DC MOTORS

Motor is a machine that takes in electrical input and gives out mechanical output.

**Principle of motors:**

A motor works on the principle that whenever a current carrying conductor is placed in a magnetic field it experiences a mechanical force.
In fig 1 the conductor ‘AB’ is under north pole and ‘CD’ is under south pole. The current direction is as shown in the figure. The main field direction is given from North Pole to South Pole. Thus the direction of the mechanical force on the conductor is given by "Fleming’s left hand rule".

**Fleming’s left hand rule:** it states that if forefinger gives the direction of the field, the middle finger gives the direction of current, thumb gives the direction of the force on the conductor.

Now according to Fleming’s left hand rule, the direction of force on the conductors is in clockwise direction and hence force on conductor AB is inward and force on conductor ‘CD’ is outward.

With this let us assume that now the conductor AB comes under south pole and CD comes under north pole. But due to the action of split rings and brushes through the conductors change their positions but the current direction through the conductor under respective poles remains unchanged. Thus from fig 2. We can identify the direction of current and the direction of main magnetic field.
Once again the direction of force on the conductors is obtained by applying Fleming’s left hand rule, thus the force on conductor CD is now inward and the that on conductor AB is outward.

Hence this process is continuously repeated and thus the rotational torque on the motor is continuous in one direction. If the direction of rotation of motors is to be reversed, the supply is to be reversed.

In a DC motor, commutator converts the DC in the supply terminals to the AC in the armature conductors. Therefore it will behave as a mechanical rotating inverter.

And now that the rotor is set in rotation and it is cutting the main magnetic field, due to generators action an emf is induced in the armature terminals. The current due to that e.m.f is in a direction opposite to that of main current because according to lenz law the e.m.f induced must be in a direction so as to produce current that opposes the cause that produced it. Hence this e.m.f is refused to as back e.m.f and is denoted by $E_b$. 
$I_a$ is due to supply voltage $E_1$ and $I_{ab}$ is a current due to back e.m.f $E_b$.

Therefore, applying K.V.L, we get

$$V = E_b + I_a R_a$$

Electrical power ($P_e$) = $V. I_a$

Mechanical power ($P_{mech}$) = $E_b. I_a$

**Constructional details:** Constructional details of a motor are similar to that of a generator.

**Types of motors:** Similar to that of generators, we have three types of motors.

1. Shunt motor
2. Series motor
3. Compound motor
Shunt motor: in this type of motor the field is connected in shunt to that of armature.

We will simultaneously study the load characteristics of these motors. Under load characteristics we will study three different characteristics.

I. Speed Vs $I_a$
II. $\tau$ Vs $I_a$
III. N Vs $\tau$

a) Speed Vs $I_a$:

Speed of a DC shunt motor; is considered to be almost constant. But practically as the load on the shaft increases, the speed slightly decreases.
b) $\tau$ Vs $I_a$:

Torque is proportional to armature current, but practically as the load increases, the torque also deviates from its linearity.

N Vs: The shunt motor is expected to give a constant speed irrespective of the load on the shaft. But practically the speed slightly deviates with an increase in the torque.
1. series motor:

A series motor is a motor in which field winding is in series with the armature winding.

In a series motor the flux is directly proportional to armature current.
\[ \varnothing = K_f I_a \]
\[ K_f \rightarrow \text{constant} \]

The speed of a DC-series motor is given by

\[ N = k \left[ \frac{V}{I_a} - (R_a + R_{sc}) \right] \]
\[ K \rightarrow \text{constant.} \]

The speed relation given above is very practical and also very important. If you observe it, the speed is inversely proportional to the load current.

If we start the motor without any load, it draws zero armature current and hence from the above relation the speed must be infinity at zero armature current. Hence this stresses as a point that the DC series motor should never be started under no load.

If at all the motor is started under no load it runs dangerously high speed.

Therefore, if load=0 \( \Rightarrow \varnothing = 0 \)

\[ \Rightarrow N \rightarrow \infty \]

**Load characteristics of a DC series motor:**

1) \( N \) vs \( I_a \)
2) $\tau$ vs $I_a$

In a DC series motor $\tau \propto I_a^2$
3) \( N \) vs \( \tau \)

3) compound motor: A motor that has both series field and shunt field are called compound motors. There are two types of compound motors.

I. Cummulative compound
II. Differential compound

Cummulative compound: If the series field winding aids the shunt field winding then it is called cummulative compound motor.

Differential compound: If the series field winding does not aid the shunt field winding then it is called differential compound motor.
Load characteristics:

1) $N$ Vs $I_a$
CONVERTING ALL THE CHARACTERISTICS OF DIFFERENT MOTORS

Speed current characteristics of DC motors:

\[ \tau \text{ Vs } I_a \]
Torque current characteristics:

Speed torque characteristics:
**Torque equation:**

Torque is defined as a turning or twisting moment of a force.

Torque is given by the product of force and the radius at which this force acts.

⇒ \( \tau = f \times r \) newtons

Work done in one revolution = \( f \times \text{distance} \)

= \( f \times 2\pi r \)

∴ for ‘N’ revolutions or in N/60 rotation per second

\[
= f \times 2\pi r \times \frac{N}{60}
\]

\[
= \frac{2\pi N}{60} \times f \times r
\]

∴ \( p = \frac{2\pi N \tau}{60} \)