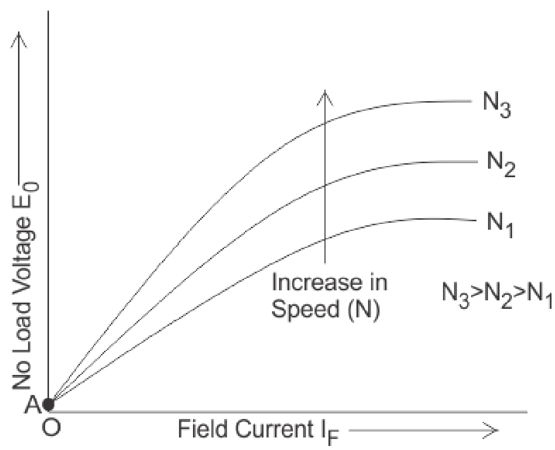
1. Write short notes on open circuit characteristic of separately excited dc generator

In a separately excited DC generator, the field winding is excited by an external independent source. There are generally three most important characteristic of DC generator:

Magnetic or Open Circuit Characteristic of Separately Excited DC Generator

The curve which gives the relation between field current (I_f) and the generated voltage (E_0) in the armature on no load is called magnetic or open circuit characteristic of a DC generator. The plot of this curve is practically same for all types of generators, whether they are separately excited or self-excited. This curve is also known as no load saturation characteristic curve of DC generator.

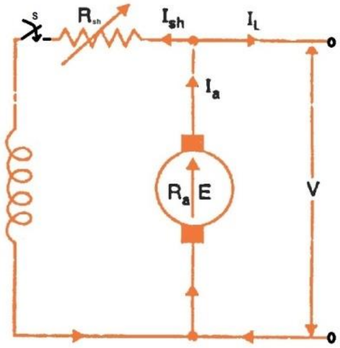
Here in this figure below we can see the variation of generated emf on no load with field current for different fixed speeds of the armature. For higher value of constant speed, the steepness of the curve is more. When the field current is zero, for the effect residual magnetism in the poles, there will be a small initial emf (OA) as show in figure.



Magnetic or Open Circuit Characteristic

2. Explain voltage build up process of shunt generator of self excited generator

Consider a DC Shunt Generator at no load as shown in figure below. The switch in the field circuit is supposed open and the armature of DC Shunt Generator is

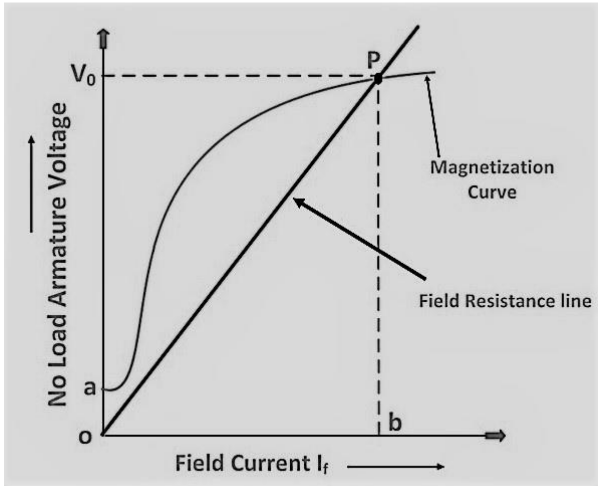


driven at rated speed.

Because of presence of small residual flux in the field poles, DC Shunt Generator will have a small voltage at its terminal even though the switch S is open when driven at rated speed. Now suppose the switch S is closed.

As there is small voltage is there across the terminals of DC Shunt Generator and Switch S is closed, therefore a small current will start flowing through the field circuit of DC Shunt Generator which in turn will produce magnetic flux and if the produced magnetic flux adds the residual magnetic flux then net flux will increase and the generated voltage ($E_a = K_a Ø \omega_m$) will increase corresponding to point J on the Magnetization curve as shown in figure below.

Since the generated voltage has increased, therefore the field current will also increase to OK corresponding to which the Generated Voltage across the Terminals of DC Shunt Generator will increase to point L. In the same manner the voltage will continue to build up till the point of intersection of Field Resistance Line and Magnetization curve / Open Circuit Characteristics of DC Shunt Generator. Beyond point of intersection of Field Resistance Line and Magnetization curve / Open Circuit Characteristics the voltage won't build up as in that case the generated voltage Ea will not be able to drive the required field current. Thus the stable point at which the voltage will remain fix is the voltage Ea corresponding to point of intersection of Field Resistance Line and Magnetization curve / Open Circuit Characteristics.



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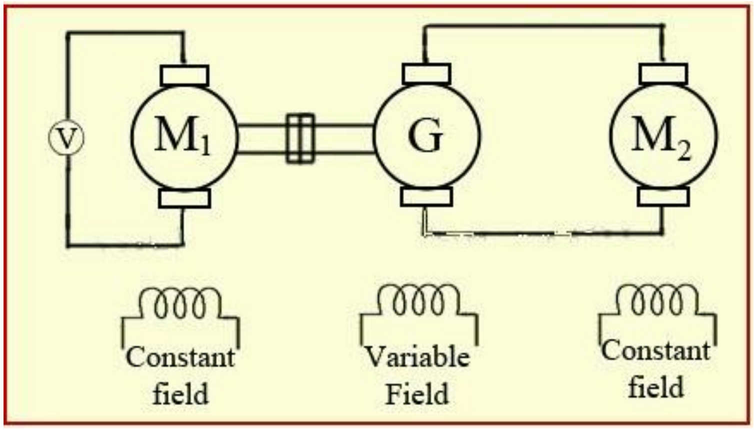
3. Write short notes on speed control of dc motor by voltage control method

a) **Multiple voltage control**:
In this method, the shunt field is connected to a fixed exciting voltage and armature is supplied with different voltages. Voltage across armature is changed with the help of suitable switchgear. The speed is approximately proportional to the voltage across the armature.

b) **Ward-Leonard System**:
This system is used where very sensitive **speed control of motor** is required (e.g electric excavators, elevators etc.). The arrangement of this system is as shown in the figure at right.
M_2 is the motor to which speed control is required.

M_1 may be any AC motor or DC motor with constant speed is a generator directly coupled to M_1.In this method, the output from generator G is fed to the armature of the motor M_2 whose speed is to be controlled. The output voltage of generator G can be varied from zero to its maximum value by means of its field regulator and, hence, the armature voltage of the motor M_2 is varied very smoothly. Hence, very smooth speed control of the dc motor can be obtained by this method.



4. write a brief notes on losses in dc machine

Copper losses

a- Armature Cu loss
b- Field Cu loss
c- Loss due to brush contact resistance

Iron Losses

a- Hysteresis loss
b- Eddy current loss

Mechanical losses

a.Friction loss
b.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.

<u>Iron losses (Core losses)</u>

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:
$W_h=\eta B_{max}^{1.6}fV$ (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.

<u>Mechanical Losses</u>

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.

<u>Stray Losses</u>

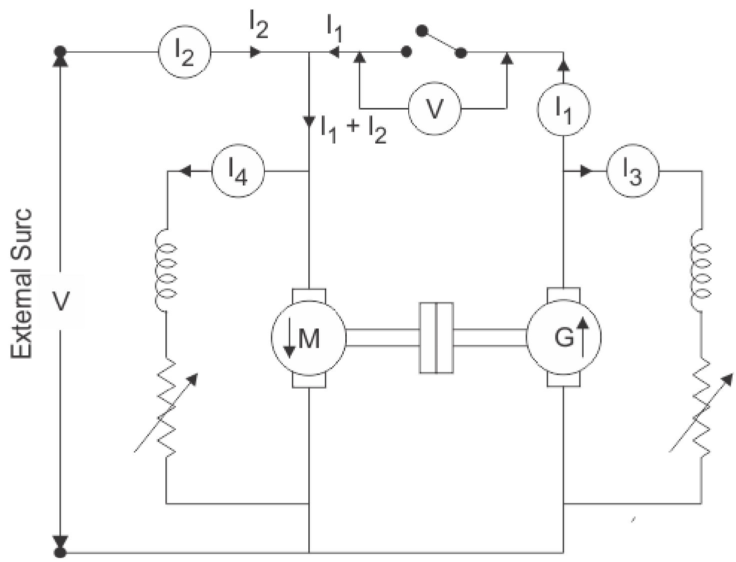
In addition to the losses stated above, there may be small losses present which are called as stray losses or miscellaneous losses. These losses are difficult to account. They are usually due to inaccuracies in the designing and modeling of the machine. Most of the times, stray losses are assumed to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

5. Write the short notes on back to back test of dc machines.

Hopkinson's Test is another useful method of testing the efficiency of a DC machine. It is a full load test and it requires two identical machines which are coupled to each other. One of these two machines is operated as a generator to supply the mechanical power to the motor and the other is operated as a motor to drive the generator. For this process of back to back driving the motor and the generator, Hopkinson's test is also called back-to-back test or regenerative test.

If there are no losses in the machine, then no external power supply would have needed. But due to the drop in the generator output voltage we need an extra voltage source to supply the proper input voltage to the motor. Hence, the power drawn from the external supply is therefore used to overcome the internal losses of the motor-generator set. **Hopkinson's test** is also called regenerative test or back to back test or heat run test.

Here is a circuit connection for the **Hopkinson's test** shown in figure below. A motor and a generator, both identical, are coupled together. When the machine is started it is started as motor. The shunt field resistance of the machine is adjusted so that the motor can run at its rated speed. The generator voltage is now made equal to the supply voltage by adjusting the shunt field resistance connected across the generator. This equality of these two voltages of generator and supply is indicated by the voltmeter as it gives a zero reading at this point connected across the switch. The machine can run at rated speed and at desired load by varying the field currents of the motor and the generator.



Hopkinson's Test of DC Machine

Calculation of Efficiency by Hopkinson's Test

Let, V = supply voltage of the machines.

Then, $Motor\ input = V(I_1 + I_2)$

I_1 = The current from the generator

I_2 = The current from the external source

And, Generator output = VI_1……………..(1)

Let, both machines are operating at the same efficiency 'η'.

Then, Output of motor = $\eta \times input = \eta \times V(I_1 + I_2)$

$$Input\ to\ generator = Output\ of\ the\ motor = \eta \times V(I_1 + I_2)$$

$$Output\ of\ generator = \eta \times input = \eta \times [\eta \times V(I_1 + I_2)] = \eta^2 V(I_1 + I_2) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From equation 1 an 2 we get,

$$VI_1 = \eta^2 V(I_1 + I_2)\ or\ I_1 = \eta^2 (I_1 + I_2)$$

$$or, \quad \eta = \sqrt{\frac{I_1}{I_1 + I_2}}$$

Now, in case of motor, armature copper loss in the motor = $(I_1 + I_2 - I_4)^2 R_a$.

R_a is the armature resistance of both motor and generator.

I_4 is the shunt field current of the motor.

Shunt field copper loss in the motor will be = VI_4
Next, in case of generator armature copper loss in generator = $(I_1 + I_3)^2 R_a$
I_3 is the shunt field current of the generator.
Shunt field copper loss in the generator = VI_3
Now, Power drawn from the external supply = VI_2
Therefore, the stray losses in both machines will be
$$W = VI_2 - (I_1 + I_2 - I_4)^2 Ra + VI_4 + (I_1 + I_3)^2 R_a + VI_3$$
Let us assume that the stray losses will be same for both the machines. Then,
Stray loss / machine = W/2

Total losses in the generator, $$W_G = (I_1 + I_3)^2 R_a + VI_3 + \frac{W}{2}$$
Generator output = VI_1
Then, efficiency of the generator,
$$\eta_G = \frac{output}{input} = \frac{output}{output + losses} = \frac{VI_1}{VI_1 + W_G}$$

Efficiency of Motor

Total losses in the motor, $$W_M = (I_1 + I_2 - I_4)^2 R_a + VI_4 + \frac{W}{2}$$
$$Motor\ input = V(I_1 + I_2)$$
Then, efficiency of the motor,
$$\eta_M = \frac{output}{input} = \frac{input - losses}{input} = \frac{V(I_1 + I_2) - W_M}{V(I_1 + I_2)}$$

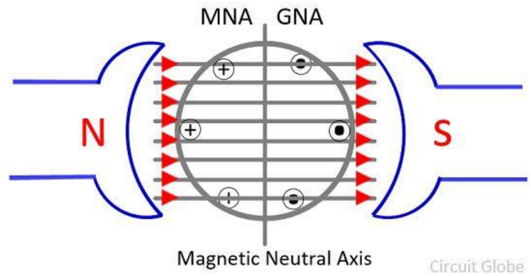
6.write short notes on armature reaction.

Definition: The armature reaction simply shows the effect of armature field on the main field. In other words, the armature reaction represents the impact of the armature flux on the main field flux. The armature field is produced by the armature conductors when current flows through them. And the main field is produced by the magnetic poles.

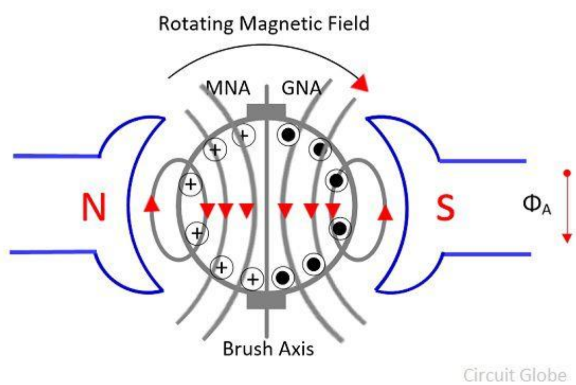
The armature flux causes two effects on the main field flux.

- The armature reaction distorted the main field flux
- It reduces the magnitude of the main field flux.

Consider the figure below shows the two poles dc generator. When no load connected to the generator, the armature current becomes zero. In this condition, only the MMF of the main poles exists in the generator. The MMF flux is uniformly distributed along the magnetic axis. The magnetic axis means the centre line between the north and south pole. The arrow in the below-given image shows the direction of the magnetic flux Φ_M. The magnetic neutral axis or plane is perpendicular to the axis of the magnetic flux.



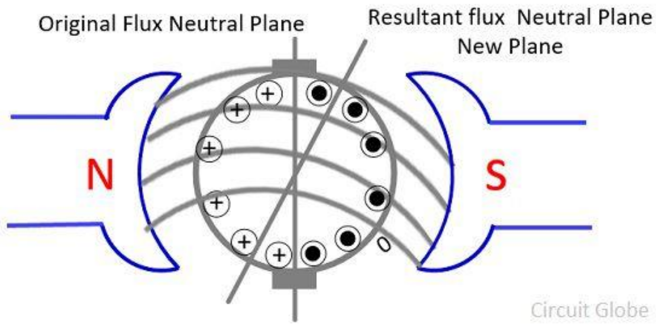
The MNA coincides with the geometrical neutral axis (GNA). The brushes of the DC machines are always placed in this axis, and hence this axis is called the axis of commutation.



Consider the condition in which only the armature conductors carrying current and no current flows through their main poles. The direction of current remains same in all the conductors which lying under one pole. The direction of current induces in the conductor is given by the Fleming right-hand rule. And the direction of flux generates in the conductors is given by the cork-screw rule.

The direction of current on the left sides of the armature conductor goes into the paper (represented by the cross inside the circle). The armature conductors combine their MMF for generating the fluxes through the armature in the downward direction.

Similarly, the right-hand side conductors carry current, and their direction goes out of the paper (shown by dots inside the circle). The conductor on the right-hand sides is also combining their MMF for producing the flux in the downwards direction. Hence, the conductor on both the sides combines their MMF in such a way so that their flux goes downward direction. The flux induces in the armature conductor Φ_A is given by the arrow shown above.



This happens when machines running at no load condition. Now the machine has two fluxes, i.e., the armature flux and the field pole flux. The armature flux is produced by the current induces in the armature conductors while the field pole flux is induced because of the main field poles. These two flux combines and gives the resultant flux Φ_R as shown in the figure above.

When the field flux enters into the armature, they may get distorted. The distortion increases the density of the flux in the upper pole tip of N-pole and the lower pole tip of the south pole. Similarly, the density of flux decreases in the lower pole tip of the north pole and the upper pole tip of the south pole.

The resultant flux induces in the generator are shifted towards the direction of the rotation of generator. The magnetic neutral axis of poles is always perpendicular to the axis of the resultant flux. The MNA is continuously shifted with the resultant flux.

Effect of Armature Reaction

The effects of Armature Reaction are as follows:-

- Because of the armature reaction the flux density of over one-half of the pole increases and over the other half decreases. The total flux produces by each pole is slightly less due to which the magnitude of the terminal voltage reduces. The effect due to which the armature reaction reduces the total flux is known as the demagnetising effect.

- The resultant flux is distorted. The direction of the magnetic neutral axis is shifted with the direction of resultant flux in case of the generator, and it is opposite to the direction of the resultant flux in case of the motor.
- The armature reaction induces flux in the neutral zone, and this flux generates the voltage that causes the commutation problem.

7. Write short notes on commutation process of generator.

The currents induced in the armature conductors of a DC generator are alternating in nature. The change from a generated alternating current to the direct current applied involves the process of **Commutation**. When the conductors of the armature are under the north pole, the current which is induced flows in one direction The current flows in the opposite direction when they are under south pole.

As the conductor passes through the influence of the north pole and enters the south pole, the current in them is reversed. The reversal of current take place along the MNA or brush axis. When the brush span has two commutator segments, the winding element connected to those segments is short-circuited.

The term **Commutation** means the change that takes place in a winding element during the period of a short circuit by a brush. Let us understand Commutation more clearly by considering a simple ring windings shown below in Figure A.

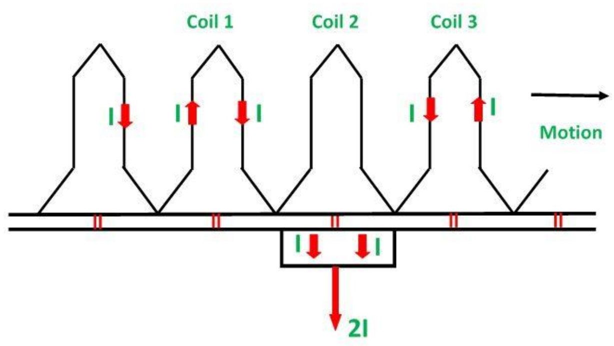


Figure A

In the position shown in Figure A, the current I flowing towards the brush from the left-hand side passes round the coil in a clockwise direction. Now consider the other figure B shown below.

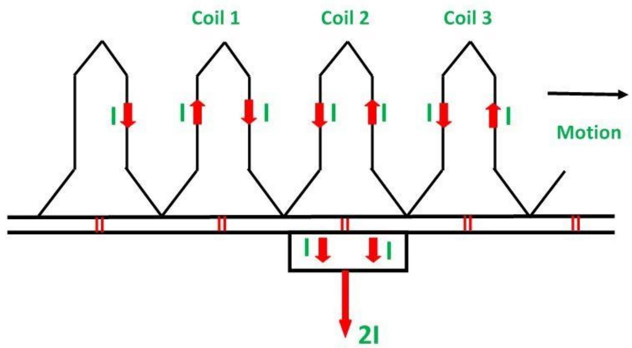


Figure B

In the above figure, the position of the coil shows that the same amount of current is carried by all the coils, and the direction of the current is also similar, but the coil is too short-circuited by the brush.

In the Figure C shown below the brush makes contact with bars a and b, thereby short-circuiting coil 1. The current is still I from the left-hand side and I from the right-hand side. It is seen that these two currents can reach the brush without passing through coil 1.

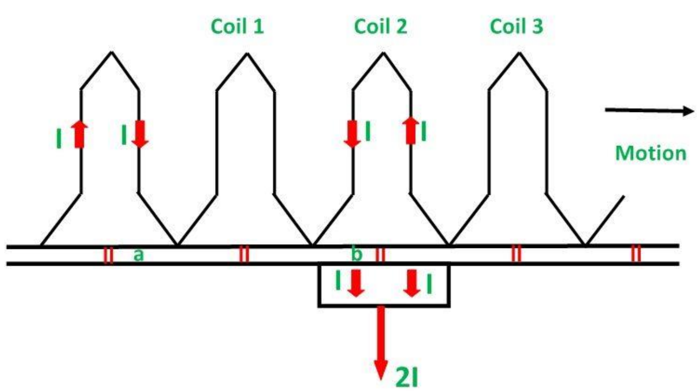


Figure C

In the figure D shown below, the bar (b) has just left the brush, and the short circuit of coil one has ended. It is now necessary for the current I reaching the brush from the right-hand side in the anticlockwise direction.

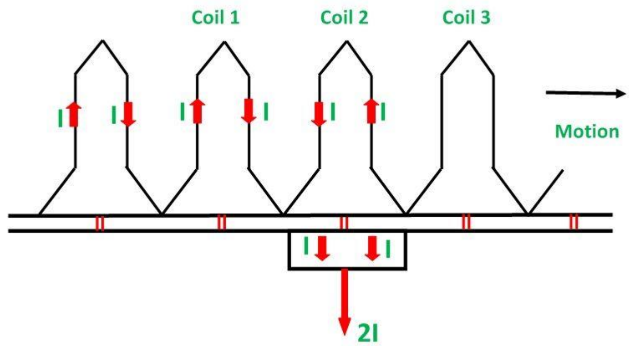


Figure D

From all the above discussion, it is seen that during the period of the short circuit of an armature coil by a brush the current in the coil must be reversed and also brought up to its full value in the reversed direction. The time of the short circuit is called the period of commutation.

The figure shown below shows how the current in the short-circuited coil varies during the brief interval of the short circuit. Curve b shows that the current changes from +I to –I linearly in the commutation period. Such a commutation is called **Ideal Commutation** or **Straight-line Commutation.**

8. DERIVE THE EMF EQUATION OF DC GENERATOR

Emf equation of dc generator:

Consider a DC generator with the following parameters,

P = number of field poles
Ø = flux produced per pole in Wb (weber)
Z = total no. of armature conductors
A = no. of parallel paths in armature
N = rotational speed of armature in revolutions per min. (rpm)

Now,
Average emf generated per conductor is given by $d\Phi/dt$ Volts ... eq. 1

Flux cut by one conductor in one revolution $= d\Phi = P\Phi$
Number of revolutions per second (speed in RPS) $= N/60$
Therefore, time for one revolution $= dt = 60/N$ Seconds

From eq. 1, emf generated per conductor $= d\Phi/dt = P\Phi N/60$
Above equation gives the emf generated in one conductor of the generator. The conductors are connected in series per parallel path, and the emf across the generator terminals is equal to the generated emf across any parallel path.
Therefore, **$E_g = P\Phi NZ / 60A$**
For simplex lap winding, number of parallel paths is equal to the number of poles (i.e. A=P),
Therefore, for simplex lap wound dc generator, **$E_g = P\Phi NZ / 60P$**

Short question and answer

1. What purpose is served by the pole shoe in a dc machine

Ans: The main function of the pole shoe is to spread the magnetic flux and to prevent the field coil from slipping.

2. What are the advantage and disadvantage of carbon brushes?

Ans: **advantage:**

High Melting Point
Soft metal
Negative temperature co-efficient
Self lubricating

Disadvantage:

(a) Due to high voltage drop the commutator must be made larger than copper brushes
(b) Their low current density necessitates large carbon brush.

3. What is the essential difference between lap and wave winding?

Ans: the essential difference between a lap winding and a wave winding is in the commutator connection. In lap winding, the commutator pitch is 1 whereas for a wave winding it is about twice the pole pitch.

4. Why the armatures winding of a dc machine always a double layer winding?
Ans: when the coil sides are arranged in one layer, it is difficult to arrange their end so that they will pass each other. In order to avoid difficulty, the coils are generally arranged in two layers. Each coil has one of its sides at top of the slot and other at the bottom of some other slot. The coil ends will then lie side by side.

5. Why lap winding is used in large multipolar dc generator?
Ans: for a given number of armature conductor, a lap winding carry a heavier current than a wave winding because it has more parallel path.therefore,lap winding is used in large miltipolar machine dc generator to avoid having conductor of large cross-section.

6. What is geometrical neutral axis (G.N.A?)
ANS: MNA (Magnetic Neutral Axis) may be defined as the axis along which no emf is generated in the armature conductors as they move parallel to the flux lines.

7. **What is armature reaction?**
Ans: In a DC machine, two kinds of magnetic fluxes are present; 'armature flux' and 'main field flux'. The effect of armature flux on the main field flux is called an armature-reaction

8. Why the resistance of the field winding of a dc shunt generator kept below critical field resistance?
Ans: The critical resistance in a DC generator can be referred as the maximum value of field resistor beyond which value the EMF in the armature winding will not be induced any more or voltage build up is impossible.. ..It is the rated value of field resistance termed as critical resistance..

9. What is critical speed of dc generator?
Ans: t is the minimum speed of the armature which Is required to build up EMF by the generator, so all the generators works above the critical speed.

10. What is voltage build up condition of self excited generator?
Ans: the following condition must be satisfied for voltage buildup in a self-excited generator.

(a)There must be sufficient residual flux in the field poles.

(b) The field terminal should be connected such a way that the field current increases flux in the direction of residual flux.

(c)The field circuit resistance should be less than the critical field circuit resistance.

11. What is back emf and what is its significance?

Ans: As the armature rotates, armature conductors cut the pole magnetic field, therefore, as per law of electromagnetic induction, an emf called ***back emf*** is induced in them.

The back emf (also called counter emf) is given by

$$E_b = \frac{P\Phi ZN}{60A}$$

Where, P=number of poles of dc motor

Φ= flux per pole

Z=total number of armature conductors

N=armature speed

A=number of parallel paths in armature winding

Significance: (a) energy conversion in a dc motor is only possible due to the production of back emf.

(b) Back emf makes dc motor a self-regulating motor i.e E_b makes motor to adjust I_a automatically as per the load torque requirement.

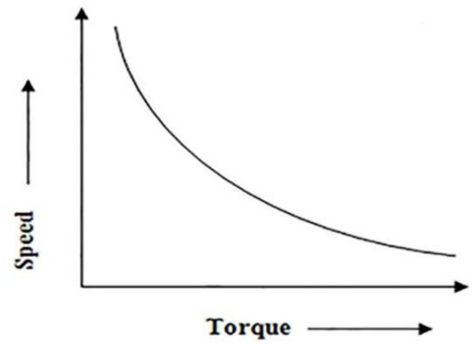
12. What are the advantages of Hopkinson's test?

Ans: The main advantages of using Hopkinson's test are as follows:-

- This method is very economical.
- The temperature rise and the commutation conditions can be checked under rated load conditions.
- Stray losses are considered, as both the machines are operated under rated load conditions.
- Large machines can be tested at rated load without consuming much power from the supply.
- Efficiency at different loads can be determined.

13. Draw the torque speed characteristic of dc motor

Ans:



14. What is the function of commutator?

Ans: commutator is also known as mechanical rectifier which is used to convert the sinusoidal induced emf in the armature to direct voltage across the brushes.
15. **What are the effects of armature reaction?**

Ans: The effects of Armature Reaction are as follows:-

- Because of the armature reaction the flux density of over one-half of the pole increases and over the other half decreases. The total flux produces by each pole is slightly less due to which the magnitude of the terminal voltage reduces. The effect due to which the armature reaction reduces the total flux is known as the demagnetizing effect.
- The resultant flux is distorted. The direction of the magnetic neutral axis is shifted with the direction of resultant flux in case of the generator, and it is opposite to the direction of the resultant flux in case of the motor.

16. What are the methods to reduce armature reaction?

Ans: compensating winding and interpoles are used to get rid of the ill effects of armature reaction.

Compensating winding: Now we know that the armature reaction is due to the presence of armature flux. Armature flux is produced due to the current flowing in armature conductors. Now, if we place another winding in close proximity of the armature winding and if it carries the same current but in the opposite direction as that of the armature current, then this will nullify the armature field. Such an additional winding is called as compensating winding and it is placed on the pole faces. Compensating winding is connected in series with the armature winding in such a way that it carries the current in opposite direction.

Interpoles: Interpoles are the small auxiliary poles placed between the main field poles. Winding on the interpoles is connected in series with the armature. Each interpole is wound in such a way that its magnetic polarity is same as that of the main pole ahead of it. Interlopes nullify the quadrature axis armature flux.

17. **What will happen if the shunt field winding of a loaded shunt motor accidentally breaks?**

Ans: if the shunt field winding of a loaded shunt motor accidentally breaks, the loss of shunt field current would result in stopping of the motor or burn out the armature or fuse.

18. **What will happen if a shunt motor running at no load has its shunt winding opened accidentally?**

Ans: if a shunt motor, running at no load has its shunt field opened or burnt out, the back emf will fall to nearly zero .the armature current will continuously increase the speed of the motor until its parts fly apart.