Assuming $\phi_2 = \phi_1 = \phi$

$\therefore$ Approximate voltage drop $= I_2 R_{2e} \cos\phi_2 + I_2 X_{2e} \sin\phi_2$

If all the parameters are referred to primary then we get,

Approximate voltage drop

$$= I_1 R_{1e} \cos\phi + I_1 X_{1e} \sin\phi$$

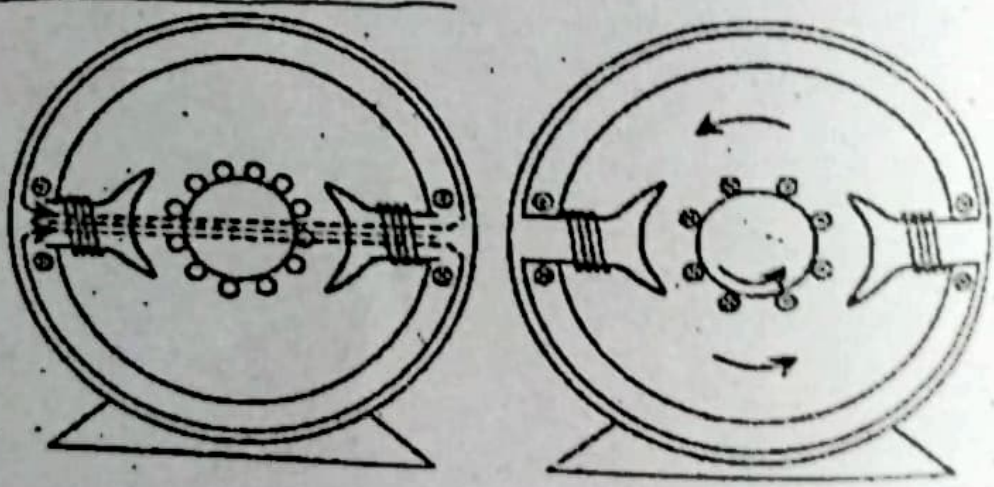
5.11 D.C. Motors

5.11.1 Principle of operation of D.C. motor

The basic principle of operation of D.C. motor is based on Fleming's left hand rule. Fleming's left hand rule states that, whenever a current carrying conductor is placed in magnetic field, it experience a force whose magnitude is given by,

$$F = BI\ell \text{ Newton}$$

Where, B = flux density, I = current through the conductor and ℓ = length of conductor.



(a) (b)

Figure 5.10

Figure 5.13 shows the two pole d.c. motor which field winding is energized with d.c. supply. Hence magnetic flux will be set up which flows from N pole to S pole. As shown in figure 5.13 (a) with no current in the armature

(rotor) winding. Figure 5.13 (b) shows d.c. motor with armature windings carrying current.

The direction of current in the armature coil is indicated by cross under North Pole and by dot under South Pole. Since it is known that, a current carrying conductor is placed in magnetic field experience a force. So these conductors will experiences a force whose direction will be given by Fleming's left hand rule.

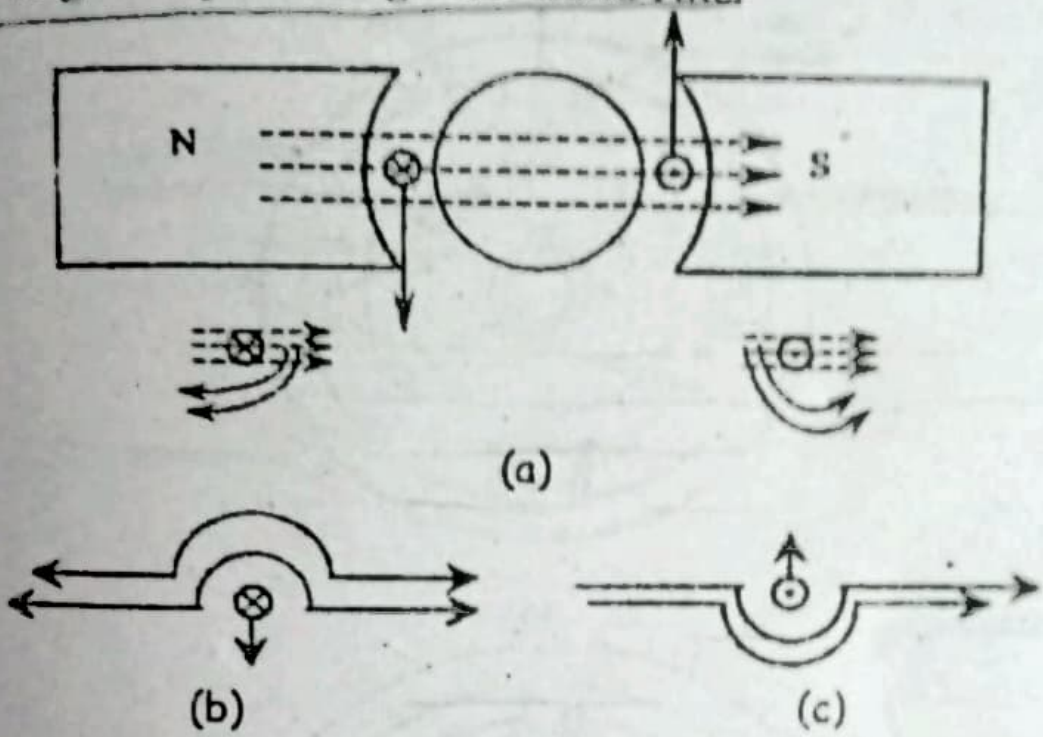


Figure 5.11

The motor action can also be explained as shown in figure 5.10 (a). As armature conductor is a current carrying conductor, so it produces the flux around it, as shown in the figure 5.10 (b). Hence flux density increases above the conductor, which push the conductor experiences a force in upward direction. There are number of armature conductor on armature core and all of them experiences a force and hence rotor starts rotating.

5.11.2 Construction of D.C. Motor

The d.c. generators and d.c. motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a d.c. generator or motor. Any d.c. generator can be run as a d.c. motor and vice-versa. All d.c. machines have five principal components viz.,

1. field system
2. armature core
3. armature winding
4. commutator
5. brushes.

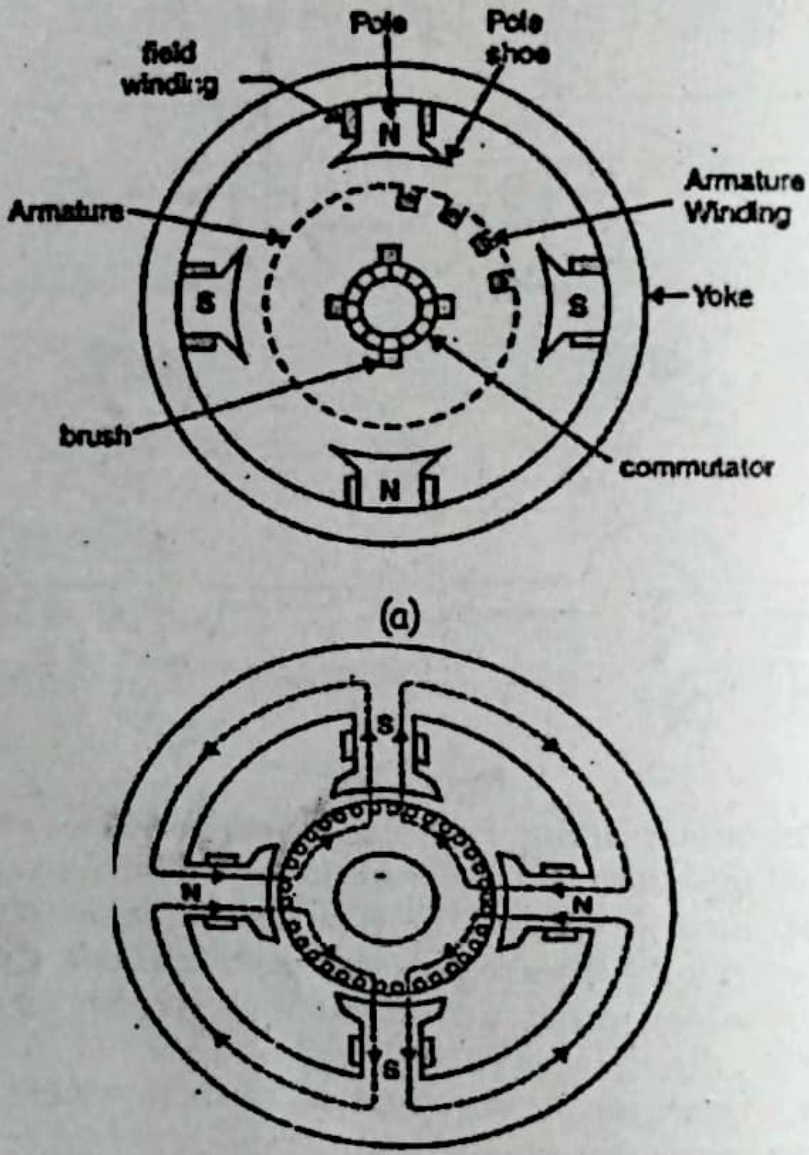


Figure 5.12 DC Machine

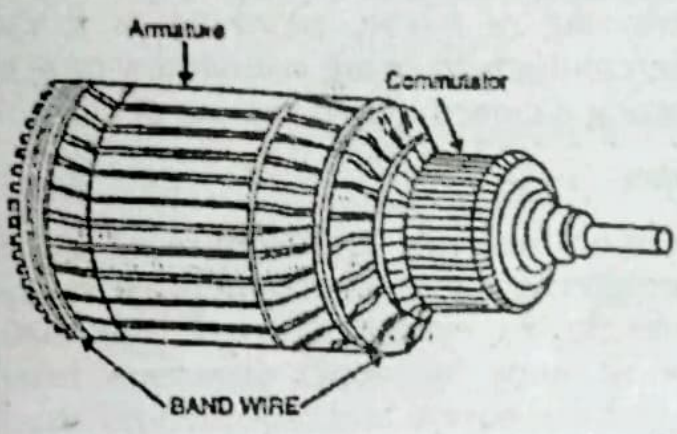
1. Field System

The function of the field system is to produce uniform magnetic field within which the armature rotates. It consists of a number of salient poles bolted to the inside of circular frame (generally called yoke). The yoke is usually made of solid cast steel whereas the pole pieces are composed of stacked laminations. Field coils are mounted

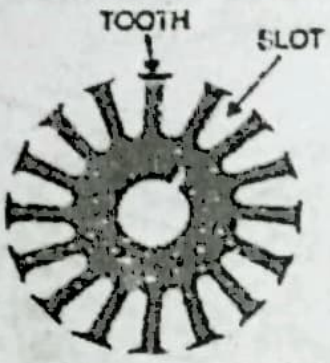
on the poles and carry the d.c. exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity.

2. Armature Core

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in Figure 5.13 (a).



(a)



(b)

Figure 5.13 Armature Core

The laminations (See Figure 5.12 (b)) are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".