Model Answers

Winter – 2018 Examinations

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.

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1 Attempt any TEN of the following: 20

1 a) State the function of commutator in DC generator and name the material used for commutator.

Ans:

Function of Commutator: 1 mark

Commutator converts AC induced in armature winding into DC for external load.

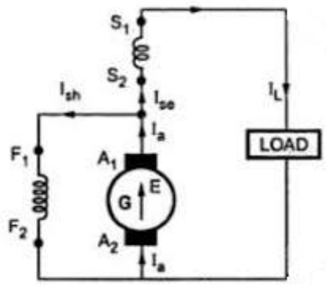
Material:

i) Commutator segments are made up of **Copper**. ½ mark

ii) Commutator segments are insulated from each other by **Mica**. ½ mark

1 b) Draw a neat connection diagram of dc short shunt differential compound generator showing the direction of all the currents.

Ans:



DC Short Shunt Differential Compound Generator

2 marks for labeled diagram OR 1 mark for unlabeled diagram

1 c) State Fleming's Left Hand Rule.

Ans:

Fleming's Left Hand Rule:

Stretch out the first three fingers of your left hand such that they are mutually perpendicular to each other, *align* first finger in direction of magnetic field, middle finger in direction of current flowing through the conductor *then* the thumb will give the direction of force acting on the current carrying conductor. 2 marks for correct statements

1 d) State any four applications of DC shunt motor.

Ans:

Applications of DC shunt motor:

DC shunt motors are fairly constant speed and medium starting torque motors, hence they are used in applications requiring constant speeds. ½ mark for each of any four applications = 2 marks

i) Lathe machine
ii) Drilling machines
iii) Grinders
iv) Blowers & fans
v) Compressors
vi) Centrifugal and reciprocating pumps
vii) Machine tools
viii) Milling machine

1	e)	A DC shunt motor operating on a supply voltage of 200V dc has armature resistance of 0.5Ω. If it's armature current is 25A then calculate back emf. **Ans:** $V = E_b + I_a R_a$ $E_b = V - I_a R_a = 200 - 25 \times 0.5$ = **187.5 volts**	1 mark for voltage equation 1 mark for final answer
1	f)	State the function of overload coil and No volt coil in dc motor starter. **Ans:** **Function of Overload Coil:** When DC motor is overloaded, the overload coil carries the overload current and produces strong magnetic field to attract a plunger, which short the terminals of no-volt coil. The no-volt coil current then becomes zero, its magnetism is lost and it releases the starter handle so that by spring tension it goes to off position and motor is disconnected from the supply. Thus the dc motor is protected from overload. **Function of No-volt Coil:** When supply fails, the no-volt coil current becomes zero, its magnetism is lost and it releases the starter handle so that by spring tension it goes to off position and motor is disconnected from the supply. On recovery of supply, one has to restart the motor using the starter. Thus the dc motor is prevented from restarting automatically on recovery of supply without starter and protected.	1 mark 1 mark
1	g)	State any four characteristics of core type transformer. **Ans:** **Characteristics of core type transformer:** i) It has one window. ii) It has one magnetic circuit. iii) Core surrounds the winding. iv) Average length of core is more. v) Area of cross section is less so more turns are required. vi) Better cooling for winding. vii) Mechnical strength is comparatively less. viii) Repair and maintenance is easy.	½ mark for each of any four characteristic s = 2 marks
1	h)	A 100 KVA transformer has iron loss 3 kW on full load. Calculate its iron loss at 50 % of full load. **Ans:** Iron loss at 50% of full load = 3 kW	2 marks
1	i)	State and justify which of the following two transformers is better: Transformer A = 4% voltage regulation Transformer B = 6% voltage regulation **Ans:** Transformer A with 4% voltage regulation is better. **Justification:** Voltage regulation refers to the percentage change in secondary voltage when load is changed from no-load to full-load with primary voltage kept constant. Ideally the	1 mark 1 mark for justification

secondary voltage should remain constant in spite of change in load. However, in practice, due to winding resistance and reactance, the secondary voltage changes with change in load. Therefore, the transformer with minimum change in secondary voltage is preferred. Since transformer A has 4% voltage regulation, which is less as compared to 6% of transformer B, it is better.

1 j) Define all day efficiency of transformer.
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. — 2 marks

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

1 k) Why phasing out and polarity test is carried out on three phase transformer?
Ans:
The phasing out test is carried out to identify the windings (primary and secondary) of corresponding phase of the three phase transformer. — 1 mark

The polarity test is carried out to identify the terminals of identical polarity of the primary and secondary windings of each phase of the three phase transformer. — 1 mark

1 l) State different types of cooling systems used for three phase transformer.
Ans:
Different Types of Cooling System used for 3 phase Transformer:

- Air Natural (AN)
- Air Forced (AF)
- Oil Natural Air Natural (ONAN)
- Oil Natural Air Forced (ONAF)
- Oil Forced Air Natural (OFAN)
- Oil Forced Air Forced (OFAF)
- Oil Natural Water Forced (ONWF)
- Oil Forced Water Forced (OFWF)

½ mark for each of any four systems = 2 marks

2 Attempt any FOUR of the following: 16

2 a) Derive the E.M.F. equation of DC generator.
Ans:
Derivation of E.M.F. Equation of Generator:
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, — 1 Mark
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. 1 Mark
Hence e_c = (flux cut in one revolution)/(time for one revolution) volt

$$= \frac{P\,Ø}{\frac{60}{N}} = \frac{P\,Ø\,N}{60} \quad volt$$

For Z conductors the total emf will be 1 Mark

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

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 $E_g = E_Z/A = \frac{ØZN}{60}\frac{P}{A}$ volts 1 Mark

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

2 b) A 4 pole, Lap wound DC shunt generator has 1230 armature conductor. Calculate flux developed per pole. If the terminal voltage of generator is 220V and it is driven at 1500 rpm. The armature is delivering a current of 120A and has resistance of 0.5Ω.

Ans:

Data given: Poles P = 4, For Lap winding, no. of parallel paths A=P=4
No. of conductors Z = 1230, Terminal Voltage V = 220V,
Speed N = 1500 rpm, Armature Current I_a = 120A, Armature resistance R_a = 0.5Ω 1 mark for voltage equation
The voltage equation of DC shunt generator is given by,
$V = E – I_a R_a$
∴ Induced emf $E = V + I_a R_a$
= 220 + (120)(0.5) 1 mark for E
= 280V

The induced emf can be obtained as, 1 mark for emf equation

$$E = \frac{ØZN}{60}\frac{P}{A}$$

$$\therefore Flux\ per\ pole\ Ø = \frac{60AE}{ZNP} = \frac{60(4)(280)}{(1230)(1500)(4)} = 0.009106\ Wb = \mathbf{9.106\ mWb}$$ 1 mark

2 c) Explain concept of back emf in DC machine. State how it governs armature current.

Ans:

Back emf:

When the armature of DC machine rotates under the influence of driving torque, the armature conductors move in the magnetic field and cut it and hence 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:

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

i) If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore the speed of armature is reduced. Hence back emf falls. This allows a larger current flow through armature means increased driving torque, 1 mark 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. — 1 mark, 1 mark

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.

2 d) Explain with suitable diagrams armature diverter method and armature voltage control method for speed control of DC series motor.

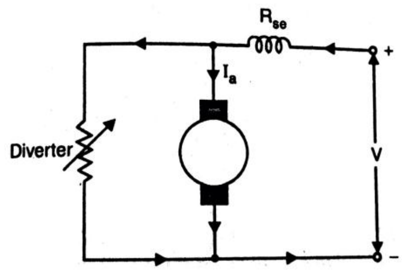
Ans:

(i) Armature diverter method:

-Resistance is connected in parallel with armature winding.

-This diverter resistance shunts some of the line current, thus reducing armature current.

-Thus for a given load if armature diverter resistance is reduced, it draws more current, the field current increases, flux increases and speed decreases.

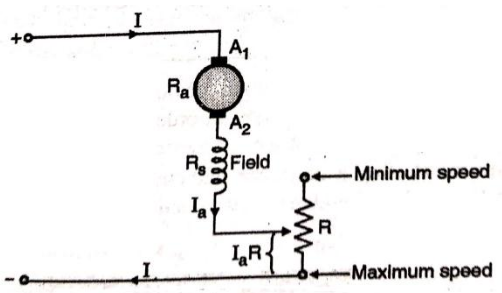


(ii) Armature Voltage Control Method:

-Resistance is connected in series with armature winding and field winding.

-Because of voltage drop in this resistance the voltage available across the armature gets reduces. Hence the speed of motor falls accordingly.

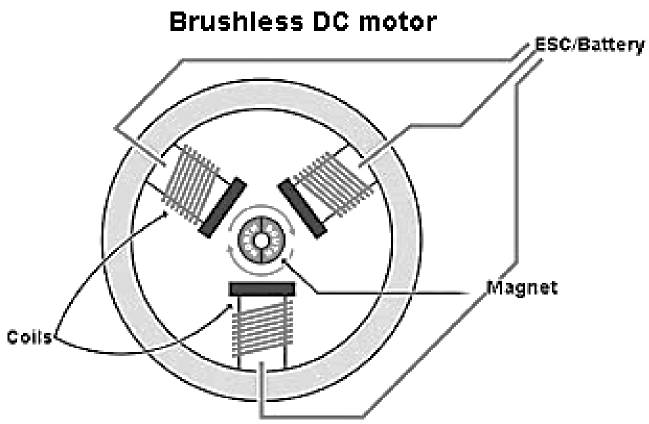
-By changing the value of variable resistance, any speed below normal can be obtained.



2 e) With the help of neat diagram, explain in brief the working of brushless DC motor.

Ans:

Working of Brushless D.C. (BLDC) motor:



2 marks for 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 explanation

OR any other equivalent diagram & its explanation

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

Ans:

For DC series motor, the voltage equation is:

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

$E_{B2} = V - I_{A2}(R_A + R_{SE}) = 230 – 50(0.12 + 0.03) = 222.5$ V. — 1 mark for back emfs

The back emf is related to flux and speed by, $E_B \propto \phi.N$ — 1 mark

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

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

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

$\therefore \phi_2 = 0.5\,\phi_1$ — 1 mark for flux ϕ_2

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

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

$\therefore$ Speed $N_2 = 1241.86$ rpm — 1 mark

3 Attempt any FOUR of the following: 16

3 a) Give detail classification of transformer.

Ans:

Classification of Transformer Based On:

i) Construction:
Shell type, Core type, Berry type

ii) Change in voltage level:
Step-Up, Step-Down,

iii) Number of phases:
Single phase, Three phase

iv) Purpose:
Power T/F, Distribution T/F

1 mark for each of any four basis = 4 marks

v) Use:
Instrument, Protection, Control

vi) Cooling:
Self-cooled, Air-cooled, Forced-air cooled, Oil-cooled, Forced-oil cooled.

3 b) Derive the emf equation of a transformer.

Ans:

Emf equation of transformer:

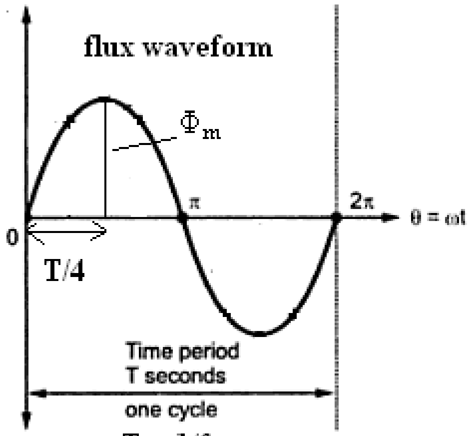
N_1 = No. of turns on primary winding

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

1st method



T = 1/f

1 Mark

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

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 $4\Phi_m f$

= 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 — 1 Mark

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

OR

OR

2nd method:

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

According to Faraday's laws of electromagnetic induction

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

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

$= \omega\Phi_m \sin(\omega t - \pi/2)$ volts — 1 Mark

Maximum value of emf/turn= $\omega\Phi_m$

But $\omega = 2\pi f$

Max. value of emf /turn $= 2\pi f\, \Phi_m$ — 1 Mark

RMS value of emf /turn $= 0.707 \times 2\pi f\, \Phi_m = 4.44\Phi_m f$ volts

RMS value of emf in primary winding — 1 Mark

$E_1 = 4.44\Phi_m f N_1$ volts

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

3 c) A single phase transformer has 400 primary and 800 secondary turns. The net cross-sectional area of the core is 40 cm^2.If the primary winding is connected to 50 Hz supply at 500V,

Calculate:

(i) Peak value of the flux density in the core.

(ii) Voltage induced in secondary.

Ans:

Given:

Cross sectional Area, $A = 40\ cm^2 = 40\times10^{-4} m^2$

Primary turns=N_1=400

Secondary turns=N_2=800

Frequency f = 50Hz

Primary voltage=V_1=E_1=500 V

Calculate:

(i) Φm=?

(ii) E_2=?

$E_1 = 4.44\ \Phi_m f N_1$ volt

$500 = 4.44 \times\Phi_m\times50 \times 400$ — 1 Mark

$\Phi_m = 500/4.44\times50 \times 400$

$\Phi_m = 0.0056$ weber

As $\Phi_m = B_m \times A$

i) $B_m = \Phi_m/A = 0.0056 /(40\times10^{-4}) = 1.4075\ Wb/m^2$ — 1 Mark

ii) $E_2 = 4.44\ \Phi_m f N_2$ volt

$E_2 = 4.44 \times0.0056\times50\times800$ — 2 Mark

$E_2 = 994.56$ V

3 d) **Explain why rating of a transformer is in KVA and not in KW?**

Ans:

1) The output of transformer is limited by heating due to the losses. Two types of — 1 mark for

losses in the transformer are (i) Iron loss, (ii) Copper loss. each point

2) Iron loss depends on the magnetic flux and the flux depends upon the transformer voltage (V). Copper loss depends on current (I).
3) As the losses depends on Voltage (V) and Current (I) and almost unaffected by load power factor.
4) Hence the transformer output is expressed in VA or kVA and not in kW.

3 e) A single phase transformer with ratio of 500/200 V takes a no load current of 3A at 0.4 p.f. lagging. If secondary supplies a current of 50 A at a p.f.0.85 lagging, estimate the current taken by primary.

Ans:

I_o=3 A at $\cos\Phi_o$=0.4 Φ_o=66.42 1 Mark

I_2 =50 A at $\cos\Phi_2$=0.85 Φ_2=31.78 1 Mark

$I_2' = V_2/V_1 \times I_2$

$I_2' = 200/500 \times 50$

I_2'=20 A 1 Mark

Current taken by the primary:

$I_1=\sqrt{(Io)^2 + (I_2)'^2 + [2\times Io \times I_2' \times \cos(\emptyset o - \Phi_2)]}$

$I_1=\sqrt{(3)^2 + (20)^2 + [2\times 3\times 20\times \cos(66.42 - 31.78)]}$ 1 Mark

I_1=22.53 A

3 f) OC test is performed on L.V. winding and SC test is performed on H.V. 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 L.V. side (HV open) to overcome the following difficulties: 2 Marks for OC test Justification

i) Meters required 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 H. V. 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. 2 Marks for SC test justification

S. C. 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.

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, low range ammeters can be used.
iii) Working with higher current is unsafe.
Hence S.C. test is conducted on HV by keeping LV short circuited.

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

4 a) Performance of a transformer is analyzed on all day efficiency. Justify the statement.

Ans:

(i) The distribution transformers are energized of 24 hours of the day.
(ii) The constant losses occur continuously and the copper (load dependent) losses occur varyingly with respect to the load for different times of the day. — 1 mark for each point
(iii) Thus varying powers are drawn due to which the efficiency varies drastically over the whole day.

Thus the performance of the transformers need to be judged in terms of the energy efficiency (or in terms of the energy it supplies) rather than the commercial (power) efficiency over the whole day.

4 b) A 20 KVA ,1000/400 V single phase 50Hz transformer has iron and full load copper losses as 300 watt and 500 watt respectively calculate:

(i) Efficiency at full load and 0.8 p.f. lagging. ,
(ii) Efficiency at half load and unity p.f.

Ans:

% full load efficiency at any p.f:

$$= \frac{[(full\ load\ KVA) \times 1000 \times pf]}{[\ (full\ load\ KVA) \times 1000 \times pf] + Iron\ loss + Full\ load\ copper\ loss} \times 100$$

% full load efficiency at 0.8 lag p.f: — 1 Mark

$$= \frac{20 \times 1000 \times 0.8}{[(20 \times 1000 \times 0.8) + 300 + 500\ ]} \times 100$$

1 Mark

$$= 95.23\%$$

% half load efficiency at any p.f:

$$= \frac{[x \times (full\ load\ KVA) \times 1000 \times pf]}{[\ (x \times full\ load\ KVA) \times 1000 \times pf\ ] + Iron\ loss + x^2 Full\ load\ copper\ loss} \times 100$$ — 1 Mark

% half load efficiency at unity p.f:

$$= \frac{(0.5 \times\ 20 \times 1000 \times 1\ )}{\{[0.5 \times\ 20 \times 1000 \times 1] + 300 + [(0.5)^2 \times 500]\}} \times 100$$

1 Mark

$$= 95.92\%$$

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4 c) A 1000 kVA, single phase transformer has full load copper and iron losses of 9 kW and 7 kW respectively. During a day of 24 hours it is loaded as given below

Sr. No.	No. of hrs.	Loading	Power Factor
1	6	800 KW	0.8
2	10	600 KW	0.75
3	04	200 KW	0.8
4	04	00 KW	-------

Calculate the all-day efficiency.

Ans:

The problem can be solved by using following steps:

Step-I Calculate output energy in KWh
Step-II : Convert the loading from kW to KVA
Step-III : Calculate copper losses at different KVA values
Step-IV: Calculate copper losses in 24 hours
Step-V: Calculate iron losses in 24 hours
Step-VI: Calculate All day efficiency

1 mark for step-I

1 mark for step-II

1 mark for step-III

1 mark for step-VI =4 marks

No of Hrs	Load in KW	P.F	Output energy in KWh= $load\ in\ KW \times No.of\ hrs$	Load in KVA= $\frac{Load\ in\ KW}{power\ factor}$	Copper Losses at different KVA= Copper Losses at Full load $\times\left(\frac{Load\ KVA}{RatedKVA}\right)^2$	Total cu Losses in kwh=	Total Iron losses
06	800	0.8	4800	$\frac{800}{0.8}$=1000	$9\ kw \times \left(\frac{1000}{1000}\right)^2$ = 9 kw	6×9 = 54 kWh	$7 \times 24 = 168\ kwh$
10	600	0.75	6000	800	5.76kw	57.6	
04	200	0.8	800	250	0.56 kw	2.24	
04	00	---	00	0	0	0	
			Total= 11600 kwh			Total= 113.84 kwh	Total=168 kwh

$$\%Efficiency_{Allday} = \frac{Output\ Energyin\ 24\ hrs}{Output\ Energy\ in\ 24\ Hrs + Lossesin\ 24\ Hrs} \times 100$$

$$= \frac{11600}{11600 + 113.84 + 168} \times 100 = \frac{11600}{11881.84} \times 100 = 97.62\%$$

$$\%\ Efficiency_{Allday} = 97.62\%$$

4 d) Explain polarity test on single phase transformer.

Ans:

Polarity test of single Phase transformer:

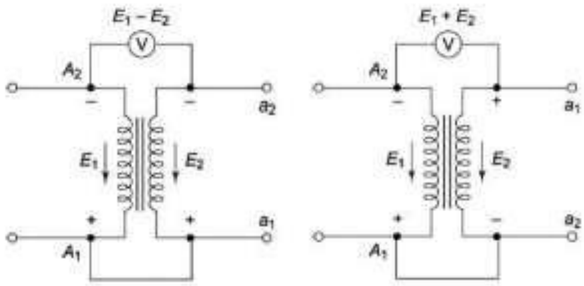
This test is conducted to identify the corresponding polarity terminals of the transformer HV and LV windings. — 2 marks for Explanation

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.

If the voltmeter reading appears to be $V = (E_1 - E_2)$ then it is referred as subtractive polarity. The terminals connected to each other 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 diagram

4 e) State condition of parallel operation of transformer**.**

Ans:

Conditions of Parallel operation of 3 phase transformer:

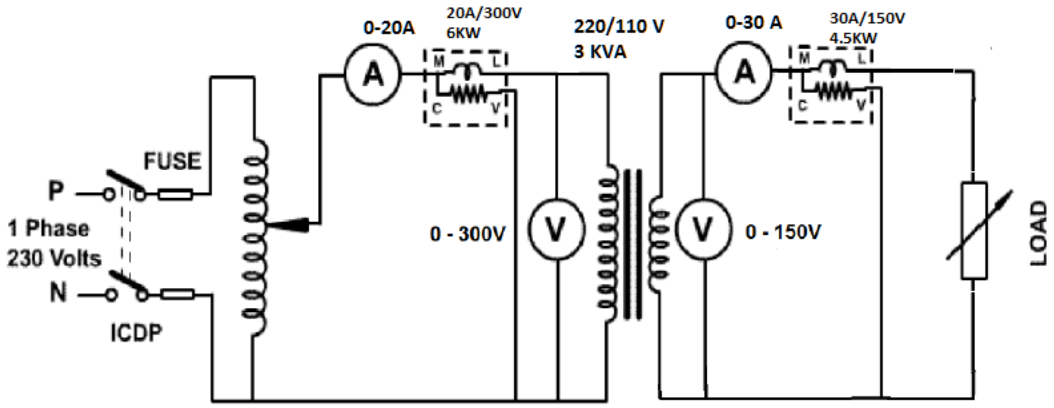
1) Voltage ratings of both the transformers must be identical.
2) Phase sequence of both must be same. — 1 Mark for each point
3) Transformer polarity wise connections must be carried out.
4) Percentage / p.u. impedances should be equal in magnitude.
5) X/R ratio of the transformer windings should be equal.

4 f) For a 3 KVA, 220/110V, 50 Hz single phase transformer, draw an experimental set up to conduct direct loading test on it. Determine the range of instruments to be used for the direct loading test.

Ans:

Primary full load current=(3×1000/220)=13.63 A — 1 Mark

Secondary full load current=(3×1000/110)=27.27A



3 Marks for Neat labeled diagram

2 Marks for Partially labeled diagram

5 Attempt any FOUR of the following: 16

5 a) List various losses in a transformer. State their location. State method to minimize these losses.

Ans:

Various Losses in Transformer:

1) **Copper losses (P_{cu}):** (1 mark for losses)
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.
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.

2) **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 = $K_E B_m^2 f^2 T^2$
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.

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

Location of Losses: (1 mark for location)
1) The Copper loss takes place in primary and secondary winding of transformer.
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) The eddy current loss is minimized using laminated core.
3) The hysteresis loss is minimized by using special magnetic materials like (1 mark)

Silicon Steel having small hysteresis loop area.

5 b) Two 1ϕ transformers with equal turns have impedances of (0.5+j3)Ω and (0.6+j10)Ω with respect to secondary. If they operate in parallel, determine how will they share a load of total 100kW at p.f. of 0.8 lagging?

Ans:

Ans:

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

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

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

Total load= 100kW at 0.8pf lagging.

$\therefore kVA = \frac{kW}{pf} = \frac{100}{0.8} = 125kVA,$

$cos^{-1}(0.8) = 36.87°$

$i.e. \quad S = 125\angle -36.87° \quad kVA$

$$S_A = S \times \frac{Z_B}{Z_A + Z_B} = 125\angle{-36.87^0} \times \frac{10.02\angle 86.6^0}{13.05\angle 85.2^0}$$

$= 95.97\angle{-35.47^0} \quad kVA$ 1 mark

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

$$kVA \times pf = 95.97 \times \cos(-35.47^0) = 78.16 \ \ kW$$ 1 mark

Similarly,

$$S_B = S \times \frac{Z_A}{Z_A + Z_B} = 125\angle{-36.87^0} \times \frac{3.04\angle 80.6^0}{13.05\angle 85.2^0}$$

$= 29.11\angle{-41.47^0} \quad kVA$ 1 mark

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

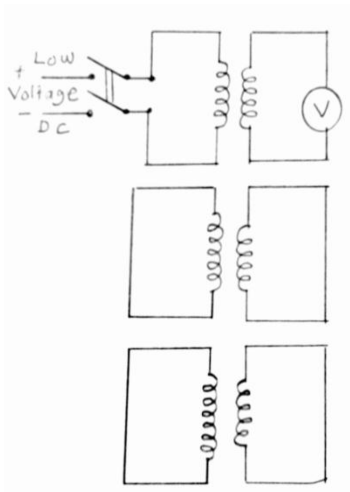
$$kVA \times pf = 29.11 \times \cos(-41.47^0) = 21.81 \ \ kW$$ 1 mark

5 c) Explain with neat diagram the procedure of conducting phasing out test on 3ϕ transformer.

Ans:

Procedure of conducting Phasing out test on 3 phase transformer:

- Phasing out test is conducted to identify the primary and secondary windings of a corresponding phase.
- Short primary & secondary windings of other phases except the one under test.
- Connect voltmeter/galvanometer to concerned 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.
- If voltmeter/galvanometer shows noticeable momentary deflections then it indicates that the two windings under test are belonging to the same phase.
- If voltmeter/galvanometer does not show deflection or shows very small deflections then two windings do not belong to same phase.
- Repeat the procedure by connecting voltmeter/galvanometer to other secondary winding till voltmeter gives deflection.
- In this way we can search the windings of corresponding phase.



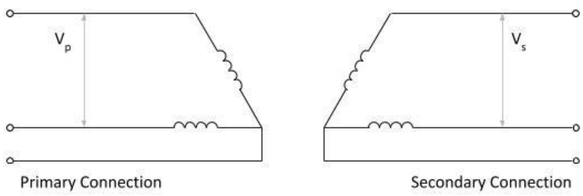
1 mark for diagram

3 marks for explanation

5 d) Explain with neat diagram open delta connection of 3ϕ transformer.

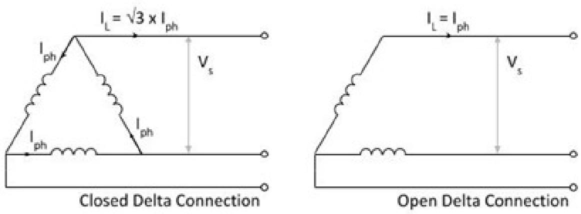
Ans:

Open delta connection of 3ϕ transformer:



1 mark for diagram

A bank of three single-phase transformers can be used for three-phase power transformation using delta-delta connection. However, during operation, if one of the transformers fails, then the faulty transformer is removed from service and using two single-phase transformers the three-phase transformation is continued with the help of what is called "Open-delta connection". The figure shows open-delta connection for three-phase power transformation.

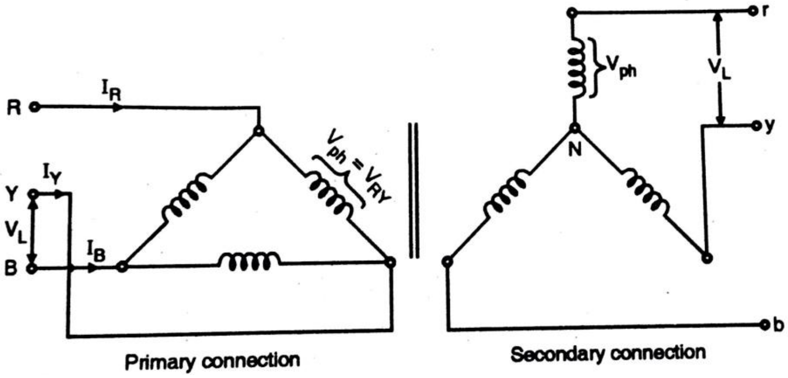


3 marks for explanation

With closed delta connection, the three-phase power is,
$P_{closed-delta} = \sqrt{3}V_L I_L = \sqrt{3}V_L\sqrt{3}I_{ph} = 3V_L I_{ph}$
With open-delta connection, the three-phase power is,
$P_{open-delta} = \sqrt{3}V_L I_L = \sqrt{3}V_L I_{ph}$ since the line current need to be maintained to the phase current value, otherwise winding may get damaged.
$\therefore P_{open-delta} = \frac{1}{\sqrt{3}}P_{closed-delta} = 57.73\%\ of\ P_{closed-delta}$
Thus with open-delta connection the power is restricted to 57.73% and not 2/3 or 66.67%. The open-delta connection is preferred as an emergency measure to continue the supply under the failure of one transformer in the bank.

5 e) For Delta-Star connection of 3ϕ transformer:
(i) Draw the connection diagram.
(ii) List any two advantages of this connection.
(iii) State the area of application.

Ans:
Connection diagram of Delta-star connection of 3-ϕ Transformer:



1 mark

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.
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.

1 mark for each of any 2 advantages = 2 marks

Area of Application:
This type of connection is preferred for distribution transformers, due to following reasons:

1 mark

i) Availability of neutral makes it possible to supply single-phase as well as three-phase loads.
ii) Earthed neutral is used in protection scheme against earth faults.

5 f) State criteria for selection of distribution transformer.

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

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) Impedance
7) Phasor group
8) Availability of space for transformer erection (indoor /outdoor).
9) Distance of loads from transformer substation.
10) Times of low loads and maximum loads.
11) Future expansion plans or trends or forecasting.
12) Ambient conditions for deciding insulation class.
13) Tap changing requirement.

½ mark for each of any 8 criteria = 4 marks

6 Attempt any FOUR of the following: 16

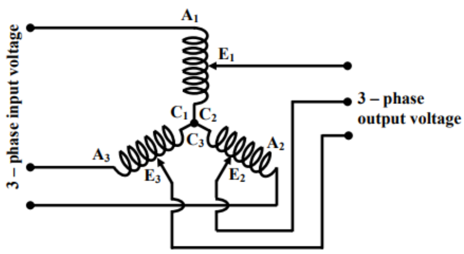
6 a) Explain with neat diagram construction of three phase autotransformer.

Ans:

Construction of three phase auto transformer:

- Three 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 electromagnetic core is 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 can be obtained by tapings to which the output terminals are connected as required.
- As only one winding per phase is available, part of it acts as secondary between variable terminal and neutral.

2 marks for explanation



3 – phase autotransformer

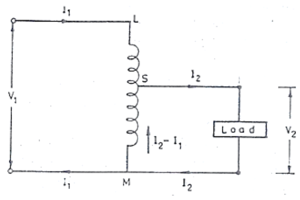
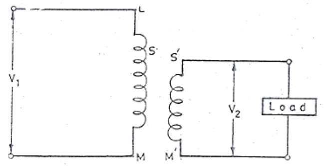
2 marks for diagram

6 b) Compare single phase auto transformer with two winding transformer. (any four points)

Ans:

Comparision between Single phase auto transformer and Two winding Transformer:

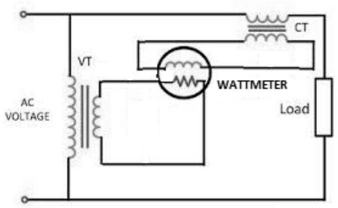
Parameters	Single phase Auto Transformer	Two-winding Transformer
Movable contact	Movable contact	No movable contact

Symbol		
Copper saving	Cu saving takes place	None
Electrical Isolation	No	Yes
Cost	Less	More
Efficiency	More than Two-winding transformer	Less than Auto transformer
Regulation	Better	Poor than Auto transformer
Applications	Variac, Starting of motor, dimmerstat, power transformer when voltage ratio is close to 1	Main transformer , power supply, welding, Isolation transformer, Distribution and power transformers

1 mark for each of any four points = 4 marks

6 c) Draw a neat circuit diagram of connection of CT and PT in power measurement circuit, also explain its working.

Ans:



2 marks for diagram

The figure shows schematic arrangement of electrical connections of CT, PT (or VT) and low range wattmeter for measurement of power in single-phase circuit.

The CT primary winding is connected in series with the load, so that it carries load current. The secondary winding of CT supplies reduced current to current coil of wattmeter.

The PT primary is connected across load so that it supplies proportionately reduced voltage to pressure coil of wattmeter.

2 marks for explanation

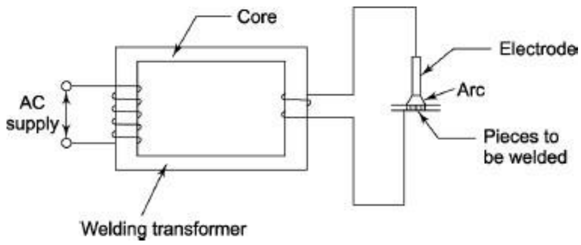
Thus CT and PT are used here to proportionately reduce the load current & load voltage to level in the range of low range wattmeter. The wattmeter measures the power proportional to CT secondary current & PT secondary voltage. The load power is then given by,

Load Power = (CT Ratio)×(PT Ratio)× Wattmeter reading

Thus low-range wattmeter can be used to measure high load power using Ct and PT.

6 d) Describe working of welding transformer.

Ans:



2 marks for diagram

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.

ii) Winding used is highly reactive or a separate reactor winding is added in series with the secondary winding. — 2 marks for explanation

iii) It has large & thin primary turns and few 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 I2R 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.

viii) Common ratings:
Primary voltage – 230 V, 415 V
Secondary voltage – 40 to 60 V
Secondary current – 200 to 600 A

6 e) What is the most important precaution while operating a C.T.

Ans:

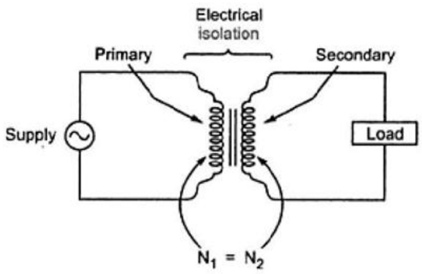
The most important precaution while operating a CT is that the secondary of CT should never be kept open circuited during its use. The secondary winding of C.T. has a large no. of turns of thin wire. If secondary winding of C.T. remains open circuited, the secondary current becomes zero resulting no secondary mmf. The secondary mmf opposes the primary mmf, thereby maintaining core flux to low value. However, when there is no secondary mmf, the opposition falls to zero & primary mmf produces a large flux in core. It produces high eddy current and hystresis losses. It would increase the temperature of the core which may result in damage of insulation & core. The larger core flux also cause high voltage induced in open circuited secondary and this may be dangerous to the equipment and working personnel. In the event of fault, if secondary is open, the large primary current causes large core flux and very high emf induced in the secondary winding, which can breaks down the insulation. Therefore the secondary of CT should never be kept open-circuited.

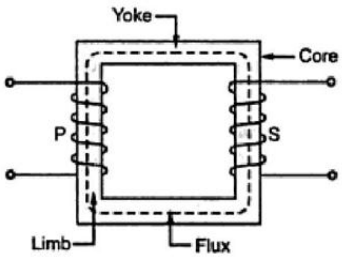
4 marks for correct answer

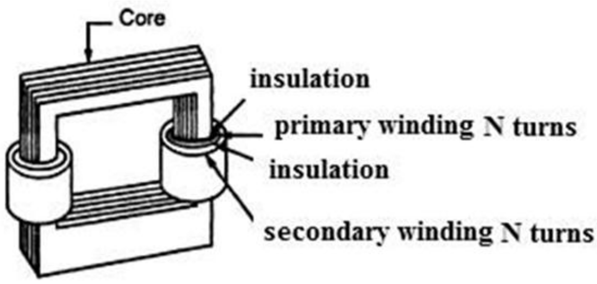
6 f) Explain construction and working of isolation transformer.

Ans:

Construction and Working of isolation transformer:







2 marks for diagram

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.

2 marks for explanation

ii) These are built with special insulation between primary and secondary.
iii) When supply is given to primary it causes primary current to flow in primary winding and inducing ac fluxes in core. The secondary winding is wound on common magnetic core, hence these ac fluxes are linked with it. Now secondary emf is induced according mutual induction action and secondary current flows through load if connected.
iv) Unwanted voltage spikes, transients are prevented by isolations transformer from reaching to delicate and costly sensitive load/equipment. It acts as a decoupling device.
v) These transformers block the transmission of direct current (DC) signals, but allow AC signals to pass from one circuit to another.
vi) It isolates the load equipment from supply ground
vii) It reduces the voltage spikes