Inductance

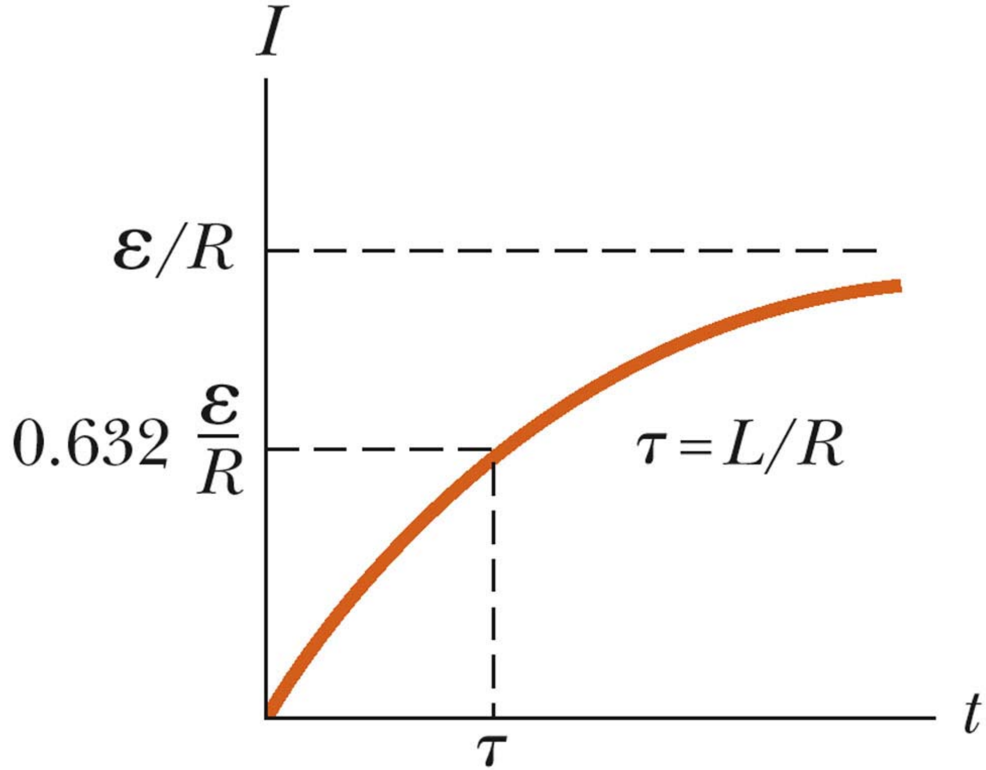
Motors

Generators

Self-inductance

***Self-inductance* occurs when the changing flux through a circuit arises from the circuit itself.**

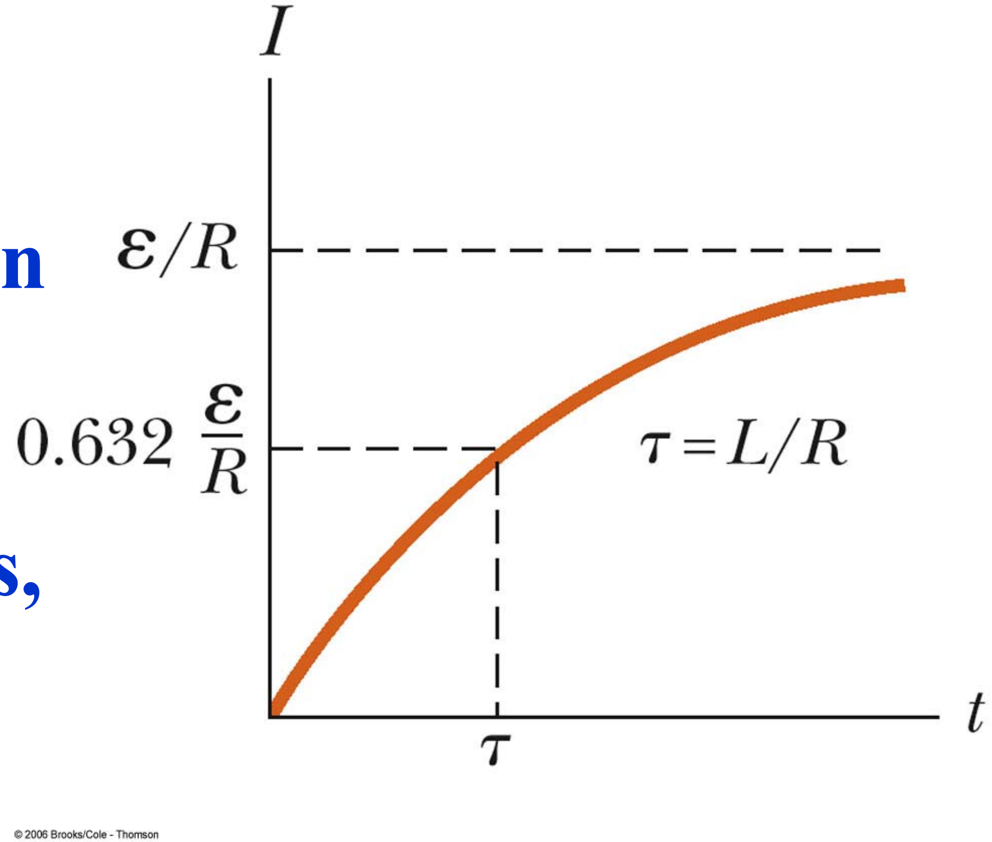
As the current increases, the magnetic flux through a loop due to this current also increases.



<u>Example</u>: a solenoid in series with a battery and resistance.

Self-inductance

The increasing flux induces an emf that opposes the change in magnetic flux.
As the magnitude of the current increases, the rate of increase lessens and the induced emf decreases.



This opposing emf results in a gradual increase of the current to its “steady state” value.

Self-inductance

The self-induced emf is proportional to the time rate of change of the current:

$$\mathcal{E} = -L\frac{\Delta I}{\Delta t}$$

L **is a proportionality constant called the** **inductance** **of the device.**
The negative sign indicates that a changing current induces an emf in opposition to that change.

Self-inductance

Inductance depends on the physical properties and dimensions of the circuit element.

For a solenoid of *N* turns, cross-sectional area *A* and length *ℓ*, the inductance is

$$L = \frac{\mu_o N^2 A}{\ell}$$

The SI unit of self-inductance is the *Henry*.

1 H = 1 (V · s) / A

Generators

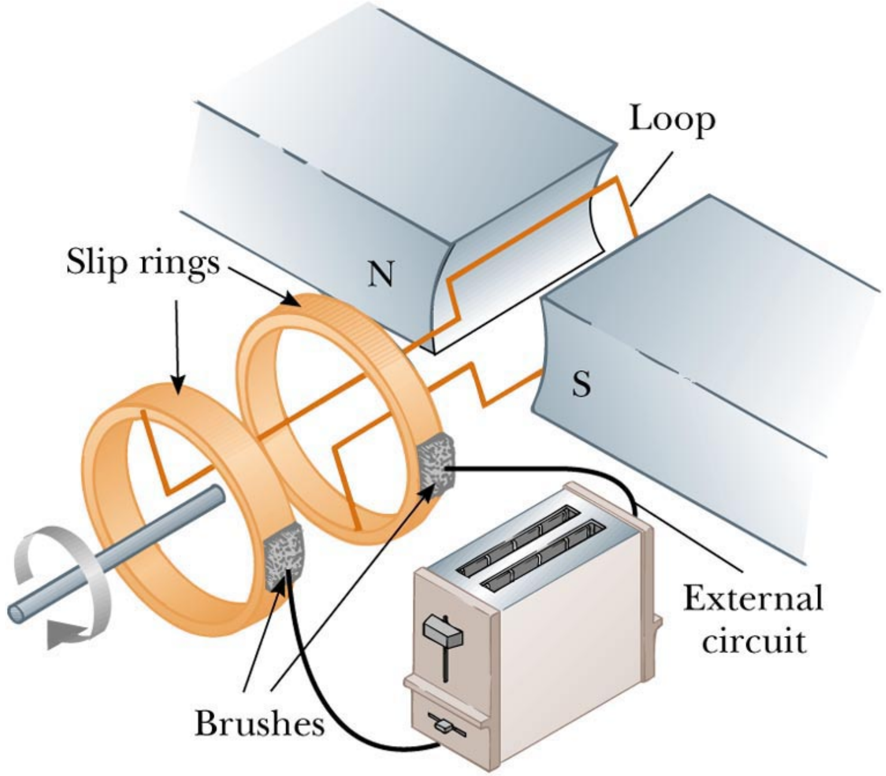
A generator converts mechanical energy to electrical energy.
The basic generator consists of a wire loop rotated by some external means.

A variety of sources can supply the energy to rotate the loop (e.g., falling water, steam turbine).

AC Generator

Basic operation of the generator

As the loop rotates, the magnetic flux through it changes with time
This induces an emf and a current in the external circuit.

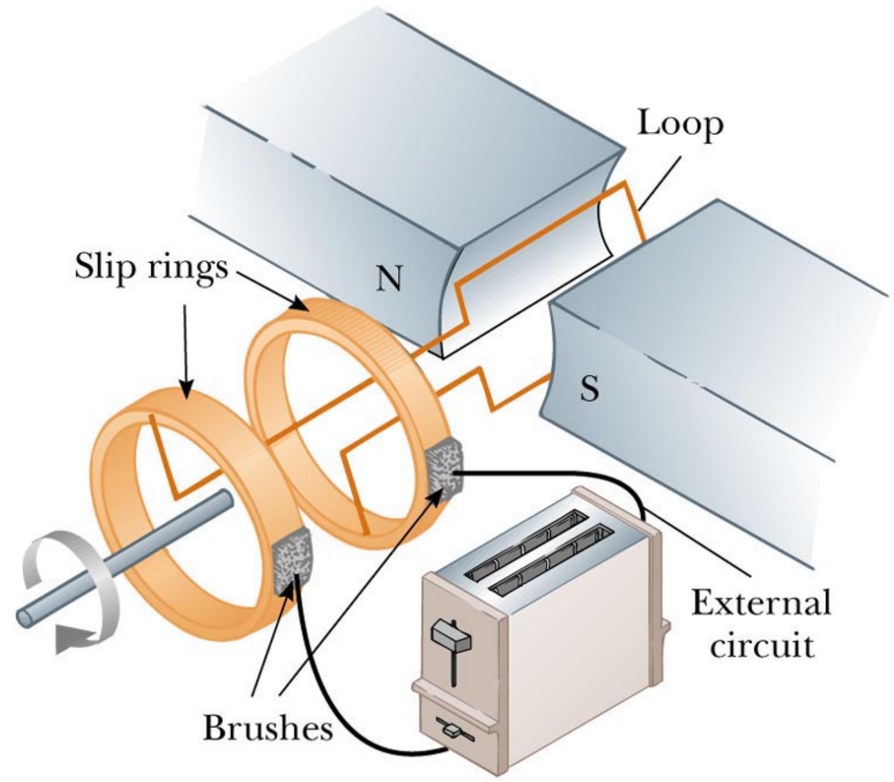


(a)

AC Generator

Basic operation of the generator

The ends of the loop are connected to *slip rings* that rotate with the loop. Connections to the external circuit are made by stationary *brushes* in contact with the slip rings.

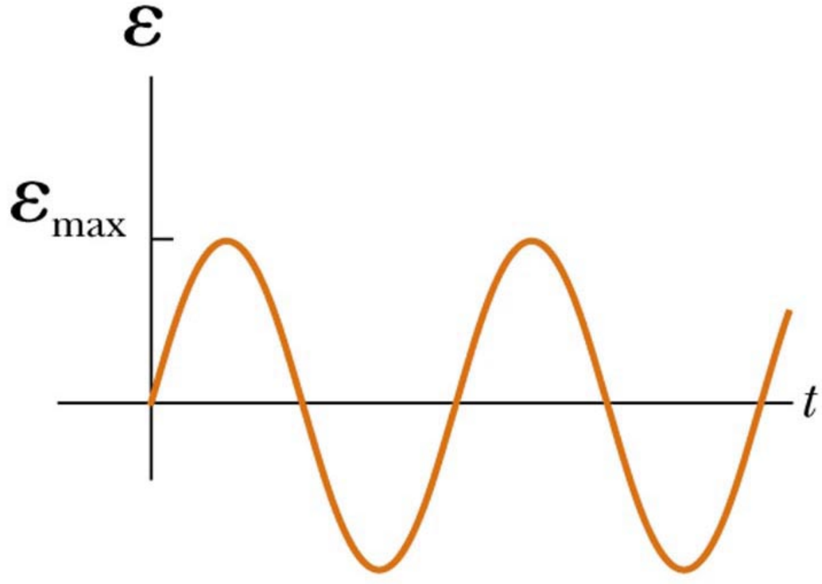


(a)

AC Generator

The emf generated by the rotating loop is

$$\mathcal{E} = B\ell v \sin\theta$$



(b)

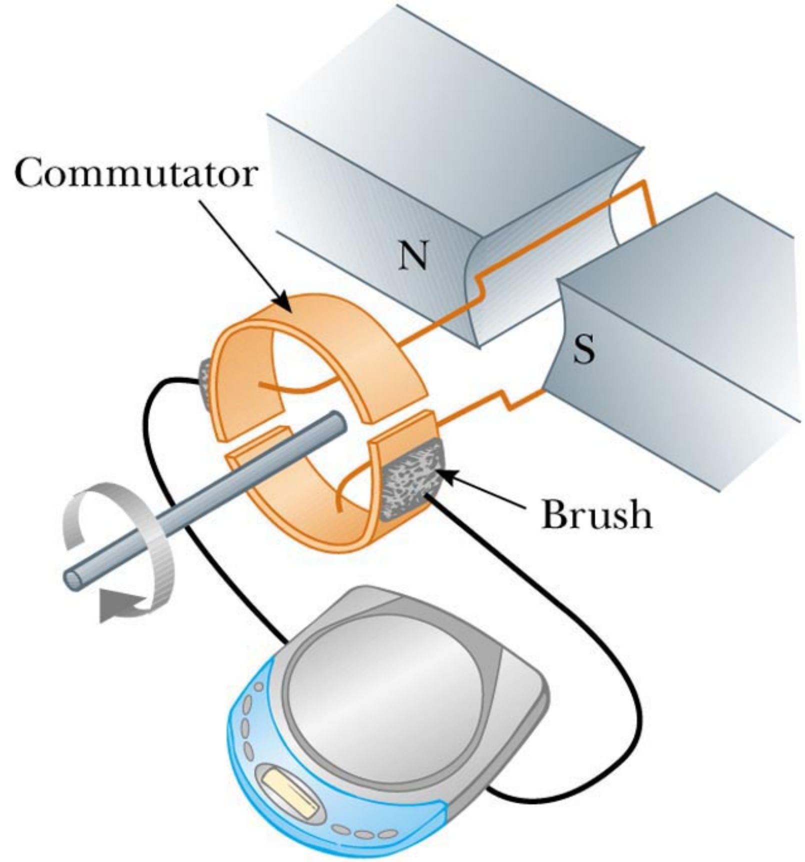
If the loop rotates with a constant angular speed, ω, and has N turns

$$\mathcal{E} = NBA\omega \sin \omega t$$

Applet → http://micro.magnet.fsu.edu/electromag/java/generator/ac.html

DC Generator

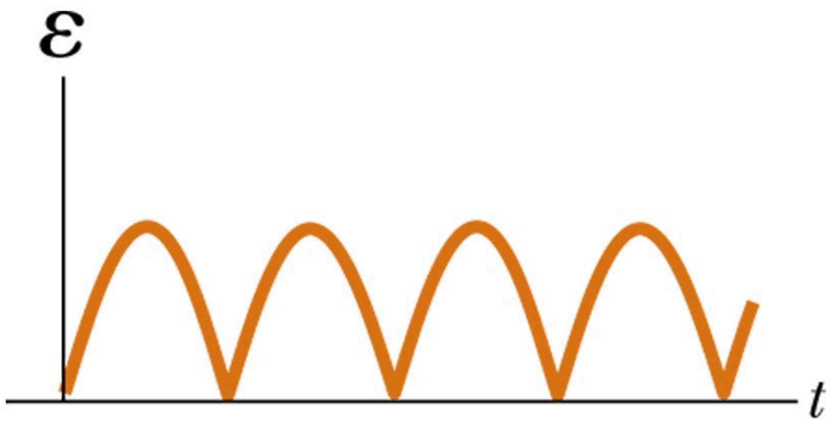
Components are essentially the same as that of an *ac* generator. The major difference is the contacts to the rotating loop are made by a split ring, or commutator.



(a)

DC Generator

The output voltage always has the same polarity.
The current is a pulsing current.



(b)

To produce a steady current, many loops and commutators around the axis of rotation are used.
The multiple outputs are superimposed and the output is almost free of fluctuations.

Motors

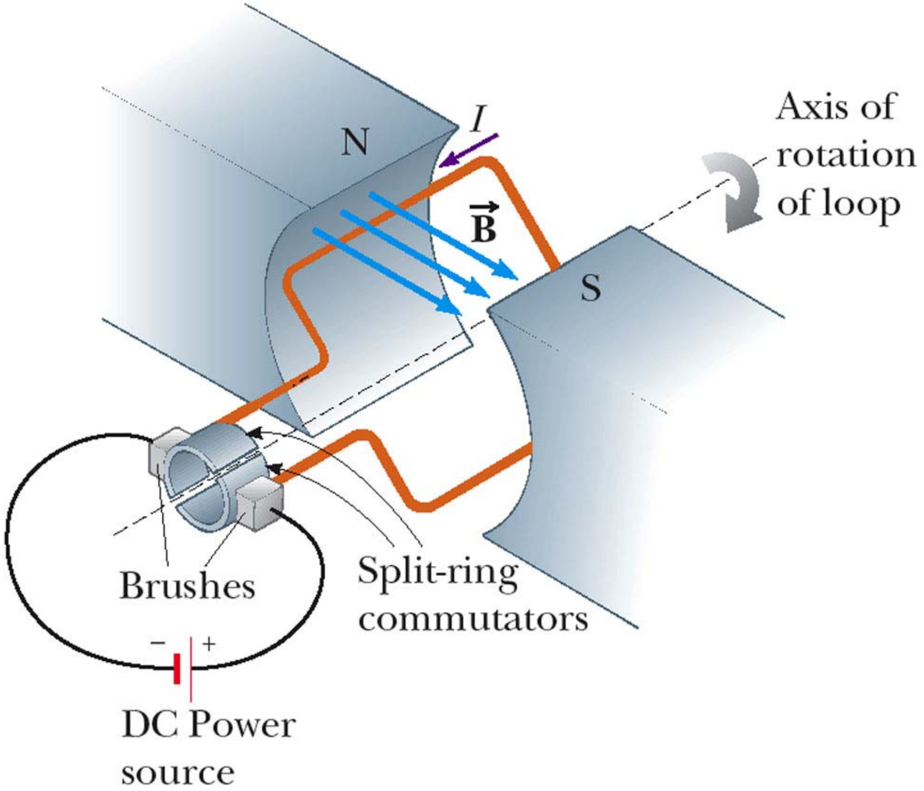
Motors are devices that convert electrical energy into mechanical energy.

A motor is a generator run in reverse.

A motor can perform useful mechanical work when a shaft connected to its rotating coil is attached to some external device.

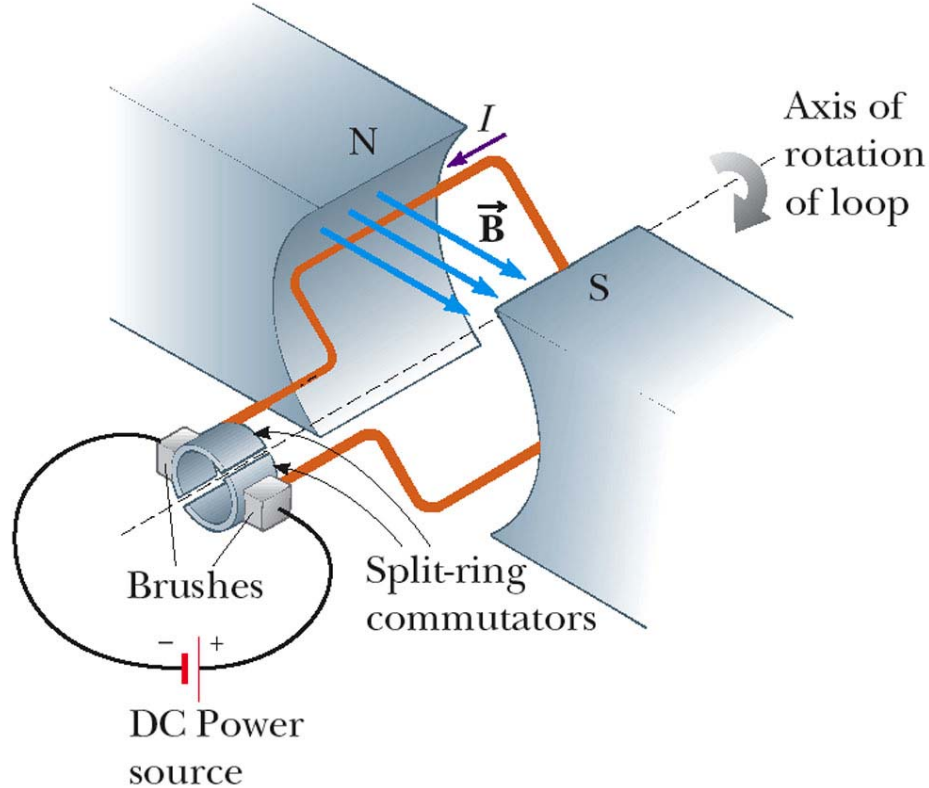
An electric motor converts electrical energy to mechanical energy.

The mechanical energy is in the form of rotational kinetic energy.



An electric motor consists of a rigid current-carrying loop that rotates when placed in a magnetic field.

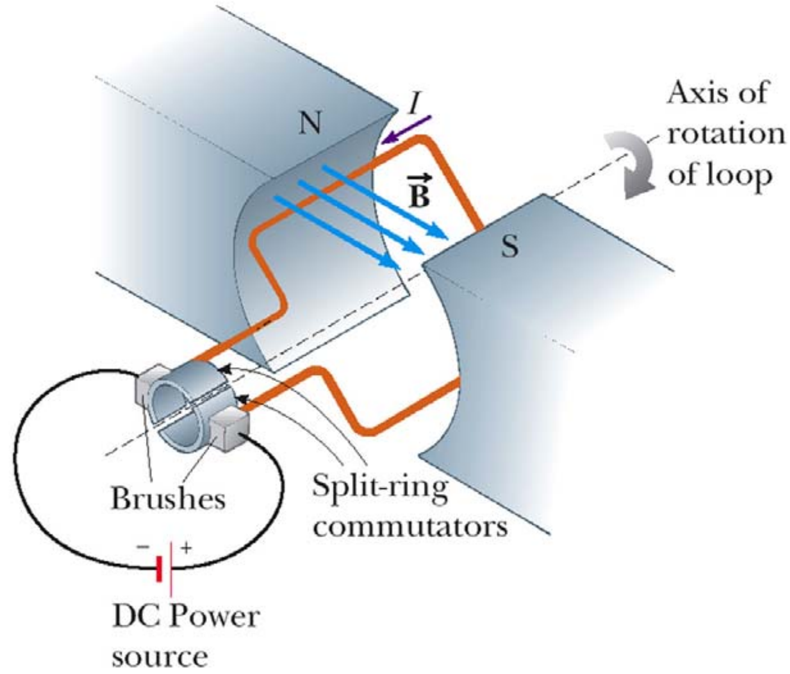
The torque acting on the loop will tend to rotate the loop to smaller values of θ until the torque becomes 0 at $\theta = 0°$.



If the loop turns past this point and the current remains in the same direction, the torque reverses and turns the loop in the opposite direction.

To provide continuous rotation in one direction, the current in the loop must periodically reverse.

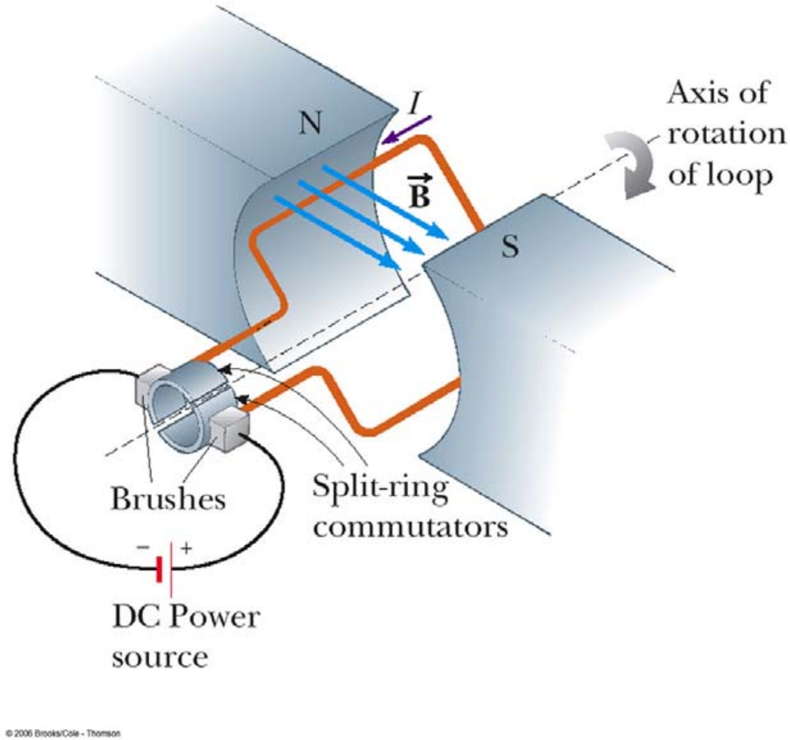
In *ac* motors, this reversal naturally occurs.



In *dc* motors, a *split-ring commutator* and brushes are used.

Actual motors would contain many current loops and commutators.

Just as the loop becomes perpendicular to the magnetic field and the torque becomes 0, inertia carries the loop forward and the brushes cross the gaps in the ring, causing the current loop to reverse its direction.



This provides more torque to continue the rotation. The process repeats itself.

More motor and generator applets

http://micro.magnet.fsu.edu/electromag/java/generator/dc.html

http://www.walter-fendt.de/ph11e/generator_e.htm

http://www.walter-fendt.de/ph14e/electricmotor.htm