Name of the teacher— Mrs. Monika Sharma

Department of Physics and Electronics

Name of the course— B.Sc. (H) Physics

Semester- IV

Name of the paper—Electrical circuits and Network Skills

Paper code-32223903

Lecture timings: 10:40 to 12:40 AM

Topics to be covered:

Name of the unit: Previous year question paper

- *Solution of the questions*

[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : 2144 **GC-3** **Your Roll No................**

Unique Paper Code : 32223903

Name of the Paper : Electrical Circuits and Network Skills

Name of the Course : **B.Sc. (Hons.) Physics – C.B.C.S. – Skill Enhancement Course**

Semester : III

Duration : 3 Hours Maximum Marks : 50

Instructions for Candidates

1. Write your Roll No. on the top immediately on the receipt of this question paper.
2. **All** questions carry equal marks.
3. Question No. **1** is compulsory.
4. Attempt **five** questions in all.
5. Use of Scientific Calculators is allowed.

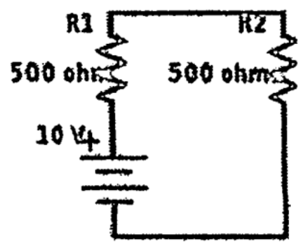
1. Attempt any **Five** :

   (i) Give one example each of electrical components which obey and disobey Ohm's Law.

   (ii) State Kirchhoff s Laws

   (iii) Define power factor. What is power factor of an ideal source ?

   (iv) Find the voltage across R1



P.T.O.

(v) Draw Electrical Symbols for a Zener Diode and a Fuse.

(vi) Define ripple factor of a Rectifier.

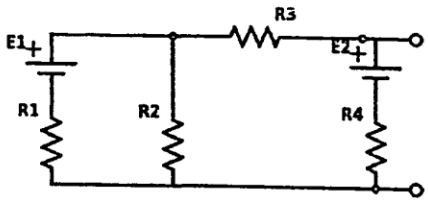
(vii) Define speed of a motor. What does the speed depends on ? (2×5)

2. (a) Explain with the help of relevant circuit diagrams, how an analog multimeter can be used as a dc voltmeter, dc ammeter and ohm meter.

(b) How can a multimeter be used to test a diode ? (8,2)

3. (a) State Thevenin's Theorem.

(b) Find the Thevenin Equivalent of the following Circuit. (2,8)



4. (a) Describe the construction and working of a dc generator. Support your answer with relevant diagrams.

(b) List the different kind of losses that occur in a dc generator. (8,2)

5. Describe the construction and working of a Bridge-Rectifier. What will be the effect of a capacitor connected in parallel with the load on the output of the bridge rectifier ? (7,3)

6. (a) Discuss the basic design and working of a single phase motor. What are the advantages of a polyphase motor ?

(b) Define the speed of an ac motor. What does it depend on ? (8,2)

7. Write a short note on any **two** of the following :

(i) Zener diode as a voltage regulator

(ii) Fuses and Surges

(iii) Relay

(iv) Conduits

(v) Ground Protection and isolated grounds (5,5)

(500)

Question 3

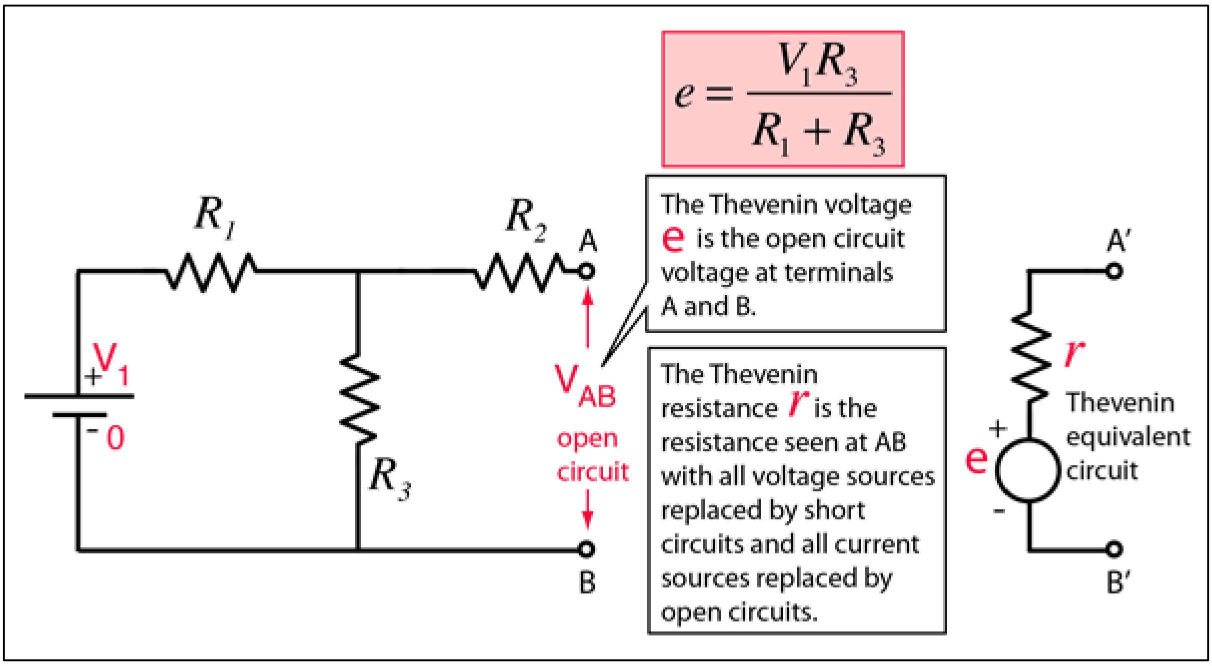
(a) State Thevenin's Theorem.

Answer

Thevenin's Theorem states that it is possible to simplify any linear circuit, no matter how complex, to an equivalent circuit with just a single voltage source and series resistance connected to a load. The qualification of "linear" is identical to that found in the Superposition Theorem, where all the parameters in the circuit must be linear (no exponents or roots). If we're dealing with passive components (such as resistors, and later, inductors and capacitors), this is true.

Thevenin Voltage

The Thevenin voltage **e** used in Thevenin's Theorem is an ideal voltage source equal to the open circuit voltage at the terminals. In the example below, the resistance R_2 does not affect this voltage and the resistances R_1 and R_3 form a voltage divider, giving

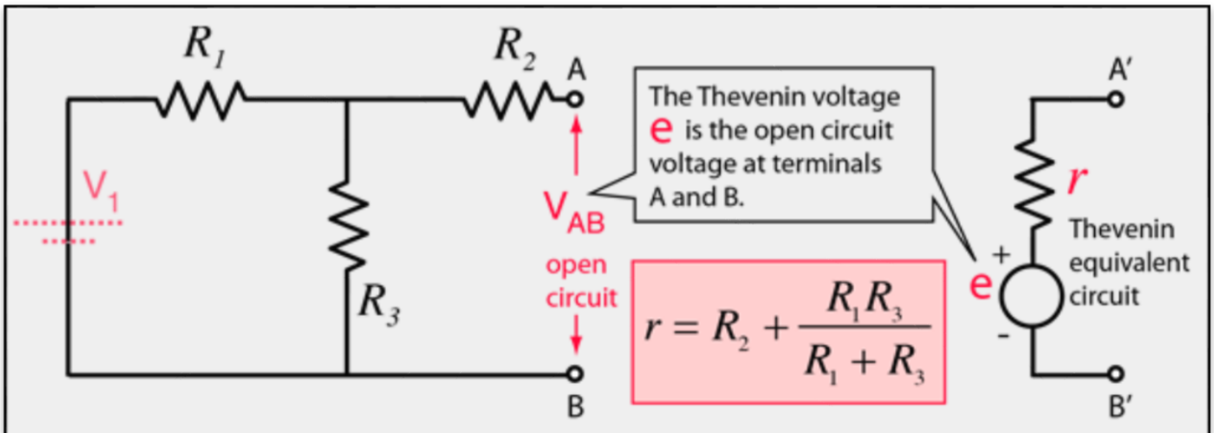


Thevenin/Norton Resistance

The Thevenin resistance **r** used in Thevenin's Theorem is the resistance measured at terminals AB with all voltage sources replaced by short circuits and all current sources replaced by open circuits. It can also be calculated by dividing the open circuit voltage by the short circuit current at AB, but the previous method is usually preferable and gives

$$r = R_2 + R_1 \| R_3 = R_2 + \frac{R_1 R_3}{R_1 + R_3}$$

The same resistance is used in the Norton equivalent.



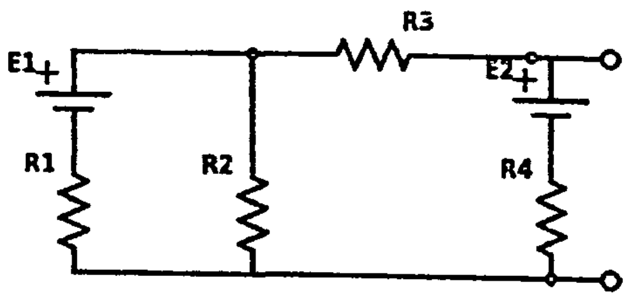
Experimentally the Thevenin resistance can be found by progressively loading the circuit until its output voltage drops to half the open circuit voltage. At that point the load resistance is equal to the Thevenin resistance.

Steps to follow for Thevenin's Theorem:

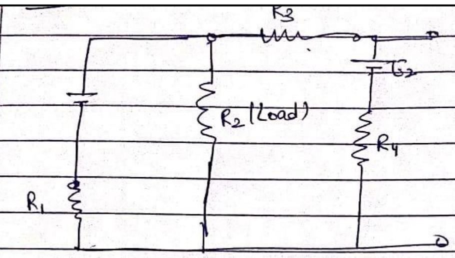
- Find the Thevenin source voltage by removing the load resistor from the original circuit and calculating the voltage across the open connection points where the load resistor used to be.
- Find the Thevenin resistance by removing all power sources in the original circuit (voltage sources shorted and current sources open) and calculating total resistance between the open connection points.
- Draw the Thevenin equivalent circuit, with the Thevenin voltage source in series with the Thevenin resistance. The load resistor re-attaches between the two open points of the equivalent circuit.
- Analyze voltage and current for the load resistor following the rules for series circuits.

Question 3

(b) Find the Thevenin Equivalent of the following Circuit.



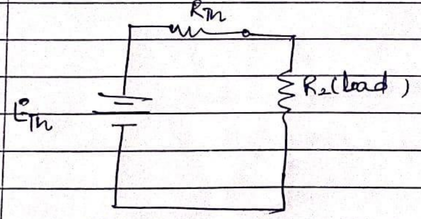
Answer



Suppose R_2 is chosen as Load Resistor

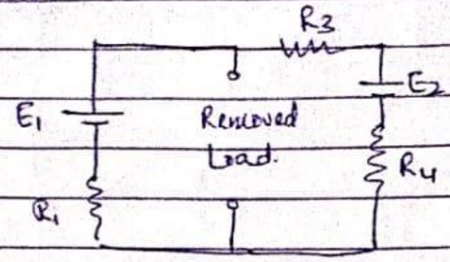
$\Downarrow$

We need to find the thevenin equivalent of the circuit

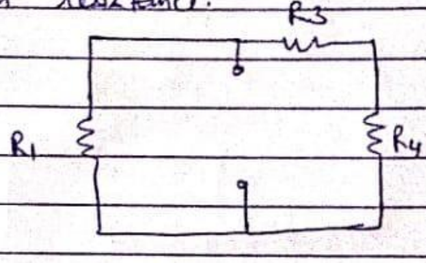


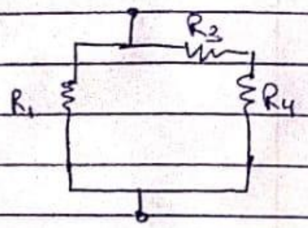
where E_{Th} and R_{Th} are the equivalent thevenin voltage and Resistance

Step 1. First of all Remove the load Resistance R_2 from the circuit



Step 2. Short all the battery sources and calculate the thevenin resistance.



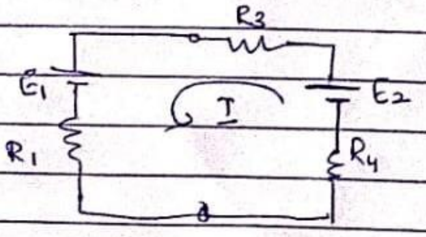


$$R_{Th} = R_1 \parallel \underbrace{(R_3 + R_4)}_{\Downarrow \text{ in series}} \Rightarrow \frac{1}{R_{Th}} = \frac{1}{R_1} + \frac{1}{R_3 + R_4}$$

$$= \frac{R_3 + R_4 + R_1}{R_1(R_3 + R_4)}$$

$$\Rightarrow R_{Th} = R_1(R_3 + R_4)$$

Step 3. Calculate the Thevenin voltage.



Simply using ohm's law

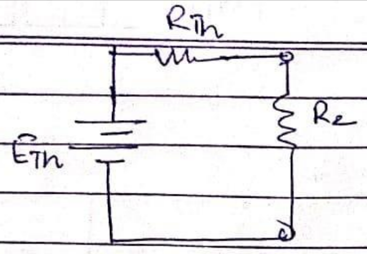
$$I = \frac{V}{R} = \frac{E_2 - E_1}{R_1 + R_3 + R_4}$$

$$E_{Th} = E_1 - \text{voltage across } R_1$$

$$= E_1 - I R_1$$

$$= E_1 - \left(\frac{E_2 - E_1}{R_1 + R_3 + R_4}\right) R_1$$

Step 4



$$E_{Th} = E_1 - \frac{(E_2 - E_1) \cdot R_1}{R_1 + R_3 + R_4}$$

$$R_{Th} = \frac{R_1 (R_3 + R_4)}{R_1 + R_3 + R_4}$$

$$I = \frac{E_{Th}}{R_{Th} + R_2} = \frac{E_1 - \frac{(E_2 - E_1) R_1}{R_1 + R_3 + R_4}}{\frac{R_1 (R_3 + R_4)}{R_1 + R_3 + R_4} + R_2}$$

$$I = \frac{E_1 (R_1 + R_3 + R_4) - (E_2 - E_1) R_1}{R_1 (R_3 + R_4) + R_2 (R_1 + R_3 + R_4)}$$

Question 4

(a) Describe the construction and working of a dc generator. Support your answer with relevant diagrams.

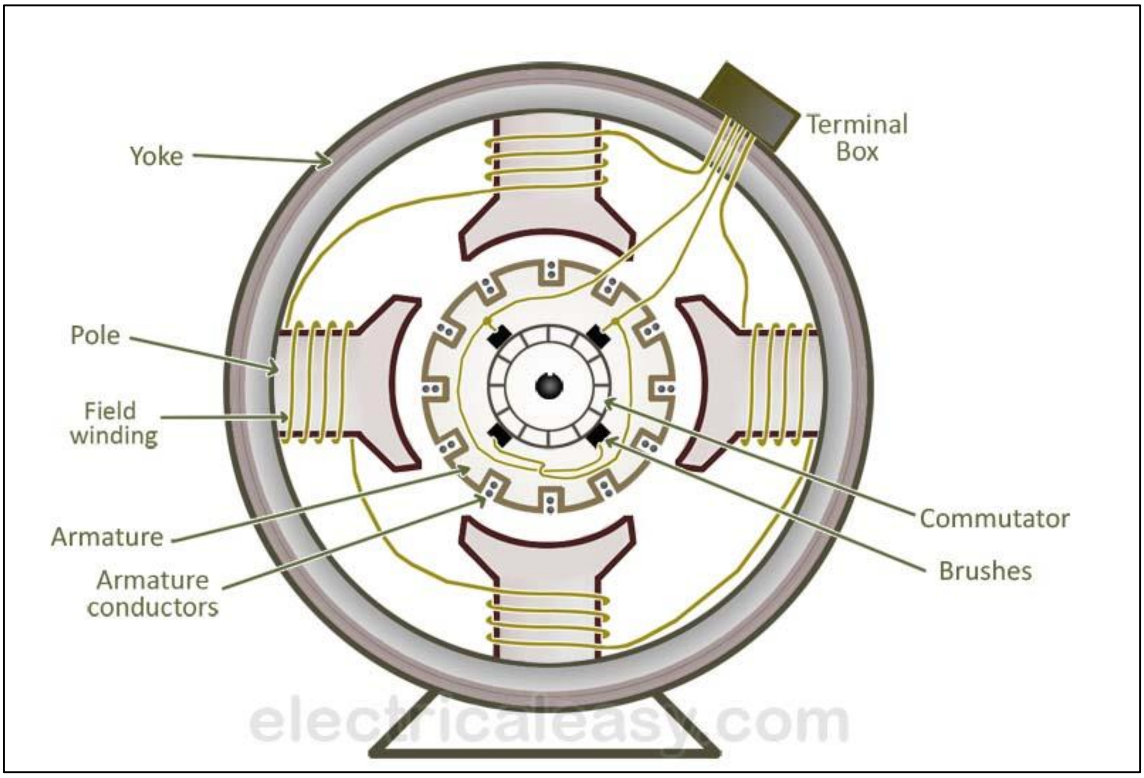
Answer

DC Generator

A dc generator is an electrical machine which converts mechanical energy into direct current electricity. This energy conversion is based on the principle of production of dynamically induced emf. Following are the basic construction and working of a DC generator.

Construction of a DC machine:

Note: A DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Thus, a DC generator or a DC motor can be broadly termed as a DC machine. These basic constructional details are also valid for the construction of a DC motor. Hence, let's call this point as construction of a DC machine instead of just 'construction of a dc generator'.



The above figure shows constructional details of a simple 4-pole DC machine. A DC machine consists of two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below.

1. **Yoke:** The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.

2. **Poles and pole shoes**: Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.

3. **Field winding:** They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.
4. **Armature core:** Armature core is the rotor of a dc machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.

Armature core (rotor)

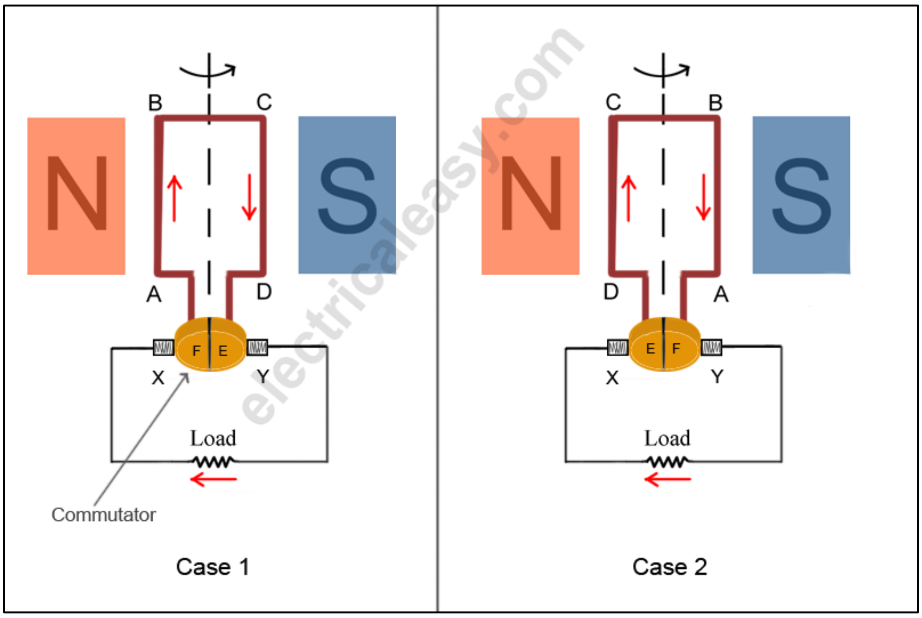
5. **Armature core:** Armature core is the rotor of a dc machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.
6. **Armature winding:** It is usually a former wound copper coil which rests in armature slots. The armature conductors are insulated from each other and also from the armature core. Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.
7. **Commutator and brushes:** Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors. A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

Commutator

Working principle of a DC generator:

According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of dc generator. If the conductor is provided with a closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. The direction of induced current is given by Fleming's right hand rule.

Need of a Split ring commutator:



According to Fleming's right hand rule, the direction of induced current changes whenever the direction of motion of the conductor changes. Let's consider an armature rotating clockwise and a conductor at the left is moving upward. When the armature completes a half rotation, the direction of motion of that particular conductor will be reversed to downward. Hence, the direction of current in every armature conductor will be alternating. If you look at the above figure, you will know how the direction of the induced current is alternating in an armature conductor. But with a split ring commutator, connections of the armature conductors also gets reversed when the current reversal occurs. And therefore, we get unidirectional current at the terminals.

Question 4

(b) List the different kind of losses that occur in a dc generator.

Answer

Following losses are using observed in the common dc machine (Generator or motor)

Losses in a rotating DC machine

- Copper losses
  - ✓ Armature Cu loss
  - ✓ Field Cu loss
  - ✓ Loss due to brush contact resistance
- Iron Losses
  - ✓ Hysteresis loss
  - ✓ Eddy current loss
- Mechanical losses
  - ✓ Friction loss
  - ✓ Windage loss

The above tree categorizes various types of losses that occur in a dc generator or a dc motor. Each of these is explained in details below.

Copper losses

These losses occur in armature and field copper windings. Copper losses consist of Armature copper loss, Field copper loss and loss due to brush contact resistance.

Armature copper loss = $I_a^2R_a$ (where, I_a = Armature current and R_a= Armature resistance)

This loss contributes about 30 to 40% to full load losses. The armature copper loss is variable and depends upon the amount of loading of the machine.

Field copper loss = $I_f^2R_f$ (where, I_f = field current and R_f = field resistance)

In the case of a shunt wounded field, field copper loss is practically constant. It contributes about 20 to 30% to full load losses.

Brush contact resistance also contributes to the copper losses. Generally, this loss is included into armature copper loss.

Iron losses (Core losses)

As the armature core is made of iron and it rotates in a magnetic field, a small current gets induced in the core itself too. Due to this current, eddy current loss and hysteresis loss occur in the armature iron core. Iron losses are also called as **Core losses or magnetic losses.**

Hysteresis loss is due to the reversal of magnetization of the armature core. When the core passes under one pair of poles, it undergoes one complete cycle of magnetic reversal. The frequency of magnetic reversal is given by,

$$f=P.N/120$$

(where, P = no. of poles and N = Speed in rpm)

The loss depends upon the volume and grade of the iron, frequency of magnetic reversals and value of flux density. Hysteresis loss is given by, Steinmetz formula:

$W_h=\eta Bmax^{1.6}fV$ (watts)

where, η = Steinmetz hysteresis constant

V = volume of the core in m^3

Eddy current loss: When the armature core rotates in the magnetic field, an emf is also induced in the core (just like it induces in armature conductors), according to the Faraday's law of electromagnetic induction. Though this induced emf is small, it causes a large current to flow in the body due to the low resistance of the core. This current is known as eddy current. The power loss due to this current is known as eddy current loss.

Mechanical Losses

Mechanical losses consist of the losses due to friction in bearings and commutator. Air friction loss of rotating armature also contributes to these.

These losses are about 10 to 20% of full load losses.

Stray Losses

In addition to the losses stated above, there may be small losses present which are called as stray losses or miscellaneous losses. These losses are difficult to account. They are usually due to inaccuracies in the designing and modeling of the machine. Most of the times, stray losses are assumed to be 1% of the full load.