MEEG 311 - Lecture 7
Vibration and Control

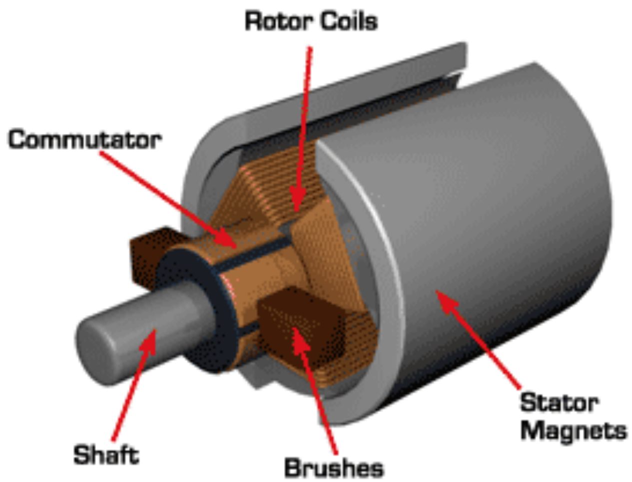
Ioannis Poulakakis

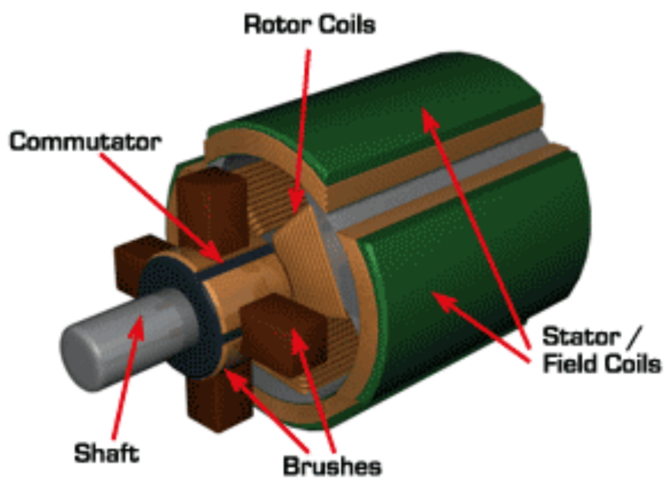
18 September 2018

Goals:

- An overview of the principles of operation of DC motors
- Modeling aspects
  - Field-controlled DC motors
  - Armature-controlled DC motors
- Example: Modeling armature control DC motors
  - State-space-representation

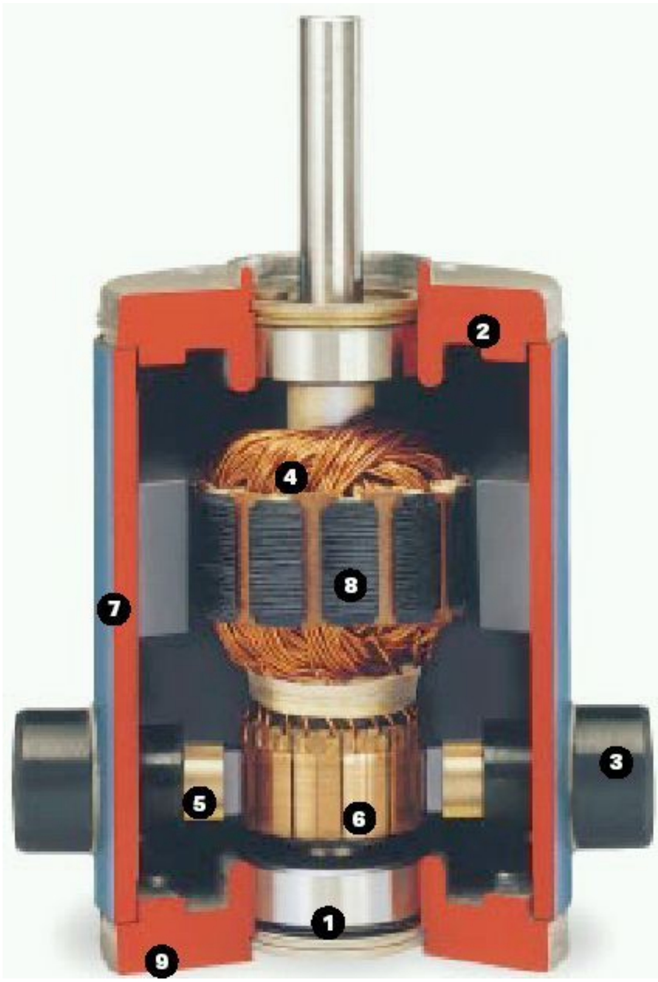
Parts of a Brushed DC motor





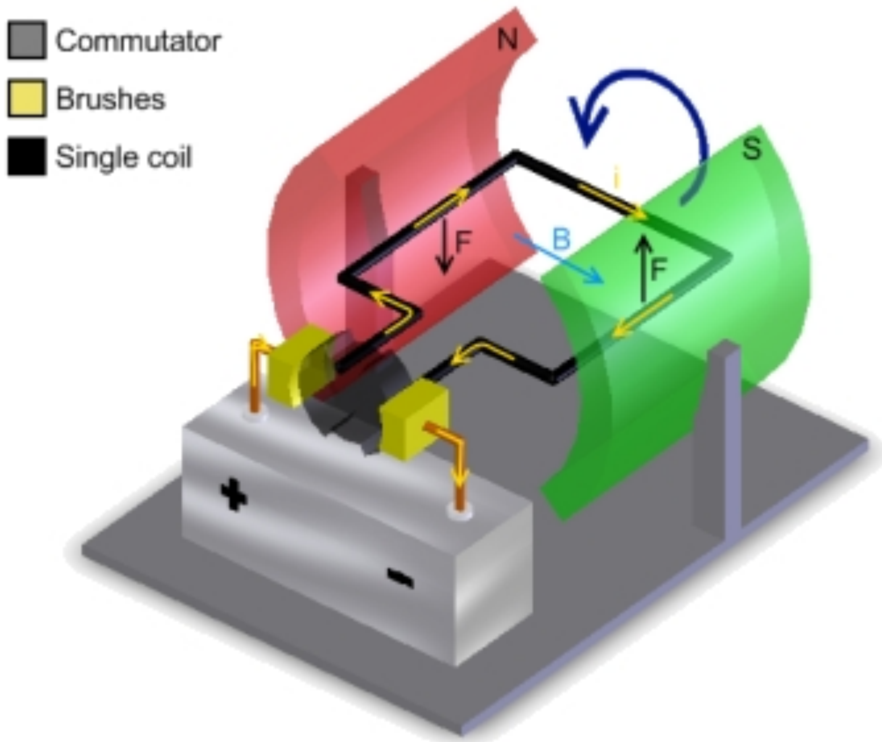
- ***Stator:*** The stationary part. Its purpose is to generate the magnetic ***field*** for the rotor to spin in. Can be a
  - Permanent magnet
  - Electromagnet (field coils): in series, shunt and separately excited motors
- ***Rotor:*** The rotating part. It is composed of coils wrapped around a core
- ***Commutator:*** The termination points of the armature coils. It switches the current flow to the rotor windings depending on the rotor angle
- ***Brushes:*** Two small strips of carbon pressing slightly against the commutator to bring current to the armature.
- Supplied by DC current (although through the commutator the DC is converted to AC for part of the motor)

Parts of a Brushed DC motor



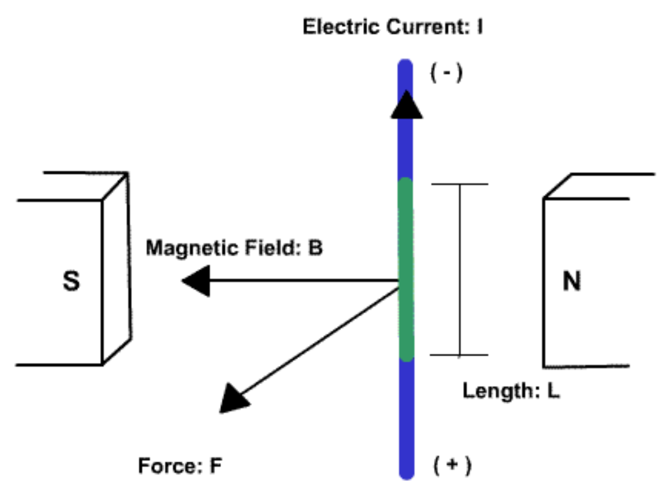
- ***Stator:*** The stationary part. Its purpose is to generate the magnetic ***field*** for the rotor to spin in. Can be a
  - Permanent magnet
  - Electromagnet (field coils): in series, shunt and separately excited motors
- ***Rotor:*** The rotating part. It is composed of coils wrapped around a core
- ***Commutator:*** The termination points of the armature coils. It switches the current flow to the rotor windings depending on the rotor angle
- ***Brushes:*** Two small strips of carbon pressing slightly against the commutator to bring current to the armature.
- Supplied by DC current (although through the commutator the DC is converted to AC for part of the motor)

Principle of Operation

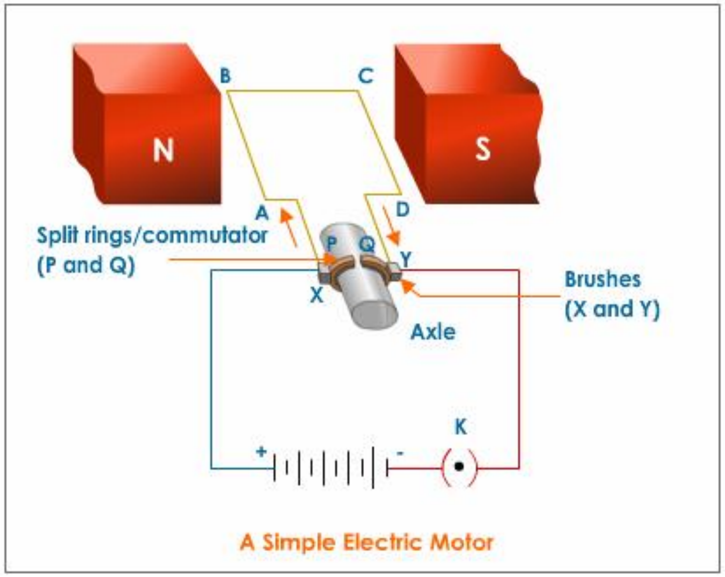


Lorentz Force:

- Any current-carrying conductor placed within an external magnetic field experiences a force known as the Lorentz force
- The force is proportional to the current and to the strength of the magnetic field and is orthogonal to both



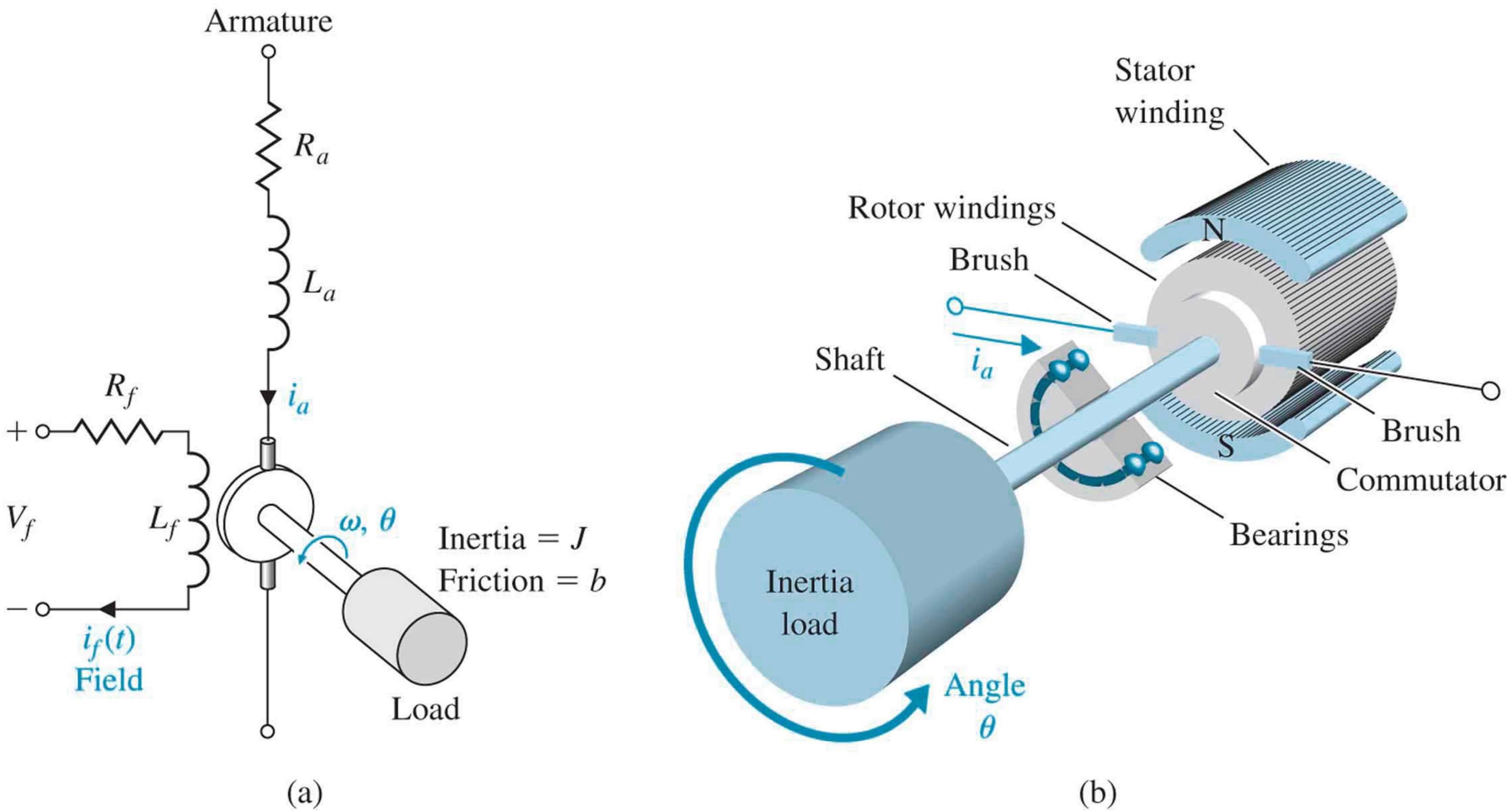
Principle of Operation



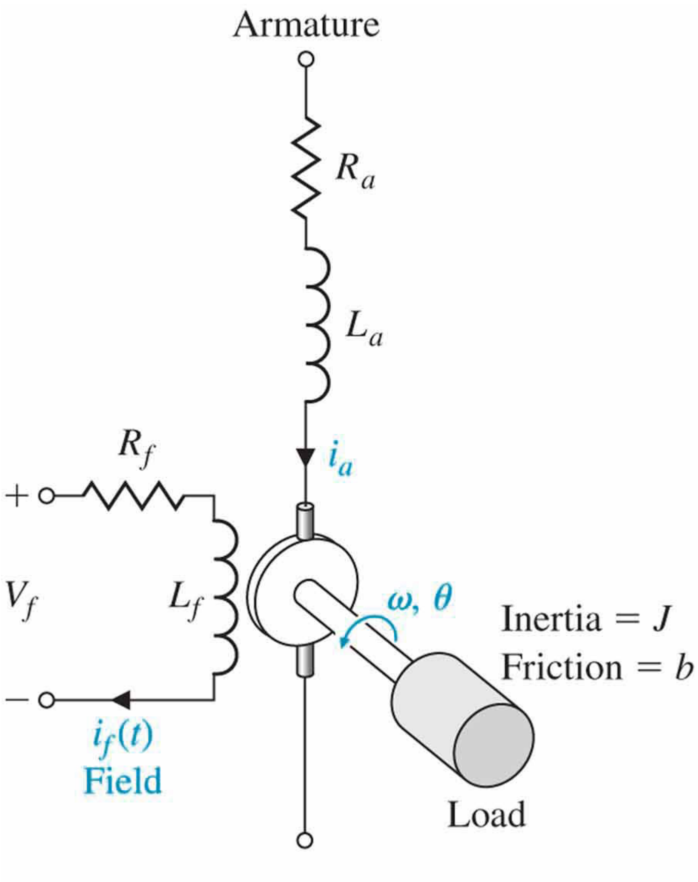
A simple two-pole motor:

- The commutator is where the armature coil terminates; it is moving
- Brushes X and Y do not move;
  - are connected with a DC voltage source
  - are in contact with the commutator
- Brush X is in contact with split ring P and brush Y in contact with Q. The current that flows in the armature causes it to rotate
- In this simple configuration,
  - As it reaches 90 deg (armature coil orthogonal to the magnetic field) the torque is zero. However, the motion continues due to inertia!
  - As it reaches 180 deg X touches Q and Y touches P causing the current in the armature to change direction!

Modeling a DC Motor via a Transfer Function



Modeling a DC Motor via a Transfer Function



(a)

Key formula:

- The air-gap flux is proportional to the current in the field coil

$$\phi(t) = K_f i_f(t)$$

- The torque delivered at the motorshaft is proportional to the air-gap flux and proportional to the armature current

$$T_m(t) = K_1 \phi(t) i_a(t) = K_1 K_f i_f(t) i_a(t)$$

Control cases:

- Field-controlled

$$T_m(t) = K_m i_f(t)$$

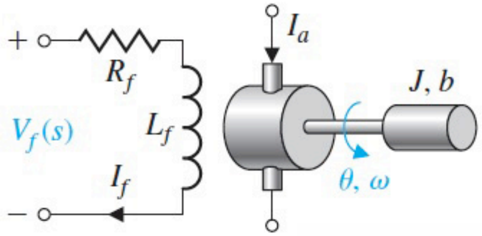
- Armature-controlled

$$T_m(t) = K_m i_a(t)$$

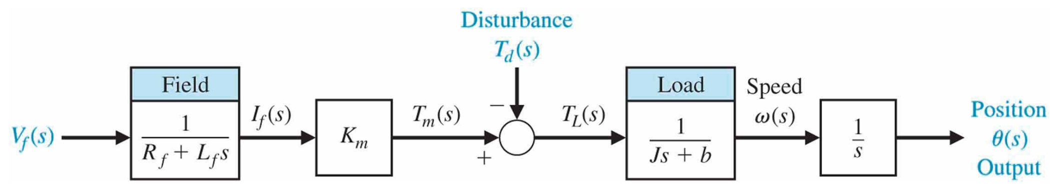
In both cases, torque is **linearly proportional** to the control current!

Modeling a DC Motor via a Transfer Function

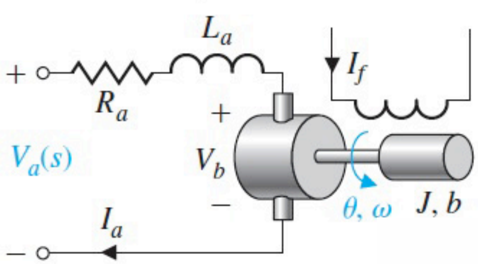
5. DC motor, field-controlled, rotational actuator



$$\frac{\theta(s)}{V_f(s)} = \frac{K_m}{s(Js + b)(L_f s + R_f)}$$



6. DC motor, armature-controlled, rotational actuator



$$\frac{\theta(s)}{V_a(s)} = \frac{K_m}{s[(R_a + L_a s)(Js + b) + K_b K_m]}$$