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 should 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 following:	20

1 a) State functions of the armature core in DC machine and name material used for armature core.

Ans:

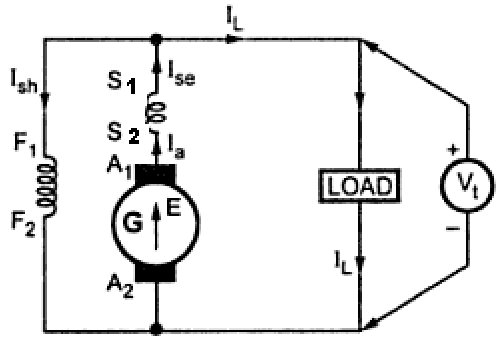
Functions of armature core:

1) Support the armature winding which is placed in its slots. — ½ mark each any 2 = 1 mark
2) Rotate as driven by the prime mover (generator) or as per the torque produced (motor). Hence it is a member that connects the mechanical aspect with the electrical one.
3) Increase the permeance (ease of magnetization) of the magnetic path to increase the magnitude of induced emf for a certain MMF created by the field winding.

Material used for armature core: 0.4 mm to 0.5 mm thick dynamo grade sheet steel laminations which are stacked together. — 1 mark

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

Ans:



Unlabeled 1 mark, labeled 2 marks

1 c) State at least four applications of DC series motor. — ½ mark each any four applications

Ans:

Applications of DC series motor:

Electric locomotives, trolley cars, cranes, hoists, conveyors.

1 d) State working principle of DC motor.

Ans:

Working principle of DC motor:

Current carrying conductor placed in a magnetic field experiences a force given by F = B I L sinΘ, the direction of which is given by Fleming's Left Hand rule. — 1 mark

where B = external magnetic field, I current in conductor,

L = length of conductor in magnetic field, Θ = physical angle between directions of I and B.

The current carrying conductors are placed on the armature core and the field is created by the DC electromagnets around the armature to get a unidirectional — 1 mark motion depending on the relativr directions of I and B.

1 e) A 400 V DC motor takes an armature current of 100 A when its speed is 1000RPM. If the armature resistance is 0.25 ohm, calculate the torque produced in Nm.

Ans:

Input power to armature = V_A x I_A = 400 x 100 = 40000 W.

Power lost in armature resistance = $(I_A)^2R_A = 100^2$ x 0.25 = 2500 W.

The remaining power in armature gets converted to mechanical power,

= 40000 – 2500 = 37500 W. ½ mark

This mechanical power is available in terms of a torque and speed. As the speed is = 1000 RPM ,

angular speed 'ω' = (2π x 1000/60) rad/sec = 104.72 rad/sec. ½ mark

T ω = Mechanical power = 37500 W, from which

T = (Mechanical power)/ ω = 37500 / 104.72

= 358 Nm. 1 mark

1 f) State any two applications of brushless DC motor.

Ans: (1 mark each any two = 2 marks)

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

1 g) State four properties of Ideal transformer:

Ans:

Properties of Ideal transformer: (Any four = ½ mark each= 2 Marks)

1) No losses (iron and copper), hence no temperature rise
2) Zero winding resistance and leakage reactance
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 résistance 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).

1 h) Enlist the various losses take place in transformer.

Ans:

Losses in the transformer: — ½ mark each any four = 2 marks

1) Primary winding copper losses ($I_1^2R_1$)
2) Secondary winding copper losses ($I_2^2R_2$)
3) Eddy current losses in core.
4) Hysteresis loss in core.
5) Dielectric losses in the insulation system.

1 i) The no load ratio of a 50 Hz single phase transformer is 6000V/250V. Find the number of turns in each winding if the maximum flux is 0.06 Wb in core.

Ans:

The no load ratio is the ratio of the induced emfs of HV aand LV sides.

$E_{LV} = 4.44Ø_M\, f\, T_{LV}$ & $E_{HV} = 4.44Ø_M\, f\, T_{HV}$.

$E_{LV} = 250$ V & $E_{HV} = 6000$ V., f = 50 Hz.

$T_{LV} = E_{LV} / (4.44Ø_M\, f) = 250/(4.44 \times 0.06 \times 50) = 18.76 \rightarrow 19$ — 1 mark

$T_{HV} = E_{HV} / (4.44Ø_M\, f) = 6000/(4.44 \times 0.06 \times 50) = 450.45 = 451.$ — (1 mark

Also $T_{HV}/ T_{LV} = E_{HV}/ E_{LV}$, from which — Or

$T_{HV} = (6000/250) \times 19 = 456.$ (more practical answer) — 1 mark)

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

OR = (output energy in kWh in 24 hrs)/(input energy in kWh in 24 hrs) x100

1 k) Give specification of three phase transformer as per IS 1180(part-I)-1989.

Ans:

Specification of 3-phase transformer – — ½ mark each any four.

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 rize.
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) State different types of cooling systems used for three phase transformer.

Ans:

Different types of cooling systems for three phase transformer:

1) ONAN: Oil Natural Air Natural where the circulation of both cooling media is natural. ½ mark each any four = 2 marks
2) ONAF: Oil Natural Air Forced where the circulation of oil is natural and air is draught forced as cooling medium on the oil tubes.
3) AN: Air natural where air cools the transformer naturally without any forcible blowing.
4) Air Forced: air is forced by draught fans on the transformer body directed properly to cool it.
5) OFAF: Oil forced Air Forced where both cooling media are forcibly circulated or driven for fast cooling.
6) OFWF: Oil Forced Water Forced where a heat exchanger is used to extract heat from the oil being pumped. Water is circulated by force.

2 Attempt any four: 16

2 a) Derive emf equation of DC generator.

Ans:

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 (driven) of generator in RPM.

By Faraday's Laws of electromagnetic induction

Induced emf in each conductor 'e_c' = d Ø/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.

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

$$= \frac{P\,Ø}{\frac{60}{N}} = \frac{P\,Ø\,N}{60}\,V$$ 1 mark

For Z conductors the total emf will be

$$Ez = Z\frac{P\,Ø\,N}{60}\,V$$ 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' = E_Z/A = $(P\,Ø\,Z\,N)/(60\,A)$ V. 1 mark

2 b) 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:

P = 4, Ø = 0.02 Wb, N = 1250 RPM.

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

E = $(P\,Ø\,Z\,N)/(60\,A)$ 1 mark

i) Lap wound:
A = number of parallel paths of armature winding = no of poles = 4.
E = (4 x 0.02 x 864 x 1250)/(60 x 4)
= 360 V. 1 mark

ii) Wave wound:
A = number of parallel paths of armature winding = 2.
E = (4 x 0.02 x 864 x 1250)/(60 x 2) 1 mark
= 720 V

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

Ans:

Necessity of the starter for d.c. motor :

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

At start speed $N = 0$, $\therefore E_b = 0$ and $I_a = \frac{V}{R_a}$. 1 mark

As R_a is very small I_a will be dangerously high at the time of starting. This high starting current may damage the motor armature (& series field winding in the 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. 1 mark

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.

1 mark each any two types = 2 marks

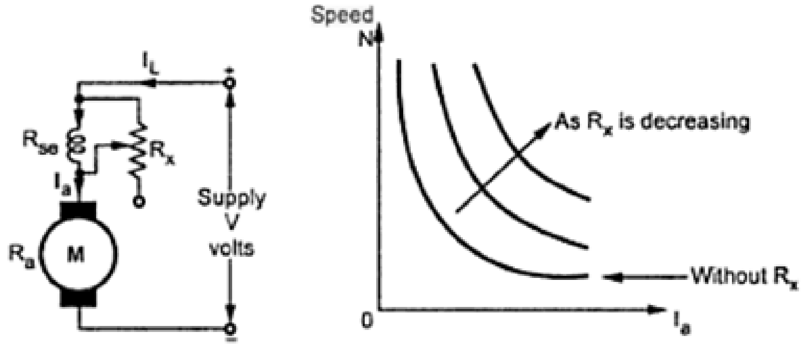
2 d) Explain with suitable diagrams flux control method and armature control method for speed control of DC series motor.

Ans:

I) Flux control methods: N α (1/Ø) α ($1/I_F$) before saturation

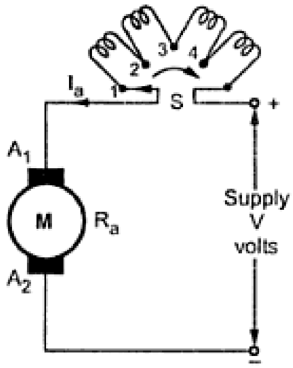
Any one method of flux control diagram 1 mark, explanation 1 mark.

i) Field divertor method:by adjusting R_X field current is controlled, flux is controlled and speed is controlled above rated value as shown in graph



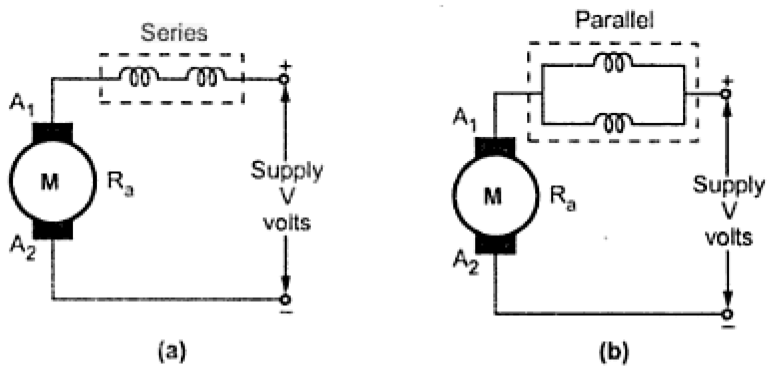
(a) Field diverter (b) Speed-current characteristics

ii) Tapped field method: as selector switch is moved from position 1 onwards the number of field turns decreases which decreases MMF, hence speed increases above rated value. Used in electric traction



iii) For same torque if field coil is arranged in series or parallel MMF of coil changes, hence flux produced also changes and speed can be controlled. Some fixed speeds can only be obtained. In parallel grouping higher speeds can be obtained.

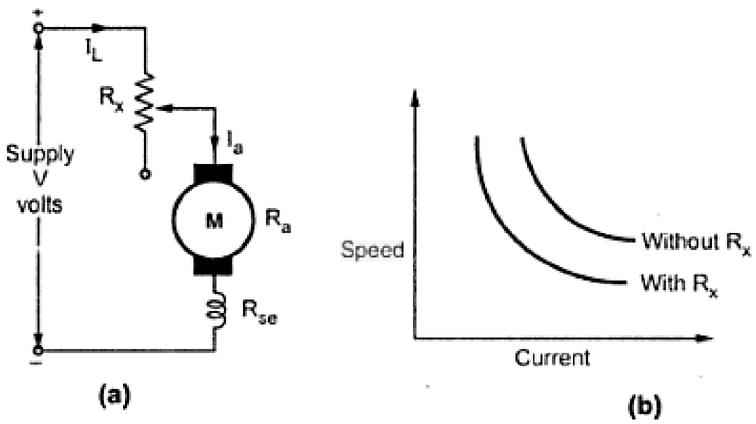
Series parallel connection of field:



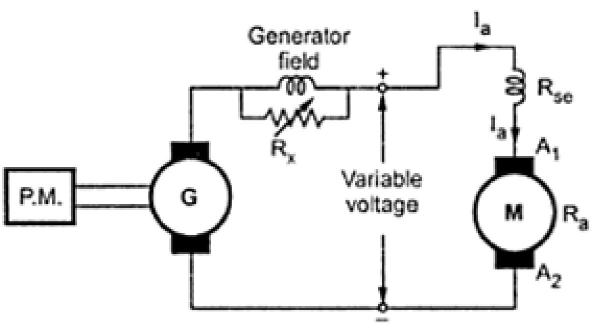
II) Armature control: N α V_A (we can use voltages below rated)

Any one method of armature control diagram 1 mark and explanation 1 mark

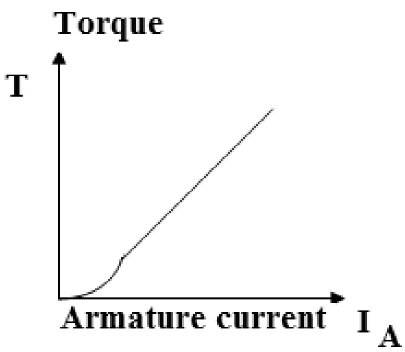
i) Here speed is directly proportional to voltage across armature. The speed reduces as armature voltage is reduced.

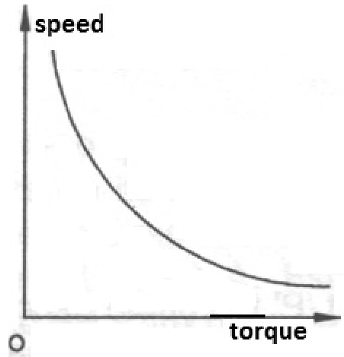


ii) Generator driven motor:
As E_G α Ø the flux change is achieved which gives variable voltage at output terminals due change in supply voltage the various speeds are obtained.



2 e) Draw torque versus armature current and speed versus torque characteristics of DC series.
Ans:





Fully labeled 2 marks each, unlabeled 1 mark each

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

Ans:

At no load:

Motor input = 250 x 4 = 1000 W.

I_{SH} = Field current at all times = (applied voltage to motor)/field resistance

I_{SH} = 250/250 = 1 A.

I_{AO} = Armature current at no load = motor input current – field current

I_{AO} = 4 – 1 = 3 A.

Field copper loss = (field voltage x field current)

= $I^2_{SH} R_{SH}$ = 250 x 1 = 250 W.

Armature copper loss = $I^2_{AO} R_A = 3^2 \times 0.8$ = 7.2 W.

$P_{constant}$ = friction, windage and stray losses are

= no load motor input – no load armature copper loss – field copper losses

= 1000 – 7.2 – 250 = 742.8 W.

Hence these losses $P_{constant}$ = 742.8 W. 1 mark

Full load efficiency:

I_A = Full load armature current = motor input current – field current

= 22 – 1 = 21 A.

Full load armature copper losses = $I^2_A R_A = (21)^2 \times 0.8$ = 352.8 W.

Total full load losses

= armature copper losses + field copper losses + $P_{constant}$

= 352.8 + 250 + 742.8

= 1345.6 W. 1 mark

Full load input power = input voltage x current drawn by motor

= 250 x 22 = 5500 W. 1 mark

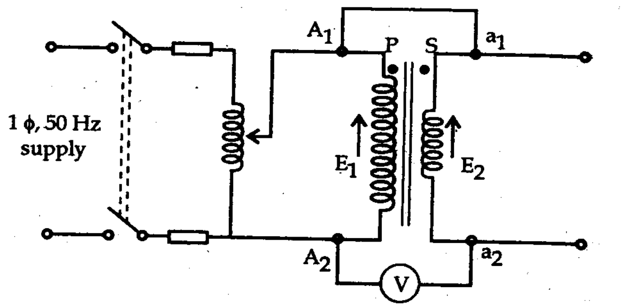
At full load efficiency

$\%\eta$ = [(motor input – losses)/(motor input)] x 100

= [(5500 – 1345.6)/5500] x100
= 75.53 %. 1 mark

3 Attempt any four 16

3 a) Explain with neat sketch the polarity test of single phase transformer. Which type of polarity marking is preferred in case of transformer?
Ans:
Polarity test is conducted to determine the relative polarity of the mutually inductive windings of a transformer (primary, secondary and tertiary).



1 Mark

- transformer is connected to a single phase AC supply.
- The primary terminals are A_1 and A_2 while secondary terminals are a_1 and a_2. 1 Mark
- Let A_1 and a_1 are shorted and a voltmeter is connected between A_2 and a_2.
- If voltmeter reading is $V = E_1 – E_2$ (subtractive), then marked polarities are correct. 1 Mark
- If voltmeter reading is $V = E_1 + E_2$ (additive) , then marked polarities are not correct. One of them should be reversed. 1 Mark

The polarity marking shown above is used for transformers, i.e.
Identical alphabets with identical suffixes are shown for similar polarity, with capital letters for HV and small case letters for LV.
Eg. A_1 (HV side) has same polarity as a_1 (LV side).

3 b) Two transformers P & Q of 150 kVA and 100 kVA respectively are connected in parallel. $\%Z_P = 1.2(\%Z_Q)$; what maximum load can be transformed without overloading either of the transformers?
Ans:

Assume common base VA = 150 kVA,
% impedance of Q, $Z_Q' = (150/100)Z_Q = 1.5\ Z_Q$. 1 mark
% impedance of P = 1.2 Z_Q.

The transformer Q has a lower % impedance [as $\%Z_P = 1.2(\%Z_Q)$], hence it will share a greater load which must be equal to 100 kVA as it should not be over loaded. — 1 mark

Therefore S_Q = 100 kVA, the total load shared is S_T.

$S_Q = S_T\,[\%Z_P/(\%Z_P + \%Z_Q')]$

$100 = S_T\,[1.2Z_Q/(1.2Z_Q + 1.5Z_Q)] = S_T(4/9)$ from which — 1 mark

S_T = 225 kVA is the maximum load that can be shared without overloading either P or Q. — 1 mark

3 c) Compare distribution transformer and power transformer on four points.

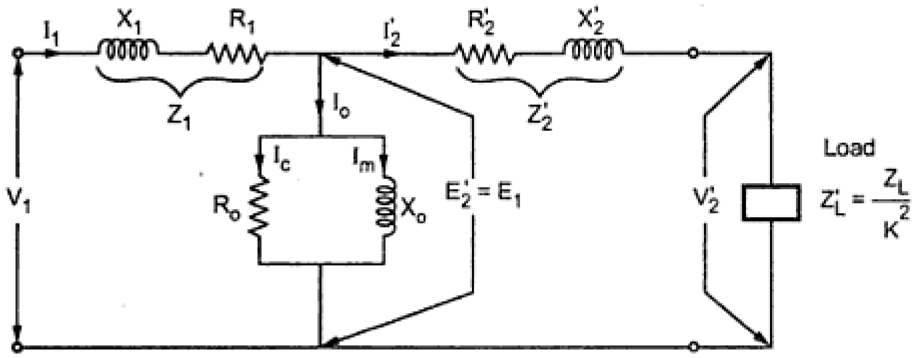
Ans:

S.No	Parameters	Distribution Transformer	Power Transformer
1	Normal rated voltages	3.3 KV, 6.6 KV, 11KV, 220V and 440V	33KV, 66KV,110KV, 220KV and 400 KV
2	Power ratings	Lower than 200 MVA	Greater than 200 MVA
3	Load of maximum efficiency	Obtained near 70 % full load	Obtained near 100 % full load
4	Efficiency preferred	All day efficiency needs to be defined	Only power efficiency is sufficient
5	Loaded times	Heavy variation of loads from no load to heavy over loads.	Nearly fully loaded at all times

1 mark each any four = 4 marks

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

Ans:



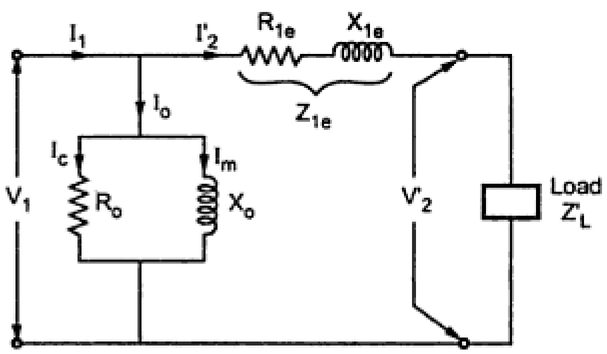
Fully Labeled 2 marks

R_1 & X_1 → resistance & leakage reactance of primary winding respectively, — 1 mark

R_O & X_O → core loss equivalent resistance & magnetizing reactance of primary

respectively,
R'_2 & X'_2 → secondary winding resistance & reactance referred to primary
where $R'_2 = R_2/K^2$ & $X'_2 = X_2/K^2$, (R_2 & X_2 → secondary winding resistance and reactance respectively) 1 mark

OR



Fully labeled 2 marks

R_{1e} = equivalent resistance referred to primary = $R_1 + R'_2$,
X_{1e} = equivalent reactance referred to primary = $X_1 + X'_2$,
R_O & X_O → core loss equivalent resistance & magnetizing reactance of primary respectively. 2 marks

3 e) A single phase transformer of 100 kVA, 11000/2200 V, 50 Hz, gave the following results:

i) OC test (input to LV side): 2200 V; 1.59 A, 980 W.
ii) SC test (LV shorted): 580 V, 9.1 A, 1100 W.

Calculate the efficiency and regulation of transformer at full load 0.8 pf lagging.
Ans:

Calculation of full load efficiency:
Full load current on HV side = kVA x 1000/V_{HV}
= (100 x 1000)/(11000) = 9.1 A.
From SC test as current is full load, full load copper loss = 1100 W.
Constant losses = iron losses = 980 W at rated voltage. 1 mark

% Full load efficiency =

$$= \frac{\text{(full load kVA) 1000 x pf}}{\text{(full load kVA)x 1000x pf} + \text{(constant losses + copper losses)}} x100$$

$$= \frac{100 \text{ x } 1000 \text{ x } 0.8}{100 \text{ x } 1000 \text{ x } 0.8 + (980 + 1100)} x100$$

= 97.46 % 1 mark

Calculation of regulation:

We require R and X (equivalent resistance and reactance respectively; referred to HV side) for the formula at lagging pf,

% regulation =

$$\frac{(I\ R cos Ø + IX\ sin Ø)}{V} x100$$

Where:
I = full load current on HV side, R = equivalent resistance referred to HV side,
X = equivalent reactance referred to HV side, Ø = pf angle of load and
V = rated voltage of HV side.
From SC test:
As current is full load I = 9.1 A, impedance voltage = 580 V,
Impedance of transformer referred to HV = Z = V_{SC}/ I = 580/9.1 = 63.73 ohms,

I^2R = 1100 W. hence R = 1100/$(9.1)^2$ = 13.28 ohms.

X = $\sqrt{(Z^2 - R^2)} = \sqrt{(63.73^2 - 13.28^2)}$ = 62.33 ohms.

For pf = cosØ = 0.8 lag, sinØ = 0.6. 1 mark

% regulation = [(9.1 x 13.28 x 0.8 + 9.1 x 62.33 x 0.6)/11000] x 100

= 3.973 %. 1 mark

3 f) A 20 kVA transformer on domestic load which can be taken as of unity power factor has full load efficiency of 95.3 %. The copper loss is twice the iron loss. Calculate the all day efficiency on following duty cycle:
No load→ 10 Hrs.
Half load → 08 Hrs.
Full load→ 06 Hrs.
Ans:
Let iron loss = P_I. P_{CUFL} = full load copper loss = $2P_I$.
From given data using expression of efficiency,

95.3/100 = (20 x 1000 x1)/[20 x 1000 x1+ P_{CUFL} + P_I)
0.953 = (20000)/(20000 + $3P_I$) from which
P_I = 329 W. and P_{CUFL} = $2P_I$ = 658 W 1 mark

Energy loss in iron:
For all loads iron loss is constant hence energy lost in iron losses in a day

= 24 x 329 = 7896 Wh = 7.896 kWh

Load energy & Energy lost in copper loss for the day: (load PF = 1)

Load→	No load	Half load	Full load	Totals
Hrs→	10	08	06	24
Power output (kW)→	0	(20kVA x 1)/2 = 10kW	20 kVA x 1 = 20kW	
Load Energy (kWh)→	0	10 x 8 = 80 kWh	20 x 6 = 120 kWh	200 kWh
Copper loss→	0	$P_{CUFL}/[2^2]$ = 658/4 = 164.5 W	P_{CUFL} = 658 W	
Energy lost (Cu) (kWh)→	0	164.5 x 8 = 1316 Wh = 1.316 kWh	658 x6=3948 Wh = 3.948 kWh	5.264 kWh

2 marks

Total energy supplied during 24 hrs = 200 kWh.
Total energy lost in 24 hrs = loss in iron + loss in copper = 13.16 kWh. 1 mark

All day efficiency %
= [(load energy of 24 hrs)/(load energy of 24 hrs+ energy lost in 24 hrs)] x 100
= [200/(200+13.16)] x 100
= 93.82 %.

4 Attempt any four: 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 pf and 0.8 pf lag.
Ans:
<u>% full load efficiency at any pf:</u>

$$= \frac{\text{(full load kVA) 1000 x pf}}{\text{(full load kVA)x 1000x pf} + \text{(iron losses + full load copper losses)}} x100$$ 2 marks

<u>% full load efficiency at unity pf:</u>

$$= \frac{500\text{x } 1000 \text{ x } 1}{500 \text{ x } 1000\text{x } 1 + (2500 + 7500)} x100$$

= 98.03 % 1 mark

<u>% full load efficiency at 0.8 lag pf:</u>

$$= \frac{500\text{x } 1000 \text{ x } 0.8}{500 \text{ x } 1000\text{x } 0.8 + (2500 + 7500)} x100$$

= 97.56 % 1 mark

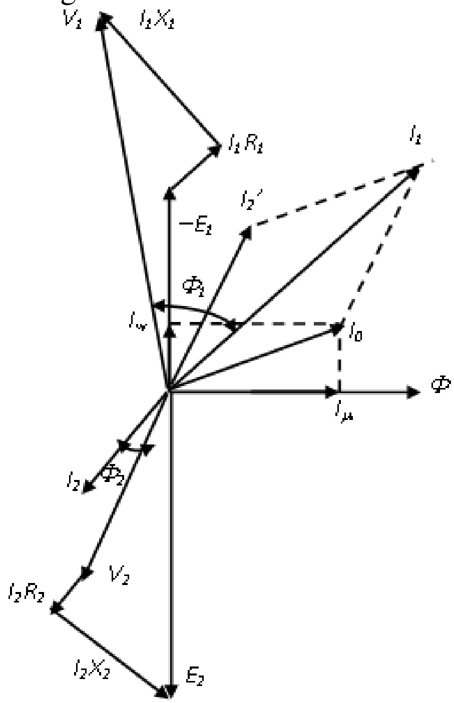
4 b) Draw the complete phasor diagram of transformer for lagging and leading pf load condition.

Ans:

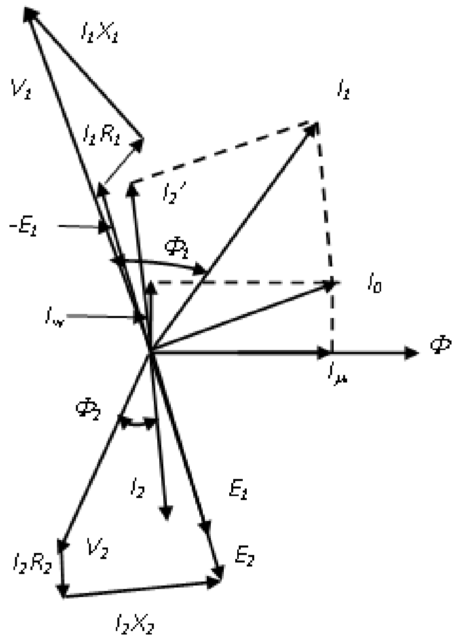
- Flux Φ is shown lagging behind E_1 by 90^0.
- The no load prrimary current $I_{0,}$ is very small and it lags behind V_1 by an angle ϕ_0 which is slightly less than 90^0.
- No load current current I_0 has two componennts, I_μ, and I_w.
- Secondary current I_2 lags or leads V_2 because the load is inductive or capacitive.
- Primary current I_1 is the sum of no load current I_0 and I_2'.
- V_1 is the vector sum of E_1, voltage drop in primary resistance and voltage drop in primary leakage reactance.

Description not compulsory

E_2 is the vector sum of V_2, voltage drop in secondary resistance and secondary leakage reactance.



Lagging PF :



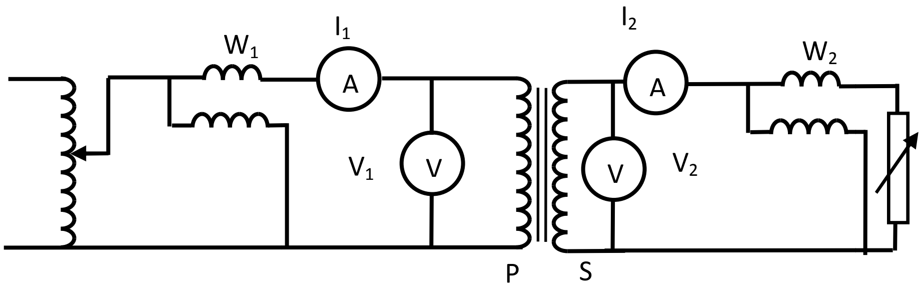
Leading PF :

For each diagram

Labeled 2 marks, partially labeled 1 mark.

4 c) Explain with circuit diagram the direct loading tests on single phase transformer. How efficiency and regulation at given load condition is determined?

Ans:



Correct circuit 2 marks

The load on the transformer is varied from no load to about 10 % overload in steps of around 15%. The readings are to be noted as below:

Primary volts V_1 (V)	Primary current I_1 (A)	Primary power W_1 (W)	Secondary terminal volts V_2(V)	Secondary current I_2 (A)	Secondary power W_2 (W)	Remarks
			V_{2NL}			No load
		W_{1FL}	V_{2FL}		W_{2FL}	Full load
						10% overload

- Calculation of efficiency for any load: ($W_1 = W_{1L}$, and $W_2 = W_{2L}$) 1 mark
  For any load condition = %η = (W_{2L}/ W_{1L}) x 100.

- Calculation of regulation for any load: ($V_2 = V_{2L}$) (1 mark Or 1 mark)
  % regulation = [($V_{2NL} - V_{2L}$)/(V_{2NL})] x 100 or

  % regulation = [($V_{2FL} - V_{2L}$)/(V_{2FL})] x 100.

OR

- Connect the circuit as shown in figure.
- Adjust primary voltage to its rated value.
- Increase the load gradually from no load to full load and note down all the meter readings.
- Calculate % Efficiency = (W_2/W_1) x 100, where, W_2 = Output power and W_1 = Input power. 1 mark

Calculate % Regulation = ($E_2 - V_2/E_2$) x 100, where V_2 = secondary voltage on load and E_2 = secondary voltage on no load 1 mark

4 d) State any two advantages of parallel operation of transformer. State conditions for connecting single phase transformers in parallel.

Ans:

Advantages of parallel operation of transformers:

1) Reliability of the supply system increases as supply to essential loads can be continued in case of failure of one of the transformers. — 1 mark each any two = 2 marks.
2) Highly varying loads result in inefficient operation of the transformers. Hence by parallel operation un-necessary low load operation is avoided by loading only the relevant capacity transformer to operate at high efficiency. Thus it leads to conservation of energy.
3) Overloading of transformers is avoided and hence of life of transformer increases.

Conditions for connecting single phase transformers in parallel:

1. Terminals with the same polarity on HV- and LV side shall be connected in parallel, — ½ mark each any four = 2 marks.
2. Primary windings of both must be suitable for supply system (V, f).
3. Transformers should have approximately the same voltage ratio, within +0.05% or -0.05%.
4. The short-circuit impedance voltage should be the same, within +10% or -10%, with X/R being nearly identical.
5. The power rating of the transformers should not deviate more than 1:3,
6. Tap changers should have tap position giving voltage ratios as close as possible.

4 e) Two transformers A of 40 kVA with % Z_A = (3+j4) and B of 25 kVA; share equally a load of 50 kVA; while working in parallel. Find how they share a load of 40 kVA. Comment on your answer.

Ans:

Let Z_B' = impedance of B at base kVA of 40 kVA.

Then by given load sharing of 50 kVA, 25 kVA is shared by A

$S_A = S_T(Z_B')/(Z_A + Z_B')$, — 1 mark

$25 = 50(Z_B')/(3+j4 + Z_B')$ from which

$Z_B' = (3 + j\,4)\ \% = \%\ Z_A$. — 1 mark

As both impedances (%) are equal referred to common base, all powers will be equally shared.

Hence for $S_T = 40$ kVA
$S_A = 40(3 + j\,4)/[(3 + j\,4) + (3 + j\,4)] = 20$ kVA. 1 mark

Comment: when the % impedances of parallel operating transformers referred to a common base are identical the power is equally shared along with identical power factors. 1 mark

4 f) Derive condition for maximum efficiency of transformers.

Ans:

Let output = S = VIcosØ, copper losses = I^2R where R = resistance referred to side of I_{FL}, P_I = constant losses (iron losses).

$\eta = (VI\cos Ø)/(VI\cos Ø + I^2R + P_I)$, the voltage is approximately constant, the power factor is assumed constant, the variable is the load current.
Let VcosØ = K (constant), divide both numerator and denominator by I. 1 mark

$\eta = (K)/(K + IR + P_I/I) = K/D$.

$D = IR + P_I/I$ 1 mark

To find maxima of η wrt I we can find condition for minima of D when η will be maximum (as denominator is minimum the η expression becomes maximum)
We differentiate D wrt I.

$dD/dI = R – P_I\, I^{-2} = 0$ gives us the condition for maxima or minima of D.

$I = \sqrt{(P_I/R)}$ or $I^2 = P_I/R$. 1 mark

Now if "d^2D/dI^2" is positive at above condition then D is minimum and η is maximum.

$d^2D/dI^2 = 2P_I\, I^{-3}$.

At $I = \sqrt{(P_I/R)}$, $d^2D/dI^2 = 2P_I/[\sqrt{(P_I/R)}]^3 = [2\, R^{3/2}]/[\sqrt{(P_I)}]$ which is positive for all conditions, hence D is minimum and η is maximum. 1 mark

Hence the for a load current of $I = \sqrt{(P_I/R)}$ or

$I^2\, R = P_I$. or

the load at which the variable loss equals the constant loss the efficiency is max.

(students may attempt by differentiating "η" i.e dη/dI to determine the condition for maxima and hence the same condition is obtained) the marks are to be awarded parallel).

5		Attempt any four	16
5	a)	Explain why rating of transformer is always in kVA and not in kW.	

Ans:

The capacity of a transformer is decided by the rated voltage and rated current it can safely handle without over heating or damage. Also output power of transformer is given by P= VICosØ, for different types of load i.e (resistive, capacitive, inductive) cosØ changes so, for same voltage and current output powers will different, as the transformer is designed to operate at particular voltage and current levels and it not designed to deliver particular real power that is why rating of transformer is in kVA. — 1 mark, 1 mark, 2 marks

OR

As copper loss of a transformer depends on current and iron loss on voltage, Hence total transformer loss depends on volt-ampere and not on phase angle between voltage and current ie. It is independent of load power factor. That is why rating of transformer is in kVA. The heating occurs due these losses. The cooling system is designed for specified heating due to the rated values of voltage and current. Any value above the rated may lead to over heating and abnormal operation. Hence to avoid this the transformer is specified by VA rating. — 1 mark, 1 mark, 1 mark, 1 mark

5 b) State advantages of amorphous core type distribution transformers.

Ans:

Advantages of amorphous core type distribution:

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

1 mark each any four = 4 marks

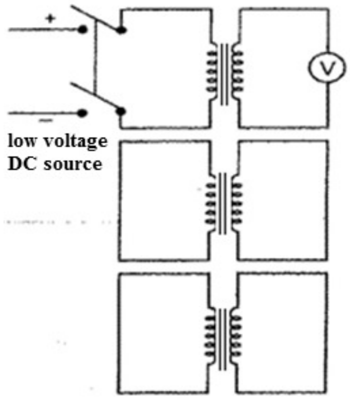
5 c) Explain why all day efficiency of distribution transformer is a more reasonable basis for comparison than ordinary efficiency.

Ans:

The distribution transformers are energized for 24 hours of the day wherein the constant losses occur continuously and the copper losses occur varyingly with respect to the load for different times of the day. Thus varying powers are drawn for different times due to which the power based efficiency varies drastically over the whole day. Thus the performance of the transformers need to be assessed in terms of the energy efficiency (or in terms of the energy it supplies) — 1 mark, 1 mark rather than the commercial efficiency (power efficiency). Thus it is reasonable basis for comparison of efficiencies of distribution transformers. 2 marks

5 d) What is the aim of conducting phasing out test on 3 phase transformer? Explain with neat sketch the procedure of conducting phasing out test.
Ans:

Aim of conducting phasing out test is to identify the windings (primary and secondary of corresponding phase) placed on a core limb. 1 mark

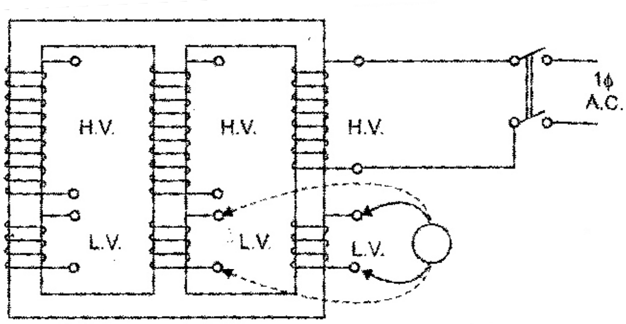


Circuit 2 marks Any one diagram

Description 1 mark of any one method.

The circuit is connected as shown and the switch is operated. The terminals across which the deflection is maximum correspond to the phase of the winding across which the supply and switch are connected. Here every time we connect voltmeter to a winding the remaining ones are to be shorted.

This can be performed using ac supply also. The terminals across which the induced emf is maximum lies on the same limb as the coil to which the supply is connected.



5 e) Explain with neat sketch the construction of three phase auto transformer.
Ans:

- 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). 2 marks

- 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.

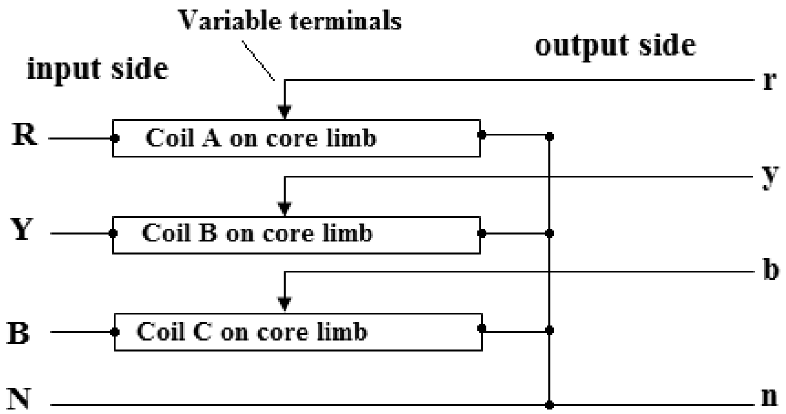


Figure 2 marks (or equivalent)

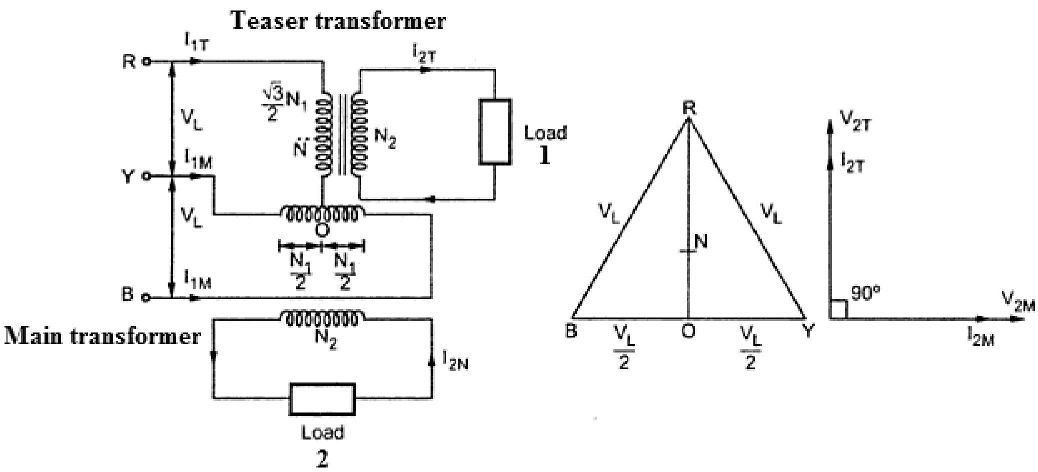
5 f) Explain with neat diagram, three phase to two phase conversion (Scott connection) of 3 phase transformer.

Ans:

Scott connection of transformers:

-- used for three phase to two phase conversion when two phase loads such as furnaces of large ratings are to be used so that the large load gets distributed equally on the three phases to have balanced load condition. 1 Marks

As seen from the phasor diagram the output voltages to the two loads are identical. The two transformers which have turns rated as shown are used.



3 Marks

6 Attempt any four 16

6 a) State the criteria for selection of distribution transformer & power transformer.

Ans:

Criteria for selection of distribution transformer:

1) Total connected load.
2) Load Diversity factor.
3) Expected daily load curve. ½ mark each any four.
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.

Criteria for selection of power transformer:
1) Power to be handled (MVA rating) or to be transformed.
2) Line kV rating.
3) Insulation class.
4) Load of maximum efficiency.
5) Tap changing requirement.
6) Protective devices required.
7) Ambient conditions.

6 b) Compare single phase auto transformer with conventional two winding transformer.
Ans:

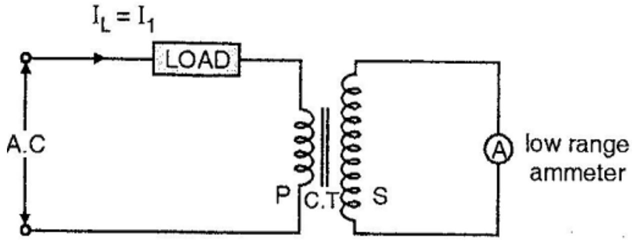
4 Marks for any four points

	Single phase auto transfromer	Two winding transformer
1	No electrical isolation of input and output sides.	Input and output are electrically isolated from each other.
2	Power transferred inductively and conductively	The power is transferred inductively.
3	Lowest power loss	Low power loss
4	Savings affected in copper	Savings not possible.
5	Very economical for ratio less than 2	Economical for higher ratios
6	Used for lower power circuits compared to 2 winding	Can be used for higher power circuits.
7	Lower cost	Higher cost
8	Lower impedance	Higher impedance

6 c) Explain with circuit diagram the use of CT and PT for measurement of high current and high voltage.

Ans:

Use of CT:

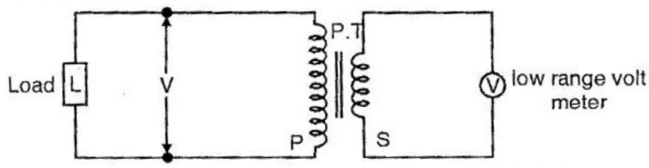


1 mark

- The high current to be measured is passed through the primary of transformer. The low range ammeter is connected in series with the secondary winding.
- C.T. is step up voltage transformer. Hence step down current transformer.
- Hence the number of turns of secondary winding is very much greater than number of turns of primary windings.
- The actual value of high current under measurement = Reading of low range meter *nominal ratio of C.T.

1 mark

Use of PT:



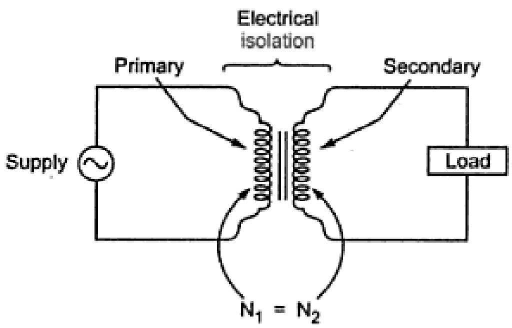
1 mark

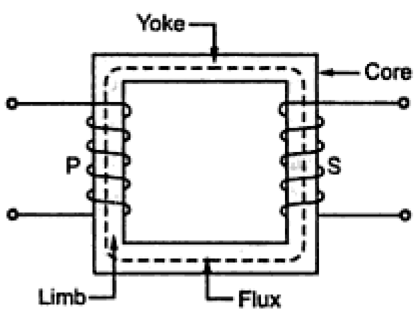
- "V" is the voltage to be measured which very high.
- Use to read high voltages on low range voltmeters.
- PT is step down transformer.
- The actual value of high voltage under measurement = Reading of low range meter *nominal ratio of P.T.

1 mark

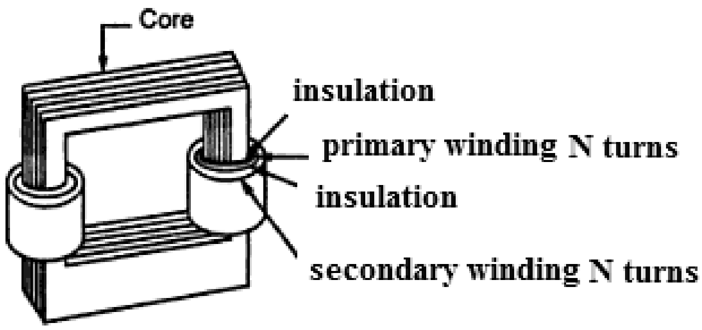
6 d) Explain construction and working of isolation transformer.

Ans:





Any two diagrams 1 mark each = 2 marks



Isolation transformer:

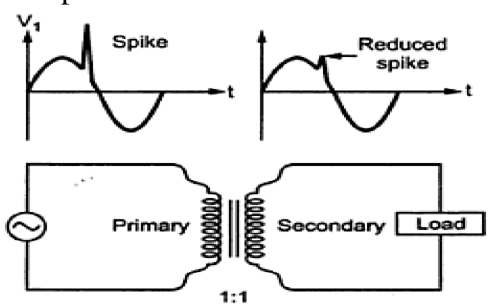
- The transformer has primary and secondary windings placed on the common core limbs which have equal number of turns so that the voltage fed to the primary is available at the secondary without any change in its magnitude. Primary purpose of isolation transformer is to isolate the two circuits and not to step-up or step-down the voltage.
- These are built with special insulation between primary and secondary.
- It acts as a decoupling device.
- These transformers block the transmission of direct current (DC) signals, but allow AC signals to pass from one circuit to another. 2 marks

6 e) State any two applications of:
i) single phase auto transformer ii) isolation transformer.
Ans:

Applications:

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

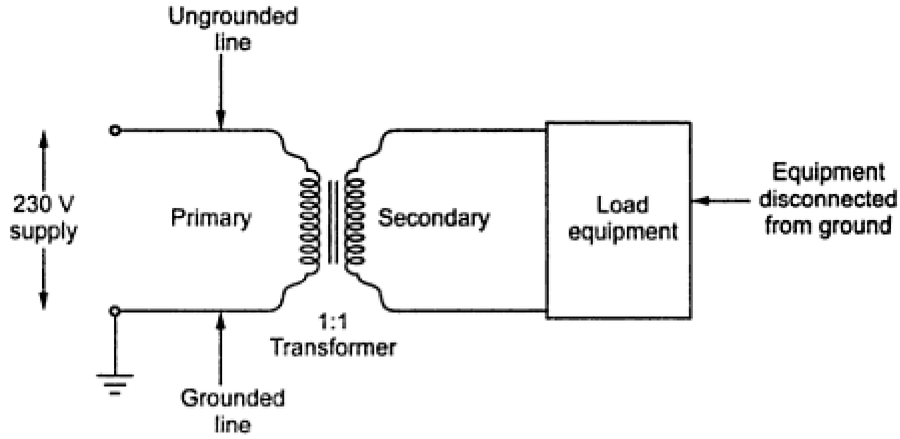
ii) Isolation transformers:
1) As spike reducers for sensitive semiconductor circuits.



The load is sensitive equipment

1 mark

2) Remove the equipment on load side from ground by disconnecting it from earth (connected on secondary) while on the primary side one terminal is earthed.



1 mark

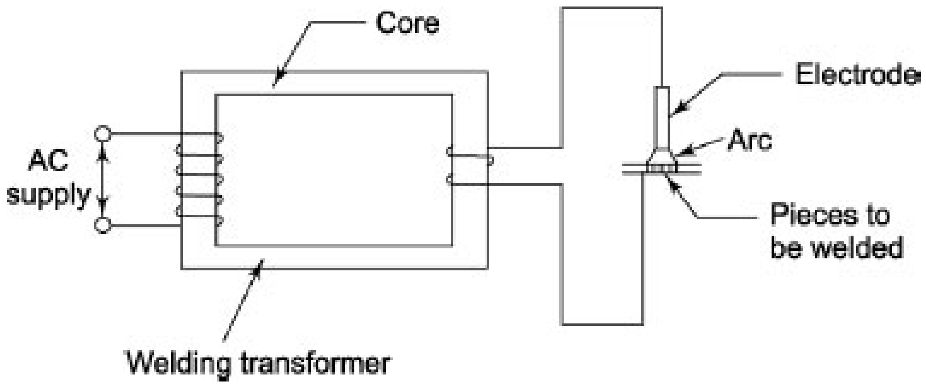
6 f) Compare single phase welding transformer with single phase two winding transformer on the basis of winding sizes, cooling, working and construction.
Ans:

Parameter	Single phase welding transformer	Single phase two winding transformer
Winding sizes	• Very thin large number of turns of primary conductors, • Secondary conductors very thick due to very high currents (step down).	• Winding sizes depend on the type of the transformers. • Not as thick depends on current rating and type of transformer.
Cooling	Air cooled for small sizes and oil cooled for larger ones.	Air cooled for smaller sizes and oil cooled for large sizes.
Working	• Principle of mutual induction. • With rated voltage on primary very low voltage is obtained on secondary side which is applied to the pieces to be welded. • Highly variable voltage may be present on secondary side.	• Principle of mutual induction. • With rated voltage applied to the primary the rated secondary voltage is obtained.
Construction	• Several taps on secondary side to adjust/control the current	• Taps are not always needed but provided if required.

One mark each

	to reasonable values. • Very highly reactive windings. • Separate reactors are used purposely. • The transformer is normally large in comparison to other step down transformers as the windings are of a much larger gauge.	• Less reactive in comparison. • No reactors used purposely. • Comparatively smaller sizes.

Diagrams showing working of both:



Two winding transformer: