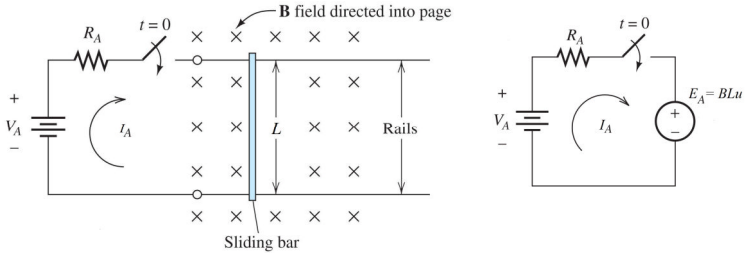
Lesson 13: Permanent magnet DC machine and equivalent circuit

Linear motor summary



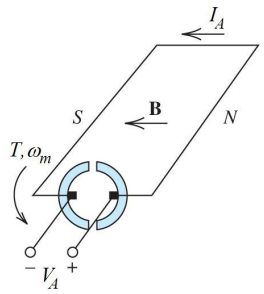
Rotating dc motor

Consider an analogous rotating dc motor.

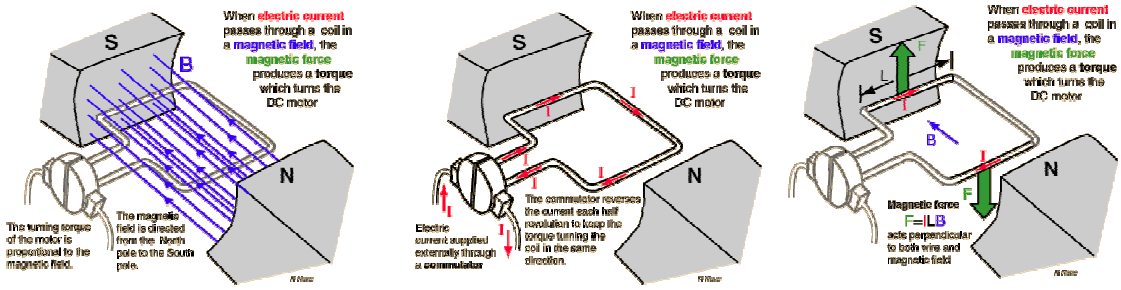
- Armature current (I_A) works is the same
- Magnetic field **B** is the similar

For rotational motion

- Force is replaced by torque T
- Linear velocity u is replace by angular velocity ω_m



DC motor operation



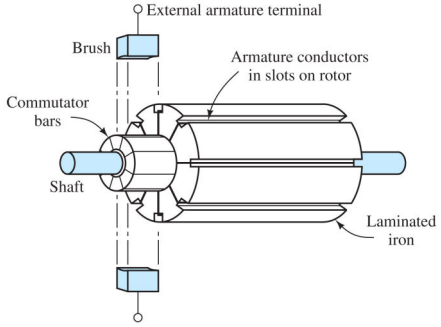
Due to the _____ law, a force **F** acts perpendicular to both wires, resulting the generation of a torque T.

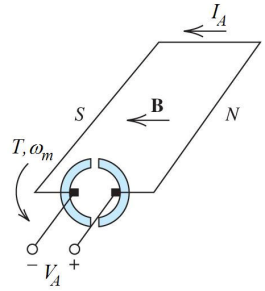
What is the force **F** when the armature is vertical?

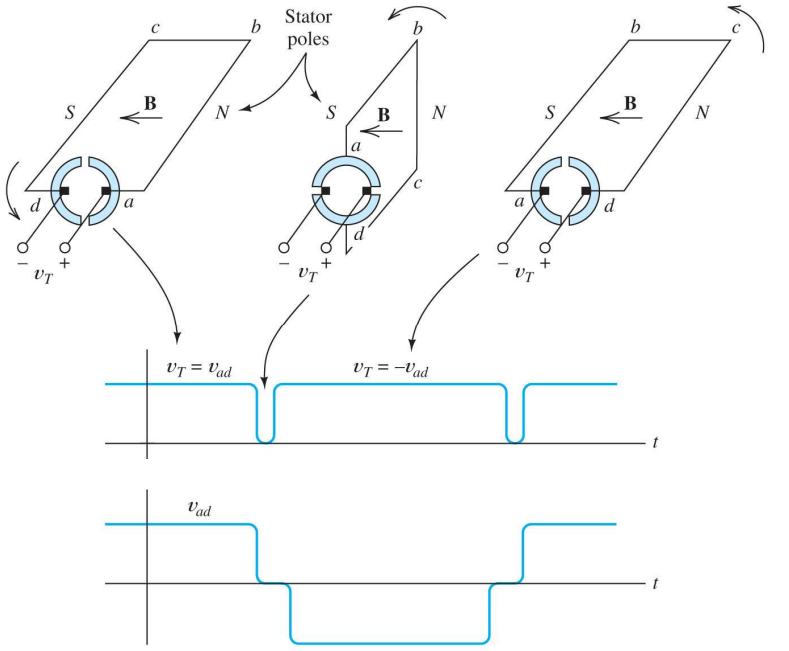
Commutation

In order to provide continuous rotation, the _____ I_A must change direction every 180° of rotation.

This process (_____) is accomplished by _____ and a segmented commutator bar.

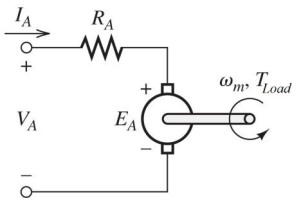


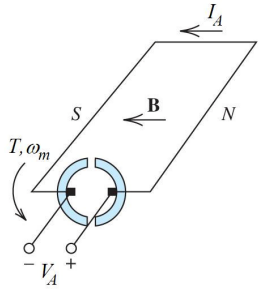




Induced armature voltage
Just as in linear motors, the time-varying flux induces a voltage that _____ the change in flux and reduces I_A (Faraday's law).
This induced voltage is known as a _____ (electromotive force).
The back emf is shown as voltage E_A.

Equivalent circuit of the dc motor
As in linear motors, it is convenient to consider the equivalent circuit model for a dc motor.
The resistance of the _____ and brushes is captured in R_A.





Induced armature voltage
The back emf E_A is given by $E_A =$

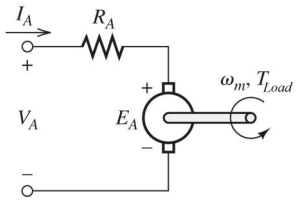
K_v is a _____ determined by the design parameters of the machine.
ω_m is the angular velocity of the rotor.

Torque and power
The torque developed T_e is given by $T_e =$

The power developed P_e is given by $P_e =$ or $P_e =$

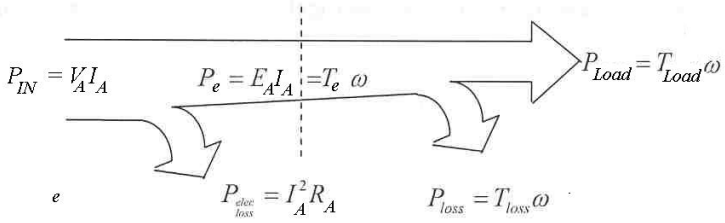
Torque losses
In addition to the power lost in the armature ( ) , there are also torque losses _____
This _____ is caused by friction, windage, eddy-current loss, and hysteresis loss.
The output torque T_{Load} is then given by

DC motor power flow



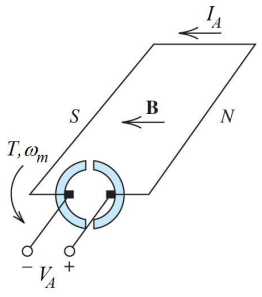
DC motor power flow terms
Power in is simply P_{in} = .
Electrical losses due to the armature resistance are given by _____ .
P_{Loss} represents losses due to the friction of mechanical parts, magnetic inefficiencies of the material, and losses coupling brushes and commutator and is expressed as P_{Loss} =
P_e represents the power developed by the motor which includes power out and rotational losses (P_{Loss}). It is expressed P_e = = =
Power out is the power that ultimately gets to the load and is expressed P_{Load} =

DC motor power flow diagram



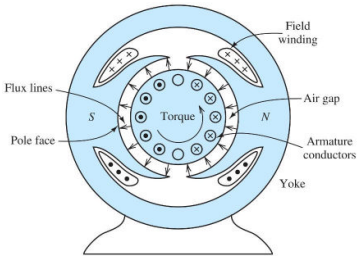
Practical dc motors
We have analyzed a very simplified model.
To develop a useful amount of power, what could we modify?

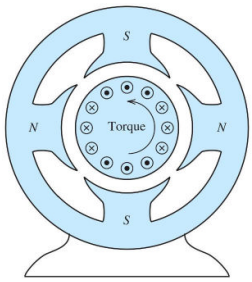
Armature windings
Instead of an armature with one turn of wire, we could use N _____ which increases the flux linkage by N.
The armature is part of the rotating assembly known as the _____.



Magnetic field

Instead of permanent magnet, we could raise the field strength **B** with an electromagnet.
The wires wrapped around a ferromagnetic core are known as _____.
The field windings are stationary and are part of the _____.



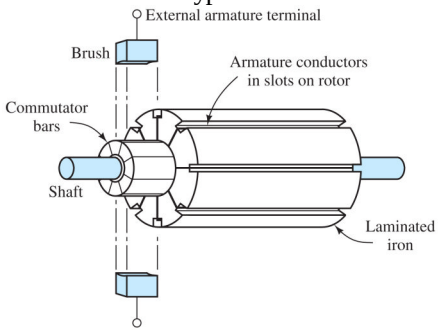


Magnetic poles

Increasing the number of poles will _____ and _____ the output torque.

Commutators

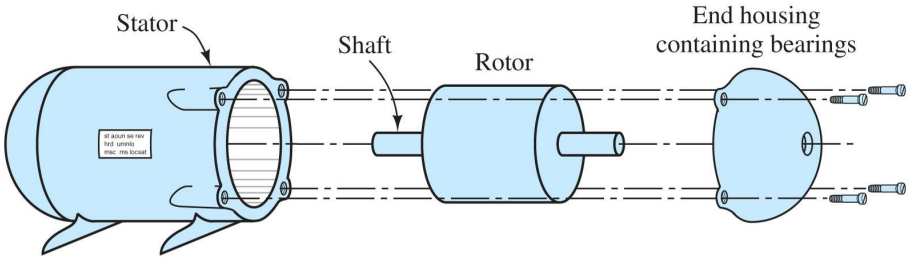
Brushes ride on the commutator bars and wear is a significant disadvantage of dc machines.
Commutators in typical machines contain 20 to 50 segments.



Parts of a DC Motor

The major parts of an electric motor are the _____ and the _____.
In the permanent magnet dc machine

- The rotor which spins contains the _____ windings and commutator bars.
- The stator which is stationary contains the _____ windings and brushes.



Example Problem 1

A permanent magnet DC motor is rated for 25V, 2A and 1300 rpm. If the machine is 90% efficient, find the power loss in R_A, K_v and if T_{Loss} = 0.0334 N·m.

Example Problem 2

A permanent magnet DC motor tested under two conditions: loaded and unloaded. Without a load the speed of the motor ω_m is 160 rad/s and I_A is 1 A. With a load, the speed of the motor ω_m is 148.6 rad/s and I_A is 2 A. Solve for R_A , K_V and T_{loss}.

Example Problem 3

We wish to design a 1/4 hp[1], 28 V DC motor with an efficiency of 96%. What current can we expect to draw? If the machine constant is $K_v = 0.2139$ v·s, determine T_{Load} if we ignore mechanical losses. Calculate rated speed in rpm.