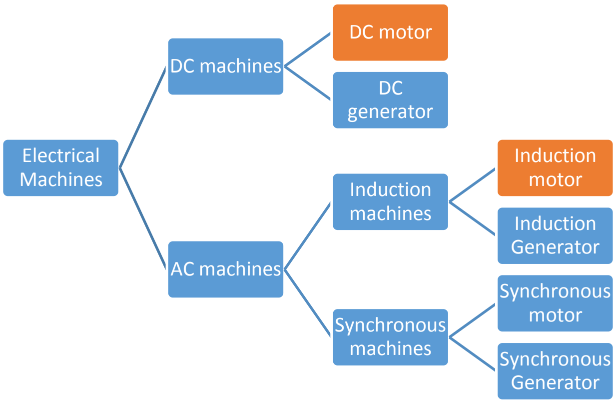
ELECTRICAL MACHINES AND TRANSFORMER

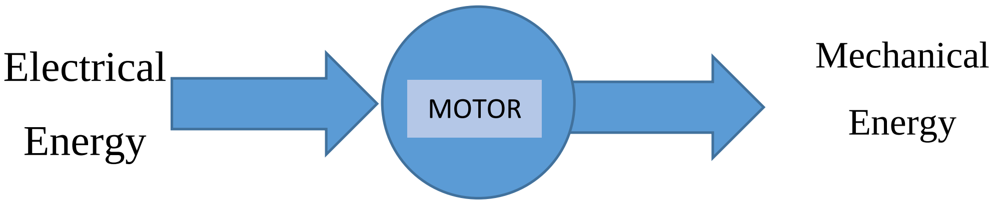
(Transformer is a device and not a machine as it does not have any moving parts)

Electrical machines are classified as:



DC MACHINES

- DC motor works on dc supply
- DC generator gives dc power output
- The same machine can work as a dc motor as well as a dc generator. For mechanical input the machine gives electrical output and thus it will be a generator. Similarly for an electrical input the machine output will be mechanical torque and thus it is then a motor.



- All electrical machines works based on the basic laws: **Faraday's Laws and Lenz's Law**

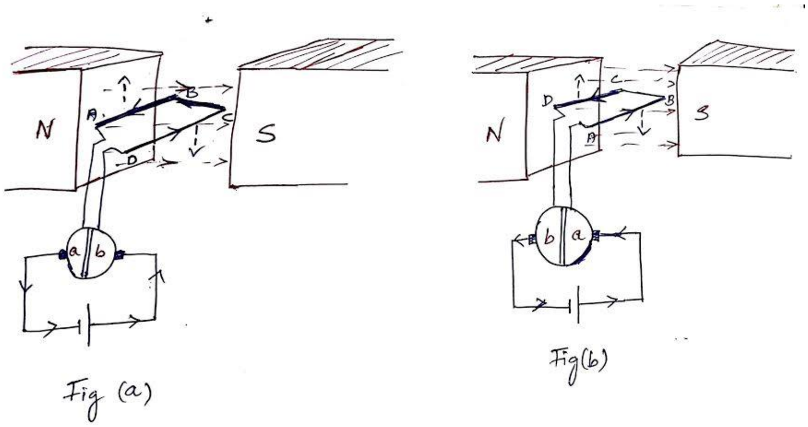
DC MOTOR

WORKING PRINCIPLE

When a current carrying conductor is placed in a uniform magnetic field it will experience a force acting on it.

The direction of 'Motion of the conductor', the 'Field' and the 'Current' are mutually perpendicular and is given by 'Fleming's left hand rule'.

According to Fleming's left hand rule, if the middle finger of one's left hand points in the direction of the **C**urrent and the fore finger points towards the direction of the **F**ield then the thump will point towards the direction of **M**otion of the conductor when the fingers are kept mutually perpendicular to each other.



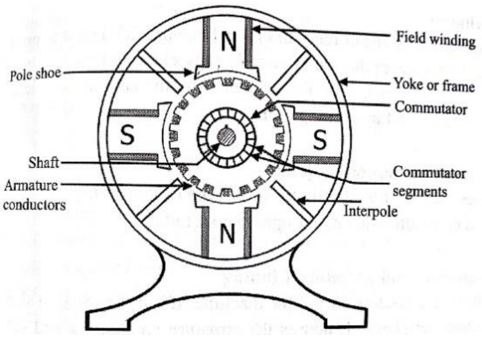
Consider fig(a). A *coil* (consists of two conductors) ABCD is connected across a dc supply through a *split-ring* (a ring split into two where the two pieces are insulated from each other) and *brush (used to maintain contact between moving and stationary points)* arrangement. The current carrying coil is placed in a uniform magnetic field. According to Fleming's left hand rule conductor AB near the north-pole will experience a force upwards and conductor CD near the south-pole will experience a force downwards. As a result of the force experienced the coil will rotate in clockwise direction. As the coil becomes vertical total force experienced will be zero but the coil will move forward due to centrifugal force. Now, consider fig.(b) where the position of the conductors is reversed from rotation. Here the current through the coil is also reversed due to the split-ring brush arrangement. Hence, the conductors AB and CD will experience a force downwards and upwards respectively according to Fleming's left hand rule. Thus the coil will continue to rotate in clockwise direction.

The split-ring and brush helps to reverse the currents in the conductors such that the direction of current through each conductor that comes under a particular pole remains the same. Here current through the conductor near the north-pole is always outwards and that under south –pole is always inwards.

In a DC machine there will be more number of coils for smooth rotation. The split-ring is replaced by a *commutator.* Each coil ends or each conductor is connected to each segment of the commutator where the segments are insulated from each other.

Back emf (E_b) : When the armature conductors rotate in the magnetic field an emf is induced in the conductors according to Faraday's Law. This is consistant with the lenz's law as the **cause** of rotation of the motor is the applied voltage and this back emf induced will oppose the cause producing it i.e its polarity will be opposite to that of the supply voltage.

CONSTRUCTION OF A DC MACHINE



All electrical machines have mainly two parts- Stator (stationary part) and Rotor (rotating part)

Parts of a DC Machine: Field system and Armature

Field system: Field core, Field winding, Pole shoe, Yoke or Mechanical Frame

Armature: Armature core, Armature winding

*(Additionally) Commutator and Brushes***:**

Field system:

Electromagnet, producing magnetic field

Field winding: Pole coil or exciting coil are copper coils wound over the pole core. Whenever they carry current they electro magnetise the poles to produce necessary magnetic field.

Field core or pole core: Made of steel laminations, insulated from each other and riveted together. Use of Steel reduces hysteresis loss and provides low reluctance path for the flux. Lamination reduces eddy current loss.

Pole shoe: Pole core ends in a pole shoe which has the following purposes namely- To mechanically support the field coil, to increase the area of cross-section for the magnetic flux reducing the reluctance of the magnetic path.

Yoke or Mechanical Frame: It is the outer covering of the machine. An even number of pole cores are bolted to it. Yoke serves the following purposes namely-

- To provide mechanical protection to the machine.
- It is part of the magnetic circuit and carries the flux in machine completing the magnetic path.

Armature:

Armature conductors are wound over the armature core. Rotating part of the machine. Mounted on the shaft.

Armature core: A solid cylinder made of laminated steel, with slots on the periphery (outer surface) to house the armature conductors. Made of steel laminations to reduce hysteresis loss and eddy current loss.

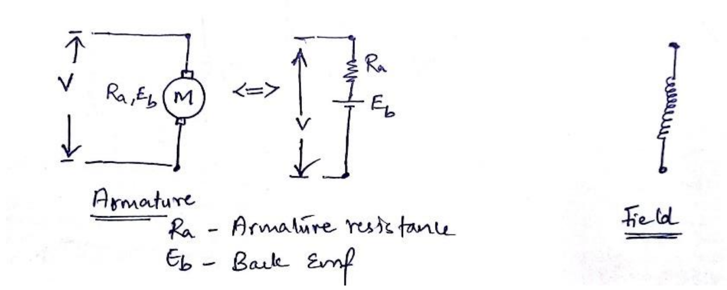
Armature Winding: Copper winding over the surface of armature core. Conductors are placed into the slots on the outer periphery of the core. Two kind of winding methods are implemented namely, *Wave winding* or *Lap winding.*

Commutator and Brushes:

Commutator: Mounted on the shaft in front of the armature. Hollow cylinder made of wedge shaped segments of hard drawn copper and insulated from each other by thin layer of mica. Number of segments is equal to number of armature conductors. Used to reverse the current in the armature conductors which is known as commutation.

Brushes: Helps the transfer of power between the rotating and stationary parts of the machine. They are made of carbon. The commutator slides over the brushes. They are mounted on a brush holder and are held on to the machine by springs.

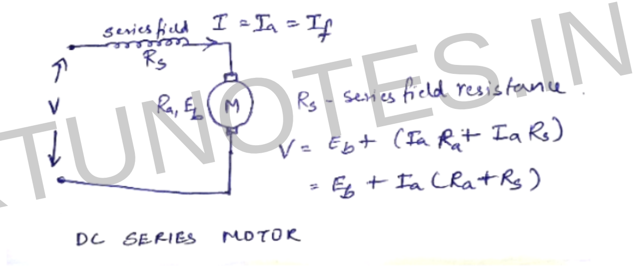
Equivalent Circuit of armature and Field



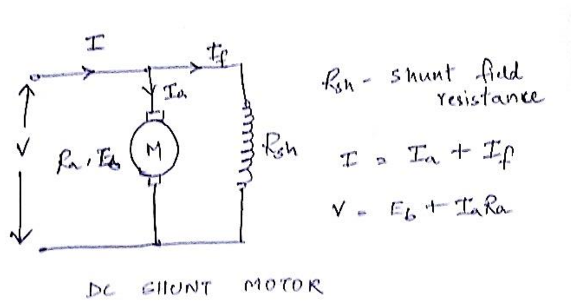
TYPES OF DC MOTORS

The Armature and field windings are supplied from the same DC supply. DC motors are classified based on how these two windings are connected together.

DC Series motor: Armature and field are connected in series.



DC shunt motor: Armature and field are connected in parallel also known as shunt connection.



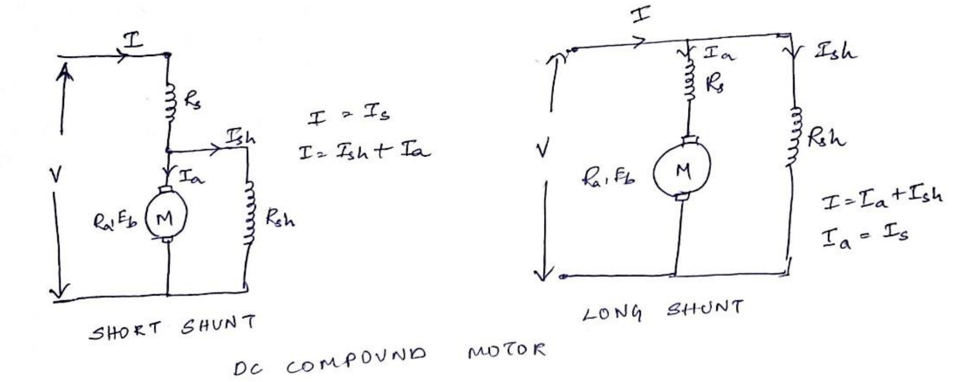
DC compound motor: Contains both series connected field windings as well as shunt connected field windings. Compound motors are further classified as:

Long shunt: Shunt winding is connected across armature and series field.

Short shunt: Shunt winding is connected across armature alone and the series winding is connected in series to this parallel combination.

Cumulatively compound: Aiding magnetic fields are produced from both field windings

Differentially compound: Opposing magnetic fields are produced from both field



windings

EQUATIONS

$E_b = \frac{\emptyset Z N}{60}\frac{P}{A}$	Where, E_b = Back emf φ=Flux per pole (Wb) Z= No. of armature conductors N=Speed (rpm) P=No.of poles (always an even no.) A=No. of parallel path. (A=P for lap winding and A=2 for wave winding)
$E_b \ \alpha \ \emptyset N$ $\Phi \ \alpha \ I_f$	
Shunt motor: $I_f = constant$ $\therefore N \ \alpha \ E_b$	For problems, you can take, $\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}}$
Series motor: $I_f = I_a \ which \ varies \ with \ load$ $\therefore N \ \alpha \ \frac{E_b}{\emptyset}$ $or \ N \ \alpha \ \frac{E_b}{I_a}$	For problems, you can take, $\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} * \frac{I_{a2}}{I_{a1}}$
$V = E_b + I_a R_a$	V= Supply voltage(V) I_a=Armature current(A) R_a = Armature resistance (Ω)
$VI_a = E_b I_a + I_a^2 R_a$	VI_a –power **input** to armature $I_a^2 R_a$ –Copper **loss** in armature $E_b I_a$- Mechanical **output** power developed
P= Tω= $E_b I_a$	P-Mechanical power output (Watts) T-Torque developed (Nm) ω- Angular speed (rad/s) = 2πN/60

APPLICATIONS OF DC MOTOR

DC-Series motor: Used when high starting torque is required such as Electric traction (electric trains), cranes etc.

DC Shunt motor: Where constant speed is required and very high starting torque is not required, such as lathe, centrifugal pump, machine tools etc.

Cumulative Compound motors: Used where load fluctuates frequently, such as reciprocating pumps, crusher units, rolling mills etc.

Differential compound motors: Rarely used due to poor torque characteristics.

(REFER CLASS NOTES FOR PROBLEMS)