MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2013 Certified)

Summer – 2019 Examinations

Model Answers

Subject & Code: D.C. Machines & Transformers (17415)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

1 **Attempt any TEN of the following:** **20**

1 a) State Fleming's Right Hand Rule.

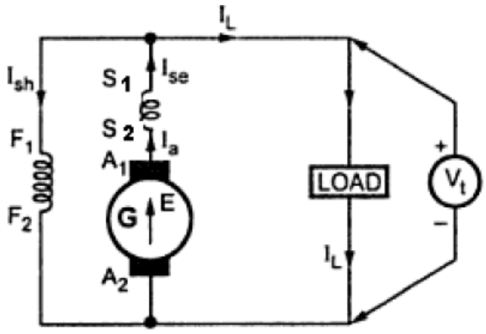
Ans:

Fleming's Right Hand Rule :

Stretch the first three fingers of your right hand such that they are mutually perpendicular to each other, if first finger indicates direction of magnetic field, thumb indicates direction of force, then the middle finger will indicate the of induced EMF. 2 marks

1 b) Draw the connection diagram of long shunt differential D.C. compound generator.

Ans:



Labeled diagram 2 marks

Unlabeled diagram 1 mark

1 c) List the various losses ~~on~~ in DC motor.

Ans:

The various losses on a DC Motor are:

1) Winding losses (Copper or Cu losses):
   i) Armature winding Cu loss.
   ii) Shunt field Cu loss.
   iii) Series field Cu loss
2) Core losses (Iron losses): (i) Eddy Current loss (ii) Hysteresis Loss
3) Brush contact loss:
4) Windage and frictional losses (Mechanical losses).

½ mark each = 2 marks

1 d) Write the voltage equation and power equation of D.C. shunt motor.

Ans:

Voltage equation:

$V = E_B + I_A.R_A$

V = applied voltage (volt), E_B= back emf generated (volt), I_A = armature current (amp), R_A = armature winding resistance in ohm.

1 mark for Voltage equation

Power equation:

$VI_A = E_B\ I_A + (I_A)^2\ R_A$

V = applied voltage (volts), E_B = back emf generated (volts), I_A = armature current (amp), R_A = armature winding resistances

1mark for Power equation

1 e) Define armature torque and shaft torque.

Ans:

Armature torque: Torque developed by the armature of DC motor is 1 mark known as Armature Torque.

$$T_a = \frac{\emptyset Z I_a}{2\pi}\frac{P}{A} \text{ newton-metre}$$

Where, Z = total number of armature conductors,
P = number of poles,
A = number of parallel paths in armature,
I_a = armature current (A),
Ø = flux per pole in weber

Shaft torque: It is the torque available at the shaft of the motor for doing useful work. It is less than armature torque due to windage, friction, stray and iron losses in the motor. 1 mark

$$T_{sh} = \frac{\text{Output x 60}}{2\pi N} \text{ newton-metre}$$

Where, the output is the mechanical power in watts & N = Speed in RPM.

1 f) State any four properties of Ideal transformer.

Ans:

Properties of Ideal transformer:

1) No losses (iron and copper losses), hence no temperature rise.
2) No magnetic leakage i.e (Coefficient of coupling between primary and secondary windings is unity)
3) Zero winding resistance and leakage reactance (zero impedance).
4) No voltage drop i.e. E1 = V1, E2 = V2
5) Efficiency 100 %.
6) Regulation 0 %.

½ mark for each of any four = 2 marks

1 g) A 50 KVA transformer has iron loss 2 kW on full load. Calculate its iron loss at 75% of full load.

Ans:

Iron loss is dependent on voltage and independent of load. 2 marks

Hence iron loss at 75% of Load = Iron loss at full load = **2 kW**

1 h) Define: (i) Commercial efficiency of a transformer and
(ii) All day efficiency of a transformer.

Ans:

(i) Commercial Efficiency :

It is the ratio of output power in watt to the input power in watt. 1 mark

$$\text{Commercial Efficiency} = \frac{\text{Output in W or KW or MW}}{\text{Input in W or KW or MW}}$$

(ii) All day efficiency of a transformer:

It is the ratio of output energy in kWh to the input energy in kWh in the 24 hours of the day

$$\text{All Day Efficiency} = \frac{\text{Output Energy in kWh in 24 Hrs}}{\text{Input Energy in kWh in 24 Hrs}}$$ 1 mark

1 i) Define transformation ratio in terms of current and voltage.

Ans:

(i) Transformation Ratio (K) is defined as the ratio of the primary current to the secondary current. 1 mark

$$K=\frac{\text{Primary Current}}{\text{Secondary Current}}=\frac{I_1}{I_2}$$

(ii) Transformation Ratio (K) is defined as the ratio of the secondary voltage to the primary voltage. — 1 mark

$$K=\frac{\text{Secondary Voltage}}{\text{Primary Voltage}}=\frac{V_2}{V_1}$$

1 j) Compare core type transformer and shell type transformer on the following parameters.

(i) Types of winding used, (ii) Application

Ans:

1 mark for each point = 2 marks

Sr. No.	Parameter	Core Type Transformer	Shell Type Transformer
1	Types of winding used.	Cylindrical type winding	Sandwich type winding
2	Application	Low current, High voltage application	High Current, Low voltage application

1 k) State any two conditions for parallel operation of 3-phase transformer.

Ans:

Conditions for Parallel operation of 3 phase transformer

1 mark for each of any two conditions = 2 marks

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

1 l) State any two applications of single phase autotransformer.

Ans:

Applications of single phase auto transformers:

1 mark for each of any two = 2 marks

1) Give small boost to distribution cable to correct the voltage drop.
2) As auto transformer starter for induction motors.
3) As furnace supply transformer to give variable voltage as required
4) As interconnecting transformers in 132 kV/ 33 kV systems.
5) In control equipment for single phase locomotives.
6) As dimmer in lighting circuits.

2 Attempt any FOUR of the following: 16

2 a) Derive EMF equation of D.C. generator.

Ans:

Derivation of e.m.f. Equation of Generator:

Let P = no of poles,

Ø = average flux per pole (Wb), — 1 mark

Z = total no of armature conductors.

A = number of parallel paths of armature winding,

N = speed of generator in RPM.

E_g = emf of generator
By Faraday's Laws of electromagnetic induction
Induced emf in each conductor $e_c = \frac{d\emptyset}{dt}$
Here, the flux cut by one armature conductor in one revolution = P Ø.
The time for one revolution = (60/N) sec.
Hence e_c = (flux cut in one revolution)/(time for one revolution) volt

$$= \frac{P\,\emptyset}{\frac{60}{N}} = \frac{P\,\emptyset\,N}{60} \quad volt$$ 1 mark

For Z conductors the total emf will be

$$Ez = Z\frac{P\,\emptyset\,N}{60} \quad volt$$ 1 mark

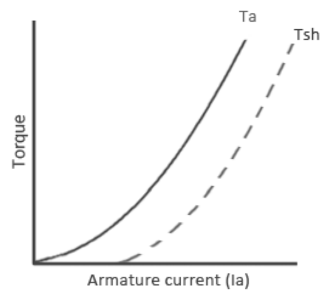
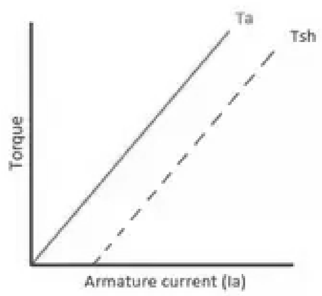
Depending on the number of identical parallel paths the conductors get divided into those many paths (depending on the armature winding type as wave and lap winding)

Hence induced emf $E_g = E_Z/A = \frac{\emptyset ZN}{60}\frac{P}{A}$ volts 1 mark

A= P (lap winding) A= 2 (wave winding)

2 b) Describe $T_a – I_a$ characteristics for DC series and DC shunt motor with graph.

Ans:

DC series motor	**DC shunt motor**
	
$T_a \propto \phi .I_a$ Up to magnetic Saturation $\phi \propto I_a$, Therefore $T_a \propto (I_a)^2$ Hence the characteristic is a parabola passing through origin. Beyond saturation, ϕ is constant, Therefore $T_a \propto I_a$ Hence the characteristic is straight line.	$T_a \propto \phi\, I_a$ Field current is constant Flux is also constant Therefore $T_a \propto I_a$ Hence the characteristic is straight line passing through origin.

1 mark for Each Characteristic curve = 2 marks

1 mark for description of each = 2 marks

2 c) What is back e.m.f. in DC motor? Explain its significance.

Ans:

Back EMF in DC Motor:

- As the armature of the DC motor starts rotating, the magnetic flux in the air gap, which is responsible for their rotation, is cut by armature conductors and consequently an e.m.f. is induced in them in accordance with Faraday's law of electromagnetic induction. — 2 marks for back emf

- The direction of this induced emf is such that it always opposes the cause of its production. The emf is induced because of cutting of the magnetic flux, the flux is cut because of rotating motion, the rotating motion is because of force on the rotor or armature, the force is because of armature current and armature current is because of applied voltage. Hence the main cause of emf is the applied voltage. Therefore, the induced emf opposes the cause of its production i.e applied voltage. Due to its opposing nature, it is termed as back emf E_b or counter e.m.f.

Significance Of Back Emf In D.C. Motor:

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

2 marks for significance

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 to flow through armature and produces increased driving torque. Thus the driving torque increases as motor slows down.
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.
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.
iv) It also decides the output mechanical power.

2 d) A 250 V shunt motor on no load runs at 1000 rpm and takes 5A. The total armature and shunt field resistances are 0.2Ω and 250Ω respectively. Calculate the speed when loaded and taking a current of 50 A, 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 — 1 mark

Armature current I_{a1} = Motor I/P current - Field current = 5 – 1 = 4A

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

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

$$N_2 = \frac{\emptyset_1 N_1 E_2}{\emptyset_2 E_1} = \frac{\emptyset_1 N_1 (V - I_{a2}R_a)}{\emptyset_2 (V - I_{a1}R_a)}$$ — 1 mark

The armature current on load is given by,

$I_{a2} = I_{L2} – I_{F2}$

= 50 -1 = 49 A

Due to armature reaction, the field is weakened by 3%,

If ϕ_1 =100% = 1 then ϕ_2 =97% = 0.97 — 1 mark

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

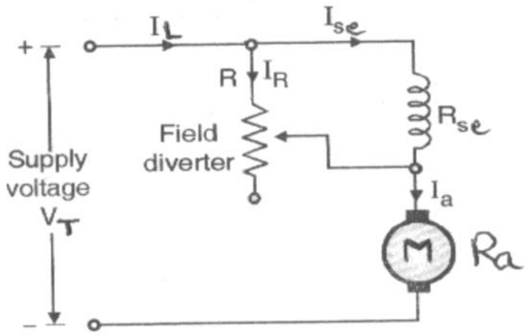
$$N_2 = \frac{(1)(1000)(250 - 49 \times 0.2)}{0.97\,(250 - 4 \times 0.2)}$$ 1 mark

N_2 = 993.69rpm

2 e) Describe the flux control method using field diverter method for speed control of D.C. series motor with the help of neat diagram.

Ans:

Flux control method using field diverter method for speed control of DC series Motor:



2 marks for circuit diagram

Or equivalent diagram

- Variable resistance 'R' called field diverter is connected in parallel with series field resistance R_{se}.
- By varying filed diverter 'R', the effective value of field current through the filed winding can be varied.
- When R = 0, all the current will be diverted from the field winding, therefore flux (ϕ) will be minimum and speed will be maximum because

$$N \propto \frac{E_b}{\emptyset}$$

- If 'R' increases speed decreases.

2 marks for description

By using this method we can control those speeds which are below rated value.

2 f) The no load current of a transformer is 15 Amp at 0.2 pf. when connected to a 460 V, 50 Hz supply. If the primary winding has 550 turns, calculate:

(i) Magnetizing component.
(ii) Core loss component of no load current.
(iii) Maximum flux.

Ans:

Data Given: 1 mark for

$I_o = 15$ A, $\cos\phi_0 = 0.2$ $\phi_0 = \cos^{-1}(0.2) = 78.46°$ — ϕ_0
$V = 460V$, $f = 50$ Hz, $N_1 = 550$ turns

i) Magnetizing component: — 1 mark

$I_m = I_o \sin\phi_0 = 15 \sin(78.46°)$

$\mathbf{I_m = 14.697}$ **Amp.**

ii) Core loss component of no load current: — 1 mark

I_c or $I_w = I_o \cos\phi_0 = 15 \cos(78.46°)$

$\mathbf{I_c}$ **or** $\mathbf{I_w = 3}$ **Amp.**

iii) Maximum flux:

$$E_1 = 4.44\phi_m f N_1$$

$$\emptyset_m = \frac{E_1}{4.44 \times f \times N_1} = \frac{460}{4.44 \times 50 \times 550}$$ — 1 mark

$$\emptyset_m = 3.76 \text{ mWb} = 3.76 \times 10^{-3} \text{ Wb}$$

3 Attempt any FOUR of the following: 16

3 a) A 4 pole, 1250 RPM DC generator has 72 slots & 12 conductors per slot on armature. The flux per pole is 0.02 Wb. Calculate the emf induced when the armature is,
(i) Lap wound and (ii) Wave wound.

Ans:

Data Given: P = 4, Ø = 0.02 Wb, N = 1250 RPM.

Z = total no of armature conductors = 72 x 12 = 864 — 1 mark for Z

$E = \frac{\emptyset ZN}{60}\frac{P}{A}$ volt — 1 mark for E

i) Lap wound:

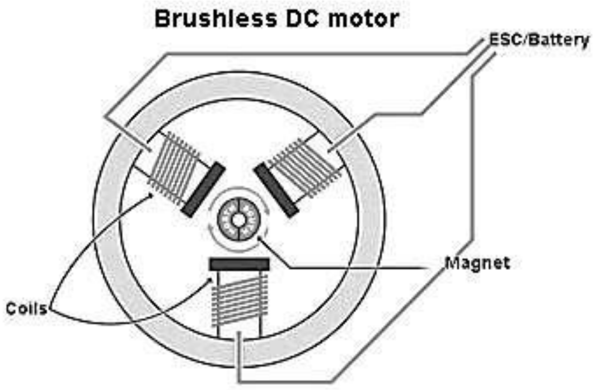
A = number of parallel paths of armature winding = no of poles = 4. — ½ mark
E = (0.02 x 864 x 1250 x 4)/(60 x 4) — ½ mark
= 360 V

ii) Wave wound:

A = number of parallel paths of armature winding = 2 — ½ mark
E = (4 x 0.02 x 864 x 1250)/(60 x 2) — ½ mark
= 720 V

3 b) Explain working of Brushless D.C. motor with neat sketch.

Ans:



2 marks for Diagram

OR
Any equivalent Diagram

Working of BLDC motor:

In case BLDC motor, the current carrying conductor is stationary while the permanent magnet rotor moves. When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate. — 2 marks for Working

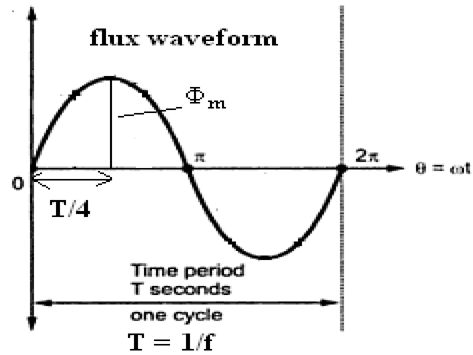
3 c) Derive the emf equation of a transformer.

Ans:

Emf equation of transformer:

Let N_1 = No. of turns on primary winding
N_2 = No. of turns on secondary winding
Φ_m= maximum flux in core in Wb = $B_m \times A$
f = Frequency of supply in Hz

1st method



1 mark

Maximum value of flux is reached in time t = 1/ 4f — 1 mark

Av. 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
$= 4\Phi_m f$ Wb/sec or volt

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

R.M.S. emf induced in each turn = 1.11 x Avg. value
$= 1.11 \times 4\Phi_m f$ — 1 mark
$= 4.44\ \Phi_m f$ 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 — 1 mark

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

OR Equivalent Derivation.

3 d) A single phase transformer has 300 turns on its primary side and 750 turns on its secondary side. The maximum flux density in the core is $1 Wb/m^2$, calculate:

(i) The net cross sectional area of the core,
(ii) The emf induced in the secondary side.

Ans:

(NOTE - The given **data is Insufficient**. Let us assume that the primary of the transformer is connected to 440V, 60 Hz supply.)

$E_1 = 4.44 B_m A f N_1$ volt

$$\therefore A = \frac{E_1}{4.44 B_m f N_1} = \frac{440}{4.44 \times 1 \times 60 \times 300}$$

$$\mathbf{A = 5.505 \times 10^{-3}\ m^2}$$

2 marks for area A

Also

$E_2 / E_1 = N_2 / N_1$

$E_2 / 440 = 750/300$

$\mathbf{E_2 = 1100}$ **volt**

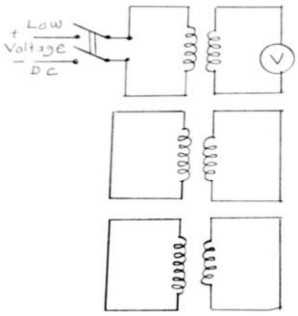
2 marks for emf E_2

(NOTE: Examiners are requested to award the marks for the procedure followed by the student for any assumed data)

3 e) With the help of neat diagram, explain the procedure of phasing out test on 3-phase transformer**.**

Ans:

Procedure of Phasing-out test on 3-phase Transformer:



1 Mark for Diagram

i) Short primary & secondary windings of other phases except the one under test, as shown above.
ii) Connect voltmeter to concerned secondary winding.
iii) A small DC current is circulated through the primary winding through switch.
iv) Now with the help of switch, interrupt the DC supply instantly & repeatedly.
v) If voltmeter pointer deflects then it indicates that the two windings under test belong to the same phase.
vi) If not deflected, then two windings do not belong to same phase.
vii) Repeat the procedure by connecting voltmeter to next secondary winding till voltmeter gives deflection.
viii) In this way we can identify the primary and secondary winding of a particular phase.
ix) Repeat the procedure to find the secondary winding of all remaining primary windings.

3 marks for Procedure

3 f) Compare distribution transformer and power transformer on the basis of connection, rating, cost and maintenance.

Ans:

Parameters	Distribution transformer	Power transformer	
Connection	Primary is connected in delta, Secondary is connected in star with neutral provided.	Usually, Primary is connected in Star, Secondary is connected in Delta. However, Δ–Δ and Y-Δ connections are also used.	1 mark each
Rating	Lower (< 1 MVA)	Higher (> 1 MVA)	
Cost	Low	High	
Maintenance	Carried out somewhat irregularly.	Carried out more regularly.	

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

4 a) A 500 KVA transformer has 2500 W iron loss and 7500 W copper loss at full load. Calculate its efficiency at full load at unity p.f and 0.8 p.f. lag.

Ans:

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

Case I:- $\cos\emptyset=1$

$$\text{Efficiency}_{\text{unity pf}} = \frac{500 \times 10^3 \times 1}{500 \times 10^3 \times 1 + 7500 + 2500}$$ 1 mark

$$= \frac{500000}{510000} = 0.9803$$

1 mark

$$\%\text{Efficiency}_{\text{unity pf}} = 98.03\%$$

Case II:- $\cos\emptyset=0.8$

1 mark

$$\text{Efficiency}_{0.8\ \text{pf}} = \frac{500 \times 10^3 \times 0.8}{500 \times 10^3 \times 0.8 + 2500 + 7500}$$

$$= \frac{400000}{410000} = 0.9756$$

1 mark

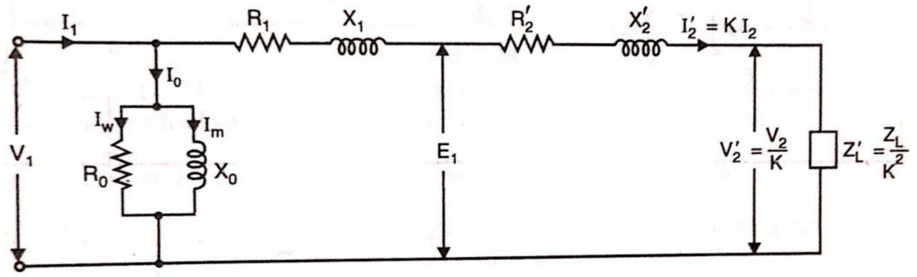
$$\%\text{Efficiency}_{0.8\ \text{pf}} = 97.56\%$$

4 b) Draw the equivalent circuit of transformer referred to primary.

Ans:

V_1 -Primary Input voltage
I_1 - Input Current — 2 marks for terminology
I_0 - Exciting current/ No load current
I_m - Magnetizing component of no load current
I_w - Working or core loss component of no load current
R_0- Core loss resistance
X_0- Magnetizing reactance
R_1 -Primary winding resistance

X_1 - Primary winding leakage reactance
E_1 – Induced emf in Primary winding
R_2' - Secondary winding resistance referred to primary
X_2'- Secondary winding leakage reactance referred to primary
I_2 - Secondary winding current
I_2' – Primary equivalent of secondary current I_2



2 marks for equivalent circuit

4 c) "OC test is performed on LV winding and SC test is performed on HV winding of transformer". Justify.

Ans:

Open Circuit Test:

OC test is conducted to determine mainly the constant or iron losses at rated voltage. Open circuit test is conducted on LV side (HV side is kept open) to overcome the following difficulties: 2 marks

i) Meters of high range will be needed when it is conducted on HV side. However, if the test is conducted on LV side, low range meter can be used without loss of accuracy.
ii) For testing, high voltage supply is required, which may not be available.
iii) Working with HV is unsafe.

Hence O.C. test is conducted on LV side by keeping HV open circuited.

Short Circuit Test:

SC test is conducted to determine the variable or copper losses at the rated or full load current. SC test is carried on HV side (LV short circuited) to overcome the following difficulties:

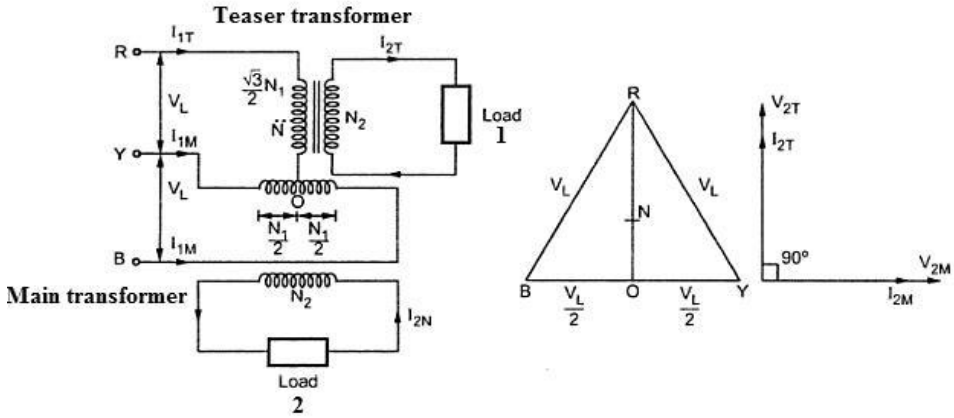
i) As full load current of LV side is very large, autotransformer capable of handling this current may not be readily available to supply the current. 2 marks
ii) High range ammeters (usually not available) will be needed when the test is conducted on LV side. However, if the test is conducted on HV side, since rated current on HV side is less, low range ammeters can be used.
iii) Making connections for higher current is troublesome.

Hence S.C. test is conducted on HV by keeping LV short circuited.

4 d) Explain with the neat diagram, three phase to two phase conversion (Scott connection) of 3 phase transformer.

Ans:

Scott connection of transformers:



2 marks for circuit diagram

Working:

i) Scott connection can be used for three-phase to two-phase conversion using two single phase transformers.

ii) Scott connection for three-phase to two-phase conversion is as shown in figure.

iii) Point 'o' is exactly at midway on V_{YB}.

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

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

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

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

2 marks for explanation

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

4 e) A 1-phase 50kVA, 2400/120V, 50Hz transformer gave following test results:
OC test (instrument on LV side): 120V, 9.85A, 396W
SC Test (instrument 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:

$V_2 = 120V$ $I_0 = 9.85$ A $W_0 = 396W$

$W_0 = V_2 I_0 \cos\phi_0$

$\therefore \cos\phi_0 = W_0/(V_2 I_0) = 396/(120\times9.85) = 0.335$

$\therefore \phi_0 = 70.43°$ hence $\sin\phi_0 = 0.942$

Core loss component of no-load current $I_c = I_w = I_0 \cos\phi_0 = 9.85\times0.335 = 3.3A$

Magnetizing current $I_m = I_0 \sin\phi_0 = 9.85\times0.942 = 9.3A$

Core loss representing resistance $R_0 = V_2/I_c = 120/3.3 =$ **36.36Ω** — 1 mark for R_0 & X_0

Magnetizing reactance $X_0 = V_2/I_m = 120/9.3 =$ **12.9Ω**

Please note that **R_0 and X_0 are referred to the LV side**.

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

$V_{SC} = 92V$ $I_{SC} = 20.8A$ $W_{SC} = 810W$

$W_{SC} = I_{SC}^2 R_{1T}$

$R_{1T} = W_{SC}/I_{SC}^2 = 810/(20.8)^2 = 1.872\Omega$ — 1 mark for R_{1T} & X_{1T}

$Z_{1T} = V_{SC}/I_{SC} = 92/20.8 = 4.423\Omega$

$X_{1T} = \sqrt{Z_{1T}^2 - R_{1T}^2} = \sqrt{(4.423)^2 - (1.872)^2} = 4\Omega$

Please note that **R_{1T}, X_{1T} and Z_{1T} are referred to the HV side**.

To find efficiency:

Pi = 396 W & Pcu = 810W

Efficiency at rated kVA:

$$\text{Efficiency}_{FL} = \frac{\text{Rated output} \times \cos\emptyset}{\text{Rated output} \times \cos\emptyset + \text{Cu. Losses} + \text{Iron Losses}}$$ — 1 mark

$$\text{Efficiency}_{0.8\ pf} = \frac{50 \times 10^3 \times 0.8}{50 \times 10^3 \times 0.8 + 810 + 396}$$

$$= \frac{40000}{41206} = 0.9707$$ — 1 mark

$$\%\text{Efficiency}_{0.8\ pf} = 97.07\%$$

4 f) State advantages of amorphous core type distribution transformers.

Ans:

Advantages of Amorphous Core type Distribution Transformers:

1) Increases efficiency of transformer 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 the core during each cycle of supply current.
4) Amorphous metal have very thin laminations, which result is lower the eddy current losses.
5) Reduced magnetizing current.
6) Better overload capacity.
7) High Reliability.
8) Excellent short circuit capacity.

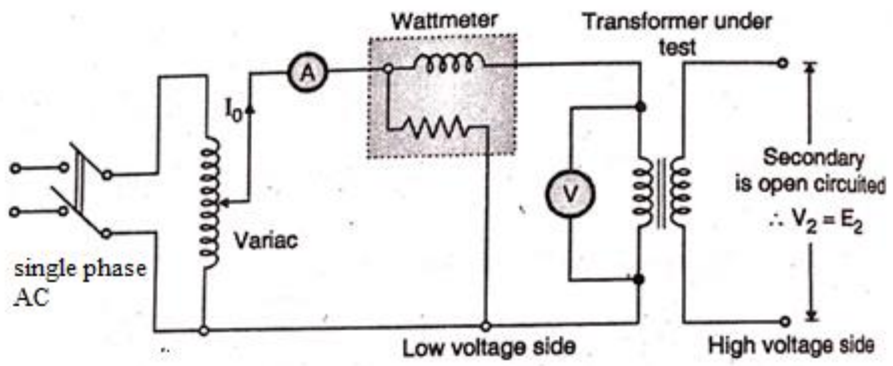
1 mark for each of any four = 4 marks

9) Less maintenance cost.

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

5 a) Draw a neat experimental setup to conduct OC test on a single phase transformer. Also give any two advantages of OC and SC test.

Ans:



Correct diagram: Labeled 3 marks, Partially or unlabeled proportionally lower marks 2 to 1 marks. Wrong diagram 0 marks

Advantages of OC and SC tests:

- Efficiency of the transformers at different loads and pf can be predetermined without actual loading them.
- Voltage regulation of the transformers at different loads and pf can be predetermined without actual loading them.
- Saving in the power that would be lost in direct loading tests.
- Loading arrangement is not needed for performance testing.

Advantages any two 1 mark.

5 b) "Transformers are rated in kVA instead of kW". Justify.

Ans:

Transformer Rating is in kVA:

The life of insulation of transformer depends upon temperature. Temperature rise results from losses of transformer. The copper losses (I^2R) of transformer depend on the load current and the iron losses (eddy current and hysteresis losses) depend on the applied voltage. Hence total transformer losses depend on volt-amperes and not on phase angle between voltage and current. 2 marks

The quantity kW is a function of the load power factor and the losses are independent of load power factor. Hence transformer rating is in kVA so that its capacity of utilization is spelt out in terms of the voltage and the current thus giving us an idea of the extent to which the transformer can be loaded safely. 2 marks

5 c) A single phase 100 kVA, 3.3 kV/230V, 50 Hz transformer has 89.5% efficiency at 0.85 lagging pf both at full load and also half load. Calculate the iron loss and full load copper loss.

Ans:

$$'n' \text{ load effciency}, \eta_{FL} = \frac{n \times KVA \times 1000 \times PF}{(n \times KVA \times 1000 \times PF) + P_i + n^2 P_{cu}} \times 100$$

n = load proportion

P_i = Iron loss which is constant.

P_{cu} = Full load Cu loss

$\therefore 0.895 = \frac{1\times100\times1000\times0.85}{(1\times100\times1000\times0.85)+P_i+P_{cuFL}} = \frac{85000}{85000+P_i+P_{cuFL}}$

$\therefore P_i + P_{cuFL} = 9972.07\ W \ldots\ldots\ldots\ldots\ldots(i)$ — 1 mark

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

Effciency at Half load, η_{HL}

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

$0.895 = \frac{1/2 \times 100 \times 1000 \times 0.85}{(1/2 \times 100 \times 1000 \times 0.85) + P_i + \frac{P_{cuFL}}{4}}$

$0.895 = \frac{42500}{(42500) + P_i + \frac{P_{cuFL}}{4}}$

$P_i + \frac{P_{cuFL}}{4} = 4986.03\ W \ldots\ldots\ldots(ii)$ — 1 mark

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

Copper losses = $P_{cuFL} = 6648.05\ W$ — 1 mark

Iron losses = $P_i = 3324.02W$ — 1 mark

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

Ans:

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

1 mark each criterion any four = 4 marks.

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

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

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

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

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

5 e) List the special features of the welding transformer.

Ans:

Special features of welding transformer:

- 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.
- Having large primary turns and less secondary turns.
- The secondary current is quite high.
- The secondary has several taps for adjusting the secondary voltage to control the welding current.
- The transformer is normally large in size compared to other step down transformers as the windings are of a much larger gauge.
- Common ratings:
  - ✓ Primary voltage – 230 V, 415 V
  - ✓ Secondary voltage – 40 to 60 V
  - ✓ Secondary current – 200 to 600 A

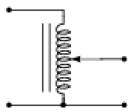
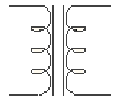
1 mark each any four = 4 marks

5 f) Compare single phase auto transformer with conventional two winding transformer (any four points).

Ans:

Sr. No.	Single phase autotransformer	Two winding Transformer
1	Only one winding, part of the winding is common for primary and secondary.	There are two separate windings for primary and secondary.
2	Movable contact exist	No movable contact between primary and secondary
3	Electrical connection between primary and secondary windings.	Electrical isolation between primary and secondary windings.
4	Comparatively lower losses.	Comparatively more losses
5	Efficiency is more as compared to two winding transformer.	Efficiency is less as compared to autotransformer.
6	Copper required is less, thus copper is saved.	Copper required is more.
7	Spiral core construction	Core type or shell type core construction
8	Special applications where variable voltage is required.	Most of the general-purpose transformers where fixed voltage is required.
9	Cost is less	Cost is more
10	Better voltage regulation	Poor voltage regulation

1 mark each point any four = 4 marks (other valid points if any must also be assessed on merit)

11	 Symbol of Autotransformer	 Symbol of Two winding transformer

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

6 a) "Performance of transformer is analyzed on all day efficiency", justify the statement.

Ans:

The all-day efficiency of transformer is defined as the ratio of its output energy to the input energy in the same 24 hours slot of time of a day. *(1 mark)*

Hence

$$\%\text{ All day Efficiency} = \frac{\text{kWh Output in 24 hrs}}{\text{kWh Input in same 24 hrs}} \text{x}100$$

(1 mark)

It is very much applicable to distribution transformers to judge their performance. As they are loaded very much varyingly during the whole 24 hours of the day, their performance cannot be judged for a particular load condition. Hence it is necessary to determine their energy efficiency taking into account their loading for the whole period. *(2 marks)*

6 b) Describe procedure to find polarity of windings of a single phase transformer.

Ans:

Polarity test of single Phase transformer:

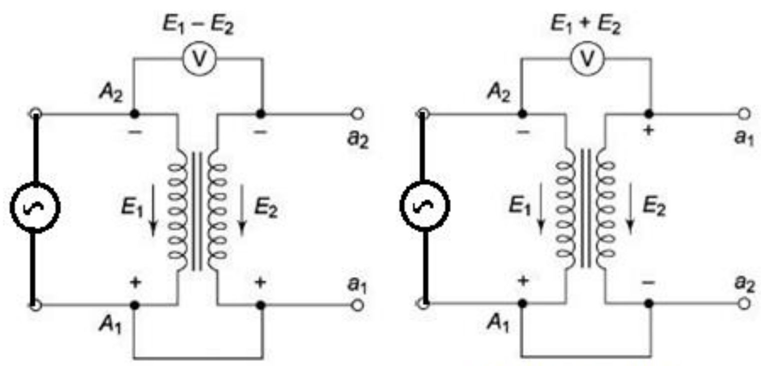
This test is conducted to identify the corresponding polarity terminals of the transformer HV and LV windings.

The primary winding (high-voltage winding) terminals of single-phase transformer are marked as A_1–A_2 and the secondary winding (low-voltage winding) terminals will be marked as a_1–a_2 after the polarity test. The transformer primary is connected to a low voltage a.c. source with the connections of link and voltmeter made as shown in the figure. The reading of the voltmeter is noted. *(2 marks for Explanation)*

This test is carried out on open circuit. Hence the primary applied voltage V_1 is equal to E_1 and the corresponding secondary voltage V_2 is E_2.

If the voltmeter reading appears to be $V = (E_1\text{-}E_2)$ then it is referred as subtractive polarity connection and the terminals so connected are of similar polarity. Therefore, the secondary terminal connected to A_1 is marked as a_1. The secondary terminal connected to A_2 through voltmeter is marked as a_2.

If voltmeter reading appears to be $V = E_1+E_2$, it is referred as additive polarity. The terminals connected to each other are of opposite polarity. Therefore, the secondary terminal connected to A_1 is marked as a_2 and the secondary terminal connected to A_2 through voltmeter is marked as a_1.



Subtractive Polarity Additive Polarity

2 marks for Diagram

6 c) State the different types of losses occuring in single phase transformer and suggest remedies to minimise those losses.

Ans:

1) **Iron losses:** It consists of eddy current and hysterisis losses occuring in the electromagnetic core depending on the flux density (voltage applied) and the frequency of the supply.
These are minimised by using insulated laminations of good quality (low loss) electromagnetic materials such as silicon steel (CRGO) and amorphous materials for core building. Using such materials having low loss per unit of core weight leads to reduced cross section of the cores used leading to lower turn lengths of the copper conductors (hence lower copper losses) up to some extent.

One loss and remedies 2 marks.

Two losses and remedies 3 marks.

2) **Copper losses:** It consists of the I^2R losses in the primary and secondary windings of the transformers. These can be minimised by using low resistance winding materials such as good quality copper and also by using larger cross section of the winding conductors to reduce the resistance of the windings.

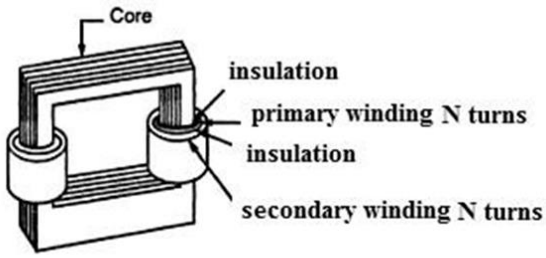
Three losses and remedies 4 marks.

3) **Dielectric losses:** It occurs in the insulation system of the transformers due to the leakage currents through them given by $I^2_{leakage}R_{insulation}$. This depends on the dielectric stresses in the systems. This can be reduced by using good quality insulation materials for the different sections and proper impregnation where ever required. Bad insulation leads to higher heating and breakdown.

6 d) Describe working of isolation transformer.

Ans:

Working of the isolation transformer:



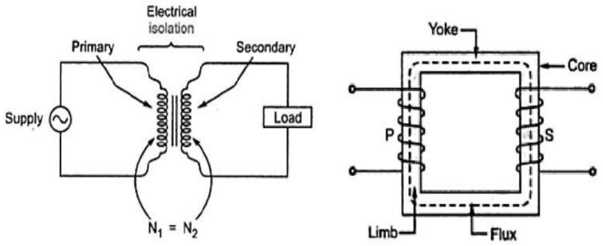


Diagram 2 mark and description 2 marks

i) Isolation transformers are specially designed transformers for providing electrical isolation between supply terminals of the power distribution system and the points where the loads are connected.
ii) 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.
iii) These are built with special insulation between primary and secondary windings.

Working:

When alternating supply is given to primary, it causes current to flow in it producing alternating flux in core. The secondary winding being on the same electromagnetic core produces a mutual induced emf equal to the primary winding value as they have equal turns. Any load connected across the secondary winding draws current but is not directly across the supply but is isolated by the transformer. Hence any voltage spike in the power supply system gets smoothed out due to the isolation transformer and its effect is minimized for the load on the secondary side of the isolation transformer.

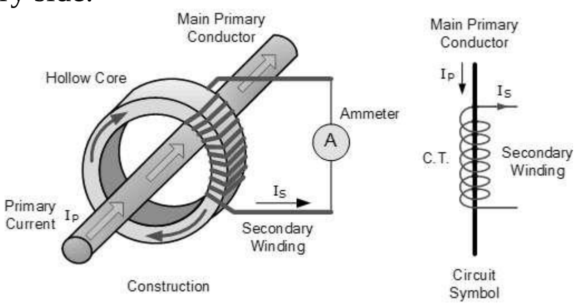
6 e) With the help of neat diagram, explain the construction of current transformer.

Ans:

Construction of current transformer:

- C.T has bar type conductor, which behaves as primary winding.
- The primary of C.T. carries large current Ip 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 it's cross sectional area is small.
- A low range ammeter normally 0 to 5 A is connected across the secondary as shown to make proportionate measurement of the current on the primary side.

Description 2 marks and diagram 2 marks (equivalent diagram allowed)

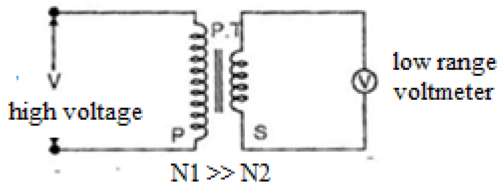


6 f) Describe the method of measurement of high voltage in an ac circuit using potential transformer.

Ans:

Potential transformer:

Labeled diagram 2 marks,



Description 2 marks

The high voltage side is normally above 500 V (1 kV and above).
Primary side P has N_1 turns such that the ratio to N_2 yields a voltage of normally 110 V on the secondary side. Hence the low range voltmeter is of 110 V calibrated proportionally to read the high voltages on the primary side. Thus isolation of high voltage side is achieved to read its voltages.