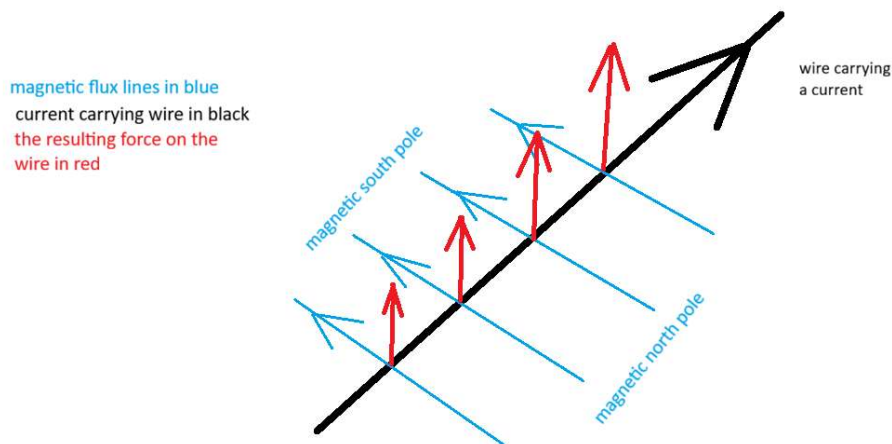


An electric motor.

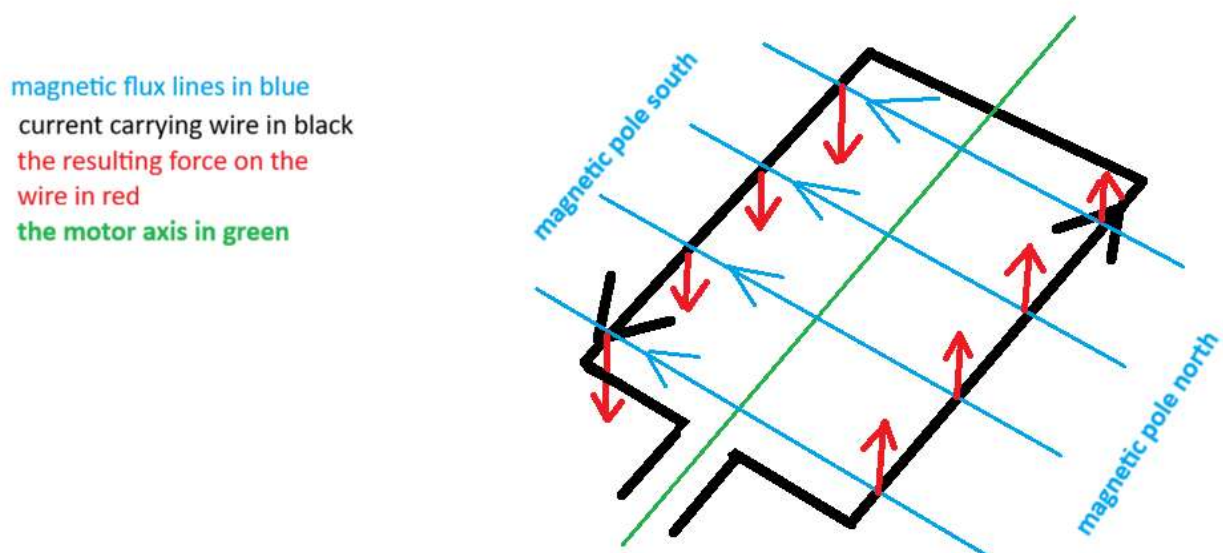
There are a couple of simple ideas you have to grasp to understand an electric motor. I will start off with a DC motor because its simpler to understand.

Firstly consider a wire carrying a current, in a magnetic field, the interaction of the current and the magnetic field creates a force or movement on the wire.



Now shape the wire into a rectangle, the sides are perpendicular to the magnetic field and hence create force, the ends are parallel to the magnetic field and do not interact with it.

As the current is in the opposite direction on the opposite sides of the rectangle the force is up on one side of the rectangle and down on the other side, hence this creates a rotating motion.

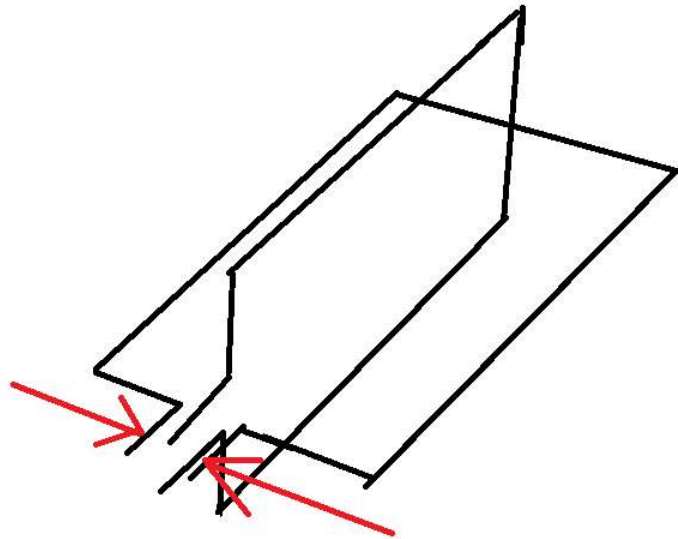


However this rotating motion comes to a stop after the rectangle has rotated by 90 degrees, there is still force on the wires forming the sides of the rectangle but its in the wrong direction to create rotation.

What we need is an extra rectangle and a means of switching these rectangles on and off, and also a means of switching them in the opposite direction, we call this switch a commutator, traditionally this switch is on the shaft of the motor and is switched by the rotation of the shaft. Today its also possible to do the commutation using sensors and transistors.

the motor windings in black
rotate with the motor

the electrical contacts in red
are stationary and make
contact with the motor
windings as they pass by.



Congratulations you now understand the simple principles behind an electric motor.

A motor versus a generator

the above description considered a current carrying wire in an electric field creating force or movement.

Conversley consider a moving wire in a magnetic field creating a current in the wire.

In terms of the physical principles, there is no difference between an electric motor and a generator.

In the case of a motor you put power in as electricity and get power out as a rotating shaft.

In the case of a generator you put power in by rotating the shaft and get power out as electricity.

It is often possible to use a particular electric machine as either a motor or a generator.

A practical electric motor,

A practical electric motor will have more turns than the simple pictures above, a lot more magnetic iron than fresh air, possibly a fan attached to the shaft to cool it, ...

.....however others have written on this level of practical construction detail and I am not going to go into it here.

A simple simulation model for an electric motor.

To start with for the sake of simplicity I assume that the magnetic field is provided by permanent magnets, and all other losses such as resistive losses in the windings and torque losses in motor bearings are set to zero. I will put these losses in later.

There are two constants that we need for the simplest simulation model

K_t is the torque constant,

K_v is the back emf constant.

these two constants are defined by the following equations.

Torque out = $K_t \times$ current input.

Voltage input = back EMF = $K_v \times$ angular velocity or speed of the motor.

If we ignore losses then the two constants K_t and K_v will be identical.

This has to be so becauseif we ignore losses then power in= power out.

so $V \times I =$ angular velocity(speed) $\times$ torque.

considering the individual terms on the left hand side of this equation that is V and I or $(V \times I)$

we multiply by $(1/K_v) \times K_t$ or K_t / K_v to get the right hand side of the equation.

as we have just shown the left and right of the equation are equal so $(K_t / K_v) = 1$

so $K_t = K_v$.

so K_t must equal K_v as if they are not equal then power has magically appeared or disappeared.

and this is not possible, the power or energy has to come from somewhere and go somewhere, it can transfer between mechanical, electrical, or thermal forms, but it cannot just appear or disappear.

As this simulation model does not account for electric or mechanical losses these will be allowed for separately in the simulation circuit.

See the attached LTspice circuit for the implementation of this simulation model.