FUNDAMENTALS OF ELECTRICAL AND ELECTRONICS ENGINEERING

CHAPTER-6 SOLUTION

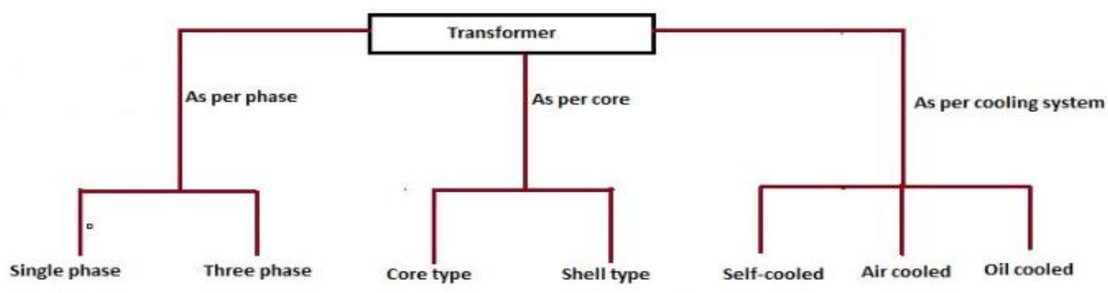
PARUL UNIVERSITY DIPLOMA STUDIES ELECTRICAL ENGINEERING DEPATEMENT

CHAPTER-6 TRANSFORMER AND MACHINES

2 MARKS QUESTIIONS

1. **Define transformer.**
   A transformer is a device used in the power transmission of electric energy. The transmission current is AC. It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC between circuits. The transformer works on basic principles of electromagnetic induction and mutual induction.

2. **State the types of transformers.**
   Transformers are used in various fields like power generation grid, distribution sector, transmission and electric energy consumption. There are various types of transformers which are classified based on the following factors;
   - Working voltage range.
   - The medium used in the core.
   - Winding arrangement.
   - Installation location.

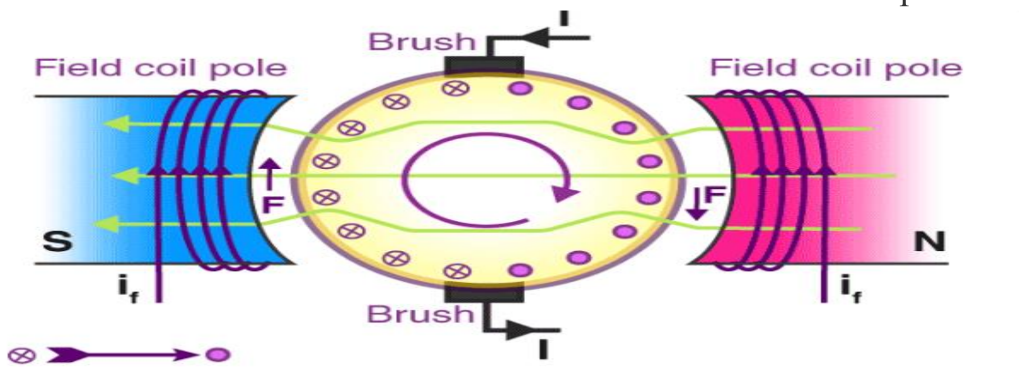


3. **Give working principle of Induction motor.**
   Induction Motors are the most commonly used motors in many applications. These are also called as Asynchronous Motors, because an induction motor always runs at a speed lower than synchronous speed. Synchronous speed means the speed of the rotating magnetic field in the stator.

There basically 2 types of induction motor depending upon the type of input supply - (i) Single phase induction motor and (ii) Three phase induction motor.

4. **Give working principle of d.c motor.**

A magnetic field arises in the air gap when the field coil of the DC motor is energized. The created magnetic field is in the direction of the radii of the armature. The magnetic field enters the armature from the North pole side of the field coil and "exits" the armature from the field coil's South pole side.



Production of torque in a DC motor

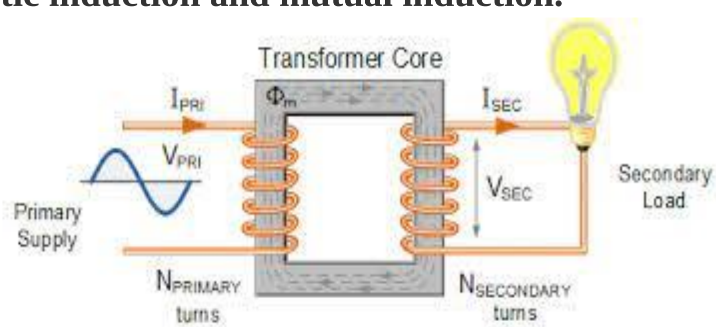
The conductors located on the other pole are subjected to a force of the same intensity but in the opposite direction. These two opposing forces create a torque that causes the motor armature to rotate.

"When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work".

3 MARKS QUESTONS

1. **Explain working principle of a 1-phase transformer.**

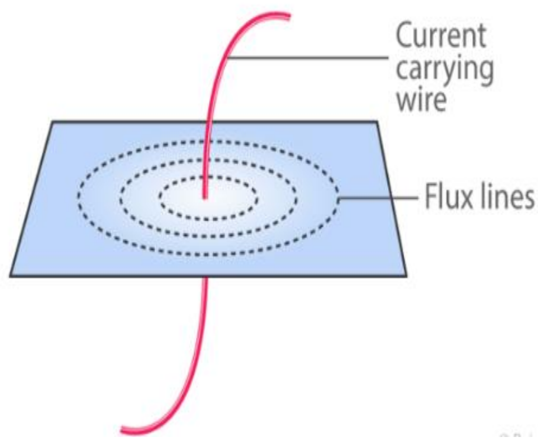
The transformer works on the principle of Faraday's law of electromagnetic induction and mutual induction.



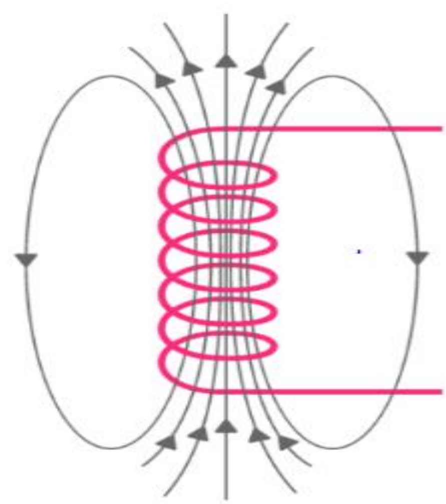
There are usually two coils primary coil and secondary coil on the transformer core. The core laminations are joined in the form of strips. The two coils have high mutual inductance. When an alternating current pass through the primary coil it creates a varying magnetic flux. As per faraday's law of electromagnetic induction, this change in magnetic flux induces an emf (electromotive force) in the secondary coil which is linked to the core having a primary coil. This is mutual induction.

Overall, a transformer carries the below operations:

- Transfer of electrical energy from circuit to another.
- Transfer of electrical power through electromagnetic induction.
- Electric power transfer without any change in frequency.
- Two circuits are linked with mutual induction.



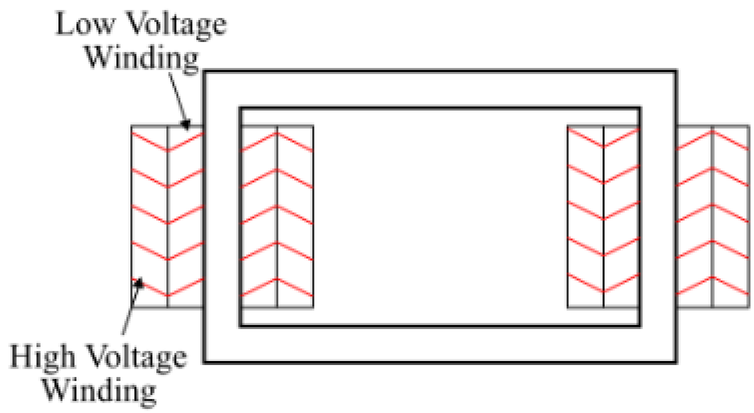
The figure shows the formation of magnetic flux lines around a current-carrying wire. The normal of the plane containing the flux lines are parallel to normal of a cross-section of a wire.



The figure shows the formation of varying magnetic flux lines around a wire-wound. The interesting part is that reverse is also true, when a magnetic flux line fluctuates around a piece of wire, a current will be induced in it. This was what Michael faraday found in 1831 which is the fundamental working principle of electric generators as well as transformers.

2. Draw and explain core type transformer.

In core type construction of the transformer, the magnetic core consists of two vertical lags called limbs and two horizontal sections called yokes. In order to reduce the leakage flux to its minimum value, half of each winding is placed on each lag of the core (see the figure).



The low voltage (lv) winding is placed next to the core and the high voltage (hv) winding is placed around the low voltage winding. This reduces the requirement of insulating material. Hence, the primary and secondary windings are arranged as concentric coils, thus known as concentric winding or cylindrical winding.

The core type construction of transformer is easier to dismantle for maintenance. The natural cooling is good in the core type transformer. Therefore, core type transformers are suitable for high voltage and small output applications.

Advantages

- It offers good mechanical strength.
- It has the advantage of preventing condensed flux leakage and iron loss.
- It is efficient for high frequencies.

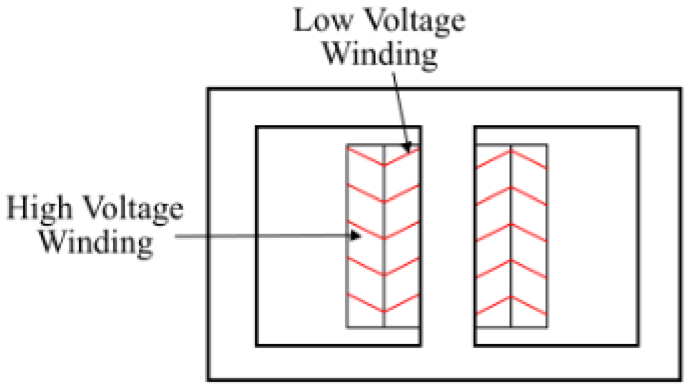
Disadvantages

- It is not good to use outdoors.

- It can be noisy.

3. **Draw and explain shell type transformer.**

In the shell type construction of the transformer, the magnetic core consists of three vertical lags and two horizontal sections. Both the primary and secondary windings are wound on the central limb and the two outer limbs provide the low reluctance flux path (see the figure).



Therefore, the shell type construction involves the use of a double magnetic circuit. The low voltage (lv) winding is placed next to the core (on the central limb) and around the low voltage winding the high voltage (hv) winding is placed. This arrangement reduces the requirement of insulating material.

The shell type construction of the transformer provides better support against the electromagnetic forces between the current carrying conductors, which are very high under short circuit conditions.

In shell type transformers, a shorter magnetic path is available, hence it requires a small magnetizing current. The natural cooling is poor in shell type transformer, because the coils are placed on the central limb. The shell type transformers are mainly used in low voltage and high output applications.

Advantages

- In shell type transformer core losses or iron losses are less.
- In shell type transformer efficiency is high.
- In shell type transformer less copper conductor required for construction so cost of transformer is less.

Disadvantages

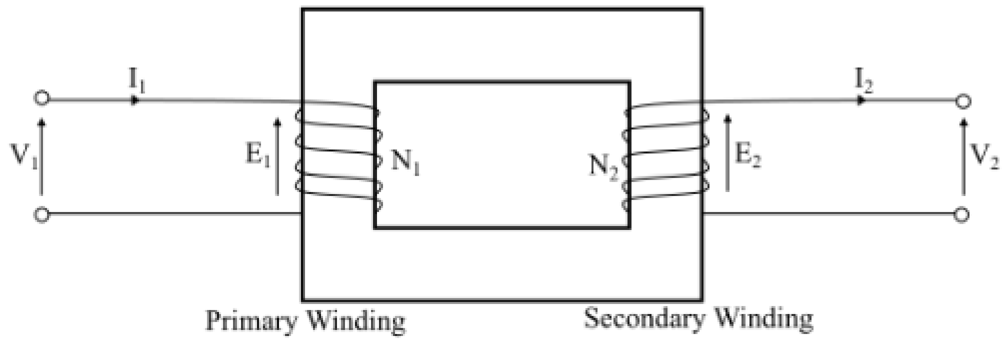
- In shell type transformer, maintenance job of windings is very hard.
- In shell type transformer, heat dissipation is not easy.
- In shell type transformer more insulation required.

- In shell type transformer natural cooling is not possible.

4. Explain turns ration of a 1-phase transformer.

The turn ratio of a single phase transformer is defined as the ratio of number of turns in the primary winding to the number of turns in the secondary winding, i.e.

$$\text{Turn Ratio} = \frac{\text{Number of Primary Turns}(N_1)}{\text{Number of Secondary Turns}(N_2)}$$



Since for a transformer, the voltage per turn being equal in both primary and secondary windings, therefore,

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

$$\Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2} = \text{Turn Ratio}$$

Also, if the given transformer is an ideal one, then E1 = V1 and E2 = V2, thus,

$$\text{Turn Ratio} = \frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{V_1}{V_2}$$

In case of ideal transformer, the input volt-ampere is equal to output volt-ampere, i.e.

$$V_1 I_1 = V_2 I_2$$

$$\Rightarrow \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\text{Turn Ratio} = \frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

4 MARKS QUESTIONS

1. **Derive e.m.f equation of a 1-phase transformer.**

Primary side of a transformer is connected with an alternating source, hence the current flowing in the primary coil is sinusoidal. The flux generated by this current is also sinusoidal and we can write it as,

$$\emptyset = \emptyset_m \sin \omega t \qquad (1)$$

According to faraday's law the induced emf can be written as

$$e = -\frac{d}{dt}(\emptyset T)$$

$$= -T\frac{d\emptyset}{dt}$$

$$= -T\tfrac{d}{dt}(\emptyset_m \sin \omega t)$$

$$= -T\omega\emptyset_m \cos \omega t$$

As we can write cosωt as sin (pi/2 – ωt) but as we can see there is negative sign in the above equation it will be modified like this

$$e = T\omega\emptyset_m \sin\left(\omega t - \frac{\pi}{2}\right) \qquad (2)$$

Equation (2) may be written as

$$e = E_m \sin\left(\omega t - \frac{\pi}{2}\right) \qquad (3)$$

Where $E_m = T\omega\emptyset_m$ it is the maximum value of induced emf.

For a sine wave, the r.m.s value of the e.m.f. is given by

$$E_{rms} = E = {E_m}/{\sqrt{2}}$$

$$E = \frac{T\omega\emptyset_m}{\sqrt{2}} = \frac{T(2\pi f)\emptyset_m}{\sqrt{2}}$$

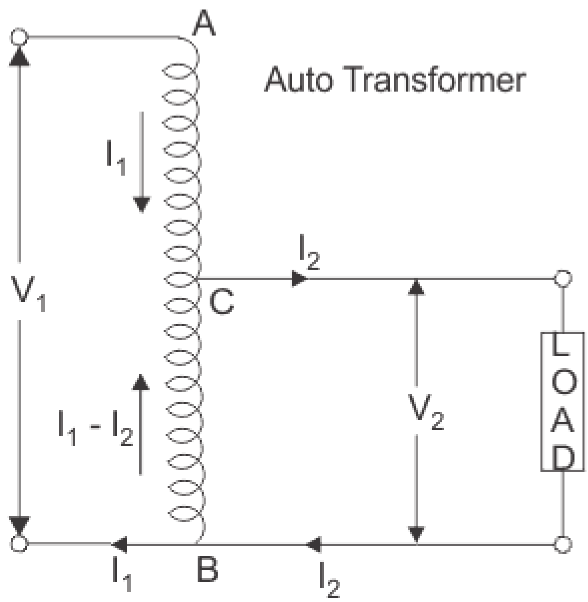
Or $$E = 4.44\emptyset_m fT \qquad (4)$$

Equation (1.2.4) is called the e.m.f. equation of a transformer.

2. Write short note on "Auto-transformer".

An **autotransformer** (or **auto transformer**) is a type of electrical transformer with only one winding. The "auto" prefix refers to the single coil acting alone (Greek for "self") – not to any automatic mechanism. An auto transformer is similar to a two winding transformer but varies in the way the primary and secondary winding of the transformer are interrelated.

In an auto transformer, one single winding is used as primary winding as well as secondary winding. But in two windings transformer two different windings are used for primary and secondary purpose. A circuit diagram of auto transformer is shown below.



The winding AB of total turns N1 is considered as primary winding. This winding is tapped from point ′C′ and the portion BC is considered as secondary. Let’s assume the number of turns in between points ′B′ and ′C′ is N2.

If V1 voltage is applied across the winding i.e. in between ′A′ and ′C′.

$$So\ voltage\ per\ turn\ in\ this\ winding\ is\ \frac{V_1}{N_1}$$

Hence, the voltage across the portion BC of the winding, will be,

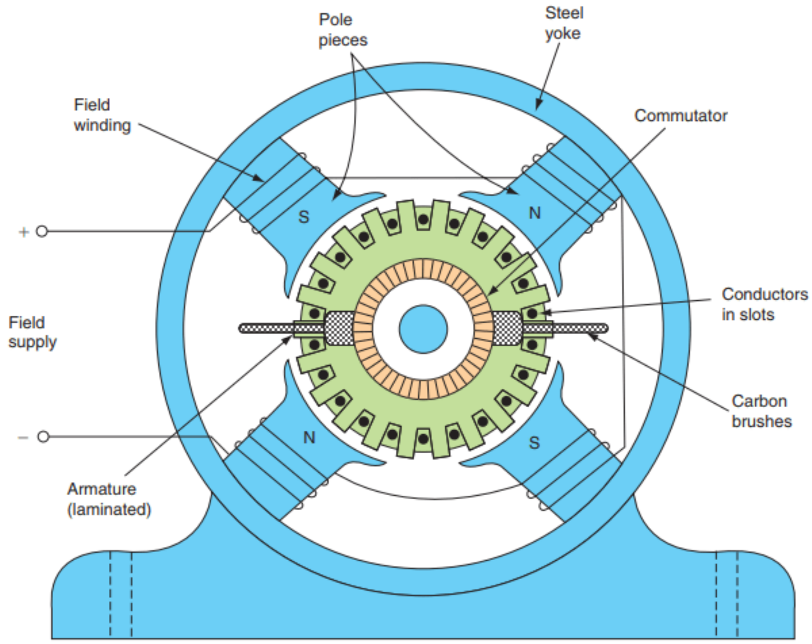
$$\frac{V_1}{N_1} X N_2\ and\ from\ the\ figure\ above,\ this\ voltage\ is\ V_2$$

$$Hence,\ \frac{V_1}{N_1} X N_2 = V_2$$

$$\Rightarrow \frac{V_2}{V_1} = \frac{N_2}{N_1} = Constant = K$$

As BC portion of the winding is considered as secondary, it can easily be understood that value of constant ′k′ is nothing but turns ratio or voltage ratio of that **auto transformer**. When load is connected between secondary terminals i.e. Between ′B′ and ′C′, load current I2 starts flowing. The current in the secondary winding or common winding is the difference of I2 and I1.

3. Draw the construction of D.C Motor and explain any three parts of it.



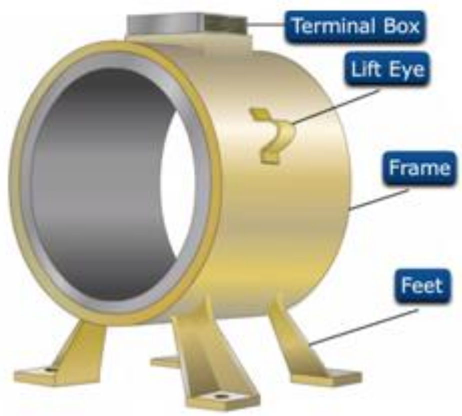
The dc generators and dc motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a dc generator or motor.
Any dc generator can be run as a dc motor and vice-versa. In this article, we will explain the construction of dc machine in detail.

All dc machines have five principal components

- Magnetic frame or Yoke
- Pole Cores and Pole Shoes
- Pole Coils or Field Coils
- Armature core
- Armature Winding
- Commutator
- Brushes and Bearings

1. **Yoke (Magnetic Frame):** The outer frame or yoke serves a double purpose:
   - It provides mechanical support for the poles and acts as a protecting cover for the whole machine.
   - It carries the magnetic flux produced by the poles.

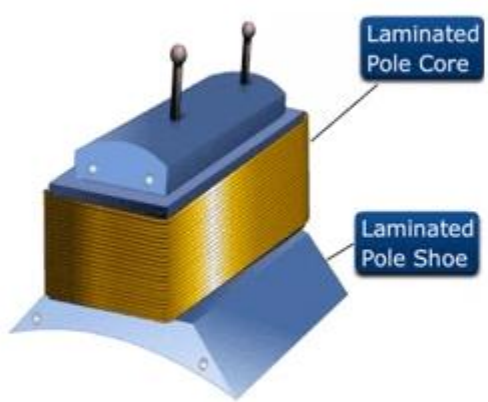
   In **small generators** where cheapness rather than weight is the main consideration, yokes are made of **cast iron**. But for **large machines usually cast steel or rolled steel** is employed.



- The modern process of forming the yoke consists of rolling a steel slab around a cylindrical mandrel and then welding it at the bottom.
- The feet and the terminal box etc. are welded to the frame afterward. Such yokes possess sufficient mechanical strength and have high permeability.

2. **<u>Pole cores and pole shoes:</u>** The field magnets consist of **pole cores and pole shoes**. The pole shoes serve two purposes:

    - they spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path.
    - they support the exciting coils (or field coils).

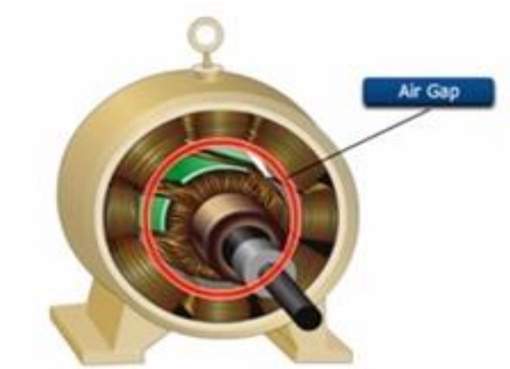


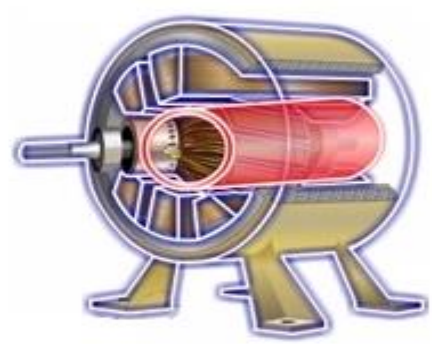
<u>There are two main types of pole construction.</u>

- The pole core itself may be a solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of countersunk screws.

- In modern design, the complete pole cores and pole shoes are built of thin laminations of annealed steel which are riveted together under hydraulic pressure. The thickness of laminations varies from 1 mm to 0.25 mm.

3. **Field System:** The function of the field system is to produce a uniform magnetic field within which the armature rotates.
    - Field coils are mounted on the poles and carry the dc exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity.
    - The mmf developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature, and the frame.
    - Practical dc machines have air gaps ranging from 0.5 mm to 1.5 mm.





- Since armature and field systems are composed of materials that have high permeability, most of the m.m.f. of field coils is required to set up flux in the air gap.
- By reducing the length of the air gap, we can reduce the size of field coils (i.e. the number of turns).