Lecture 8: Machine fundamentals

Preliminary notes

DC power systems are not very common in the contemporary engineering practice. However, DC motors still have many practical applications, such automobile, aircraft, and portable electronics, in speed control applications…

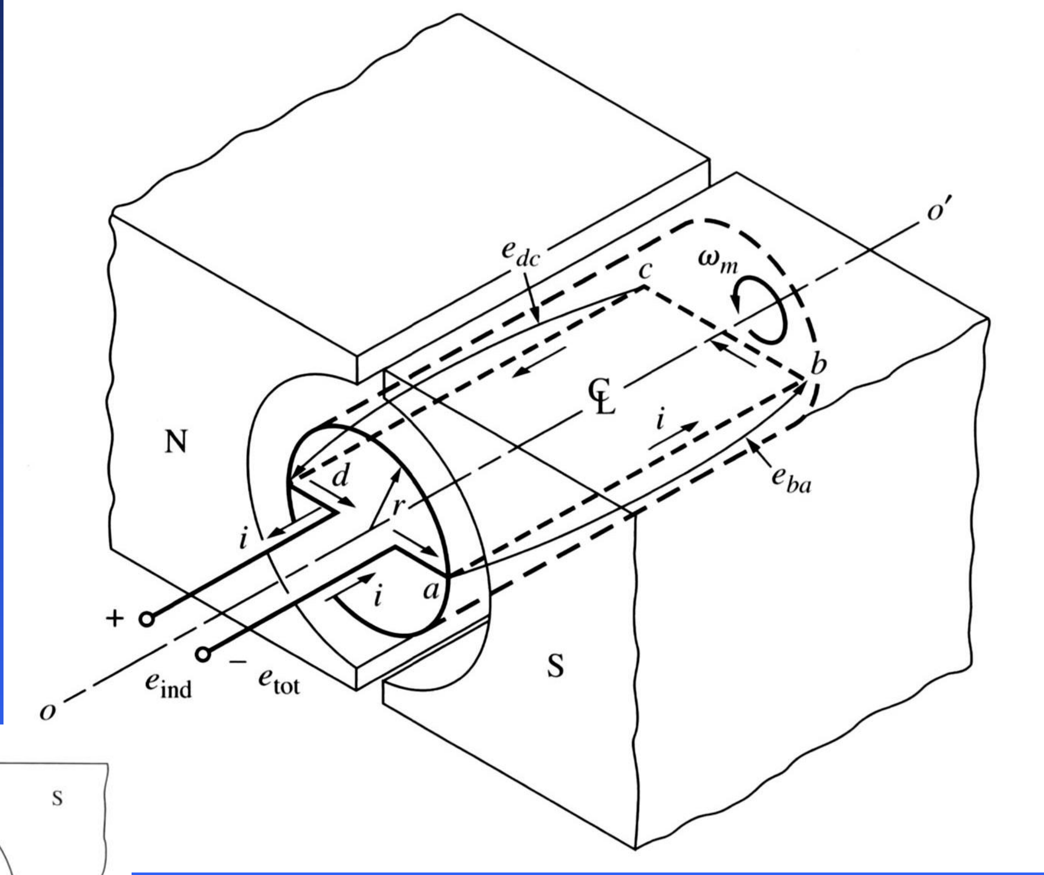
An advantage of DC motors is that it is easy to control their speed in a wide diapason.

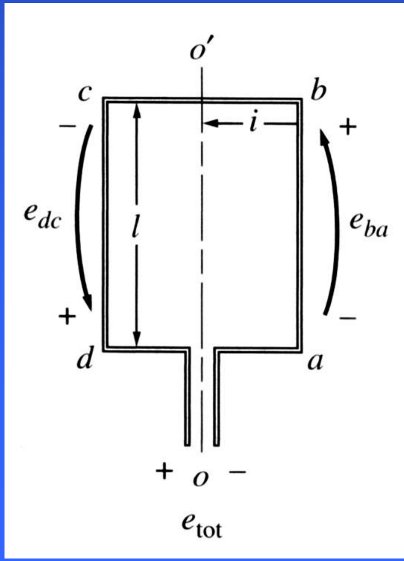
DC generators are quite rare.

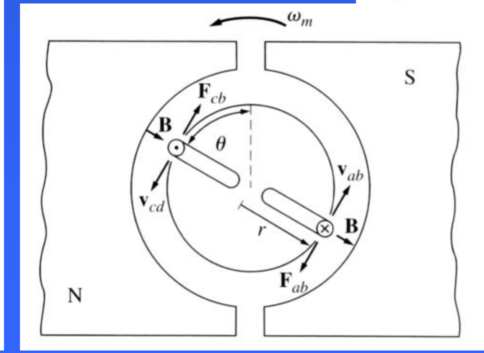
Most DC machines are similar to AC machines: i.e. they have AC voltages and current within them. DC machines have DC outputs just because they have a mechanism converting AC voltages to DC voltages at their terminals. This mechanism is called a commutator; therefore, DC machines are also called commutating machines.

The simplest DC machine

The simplest DC rotating machine consists of a single loop of wire rotating about a fixed axis. The magnetic field is supplied by the North and South poles of the magnet.
Rotor is the rotating part;
Stator is the stationary part.



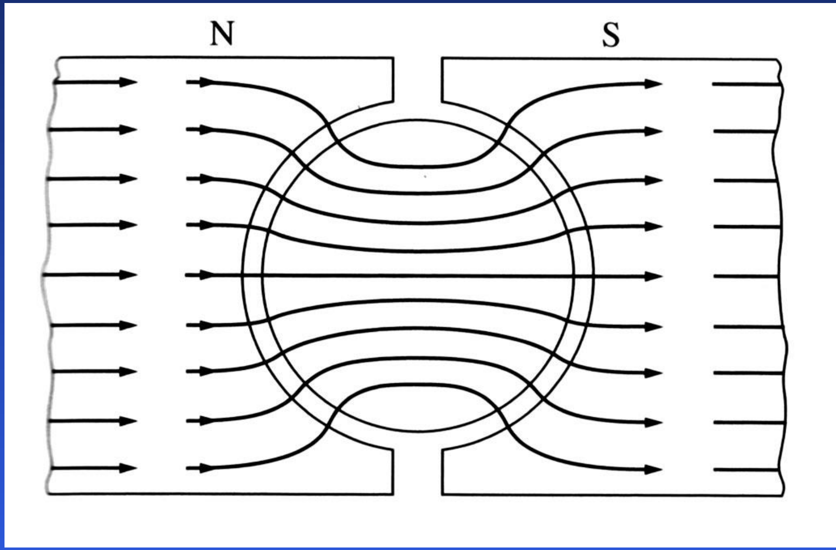




The simplest DC machine

We notice that the rotor lies in a slot curved in a ferromagnetic stator core, which, together with the rotor core, provides a constant-width air gap between the rotor and stator.

The reluctance of air is much larger than the reluctance of core. Therefore, the magnetic flux must take the shortest path through the air gap.



As a consequence, the magnetic flux is perpendicular to the rotor surface everywhere under the pole faces.

Since the air gap is uniform, the reluctance is constant everywhere under the pole faces. Therefore, magnetic flux density is also constant everywhere under the pole faces.

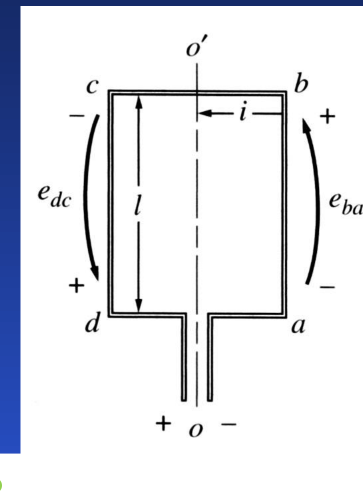
The simplest DC machine

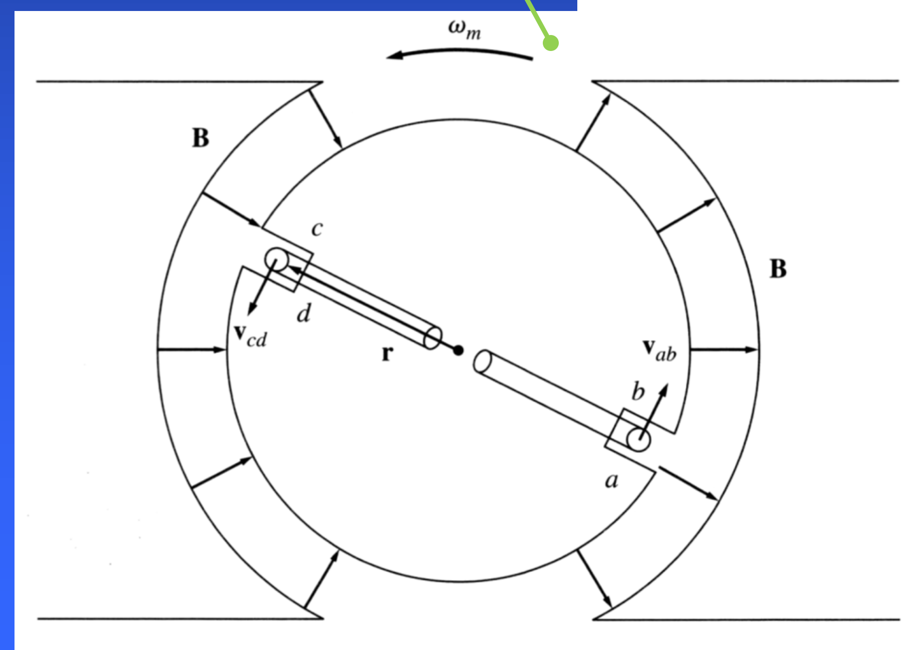
1. Voltage induced in a rotating loop

If a rotor of a DC machine is rotated, a voltage will be induced…

The loop shown has sides *ab* and *cd* perpendicular to the figure plane, *bc* and *da* are parallel to it.

The total voltage will be a sum of voltages induced on each segment of the loop.





Voltage on each segment is:

$$e_{ind} = (\mathbf{v} \times \mathbf{B}) \cdot \mathbf{l} \qquad (5.5.1)$$

The simplest DC machine

1) *ab*: In this segment, the velocity of the wire is tangential to the path of rotation. Under the pole face, velocity *v* is perpendicular to the magnetic field *B*, and the vector product *v* x *B* points into the page. Therefore, the voltage is

$$e_{ba} = (\mathbf{v} \times \mathbf{B}) \cdot \mathbf{l} = \begin{cases} vBl & \text{– into page – under the pole face} \\ 0 & \text{– beyond the pole edges} \end{cases} \quad (5.6.1)$$

2) *bc*: In this segment, vector product *v* x *B* is perpendicular to *l*. Therefore, the voltage is zero.

3) *cd*: In this segment, the velocity of the wire is tangential to the path of rotation. Under the pole face, velocity *v* is perpendicular to the magnetic flux density *B*, and the vector product *v* x *B* points out of the page. Therefore, the voltage is

$$e_{dc} = (\mathbf{v} \times \mathbf{B}) \cdot \mathbf{l} = \begin{cases} vBl & \text{– out of page – under the pole face} \\ 0 & \text{– beyond the pole edges} \end{cases} \quad (5.6.2)$$

4) *da*: In this segment, vector product *v* x *B* is perpendicular to *l*. Therefore, the voltage is zero.

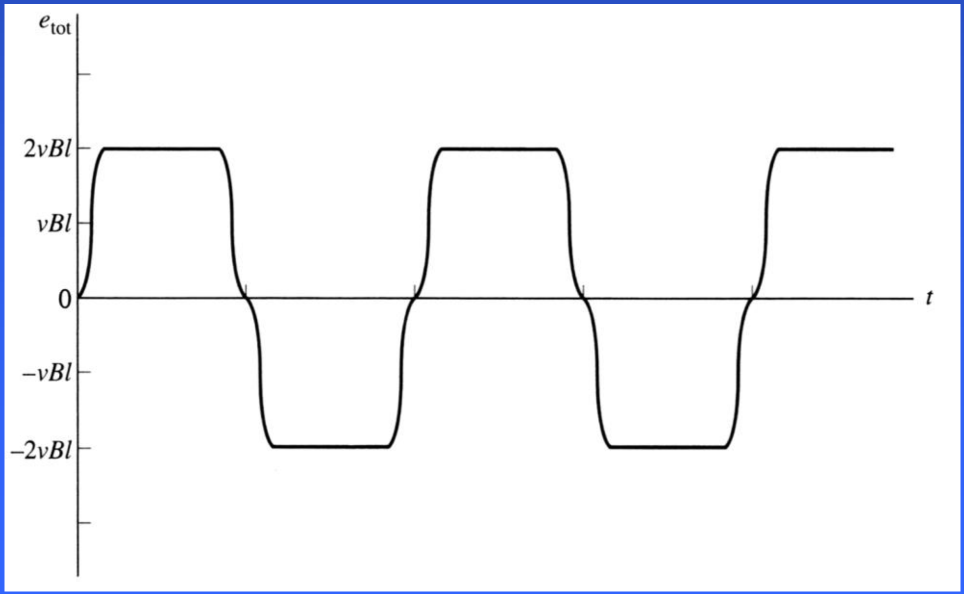
The simplest DC machine

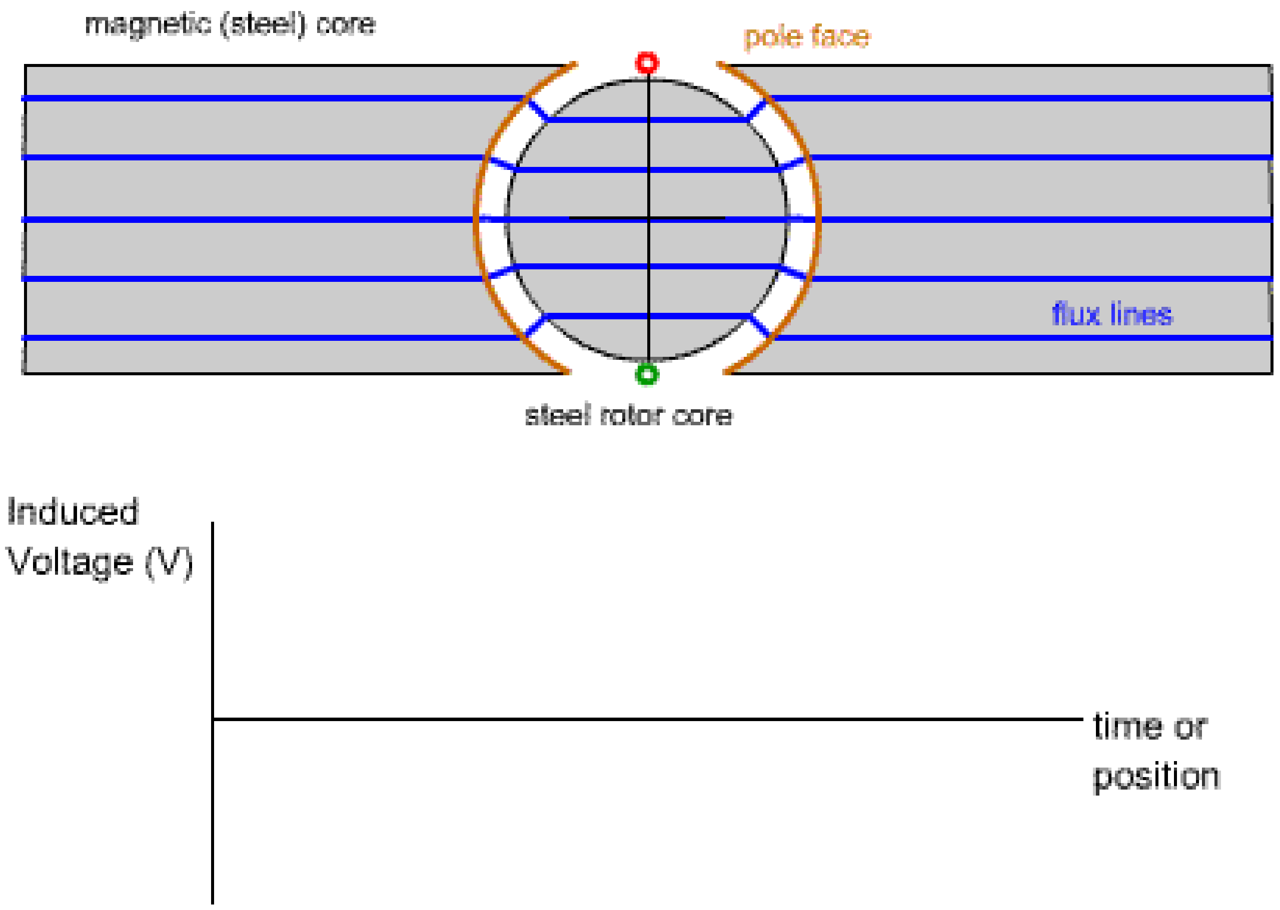
The total induced voltage on the loop is:

$$e_{tot} = e_{ba} + e_{cb} + e_{dc} + e_{ad} \quad (5.7.1)$$

$$\boxed{e_{tot} = \begin{cases} 2vBl & \text{under the pole faces} \\ 0 & \text{beyond the pole edges} \end{cases}} \quad (5.7.2)$$

When the loop rotates through 180^0, segment *ab* is under the north pole face instead of the south pole face. Therefore, the direction of the voltage on the segment reverses but its magnitude reminds constant, leading to the total induced voltage to be




magnetic (steel) core
pole face
flux lines
steel rotor core
Induced
Voltage (V)
time or
position