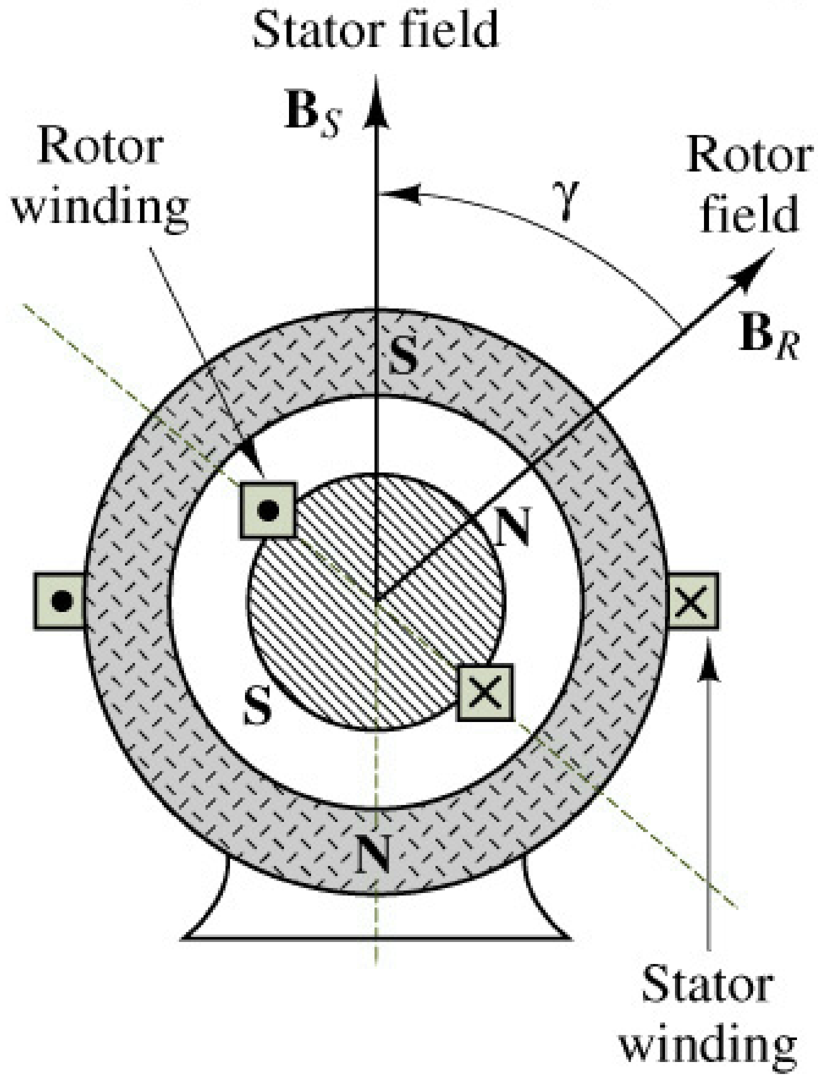
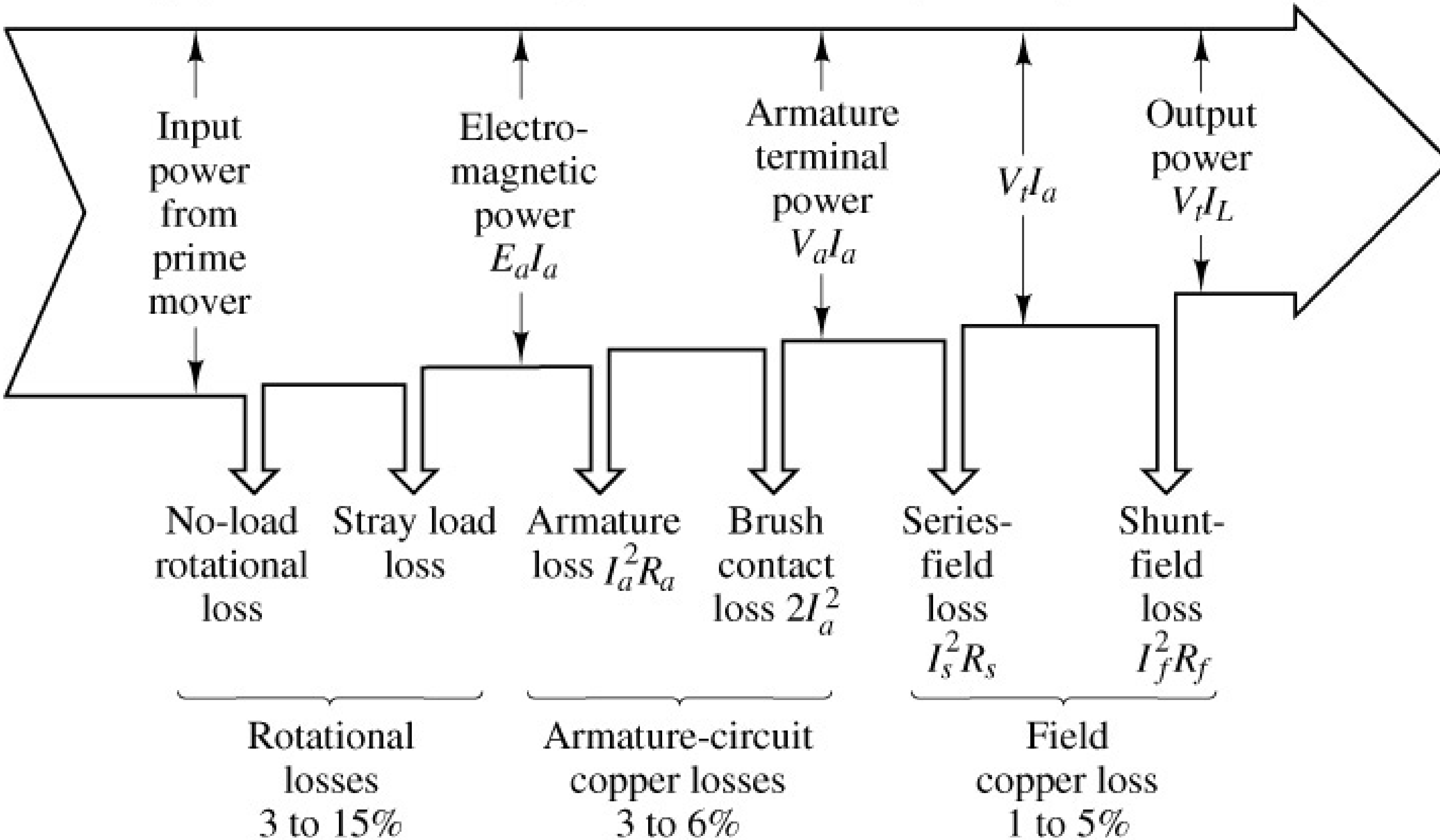
A Rotating Electric Machine



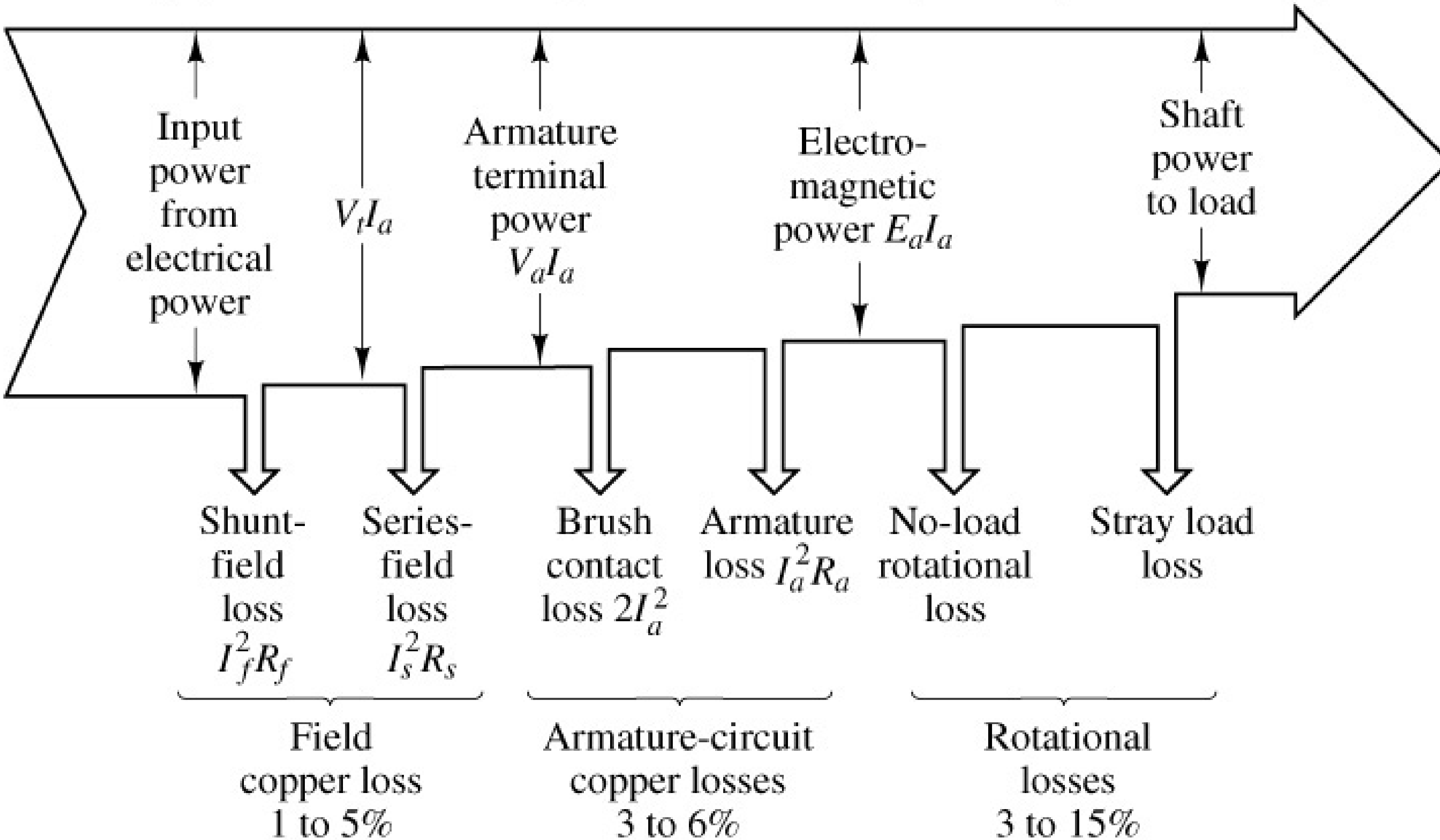
Configurations of the three types of electric machines

Machine type	Winding	Winding type	Location	Current
DC	Input and output	Armature	Rotor	AC (winding) DC (at brushes)
	Magnetizing	Field	Stator	DC
Synchronous	Input and output	Armature	Stator	AC
	Magnetizing	Field	Rotor	DC
Induction	Input	Primary	Stator	AC
	Output	Secondary	Rotor	AC

Generator Losses, Direct Current



Motor Losses, Direct Current



Basic Principles in Motors

- When a current-carrying conductor is placed in an external magnetic field vertical to the conductor, the conductor experiences a force vertical to itself and to the external magnetic field.
- The right-hand rule for force on a conductor may be used to find the direction of the force experienced on the conductor. If the right thumb points in the direction of the current in the conductor and the fingers of the right hand point in the direction of the external magnetic field, then the force on the conductor is directed outward from the palm of the right hand.
- Example: 1 ampere is the current passing through two straight parallel conductors 1 metre apart in a vacuum which produces a force of 2×10^{-7} newtons per metre of conductor.

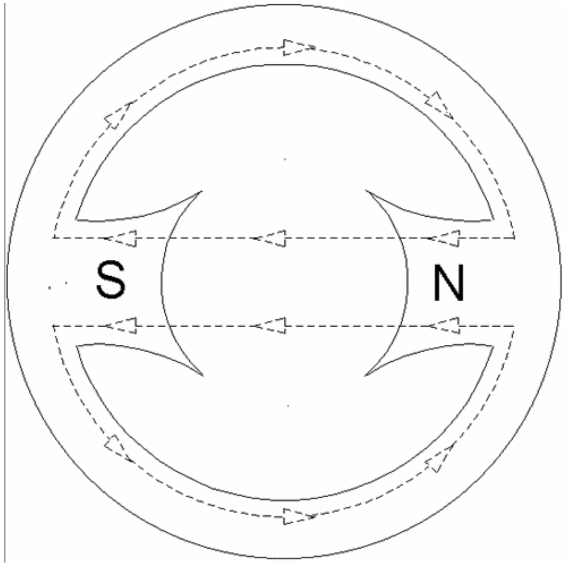
- An electric motor consists of a permanent external field magnet (stator) and a coiled conducting ammeter (rotor) which is free to rotate within the field magnet. Brushes and a commutator (are different if A.C. or D.C. current is supplied to the armature) connect the armature to an external voltage source.
- The speed of rotation of a motor depends on the value of current flowing through it, the number of coils on the armature, the strength of the field magnet, the permeability of the armature, and the mechanical load connected to the shaft.

Types of DC Motors

- Stepper Motor: It has very precise speed and position control, high torque at low speed. However, it is expensive and hard to find. Also require a switching control circuit.
- DC Motor: It has wide range of speeds and torques. It is more powerful than permanent magnet motors. However, it requires more current than permanent magnet motors, since field coil must be energized. It is heavier than permanent magnet motors. More difficult to obtain.
- Permanent Magnet Motor: It is small, compact, easy to find, and very inexpensive. However, it is small and cannot vary magnetic field strength.
- Gasoline: It is very high power/weight ratio. It provides very high torque. No batteries are required. However, it is expensive, and loud.

Principle of Operation

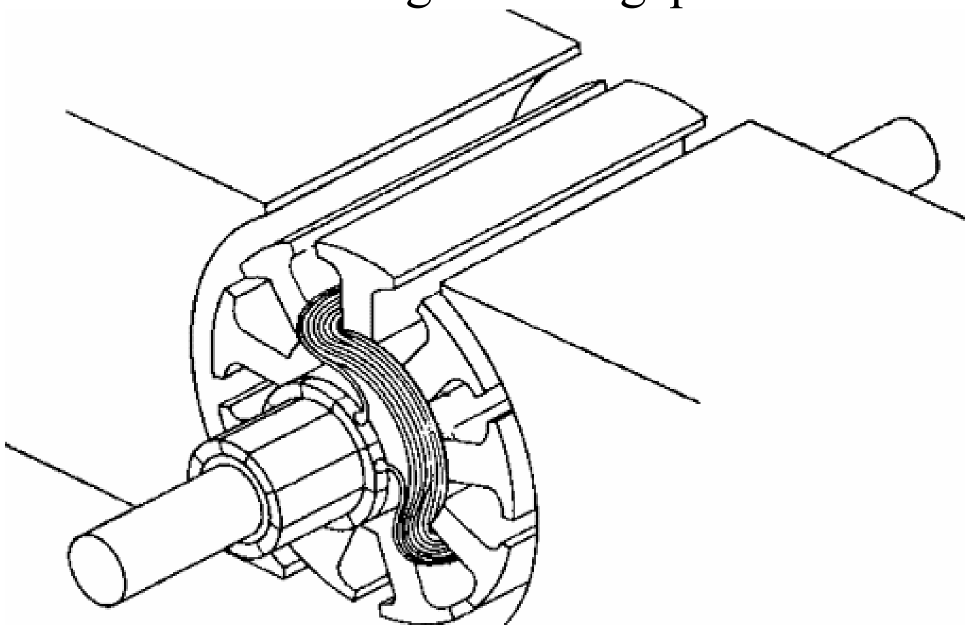
The generation of electromotive force or EMF requires a magnetic field, a current carrying conductor, and relative motion. For the single coil motor model, a constant magnetic field of flux density B was assumed without discussion of its source. The source could have been a permanent magnet or electromagnet.



Basic Parts of the DC Motor

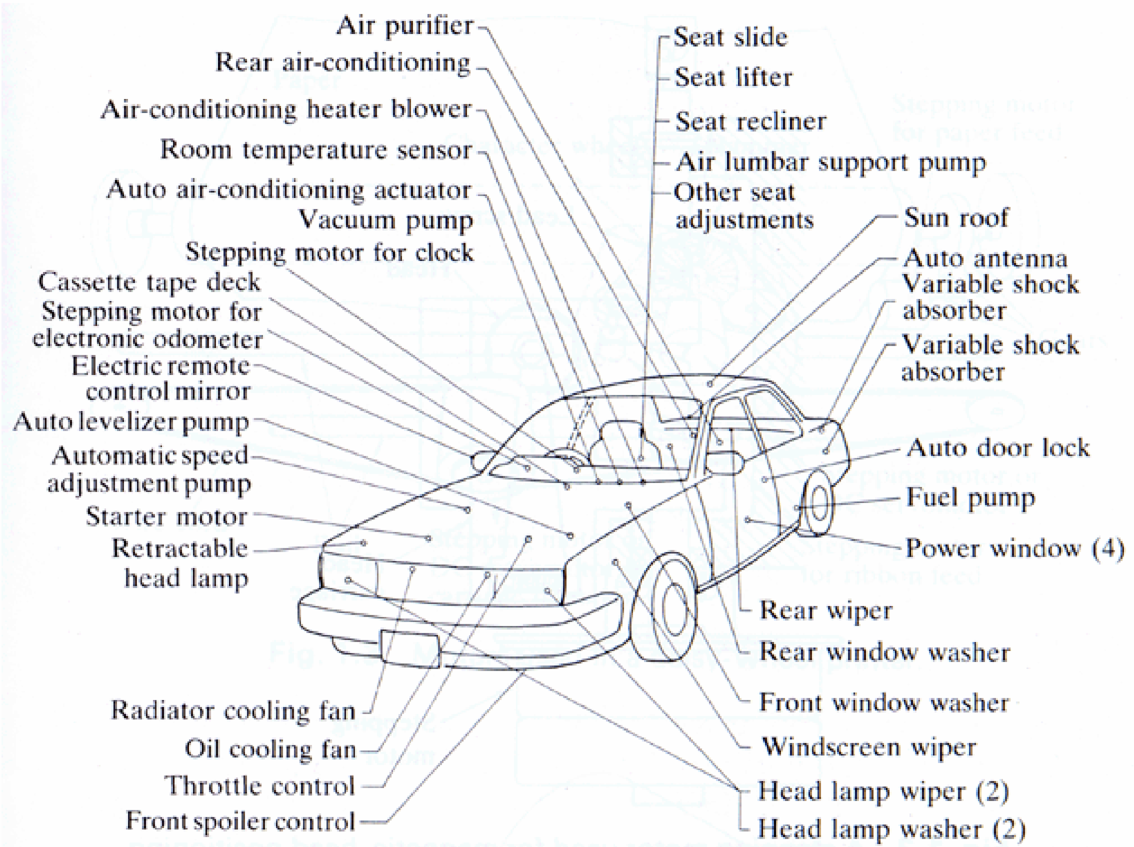
- Stator: It is cylindrical. Has an even number of magnetic poles that are established by field windings or by permanent magnets.
- Rotor: Also called Armature. It is the rotating part inside the stator. Slots cut lengthwise into the surface of the rotor to carry the armature windings.
- Since the reluctance of air is much higher that that of iron, the flux takes the shortest path from a stator north pole via the rotor to a stator south pole. Therefore the flux in the air gap is vertical to the rotor surface and the rotor conductors.
- Keep in mind that the force will be along the direction of the cross product of current and flux.

An armature made of stacked laminations with one winding in place. The armature is situated between the poles of a permanent magnet. The aim of the armature assembly is to provide a means by which current carrying conductors can be moved through the air gap of an electrical machine.



Applications of DC Motors in an Automobile!

Source: http://www.engin.umich.edu/labs/csdl/ME350/motors/dc/



Series Motors

- In a series DC motor, the field is connected in series with the armature. The field is wound with a few turns of large wire, because it must carry full armature current.
- Series motor develops a large amount of turning force (torque), from a standstill. Because of this characteristic, the series DC motor may be used to operate small electric appliances, portable electric tools, cranes, winches, hoists, etc.
- Another characteristic is that the speed varies widely between no load and full load. Series motors cannot be used where a relatively constant speed is required under conditions of varying load.

Shunt Motors

- A shunt motor is connected in the same way as a shunt generator. The field windings are connected in parallel (shunt) with the armature windings.
- When the speed of a dc shunt motor is adjusted, the speed remains relatively constant even under changing load conditions. One reason for this is that the field flux remains constant.
- A constant voltage across the field makes the field independent of variations in the armature circuit. If the load on the motor is increased, the motor tends to slow down. When this happens, the counter emf generated in the armature decreases. This causes a decrease in the opposition to DC current flow through the armature. Armature current increases, causing the motor to speed up. The conditions that established the original speed are re-established, and the original speed is maintained.

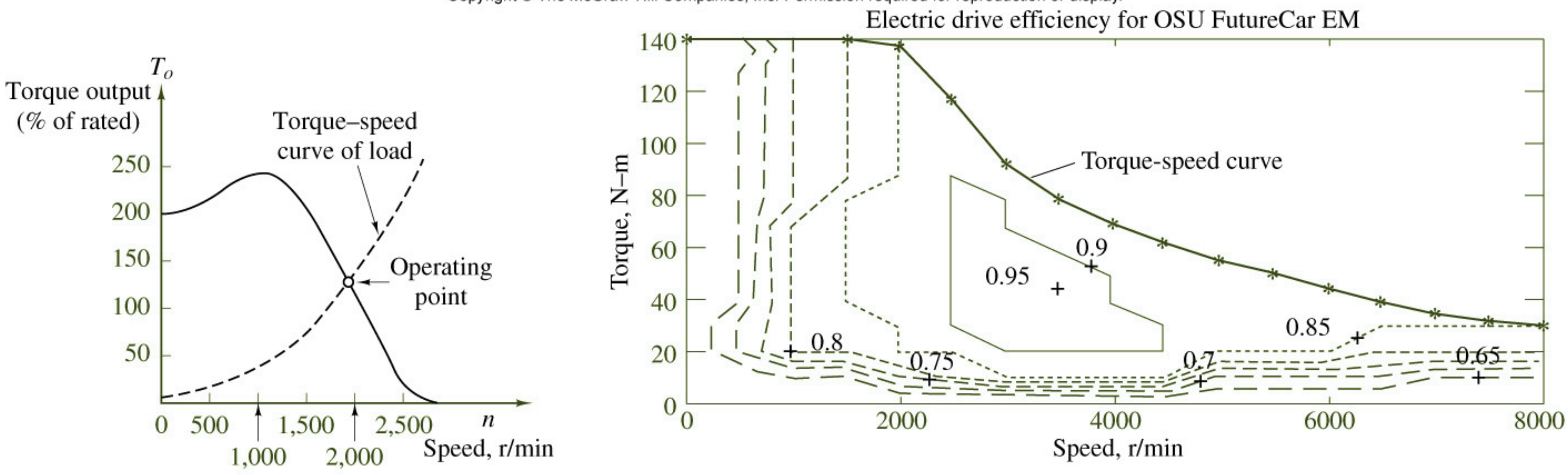
Motor Speed

- DC motors are variable-speed motors. The speed of a DC motor is changed by changing the current in the field or in the armature.

- When the field current is decreased, the field flux is reduced, and the counter emf decreases. This permits more armature current. Therefore, the motor speeds up. When the field current is increased, the field flux is increased. Higher counter emf is developed, which opposes the armature current. The armature current then decreases, and the motor slows down.

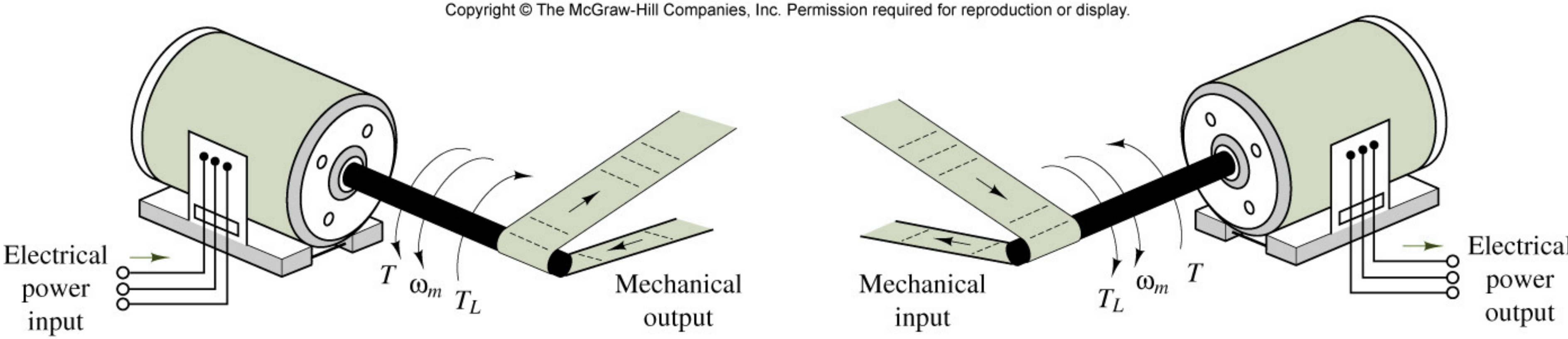
- When the voltage across the armature is decreased, the armature current is decreased, and the motor again slows down. When the armature voltage and current are both increased, the motor speeds up.

Torque-speed and Efficiency Curves for an Electric Motor



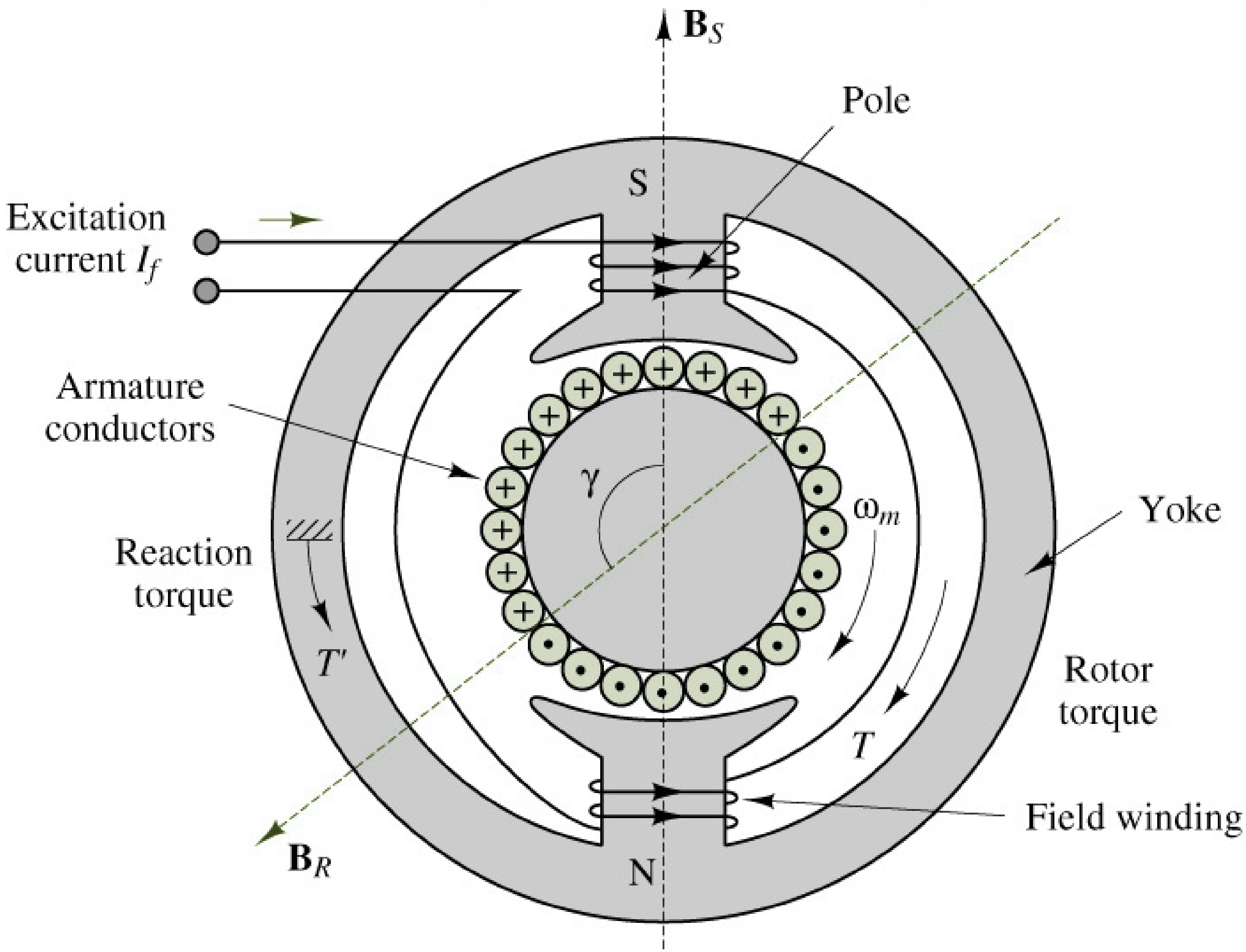
(a) Torque–speed curve (b) Efficiency map

Generator and Motor Action in an Electric Machine



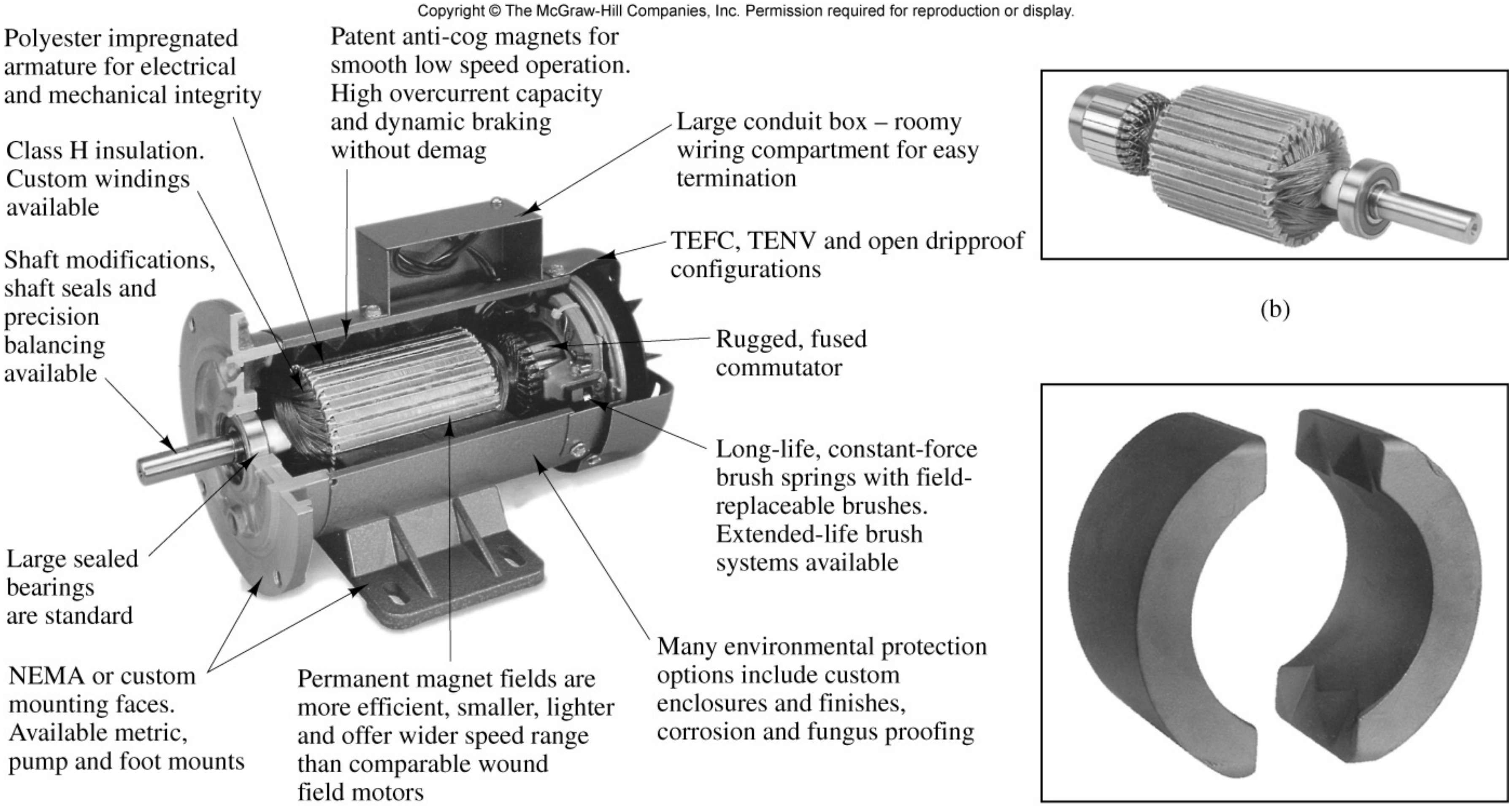
(a) Motor action (b) Generator action

A Two-pole Machine with Salient Stator Poles



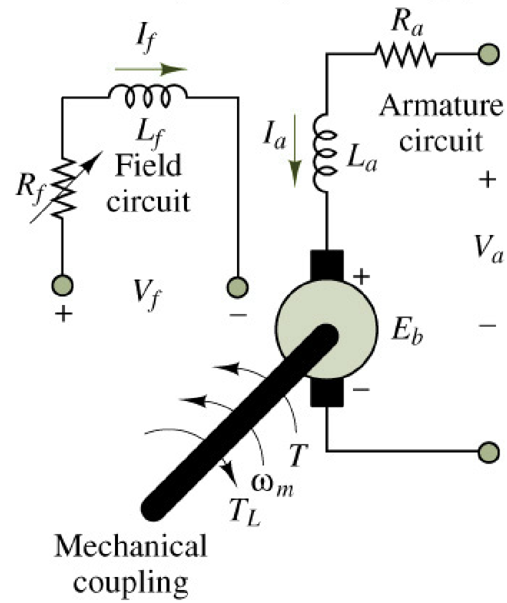
Cross section of DC machine

DC Machine; (b) Rotor; (c) Permanent-Magnet Stator

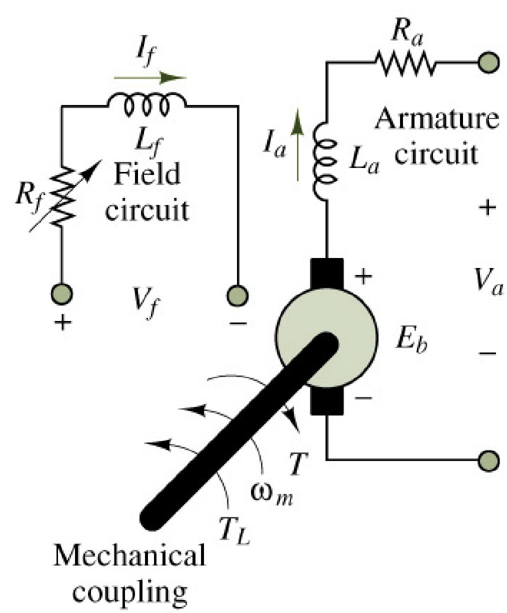


(a) (c)

Electric circuit model of a separately excited DC machine



(a) Motor reference direction



(b) Generator reference direction