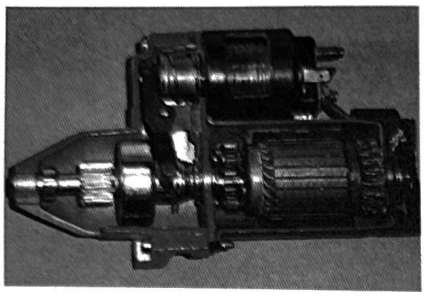
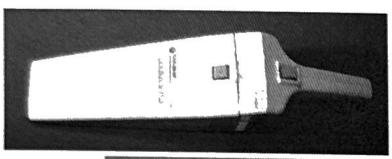
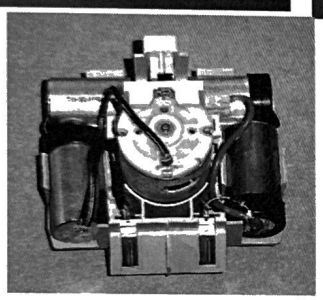
One "plant" we'll work with: The DC motor.

DC Motors show up in lots of important commercial and industrial systems. Some examples:

Starter motor in your car: (cut to reveal internals)



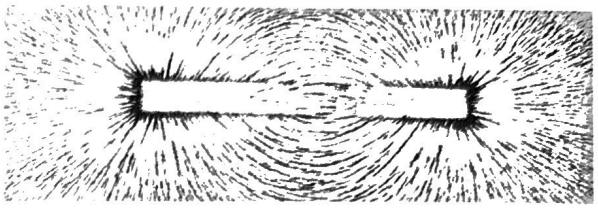




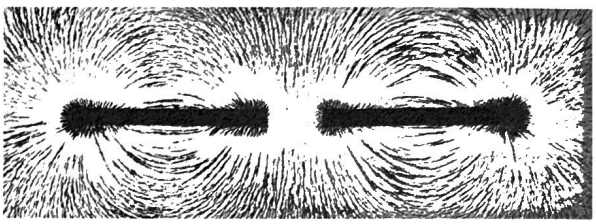
Dustbuster vacuum cleaner

Magnetic fields exposed by iron-filings around bar magnets:

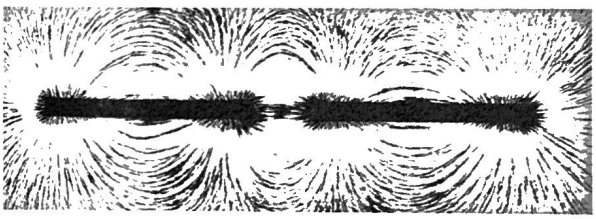
A single bar magnet:



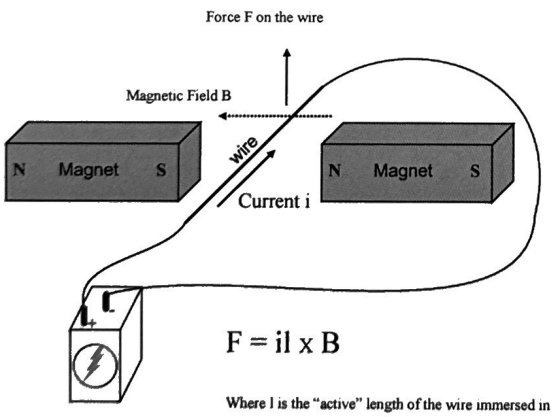
Identical poles facing:



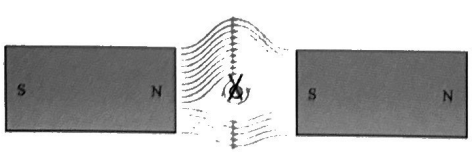
Opposite poles facing:



Force on a current-carrying wire immersed in a magnetic field:
(Lorentz Force)

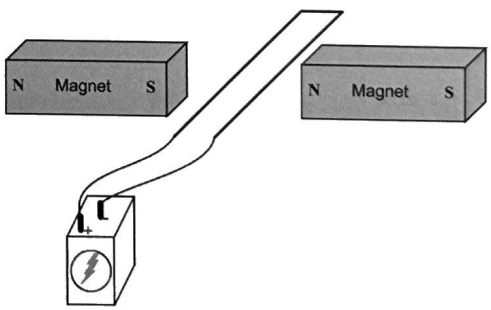


What is the direction of the force acting on this wire, which is carrying current "into" the page (indicated by the X on the wire)?



In the experiment shown below, which way will the wire rotate?

Assuming the battery never runs out, will the coil rotate forever?



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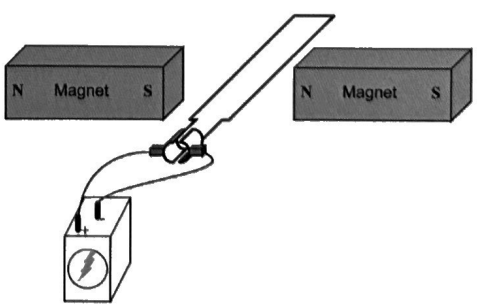
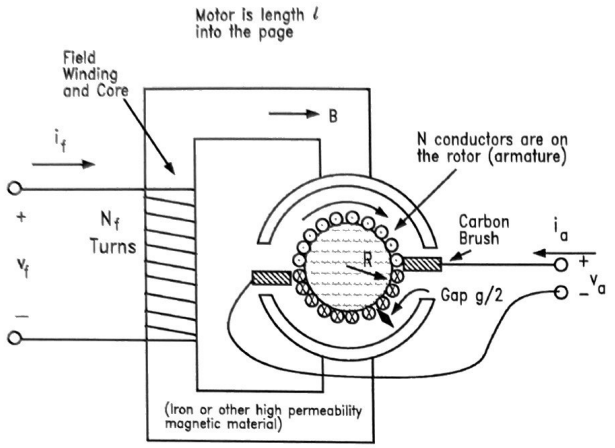


Cartoon of a real DC motor with a "wound" field winding. The field winding could also be replaced with permanent magnets.



If the electromagnetic produces a constant magnetic field B, or if we are using permanent magnets, it's convenient to define a "motor constant" K:

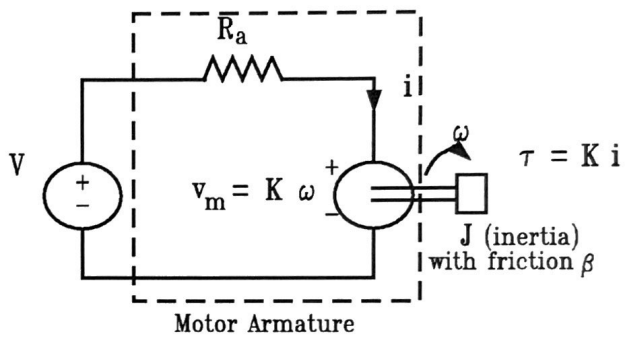
$$K = RNLB$$

Torque produced by the motor is equal to K times the armature current.

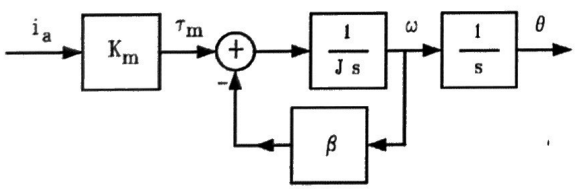
Lenz's Law: Moving a wire in a magnetic field induces a voltage across a wire.

This means that a DC motor can be used as a generator if we manually turn the shaft!

A circuit model for the DC motor driven by a voltage source:



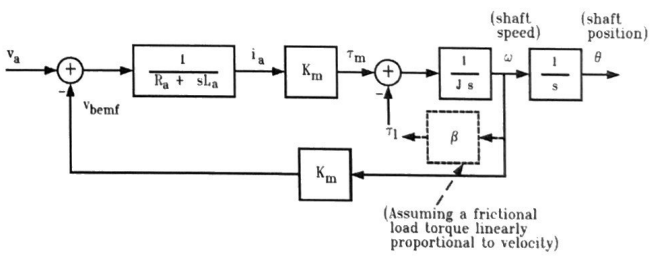
Let's practice making and manipulating block diagrams while we learn how the DC motor works: Start by examining a current source electrical drive (in these block diagrams, $K_m = K$):



Remember that "friction" is represented by β. If we drive this system with constant current, how well will it maintain a constant **speed** in the face of disturbance, e.g., a sudden change in the friction?

This drive has no ability to reject disturbances or changes in the "plant" (motor), e.g., a change in friction!

What happens if we try driving the motor with a voltage source instead?



Now, if we drive with a constant input voltage V_a, and we have small armature resistance R_a, then, in steady state, the motor speed is relatively insensitive to changes in friction!

Current injected into the DC motor controls shaft TORQUE.

Voltage applied to the DC motor roughly controls shaft SPEED.