DIPLOMA BOARD EXAMINATION- APRIL 2024

Answer key for Question Code: 238

ELECTRICAL MACHINES I

PART - A

1. What is Electromagnetic induction? (3 marks)

Whenever the flux linked with a conductor changes, an emf is induced in the conductor. This is called Electromagnetic Induction.

2. What are the effects of armature reaction? (3 marks)

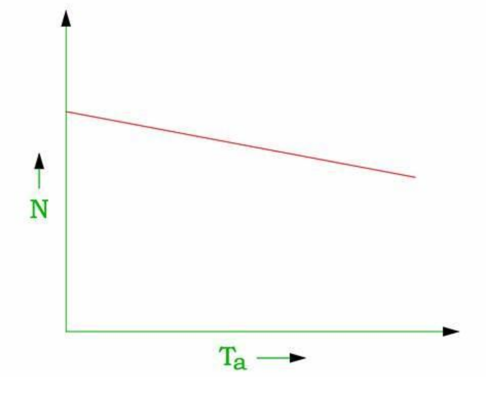
ANY 3 POINTS

- Reduces Main field Flux.
- Causes sparking in the commutator.
- Reduces the EMF generated.
- Decreases the efficiency of the machine.
- Due to MNA shift, sparking occurs in the brushes.
- Distorts the uniformity of main flux.

3. What is meant by back emf? (3 marks)

- When DC supply is given to DC motor its armature rotates and cuts the static magnetic flux produced by the field magnets.
- An e.m.f. is induced in the armature conductor as per Faraday's laws of Electromagnetic induction.
- By Lenz's law, this induced e.m.f will oppose the supply voltage. Hence the e.m.f. induced in the armature is called back e.m.f (Eb).

4. Draw the speed-torque curve of DC shunt motor. (3 marks)



Speed Torque Characteristics

5. What is transformer? (3 marks)

- A transformer is a device which is used to step up or step down the AC voltages.
- It is a static device which transfers electrical energy from one circuit to another circuit without change in its frequency.

6. **<u>What is step up and step down transformers?</u>** **<u>(3 marks)</u>**

Let,
N_1 = Number of turns in Primary
N_2 = Number of turns in Secondary.

Step Up Transformer:

1. Emf induced in Secondary winding will be greater than Primary Voltage.
2. $N_2 > N_1$

Step Down Transformer:

1. Emf induced in Secondary winding will be smaller than Primary Voltage.
2. $N_2 < N_1$

7. **<u>Mention the four vector groups of 3 phase transformer.</u>** **<u>(3 marks)</u>**

Group 1: Zero phase displacement (Yy0, Dd0, Dz0)
Group 2: 180° phase displacement (Yy6, Dd6, Dz6)
Group 3: 30° lag phase displacement (Dy1, Yd1, Yz1)
Group 4: 30° lead phase displacement (Dy11, Yd11, Yz11)

8. **<u>Write the equations of load shared by two transformers having equal and unequal ratings.</u>**

<u>(3 marks)</u>

Z_A = Equivalent Impedance of transformer A referred to secondary
Z_B = Equivalent Impedance of transformer B referred to secondary

Load shared by transformers having equal ratings,

$$Pa = P \times \frac{Zb}{Za + Zb}$$

$$Pb = P \times \frac{Za}{Za + Zb}$$

Load shared by transformers having unequal ratings,

$$I_A = \frac{E_A Z_B - (E_A - E_B) Z_L}{Z_A Z_B + Z_L (Z_A + Z_B)}$$

$$I_B = \frac{E_B Z_A - (E_A - E_B) Z_L}{Z_A Z_B + Z_L (Z_A + Z_B)}$$

9. **<u>State the objectives of the plant maintenance.</u>** **<u>(3 marks)</u>**

<u>ANY 3 POINTS</u>

The objectives of maintenance are:

1. To keep the plant running at maximum productive efficiency.
2. To keep the plant running free from shut downs.

3. To conserve the life of the plant and equipment to the predetermined period.
4. To prevent interruptions in operation of plant.
5. To keep equipment in condition for higher efficiency performance.

10. What is meant by earthing? (3 marks)

Earthing means direct electrical connection of system neutral and all metallic non-current carrying parts of electrical equipment, such as metal frame, motor body etc. to earth.

PART – B

11. (a) (i) Derive EMF equation of DC generator. (7 marks)

Let,
Φ - flux per pole in web
Z - total number of armature conductors
P - number of poles.
A - number of parallel paths
A - 2 for wave winding
A - p for lap winding
N - speed of rotation of armature in r.p.m.

According to Faraday's law of Electro-magnetic induction, average emf in each conductor is equal to the rate of change of flux in weber per second.

$$e = N.\ d\varphi/dt$$

In one revolution flux cut by each armature conductor ($d\varphi$) = φP weber

Time taken by the armature to complete 'N' revolutions = 1 minute = 60 s

Time taken by the armature to complete one revolution (dt) = 60/N s

Emf induced in each conductor = $d\varphi/dt$

$$= \varphi P / (60/N)$$

$$= \varphi PN / 60 \text{ volt}$$

Number of armature conductors connected in series in each parallel path = Z/A

Therefore, emf induced in D.C generator,

E = EMF induced in each conductor x number of conductors in each parallel path

E. M.F induced in D.C generator, $E_g = \varphi PN \times Z / 60A$

$$E_g = \frac{\phi ZNP}{60A}$$

11. (a) (ii) A DC generator having 8 poles develops an emf of 500 V at 400 rpm. The armature has 144 slots and each slot contains 6 conductors. The winding is lap connected. Calculate the flux per pole.

(7 marks)

The emf (E) of a DC generator can be calculated using the following formula:

E= ΦZNP/60A

where:

- N is the speed in rpm
- P is the number of poles
- Φ is the flux per pole in Weber (Wb)
- Z is the total number of armature conductors
- A is the number of parallel paths in the armature

Given that:

- E = 500 V
- N = 400 rpm
- P = 8 poles
- Z = 144 slots × 6 conductors/slot = 864 conductors
- A = P (since the winding is lap connected)

We can rearrange the formula to solve for Φ:

Φ = E×60A/ZNP

Substituting the given values:

Φ = 500×60×8 / (864×400×8)

Flux per pole, Φ = 0.087 weber

11. (b) Explain the load characteristics of DC shunt generator.

(14 marks)

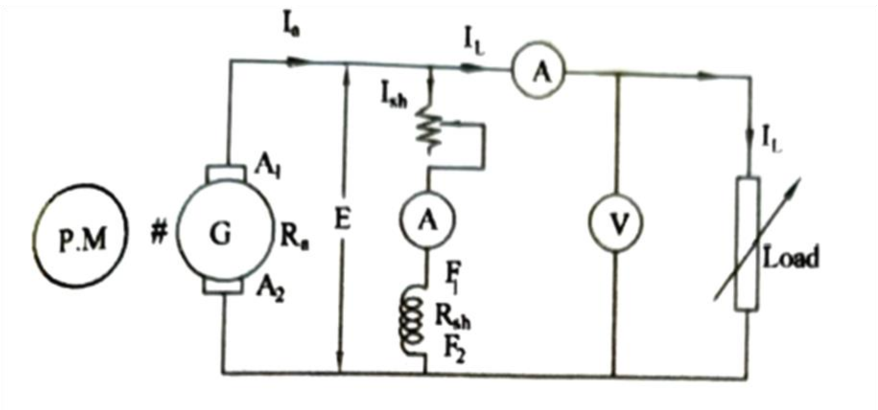
[Characteristic diagram – 5 marks, Explanation – 9 marks]

Internal characteristics: E Vs I_a

It gives the relation between the generated emf E and armature current I_a on load when field current (I_F) and Speed (N) of the generator are kept constant.

External characteristics: V Vs I_L

It gives the relation between terminal voltage V and load current I_L when field current (I_F) and Speed (N) of the generator are kept constant.

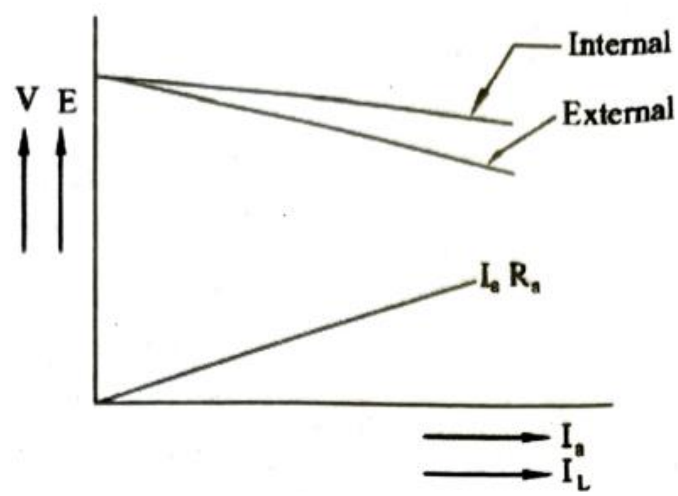


Circuit diagram

- Above diagram shows the circuit diagram of D.C shunt Generators to find out the load characteristics. In this circuit, the armature, field and load are connected in parallel. To measure the terminal voltage a voltmeter is connected. To measure the field current and load currents two ammeters are connected.

- In shunt generator $\mathbf{I_a = I_L + I_{sh}}$ **and** $\mathbf{E = V + I_a R_a}$

- The generator is started with the help of prime-mover and is run at rated speed.
- Adjust the field rheostat, so that the voltmeter reads the rated voltage.
- Then by keeping the field current constant, vary the load current, and note the terminal voltage for each Value of load current. For each value of terminal Voltage, the induced EMF and armature current are calculated.
- Then plot the load current on x - axis and terminal voltage on y - axis in the graph. We get the external characteristics curve as shown in below figure.



Characteristic Diagram

- Then plot the armature currents in x-axis and induced emf in y-axis in the graph. We get the internal characteristics curve as shown in above figure.
- From the characteristics, we find that, when the current increases, the terminal voltage decreases. The voltage is reduced due to armature resistance drop and armature reaction effect.
- When the current increases above the full load current, the voltage is reduced and becomes zero. Hence shunt generator has drooping characteristics.

12. (a) **Explain with a neat sketch, the principle of working of DC motor**.

(14 marks)

[Diagrams – 7 marks, Explanation – 7 marks]

- D.C motor converts Electrical energy into mechanical energy.
- Whenever a current carrying conductor is placed in a magnetic field, a mechanical force is produced on the conductor. D.C motor works on the above principle.
- The direction of force is given by Flemings left hand rule.
- The magnitude of the force is given by,

F = BLI Newton

Where,

F - Force produced on the conductor in Newton

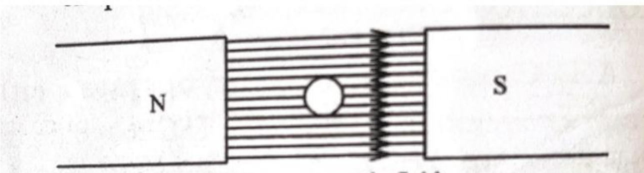
B - Magnetic flux density in Web/m?

L - The length of conductor in the magnetic field

1 - The current flowing through the conductor in ampere

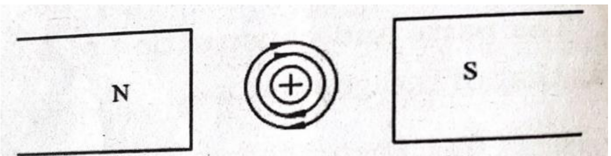
To understand the principle of operations of D.C motor, let us consider a two-pole motor.

- Figure below shows a uniform magnetic field in which a straight conductor carrying no current is placed. The direction of magnetic flux line is from North to South pole.



Uniform magnetic field
(No current in the conductor)

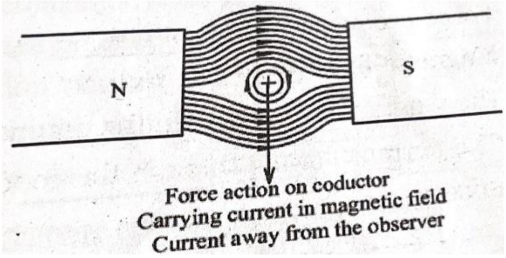
- Now assume there is no exciting current flow through the field winding and D.C current is sent through the conductor. Let the conductor carry the current away from the observer. It produces magnetic flux lines around that in clockwise direction as shown in below figure.



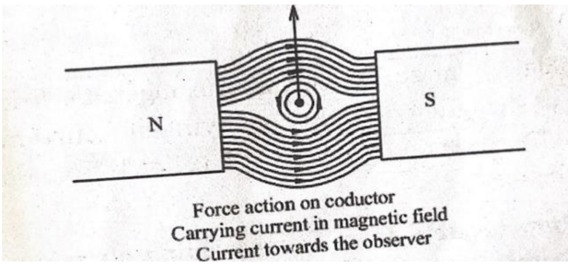
Conductor carrying current
(No magnetic field)

- There is no movement of the conductor during the above two conditions.

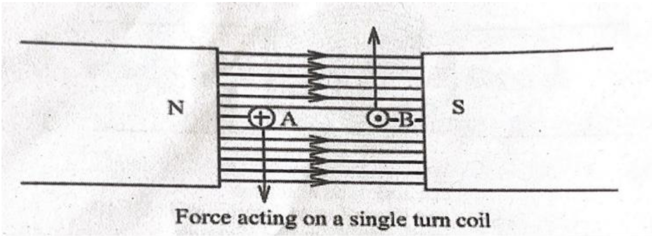
- In below figure, the current carrying conductor is placed in the magnetic field. The field due to the current in the conductor aids the main field above the conductor, but opposes the main field below the conductor.
- Hence the flux strengthens above the conductor and weakens below the conductor. It is found that a force acts on the conductor, trying to push the conductor downwards as shown by the arrow. (The conductor is pushed from high flux density to low flux density).



- If the current in the conductor is reversed (current towards the observer), the strengthening of flux line occurs below the conductor and the conductor will be pushed upward as shown in below figure.

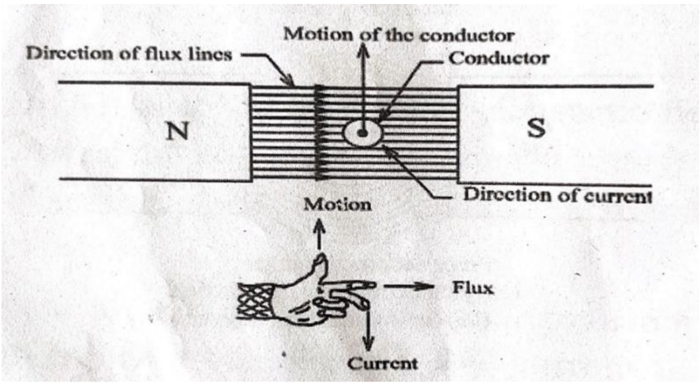


- Now consider a single turn coil carrying current as shown in below figure, the coil side 'A' will be forced to more downwards, whereas the coil side 'B' will be forced to move upwards.



- The forces acting on the coil sides 'A' and B' will be of same magnitude, but their direction is opposite to one another.
- As the coil is wound on the armature core, which is supported by the bearings, the armature will now rotate.
- The direction of rotation is found out by Fleming's left-hand rule.

FLEMING'S LEFT HAND RULE



- This rule states that if the thumb, fore finger and second finger of the left hand are kept mutually perpendicular to each other such that the fore finger points the direction magnetic flux and the second finger points the direction current flow in the armature conductors, then the thumb will indicate the direction of rotation of armature

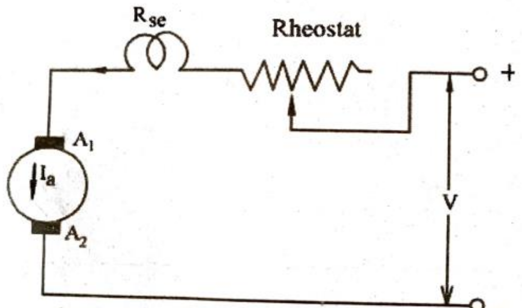
12. (b) **Explain the various speed control methods for DC series motor.**

(14 marks)

[Diagrams – 7 marks, Explanation – 7 marks]

1. Armature resistance control method:

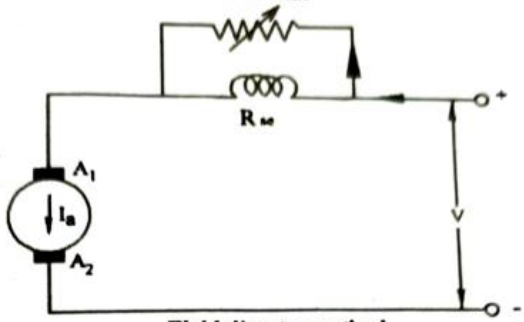
- In this method a variable resistance is directly connected in series with the supply as shown in below figure.
- This reduces the voltage available across the armature and hence the speed falls. By changing the value of variable resistance, any speed below the normal speed can be obtained. This method is mostly used to control the speed of D.C series motors



Armature resistance control in series motor

2. Field control method :

i. Field diverter method:

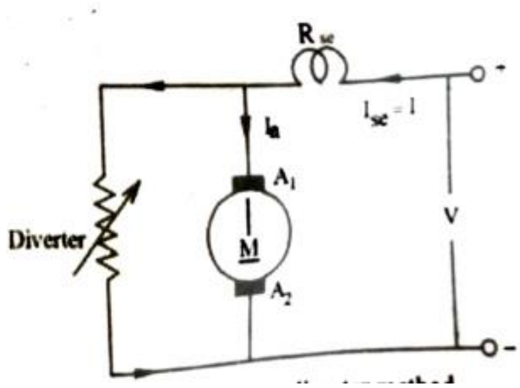


Field diverter method

- A variable resistance called field diverter is connected in parallel with the series field winding as shown in diagram.
- Any desired amount of current can be passed through the diverter by adjusting its resistance.
- Hence the flux can be decreased and hence the speed of the motor is increased ($N \alpha 1/\varphi$).
- Hence this method can provide speed above normal speed. The lowest speed obtainable is the normal speed of the motor.

ii. Armature diverter method:

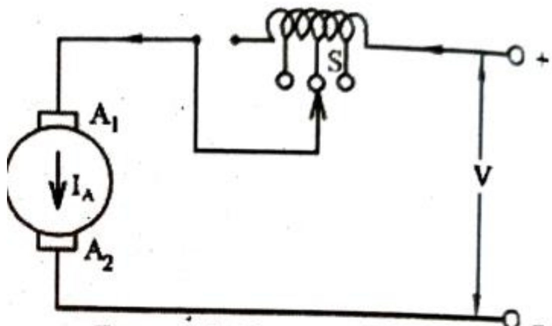
- In order to obtain a speed below the normal speed, a variable resistance called armature diverter is connected in parallel with the armature as shown in figure.
- The diverter shunts some of the line current, thus reducing the armature current.



Armature Diverter method

- Now for a given load, if I_a is decreased, the flux must increase, since T is constant ($T \alpha \varphi I_a$).
- Hence the motor speed is decreased, since ($N \alpha 1/ \varphi$).
- Hence by adjusting the armature diverter, any speed lower than the normal speed can be obtained.

iii. <u>Tapped field control method:</u>



Tapped field control method

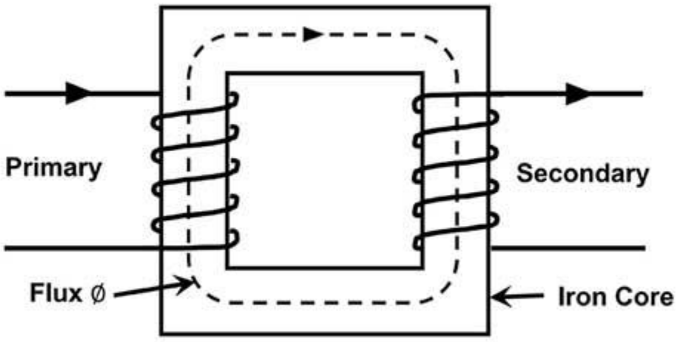
- In this method, the flux is reduced and hence the speed is increased (($N \alpha 1/ \varphi$) by decreasing the number of turns of the series field windings as shown in figure.
- The switch can short circuit any part of the field winding, thus decreasing the flux and raising the speed.
- When the field windings are in full turns, the motor runs at normal speed and when the field turns are cutout, speeds higher than normal speed are obtained.

<u>13. (a) **Explain with a neat diagram the constructional details of core type transformer.**</u>

<u>(14 marks)</u>

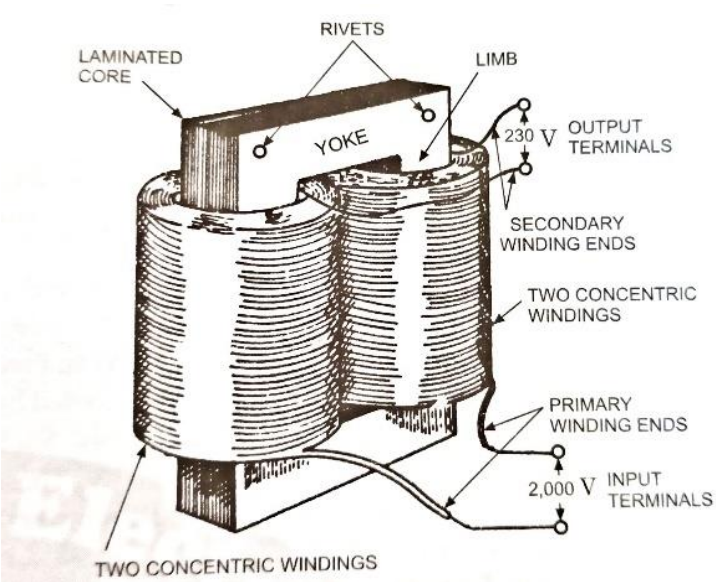
<u>[Diagrams – 7 marks, Explanation – 7 marks]</u>

- In core type transformers, the windings surround the core as shown in figure.
- Core type construction is more suitable for High voltage Transformers coil.
- The coils are wound around the two limbs of a rectangular magnetic core.



Core type transformer

- Each limb carries one half of the primary winding and one half of the secondary winding so as to reduce the leakage reactance.



Core Type transformer

- Insulations are provided between the primary and secondary windings.
- The LV winding is wound next to the insulated core and H.V winding is wound over the L.V winding in order to reduce the amount of insulation required.
- Small transformers may have cores of rectangular or square cross section, with rectangular or circular coils.
- In case of large size Transformer, stepped cruciform Core with circular coil is employed. This type of cores is built with different sizes of laminations.
- The circular coils with cruciform core provide more mechanical strength, especially when short circuit occurs.
- Other advantage of using cruciform core is reduced mean length of turns resulting in reduced copper loss.

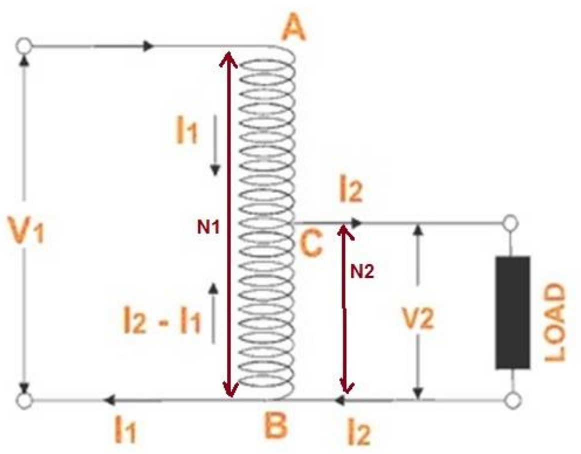
13. (b) **Explain with a neat diagram the constructional details of auto transformer.**

(14 marks)

[Diagrams – 5 marks, Explanation – 9 marks]

Principle:

- Auto transformer is a transformer which has one winding only.
- Part of the winding is common to both primary and secondary.
- So, the primary and secondary are not electrically isolated from each other.
- But theory and operation are similar to two winding transformer.



Auto Transformer

- In the figure, AB is the primary winding having N_1 Number of turns, BC is the secondary winding having N_2 number of turns.
- When the voltage is applied to the primary winding AB, alternating magnetic flux is produced in the core.
- Due to the alternating magnetic flux an emf E_1 is induced in the coil AB (primary) and emf E_2 will be induced in the coil BC (Secondary). When load is connected between the terminals BC, power will be supplied to the load.

Advantages:

1. Saving in conductor materials and less cost.
2. Power loss is reduced. So, efficiency will be high.
3. Higher KVA rating.
4. Lower percentage reactance hence better voltage regulation
5. Can be used for obtaining variable voltage supply.

Disadvantages:

1. If there is a break in the secondary winding, full voltage flows from the primary side to the secondary side load.
2. Auto transformer winding need more insulation than that of two winding transformer.

Application:

1. It is used as starters for 3 phase induction motors.
2. It is used in Electrical furnace

3. Three phase auto transformer are used in the interconnection of grids.
4. To give smooth variation of voltage to test circuits in the laboratories.
5. As a booster of supply voltage to a small extent.

14. (a) **Explain the constructional details of 3 phase transformer.**

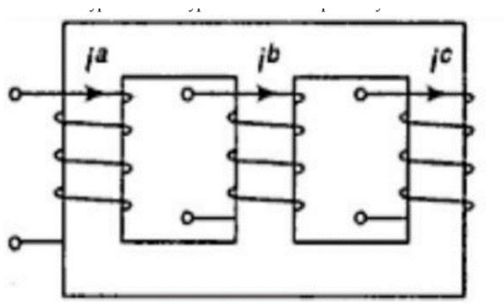
(14 marks)

[Core transformer diagram – 3 marks, Explanation – 8 marks, Connections List- 3 marks]

- In a 3-phase system the voltage is lowered or raised by 3-phase transformers.
- 3-phase transformers can be constructed in two ways. Either by a bank of 3 single phase transformer or by a single three phase transformer.
- When compared to a group of 3 single phase transformer, a single three phase transformer has the following advantages.
  1. It occupies less space
  2. The weight of three phase transformer is less.
  3. The cost of three phase transformer is usually 15% less than that of three single phase transformer banks.
- The drawback in using a 3-phase transformer is that, if any transformer windings become disabled, then we have to remove the whole transformer.
- But in 3 single phase transformers, if one transformer goes out, then the faulty transformers can be replaced by a single one.

- Based on construction, the three phase transformers are classified as

  (i) core type (ii) shell type



Core type 3 phase transformer

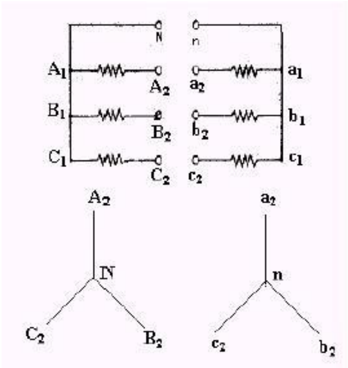
- In a 3-phase core type transformer, magnetic core has three limbs as shown in figure.
- To reduce the leakage flux, the primary and the secondary windings are wound on each limb like single phase transformers.
- When the supply is given to 3 phase primary winding, a three phase Magnetic field is set up.
- According to the mutual induction principle an emf is induced in the secondary winding.

Types of three phase transformer connections:

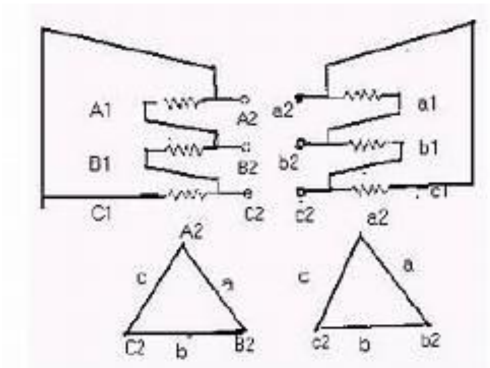
There are four possible connections for a 3-phase transformer:

1. **Δ – Δ (Delta – Delta) Connection**
2. **Y – Y (Star – Star) Connection**
3. **Δ – Y (Delta – Star) Connection**
4. **Y – Δ (Star – Delta) Connection**

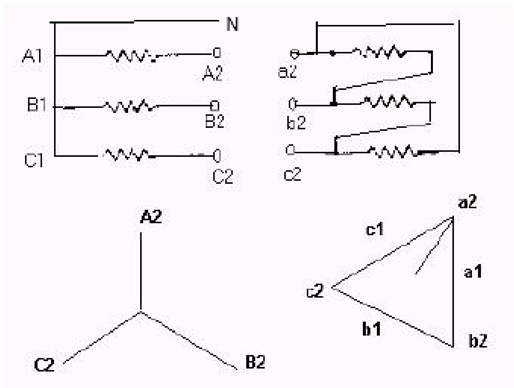
Star-star connection (Y – y):



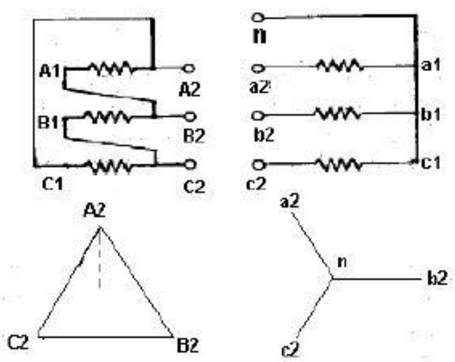
Delta - Delta Connection (Δ – d) or (Δ – Δ):



Star - Delta connection (Y – d) or (Y – Δ):



Delta - Star connection (Δ – y):



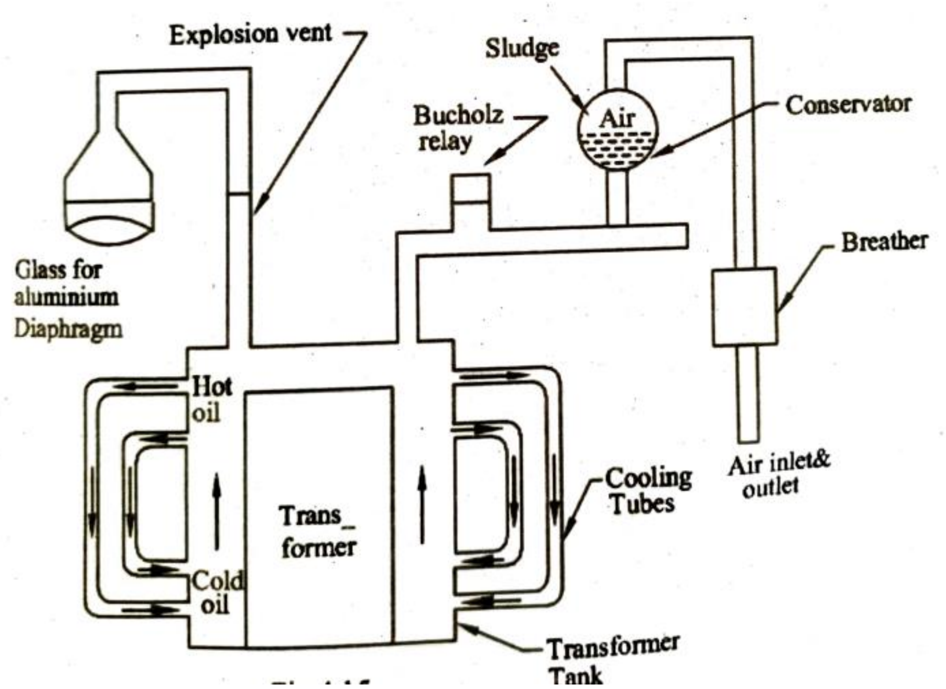
14. (b) **Explain about any three transformer accessories.** **(14 marks)**

[Diagram – 5 marks, Three Explanations – 9 marks]

ANY THREE

1. CONSERVATOR:

- If the Transformer oil in the tank comes in contact with the atmospheric air, the moisture in air reduces the dielectric strength of the oil.
- Also, the dust particles and oxygen in the air cause sludge deposits on the oil and this deposit may block the cooling tubes.
- Therefore, to prevent air coming in contact with the oil in the tank, the tank is completely filled with the insulating oil.
- When the temperature rises, the volume of oil in the tank increases and when the temperature decreases, the volume of oil decreases.
- To accommodate the changes in the volume of the oil, an auxiliary device called conservator is provided above the transformer tank.



Transformer Diagram

- The conservator is a cylindrical vessel fitted on the top of the tank as shown in figure.
- The tank is completely filled up with oil. But half of the conservator is filed with oil.
- Therefore, changes in the volume of oil in the tank are accommodated by the empty space in the conservator.
- The conservator is otherwise called expansion tank.

2. BREATHER:

- When the temperature increases (due to increasing of load) the volume of oil in the transformer tank increases, which results in the increase of oil level in the conservator tank. So, the air in the conservator tank is driven out.

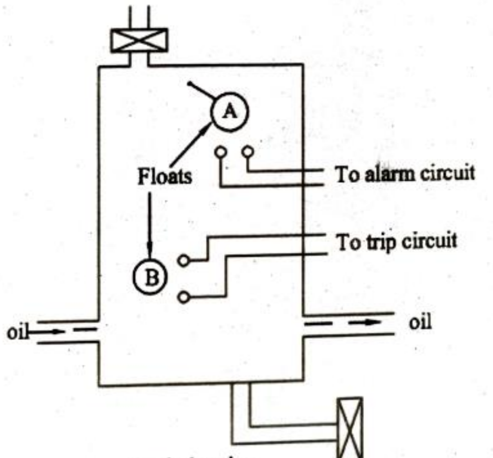
- When the temperature decreases (due to decreasing of load) the volume of oil decreases, and the atmospheric air enters into the conservator. This is called breathing.
- The air is entered into the conservator through a device called 'Breather'.
- Breather is a small vessel connected between the conservator and air outlet as shown in above figure.
- It is filled with silica gel. It removes the moisture from the incoming air.
- The silica gel is blue when dry and pink when damp (moisture).

3. EXPLOSION VENT:

- When there is an accidental internal short circuit in the transformer, an arc is struck between the turns of the winding.
- Due to this heat is generated by the arc and hence a very large volume of gas is produced.
- So, the pressure in the transformer tank increases dangerously which may lead to the explosion of the transformer tank.
- To avoid such accident an explosion vent is covered by a diaphragm, of either glass or aluminium.
- When the pressure in the tank increases critical value, the diaphragm is blown out and releases the high-pressure gas into the atmosphere.
- The hot oil may splash and cause injury to the people near the transformer tank. For this reason, the explosion vent is bent downwards.

4. BUCHOLZ RELAY:

- It is a gas operated relay.
- This relay is situated in the pipe connected between the transformer tank and the conservator as shown in the figure.



Bucholz relay

- It consists of a case in which two spherical floats A and B are provided.
- The float carries the mercury Switches.
- At normal operation of the power transformer, the relay body remains filled with oil, floats are lifted and the contacts of mercury switches are open.
- When there is a slight overload, a small volume of gas is generated.
- In these circumstances, gas accumulates slowly in the top of the relay chamber, resulting in a gradual lowering of the oil level in it.
- So, the top float will move downward and close the contacts of the alarm circuit.
- When there is severe fault like short circuit between the phases, there is a quick generation of large volume of gas.
- Due to this, oil will rush suddenly through the pipeline causing the lower float B to short circuit the two contact points of trip circuit. And relay operates then it isolates the transformer from the supply.

15. (a) **Explain the resurfacing process of commutator in DC machines.**

(14 marks)

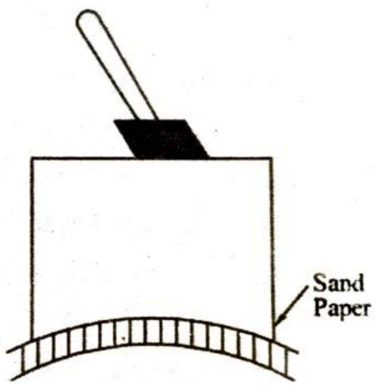
[Diagrams – 5 marks, Explanation – 9 marks]

If the commutator surface is not smooth it should be resurfaced.

There are three methods of resurfacing of commutator.

1. Sand papering
2. Hand stoning
3. Grinding and turning

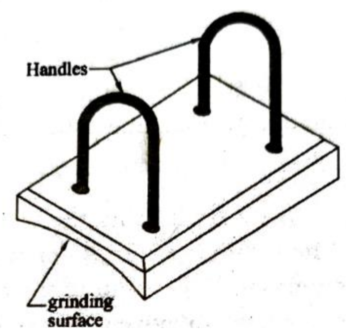
1. Sand papering:



Sand Papering

- This method is used for removing the deposits from commutator surface, correcting roughness and reducing high mica.
- But it is not suitable to remove flat spots.
- When sand papering a commutator, it is better to select a fine grain paper and take longer time to do the work.
- The sand paper is pressed against the rotating commutator surface.
- During this operation the sand paper is attached to a wooden shoe, the face of which has been formed to the same radius as the commutator as shown in figure.
- Sand papering should be done for a longer time without giving much pressure on the surface to avoid deep scratches.

2. Hand stoning:



Hand Stoning

- Hand stones are used to smoothen the surface of the commutator.

- It should be formed to suit the Curvature of the commutator.
- The stone should be pressed firmly against the commutator and moved slowly from side to side. Several grades are available from very coarse to very fine.
- The coarse stones remove copper rapidly and are used where surface is deep.
- After a coarse stone is used, fine grade should be applied to give smooth polish to the surface.

3. Grinding and turning:

If the commutator is badly out of shape, grinding and turning methods are used.

Turning:

- The commutator may be turned with armature in its own bearing or the armature may be removed and placed in a lathe or machine designed specially for this purpose.
- When turning a commutator without removing it from the machine, the machine may itself be operated as a motor at a reduced speed.
- If the size of the armature is small, the machine is turned in a lathe.

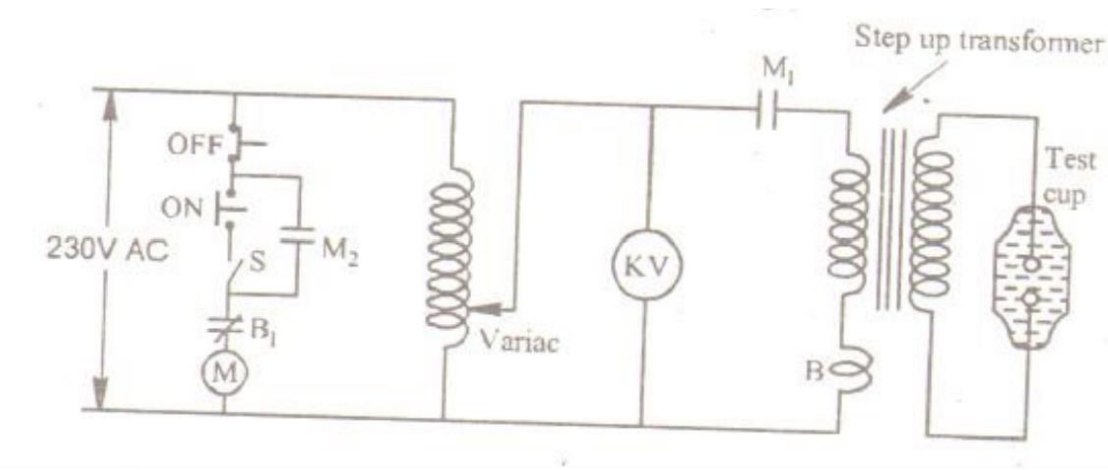
Grinding:

- Grinding is done by holding the grinding stone pressed against the rotating commutator surface.
- This is done in the motor itself by rotating the armature at full speed.
- Less copper is removed in grinding than in turning.
- By grinding a true curvature of the commutator is maintained.
- When the turning or grinding on the commutator is finished, it should be cleaned thoroughly.
- All copper chips and dust that have lodged in the windings should be removed by blowing air.
- If there is any copper bridging the mica, it should be removed.
- Finally, a high potential test (1000 - 2000 volt) should be conducted to make sure that there are no grounds.

15. (b) **Explain about BDV test with a neat diagram. (14 marks)**

[Diagrams – 5 marks, Explanation – 9 marks]

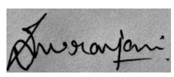
- The dielectric strength of transformer oil is determined by using BDV test.
- The BDV test should be conducted when the oil sample is cold and not hot because hot oil gives a higher BDV.
- In the testing equipment there is a test cup which has two electrodes in the form of spheres (13 mm diameter). The sphere gap should be exactly 4mm. We can adjust the gap suitably by using the test cup screws.
- Also, there is a step-up transformer. The test electrodes are connected across the secondary terminals as shown in the figure.
- The primary winding of the transformer is supplied through a variac. By operating this variac, we can gradually increase the test voltage as required. It has been so arranged that the contact "S" will be closed only when the variac output is zero volts.



Transformer Oil Tester / BDV Tester Circuit

- The test cup is filled with sample of oil. The level of the oil should be atleast 1 cm above the level of the electrodes. The cup is then covered with a clean glass plate and allowed to rest for 5 minutes. So that any air bubble that may be present will disappear.
- When the 'ON' button is momentarily pressed, the coil ‘M' is energized. Hence the main contact M_1 closes and connects the variac to the primary winding of the step-up transformer.
- The contact S is in closed condition only when the variac is in minimum position. The sealing contact M_2 also closes.
- Now the no-load current has no effect on the coil B to open the normally closed contact B. The test voltage is increased gradually.
- The voltmeter connected is calibrated to show the HV side voltage. When breakdown occurs across the electrodes, there is a corresponding surge in the primary winding and coil B hence the B energizes and B_1 immediately opens.
- Now the coil M is de-energized and the contact M_1 opens disconnecting the primary from the supply.
- The breakdown voltage is that voltage at which the arcing takes place. The reading of the voltmeter should be noted at the time of breakdown. **A good sample of oil withstand 22kv - 33kv for the minute**.

Prepared by,



Mrs. Manoranjani M,

Lecturer/EEE,

149, Government polytechnic college,

Vanavasi, Salem-636457