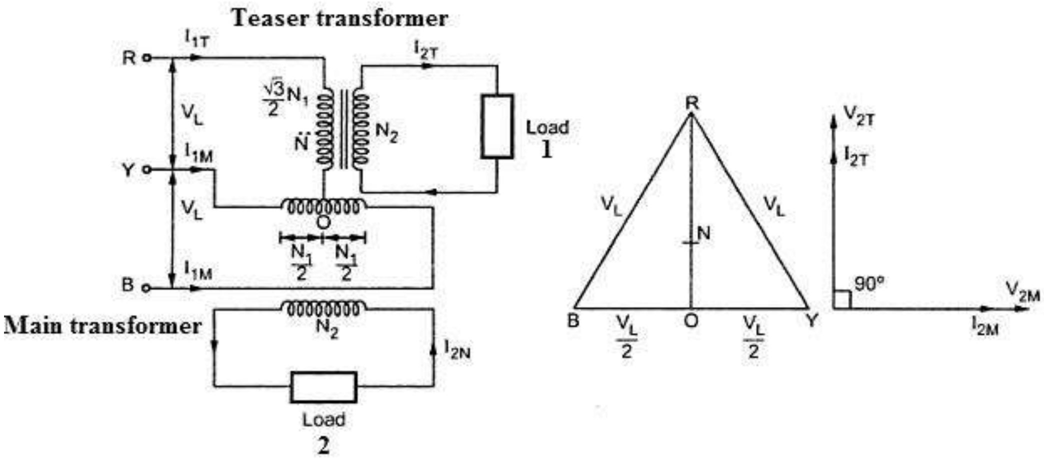
$$= \frac{6300}{[6300 + 69.3375 + 72]} \times 100$$

All day efficiency η= 97.8 %

5 d) Draw a neat diagram of Scott connected three transformers and explain the working.

Ans:

Scott Connection:



2 Marks for neat circuit diagram (3ϕ-3ϕ transformation can be considered)

Working:

i) Scott connection can be used for three-phase to three-phase or 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 midway on V_{YB}.

iv) When two phase loads such as furnaces of large ratings are to be supplied, using this connection, such large loads get distributed equally on the three phases to have balanced load condition.

2 marks for explanation

v) 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.

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

vii) 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 $N_1:N_2$.

viii) 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 $V_{2T} = V_{2M}$.

ix) As seen from the phasor diagram the output voltages to the two loads are identical

5 e) Compare between distribution transformer and power transformer (any four points).

Ans:

Parameters	Distribution Transformer	Power Transformer
Connection	Secondary star connected with neutral provided.	Neutral not always required. (other connections used)
Rating	Lower (< 1MVA)	Higher (> 1MVA)
Cost	Less	More
Size	Small	Big
Load	50-70% of full load	Full load
Insulation Level	Low	High
Flux Density	Lower	Higher
Typical Voltages	11kV,6.6kV, 3.3kV, 440V, 230V	400kV, 220kV, 110kV,66kV,33kV
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
Use	In distribution networks	In transmission networks

1 Mark for each of any four points

5 f) Explain the criteria of selection of power transformer.

Ans:

Criteria of selection of power transformer:

i) Ratings:

- The no load secondary voltage should be specified 5% above the nominal voltage in order to partially compensate for regulation of transformer.
- If the transformers need to operate in parallel with each other, then their voltage ratios should be adjusted as per guidelines given in IS:10028(Part-II)-1981

1 Mark for each of any four criteria

ii) Taps:

- On load tap changers on HV side should be specified. For On load tap changer should be 16taps of 1.25percent.
- If the oil circuit taps are to be specified, they should be in the range of ±2.5% and ±5% and should be provided on the HV side of transformer.

iii)Connection Symbol:

- For power transformers upto 66kV high voltage side(HV) rating, the most preferred connections are delta/star(Dyn) and star/star(YNyn)
- If the voltage rating is higher, then star/star(YNyn) and star/delta(YNd) connections should be preferred.
- The section of group is made on the basis of requirement of parallel operation with other transformers

iv)Impedance:

- The value of transformer impedance is decided by considering the secondary fault levels and the associated voltage dips. For deciding the precise value of transformer impedance by referring IS:2026(Part-I)-1977.
- If the transformer is to be operated in parallel then the impedance be selected as per the guidelines given IS:10028(Part-II)-1981.

v)Termination Arrangement:

- The HV & LV terminals may be one of following three types depending upon on the method of installation:
  - Bare outside bushing
  - Cable boxes
  - Bus trunking
- The types of bushings that should be specified are:
  - Upto 33kV : Porcelain bushings
  - 66kV & above: Oil filled condenser type bushings.

vi)Cooling:

Sr. No.	Rating	Voltage class	Type of cooling
1	Upto 10MVA	Upto 66kV	ONAN
2	12.5 to 40MVA	Upto 132kV	ONAN(60%), ONAF(40%)
3	50 to 100MVA	Upto 220kV	ONAN(50%), ONAF(62.5%)
4	Above 100MVA	Upto 400kV	ONAN(50%), ONAF(62.5%)

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

6 a) A single phase 3300/400V transformer has the following winding resistances and reactances R_1= 0.7Ω, R_2 = 0.011Ω, X_1 = 3.6Ω, X_2 = 0.045Ω. The secondary is connected to coil having resistance of 4.5 Ω and inductive reactance 3.2 Ω. Calculate secondary terminal voltage and power consumed by the coil.

Ans:

Given , R_1=0.7Ω, R_2=0.011Ω, X_1=3.6Ω, X_2= 0.045Ω, R_L=4.5 Ω, X_L=3.2

Transformation ratio K = $\frac{V_2}{V_a} = \frac{400}{3300} = 0.12$ 1 Mark for K

By transferring parameters from primary to secondary,

$R_1' = R_1K^2 = 0.7\times(0.12)^2 = 0.01008\Omega$

$X_1' = X_1K^2 = 3.6\times(0.12)^2 = 0.0518\Omega$

$R_T = R_1' + R_2 + R_L = 0.01008 + 0.011 + 4.5 = 4.52108\ \Omega$ 1 Mark for total R and X
$X_T = X_1' + X_2 + X_L = 3.6 + 0.045 + 3.2 = 6.845\ \Omega$

$$I_L = V_2 \Big/ \sqrt{R_T^2 + X_T^2} = \frac{400}{\sqrt{(4.52^2 + 6.845^2)}} = \frac{400}{\sqrt{67.284}} = 48.78\ A$$

i) Terminal Voltage, $V_t = I_L \times R_L = 48.78 \times 4.5 = 219.5 \cong 220V$

ii) Power consumed by coil, $P_L = I_L^2 \times R_L = 48.78^2 \times 4.5$
$= 10707.6 \cong 10708W$

6 b) Explain the different types of transformer cooling.

Ans:

Methods of cooling of transformer:

i) 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.

1 Mark for each of any four types

ii) 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.

iii) 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.

iv) 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.

v) 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.

vi) 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 used which is in MVA . (e,.g. in Generating station)

6 c) Compare two winding transformer with auto transformer on the basis of construction, copper loss, output variation and cost.

Ans:

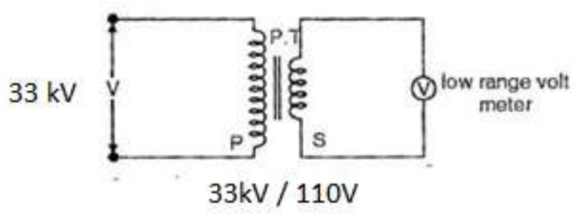
Comparison between two winding transformer with auto transformer:

Sr. No.	Parameter	Two-winding transformer	Auto-transformer
1	Construction	Primary & secondary windings are separate, heavy core for identical rating.	A part of winding is common between primary & secondary, lighter core for identical rating.
2	Copper loss	More	Less
3	Output voltage variation	Good	Better
4	Cost	More costly for same capacity	Less cost

1 Mark for each point

6 d) Explain with circuit diagram use of potential transformer to measure 33kV.

Ans:



2 Marks for circuit diagram

Circuit Diagram of PT:

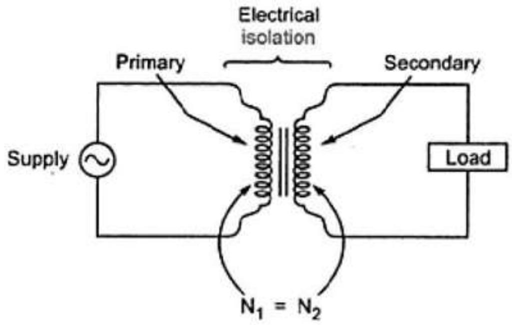
i) Higher voltage '33kV' is the voltage to be measured
ii) Primary of PT is connected across this voltage
iii) PT is step down transformer
iv) Due to PT, voltage across voltmeter gets reduced by a factor equal to the turns ratio of PT. Hence low range voltmeter is used to measure voltage.

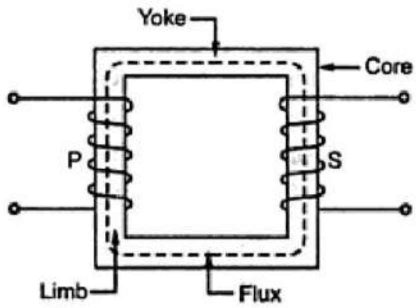
2 Marks for explanation

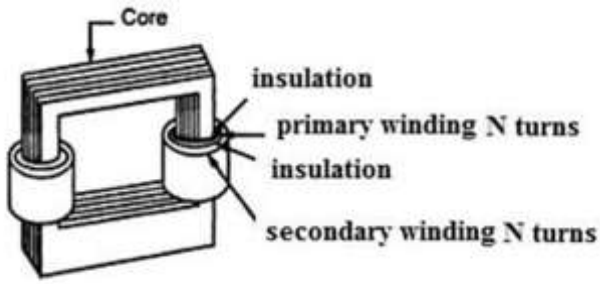
v) The secondary voltage is given by,
$V_2 = V_1 \times (N_2/N_1)$
The secondary voltage of PT is standardized to 110V.

6 e) Explain construction and working of isolation transformer.

Ans:



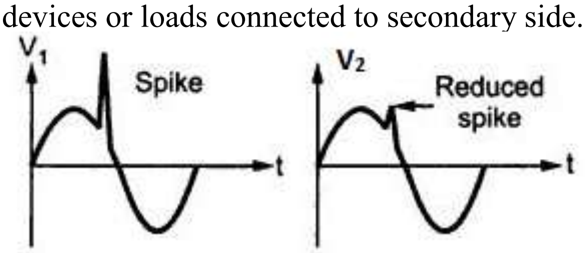




2 Marks for construction + 2 Marks for working = 4 Marks

(all diagrams not compulsory : any one or two)

i) The construction & working of isolation transformer is nearly identical to conventional transformers.
ii) Isolation transformers are specially designed transformers for providing electrical isolation **between the power source** and **the powered devices.**
iii) 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.
iv) Any spikes on the primary side are subdued and prevented from getting transformed to the secondary side to a very large extent thus protecting the devices or loads connected to secondary side.



v) These are built with special insulation between primary and secondary.
vi) It acts as a decoupling device.
vii) These transformers block the transmission of direct current (DC) signals, but allow AC signals to pass from one circuit to another.

6 f) List special features of welding transformer.

Ans:

Special features of welding transformer:

1 Mark for each of any four features

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.
ii) Have large number of primary turns and low secondary turns.
iii) The secondary currents are quite high.
iv) The secondary has several taps for adjusting the secondary voltage to control the welding current.
v) 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