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	a)	i)	Parts in armature circuit of DC machine: 1) Armature core, 2) Armature windings, 3) Commutator and 4) Brushes.	2 Marks
1	a)	ii)	Function of yoke: i) It provides mechanical support for the poles and acts as the protecting cover for the whole machine and ii) It provides a path of low reluctance to the flux produced by the field poles.	1 Mark
			Function of field windings: to produce the necessary flux when current is passed through field windings.	1 Mark
1	a)	iii)	Methods of improving commutation: i) Resistance commutation – by replacing low resistance copper brushes by comparatively high resistance carbon brushes.	1 Mark

ii) e.m.f. commutation – by using either brush lead or inter-poles. 1 Mark

1 a) iv) Applications of DC shunt motor: Lathes, centrifugal pumps, machine tools, blowers, fans, reciprocating pumps etc.

Applications of DC series motor: traction i.e., electric locomotives, trolley cars, cranes, hoists, conveyors etc.

2 Marks for any two applications of each motor

1 a) v) Transformation ratio $K = \frac{V_2}{V_1} = \frac{I_1}{I_2}$ **OR** $K = \frac{V_1}{V_2} = \frac{I_2}{I_1}$ 1 Mark each

1 a) vi) $Commercial\ efficiency = \frac{Output\ in\ watts}{Input\ in\ watts}$ 1 Mark

$All\ day\ efficiency = \frac{Output\ in\ kWh}{Input\ in\ kWh}$ (For 24 hours) 1 Mark

1 a) vii) Applications of 3-phase auto transformer: 1) as auto transformer starter for 3-phase induction motor 2) as voltage booster in transmission/distribution system 3) as furnace transformer 4) in control equipment for 3-phase locomotives 5) as interconnecting transformer in high voltage AC systems 6) to obtain 3-phase variable AC supply in laboratories.

1 mark each, max 2 Marks for any two applications

1 a) viii) $Voltage\ ratio = \frac{Phase\ voltage\ on\ secondary\ side}{Phase\ voltage\ on\ primary\ side}$ 1 Mark

$Current\ ratio = \frac{Phase\ current\ on\ primary\ side}{Phase\ current\ on\ secondary\ side}$ 1 Mark

1 b) i)

	Lap winding	Wave winding
1	The two ends of each armature coil	The two ends of each coil are

	are connected to adjacent commutator segments.	connected to the commutator segments placed between adjacent poles of the same polarity.	1 mark each max 4.
2	There are as many parallel paths for current as there are field poles. So the Number of parallel paths A = Number of poles (*P*).	There are two parallel paths, regardless of the number of field poles. i.e. $A = 2$	
3	The number of brush positions are equal to the number of poles	Only two brush positions are required regardless of the number of field poles.	
4	It is used for machines having low voltage and high current capacity.	It is used machines having low current and high voltage capacity.	

1 b) ii) Classification of transformers:

1) Based on construction: Core type and Shell type — 1 Mark each
2) Based on voltage level: Step-up and Step-down
3) Based on number of phases: Single phase and Three Phase
4) Based on application: Power transformer, Distribution transformer, Instrument transformer, Isolation transformer, Welding transformer etc.

1 b) iii) Advantages of three single phase transformers over three phase three winding transformer: — 1 mark each any four max 4 Marks

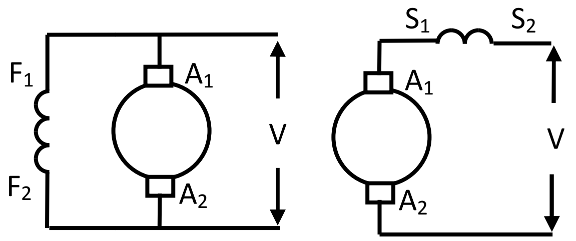
1) In three phase three winding transformer if any one phase becomes disabled then the whole transformer has to be removed from service for repairs.
2) In case of three phase bank of single phase transformers, if one transformer goes out of order, the faulty transformer can be easily replaced.
3) If one transformer goes out of order, the system can still be run open-Δ at reduced capacity.
4) Cost of spare unit is low.
5) Repairing cost is low.

2 a) ϕ = ?, Z = no. of slots x no. of conductors/slot = 80 x 10 = 800, A = no. of parallel paths in armature = P (lap winding), N = 1000 rpm, E_g = 400 V 1 Mark

Generated e.m.f. $E_g = \frac{\phi P N}{60} \times \frac{Z}{A}$ volt 1 Mark

$\therefore \Phi = 0.03$ Webers. 2 Marks

2 b) 2 Marks for each for correct diagrams and labeling



DC Shunt motor DC Series motor

2 c) Emf equation of transformer:

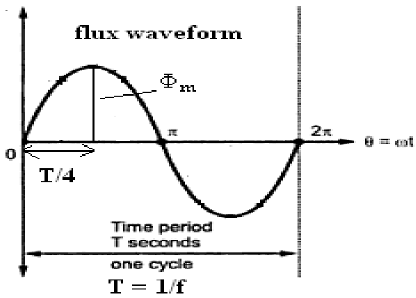
N_1 = No. of turns on primary winding

N_2 = No. of turns on secondary winding

Φ_m = maximum value of flux linking both the winding in Webers.

f = Frequency of supply in Hz

1st method:



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

Avg. rate of change of flux = $\Phi_m/t = \Phi_m/(1/4f) = 4\Phi_m f$ Wb/sec 1 M

From faraday's laws of electromagnetic induction

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

Form factor for sinusoidal waveform = (RMS value)/(Avg. value) = 1.11 1 M

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

$= 4.44\ \Phi_m f$ volts

R.M.S. emf induced in primary winding = (RMS emf / turn) x N_1 1 M

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

Similarly, $E_2 = 4.44\ \Phi_m f\ N_2$ volts 1 M

OR

II nd method OR

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

According to Faraday's laws of electromagnetic induction

Instantaneous value of emf/ turn = $- d\Phi/dt = -d/dt\ (\Phi_m \sin \omega t)$ 1 M

$= -\omega\Phi_m \cos \omega t$

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

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

But $\omega = 2\pi f$

Max. value of emf /turn = $2\pi f\ \Phi_m$ 1 M

RMS value of emf /turn = 0.707 x $2\pi f\ \Phi_m$

$= 4.44\Phi_m f$ volts

RMS value of emf in primary winding $E_1 = 4.44\Phi m\ f$ x N_1 volts and

$E_2 = 4.44\ \Phi mf\ N_2$ volts 1 M

2 d) $kVA = 5$, $V_1 = 230$ V, $V_2 = 110$ V,

$I_1 = kVA$ x 1000 / $V_1 = 21.74$ A 1 Mark

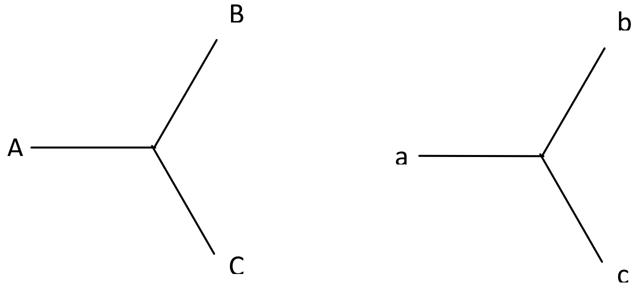
$I_2 = kVA$ x 1000 / $V_2 = 45.45$ A 1 Mark

$N_2/N_1 = V_2/V_1$, $\therefore N_2 = (110/230) \times 80 = 38.26$ 2 Marks

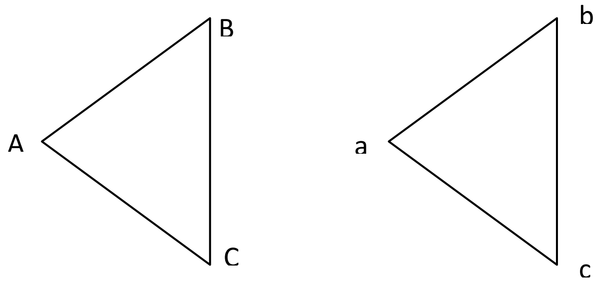
2 e) Characteristics of ideal transformer:

1) No losses (iron and copper), hence no temperature rise — 1 mark each point, any four points
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 %

2 f)



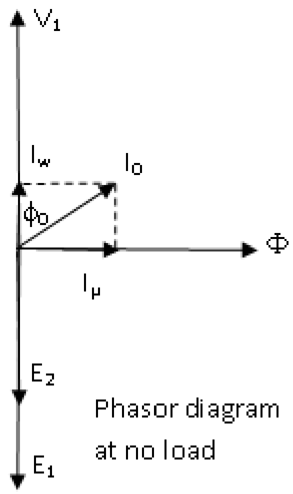
Phasor diagram for vector group Yy0



Phasor diagram for vector group Dd0

2 Marks for each phasor diagram

3 a)



2 Marks for phasor diagram.

Relations for no load parameters –

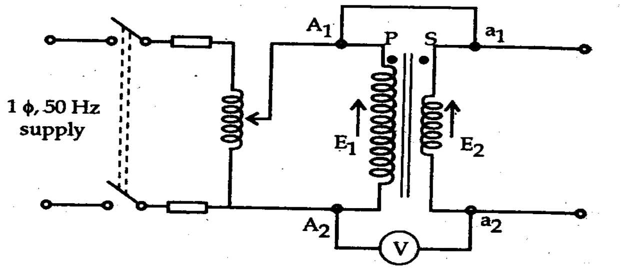
$I_\mu = I_0 \sin\phi_0,$ ½

$I_w = I_0 \cos\phi_0$ ½

$X_0 = E_1/ I_\mu$ ½

$R_0 = E_1/I_w$ ½

3 b) Polarity test is conducted to determine the relative polarity of the mutually inductive windings of a transformer (primary, secondary and tertiary). 1 Mark



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.
- 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. ½ Mark
- If voltmeter reading is $V = E_1 + E_2$ (additive) , then marked polarities are not correct. One of them should be reversed. ½ mark

Polarity marking is important while connecting two transformers in parallel 1 Mark
(other method can be considered)

3 c)

	Two winding transformer	Potential Divider
1	Input and output are electrically isolated from each other.	Input and output are not electrically isolated from each other.
2	The power is transferred inductively.	The power is transferred conductively.
3	Low power loss	High power loss
4	Voltage can be stepped up or stepped down.	Voltage can be stepped down only.
5	Can operate on AC supply only	Can be used for AC as well as DC
6	High cost	Low cost

1 mark each pt max 4 Marks

3 d) Information provided on the nameplate of 3-phase transformer –

1) Name of the manufacturer
2) kVA rating of transformer
3) % impedance of transformer
4) Allowable temperature rize.
5) Voltage ratings for the primary and secondary voltages
6) Wiring instructions for HV and LV windings/terminal diagram
7) Operating frequency of the transformer
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) Type of cooling
13) Insulation class

½ mark each pt. any 8 points = 4 marks

3 e) Features of welding transformer:

- It is a step down transformer that reduces the voltage from the source voltage to a lower voltage that is suitable for welding.
- 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 comparison to other step down transformers as the windings are of a much larger gauge.

2 marks each feature 2 features = 4 marks

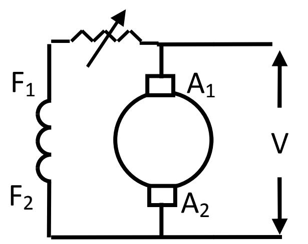
3 f) Ratio error: In practice it is said that current transformation ratio I_2/I_1 is equal to the turns ratio N_1/N_2. But the actual current ratio is not equal to the turns ratio because of losses and exciting current. It is also affected due to secondary current and power factor. Similarly in case of potential transformers, the voltage ratio V_2/V_1 is not exactly equal to the turns ratio N_2/N_1. Such an error is called as ratio error. It is defined as – 1 mark

$$\%\ Ratio\ error = \frac{Nominal\ ratio - Actual\ ratio}{Actual\ ratio} \times 100$$

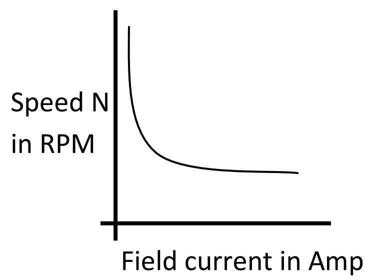
1mark

Phase angle error: In power measurements, it is must that the phase of secondary current is to be desplaced by exactly 180^{O} from that of primary current for CT. While the phase of secondary voltage is to be desplaced by exactly 180^{O} from that of primary voltage in case of PT but actualy it is not so. The error introduced due to this is called phase angle error. In case of CT it is defined as - It is the angular difference between the reversed secondary current phasor and the primary current phasor. 1 mark 1mark

4 a)



Flux control method



2 Marks for each neat diagrams and correct labeling = 4 marks

Flux control method:

- For constant load and armature voltage, speed of DC shunt motor $N \alpha 1/\phi$. 1 mark
- Speeds above normal can be obtained by reducing the field current only because voltage across armature can not be increased above rated value. 1 mark
- The flux of DC motor can be changed by changing the field current with the help of a shunt field rheostat. As the resistance is increased flux ϕ is reduced and speed increases. 1 mark
- As field current is relatively small, shunt field rheostat has to carry a small current.
- Thus I^2R loss is small and the rheostat is also small in size. Thus the method is more efficient.
- If the flux becomes very weak the speed can become gangerously high as shown in speed-field current curve. 1 mark

4 b) From O.C. test:

$\cos \Phi_0 = 70/(200 \times 0.7) = 0.5$, $\Phi_0 = 60^O$. $\sin\Phi_0 = 0.866$

$I_w = 0.7 \times 0.5 = 0.35$ A, $I_\mu = 0.7 \times 0.866 = 0.606$ A

$R_0 = V/I_w = 200/0.35 = 571.4\ \Omega$ 1 Mark

$X_0 = V/I_\mu = 200/0.606 = 330.03\ \Omega$ 1 Mark

From S.C. test:

$Z_{02} = 12/10 = 1.2\ \Omega$ 1 Mark

$K = 400/200 = 2$

$Z_{01} = Z_{02}/K^2 = 1.2/4 = 0.3\ \Omega$ 1 Mark

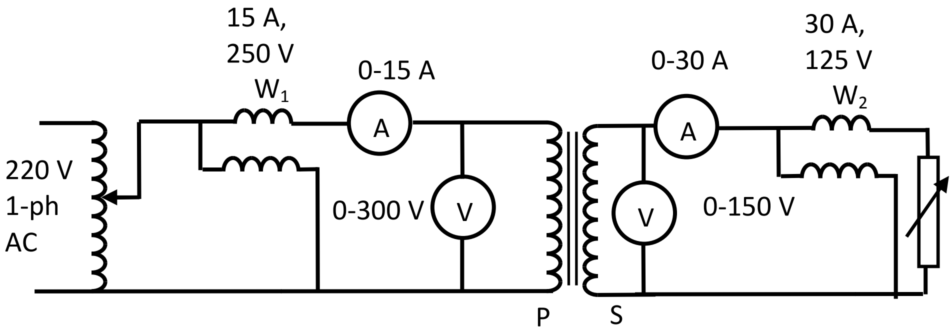
$R_{02} = W_{SC}/I_{SC}^2 = 85/100 = 0.85\ \Omega$ 1 Mark

$R_{01} = R_{02}/K^2 = 0.85/4 = 0.21\ \Omega$ 1 Mark

Similarly $X_{01} = 0.214\ \Omega$ 1 Mark

$X_{02} = 0.847\ \Omega$ 1 Mark

4 c)

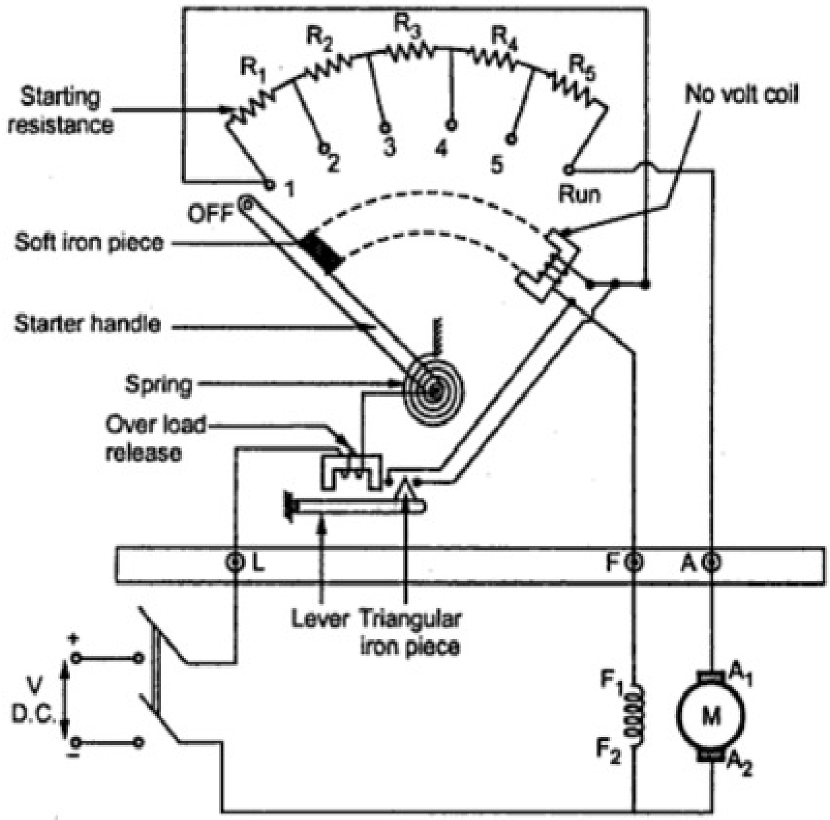


Experimental setup to perform Direct Loading Test

Circuit diagram 2 Marks, correct meter ranges 2 Marks

1. % Efficiency = (W_2/W_1) x 100, where, W_2 = Output power and W_1 = Input power. 2 marks
2. % Regulation = ($E_2 - V_2/E_2$) x 100, where V_2 = secondary voltage on load and E_2 = secondary voltage on no load. 2 Marks

5 a)



2 marks for unlabeled incomplete,

4 marks for complete but unlabeled,

6 marks for partially labeled complete,

8 Marks for neat labeled figure

5 b) Let us first calculate the losses from given maximum efficiency.

Output at full load = 25 x 1 = 25 kW, Input = 25/0.98 = 25.51 kW — 1 mark

Losses = 25.51 – 25 = 0.51 kW, since the efficiency is maximum, Iron loss = copper loss = 0.51/2 = 0.255 kW — 1 mark

Copper loss at full load = 0.255 kW and Iron loss at all loads = 0.255 kW

Total output in kWh = (15 x 0.707 x 10) + (20 x 6) + (10 x 4) + (5 x 4)

= 286.05 kWh — 1 Mark

20 kW at 0.8 p,f, = 20/0.8 = 25 kVA, 10 kW at 0.85 p.f. = 10/0.85 = 11.76 kVA, 5 kW at 0.9 p.f. = 5/0.9 = 5.55 kVA

$\therefore$ Total copper loss for 24 hours

$= 0.255(15/25)^2 \times 10 + 0.255(25/25)^2 \times 6 + 0.255(11.76/25)^2 \times 4 +$

$0.255(5.55/25)^2 \times 4$

$= 0.918 + 1.53 + 0.2257 + 0.0502 = 2.7239$ kWh — 1 mark

Total iron loss = $0.255 \times 24 = 6.12$ kWh — 1 mark

$\therefore$ All day efficiency — 1 Mark

= (output energy in 24 hrs of day)/(input energy in 24 hrs of day) — ½ mark

$= 286.05 / (286.05 + 6.12 + 2.7239) = 0.97 = 97\ \%$ — 1 ½ marks

5 c) Given that:

Volt per turn $E_t = 10.5$ V

$f = 50$Hz and $B_m = 1.1$Wb/m^2

Net area of iron core $A_i = E_t/(4.44fB_m) = 10.5/(4.44 \times 50 \times 1.1) = 0.04299\ m^2$. — 1 mark

Gross iron area $A_{gi} = Ai/K = 0.0477\ m^2$ — 1 mark

$N_1 = 2200/E_t = 2200/10.5 = 209.52 = 210$ turns — 1 mark

$N_2 = 400/Et = 400/10.5 = 38.09 = 38$ turns — 1 mark

Copper conductor area = (current/current density)

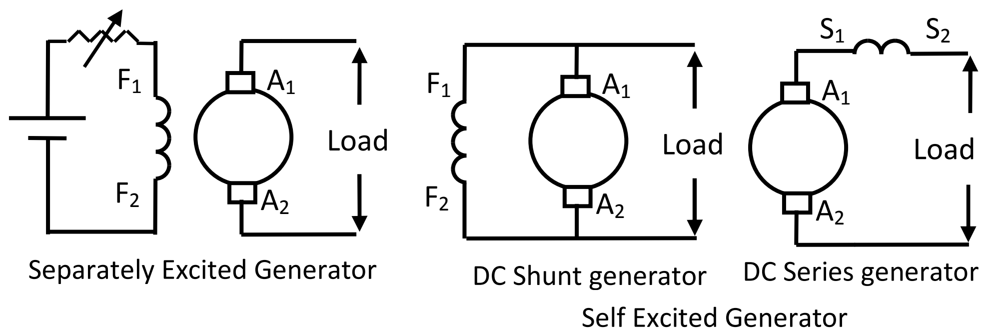
$I_1 = (100 \times 1000)/2200 = 45.45$ A — 1 mark

$a_1 = 45.45 / 2.2 \times 10^6 = 2.06 \times 10^{-5}\ m^2$ — 1 mark

$I_2 = (100 \times 1000)/400 = 250$ A — 1 mark

$a_2 = 250 / 2.2 \times 10^6 = 1.13 \times 10^{-4}\ m^2$ — 1 mark

6 a)



2 marks for neat labeled circuit diagram of separately excited generator and any one type of self excited generator.
2 Marks for difference

Separately excited generators are those whose field magnets are energised from an independent external source of dc current as shown in figure.

Self excited generators are those whose field magnets are energised by the current produced by the generator themselves as shown in figure.

6 b) The current drawn by motor $I_a = \frac{V - E_b}{R_a}$, at start speed $N = 0$, $\therefore E_b = 0$ and 1 Mark

$I_a = \frac{V}{R_a}$. 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. 2 Marks

The protective devices like overload release and no volt release are also provided in starter. 1 Mark

6 c) There are two types of power losses in the transformer:-

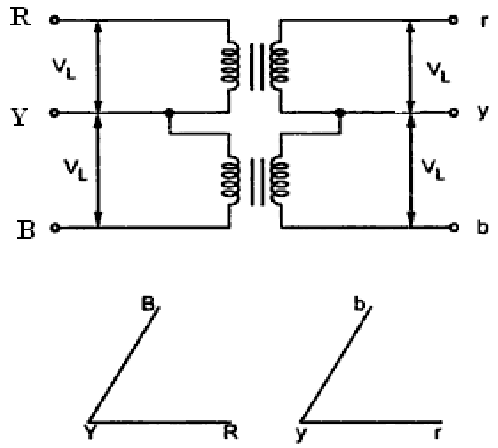
(1) Copper losses and (2) Core or Iron losses 1 mark

Core losses consist of (a) Hysteresis loss and (b) Eddy current loss 1 mark

Copper losses are minimized by using good winding material having lesser resistance, and core or iron losses are minimized by using silicon steel as core material and by using laminated construction for the core. 1 mark 1 mark

6 d)

- If one of the transformer of a Δ - Δ bank is removed and 3 phase supply is connected to the primaries as shown in fig., then 3 equal phase voltages will be available at the secondary terminals on no load.
- This method is known as open Δ or V-V connection 1 M
- Total load carried is not 2/3 but 57.7 % of the capacity
- Only 86.6 % of rated capacity of remaining two is available
- Average power factor is less 1 M
- Employed when 3 phase load is too small and when one of the transformer in a bank is disabled



2 marks

6 e) Significance of Instrument transformers for measurement in HVAC Circuit:

- Instrument transformers (CT and PT) are used with low range meters in H.V. A.C circuits where it is not practicable to connect instruments and meters directly with lines. 1 mark
- Very cheap and moderate size meters can be used for measurement of high currents and voltages. Generally CTs are standardized to secondary current value of 5 A and PTs with secondary voltage of 100-120 V. 1 mark
- Power consumption in the measuring circuit is low.
- The measuring circuit is isolated from power circuit. 1 mark
- Several instruments can be operated from a single instrument transformer 1 mark

6 f) Type of connections (vector group) in 3-phase transformer:

Group I: Zero phase displacement (Yy0, Dd0) 1 mark

Group II: 180^0 phase displacement (Yy6, Dd6) 1 mark

Group III: 30^0 lag phase displacement (Yd1, Dy1) 1 mark

Group IV: 30^0 lead phase displacement (Yd11, Dy11) 1 mark