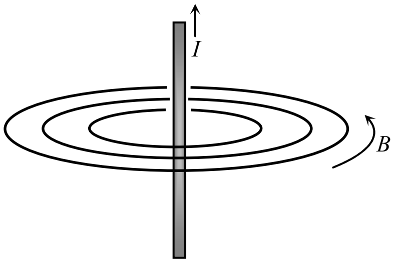
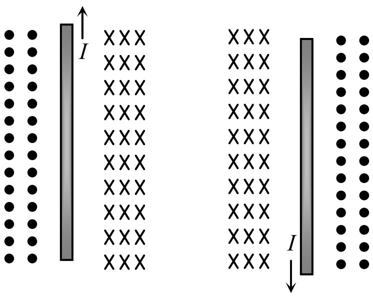
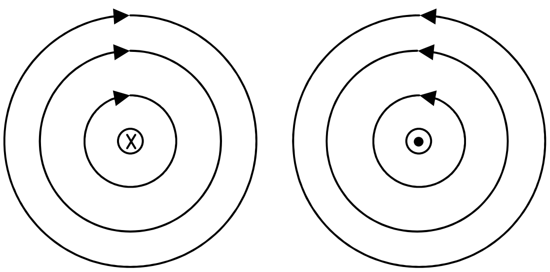


As mentioned earlier, a conductor carrying electrical current will induce a magnetic field such that if you were to grab the conductor with your right hand, and your thumb pointed in the direction of the current flow, your fingers would point in the direction of the generated magnetic field.



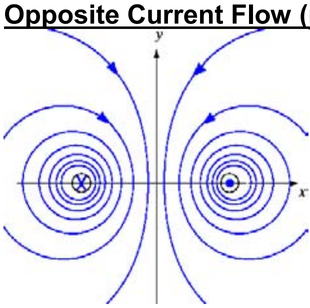
A simplified diagram for the above situation uses X to represent the magnetic field entering the page and • for magnetic fields coming out of the page.



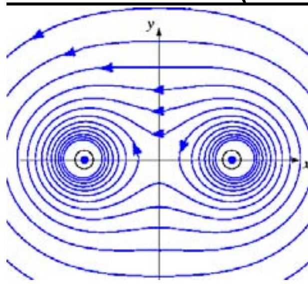
From the perspective of looking into the conductor, X represents current moving into the page and • represent going out of the page. The magnetic field lines would be generated as demonstrated.

Field lines and Force: When two conductors are in close proximity, the field lines generated depends on the direction of current. If the **current** in the conductors are traveling in **opposite directions**, the field lines between the conductors are moving in the same direction and behave like **two like poles**. Therefore, the two conductors **repel** each other. If the **current** in each conductor are moving in the **same direction**, the field lines between the conductors are moving in the **opposite** direction and behave like **two unlike poles**. Therefore, the two conductors **attract each other**.

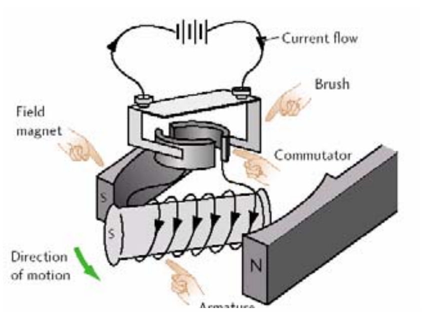
Opposite Current Flow (repulsive)



Like Current Flow (attractive)

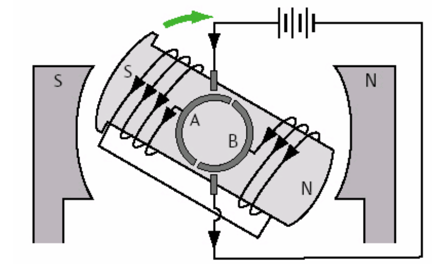


The Electric Motor:

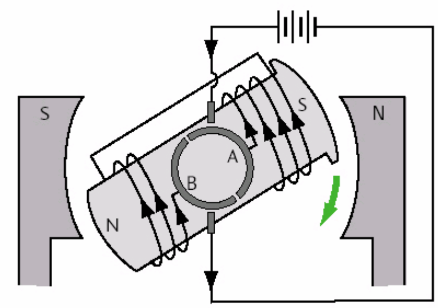


As discussed earlier, electricity through a conductor or a coil will induce a magnetic field. This phenomenon is exploited in the electric motor. Observe the diagrams of the basic motor design below.

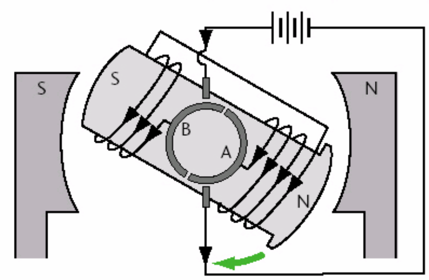
The motor consists of some basic components
1. The brushes
2. The commutator
3. The armature
4. The external magnetic field.



The brushes are the link between the power supply and the coil below. Here is how the motor works. The current follows from the power supply to the brushes. The brushes are connected to the commutator by pressure contact, with just enough pressure to make consistent contact, but still allow the armature-commutator assembly to rotate freely. The commutator is made up of 2 semi-circular halves. The commutator is designed to switch the direction of the current in the armature once the poles of the armature reach the poles of the external magnetic field.

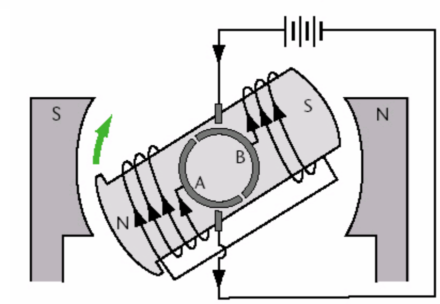


In the second diagram, the current is flowing from A to B through the armature. Using the RHR (Right Hand Rule), a south pole is generated at the end of the coil closest to point A. The force of magnetic repulsion causes the armature to rotate counter clockwise.



In the third diagram, the south pole of the armature is almost completely in line with the pole of the external magnetic field. As soon as the armature aligns horizontal, the polarity of the armature switches (i.e. the current will switches direction, the current now flows from B to A) and the south pole of the armature turns into a north pole, as illustrated in diagram 4. The momentum of the armature keeps it spinning clockwise, past the north pole of the external magnetic field. At this point the force of repulsion continues to keep the armature turning counter clockwise. (see diagram 4).

As the armature continues to rotate, the force of attraction between the north pole of the armature is attracted to the south pole of the external magnetic field and the entire cycle starts over again (see diagram 5).



The rotational speed depends on the amount of current flowing through the armature - the stronger the current, the greater the magnetic field strength, the greater the force, the greater the rotational speed.

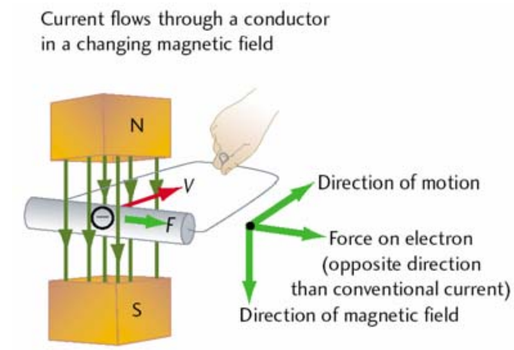
Faraday’s Concept of Induction and Lenz’s Law:

Faraday’s law of induction states that: “A magnetic field moving or changing intensity in the vicinity of a conduction will cause or induce electrons to move.”

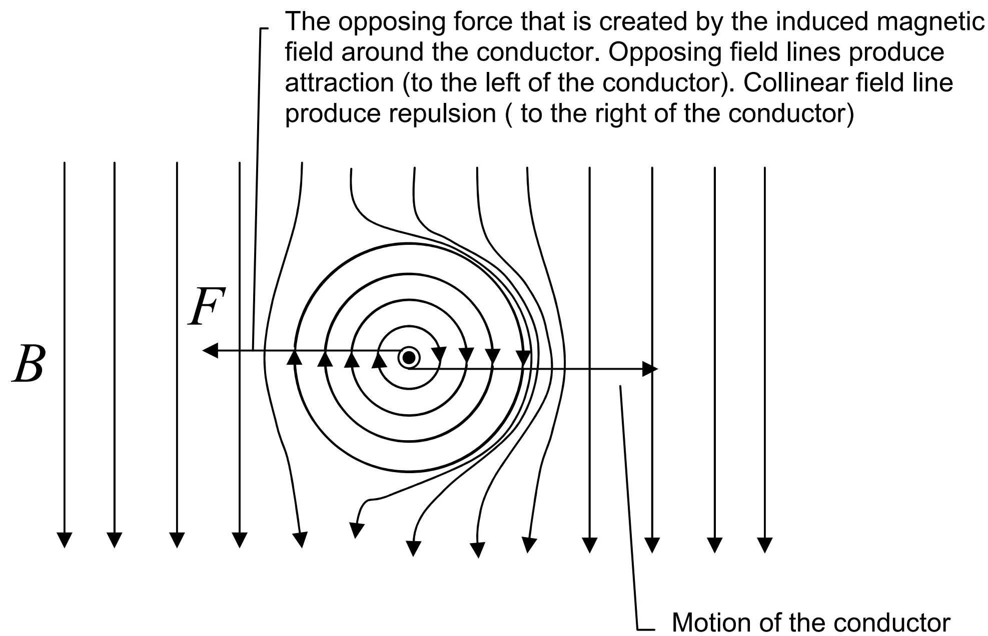
There are a few things at work here. Moving electrons produce magnetic fields; therefore it seems reasonable to assume that a moving or changing magnetic field will cause electrons to move as well. This is what precisely happens.

Consider the following diagram

1. The conductor is moving in the direction indicated in the diagram. This implies that every atom in the conductor is also moving in that direction.
2. Every conductor has free electrons just “hanging about”.
3. As the conductor moves, so do the electrons. The electrons behave just like electrons do when the flow through a conductor.
4. Using the LHR, your thumb points in the direction of the electron flow, in the same direction as v (velocity).
5. The tips of your fingers point down all the external magnetic field lines.
6. The net force acting on the electron is to the right and the electron begins to move to the right.



Now as the electron moves to the right, it’s going to produce a magnetic field due to its motion to the right.

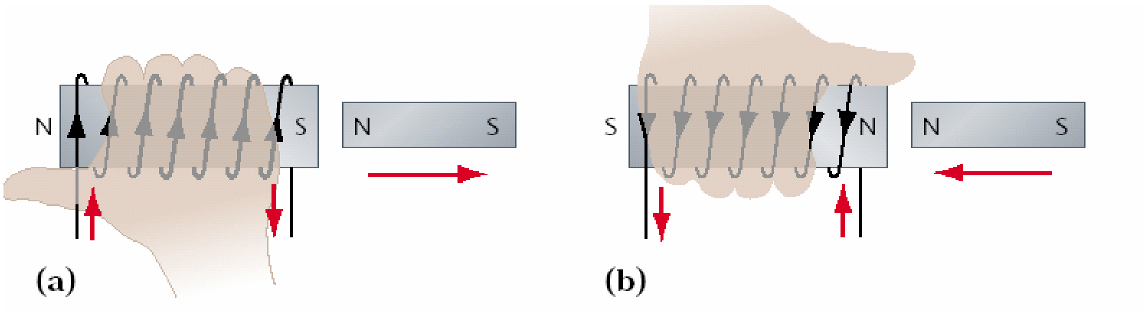


As you can see, the induced magnetic field produces a force that **opposes the motion** of the conductor. From a conservation of energy perspective, the **kinetic energy** of the moving conductor is being transferred to the **induced magnetic potential energy** of the newly formed magnetic field. Since you can’t get something from nothing, the increasing **magnetic potential** must be at the expense of the **kinetic energy**; hence a **drag force** is felt.

Lenz's Law: The direction of the induced current creates an induced magnetic field line that opposes the motion of the inducing magnetic field.

For example: our conductor will experience a drag force to the left as it moves to the right. This also applies to coils.

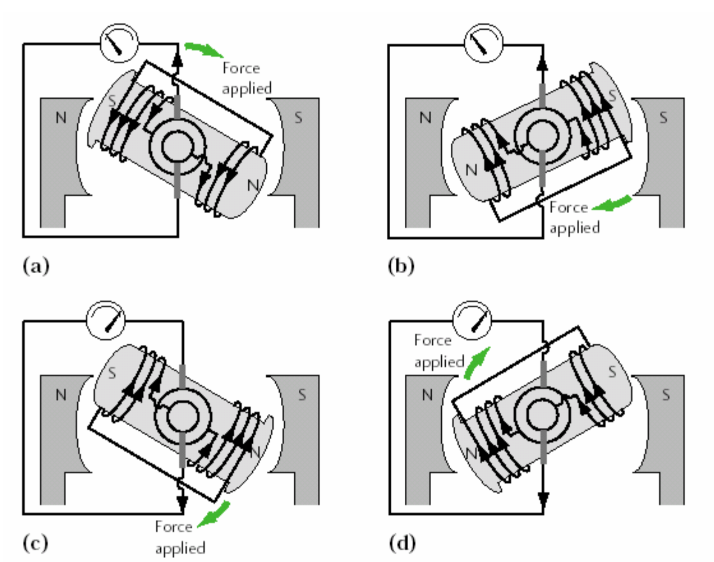
Induced Current: Flow of positive charge



(a) The inducing magnetic field (bar magnet) is being removed from the coil. The induced current will produce a magnetic field in an attempt to oppose the motion of the bar magnet. Therefore, a south pole is induced at the right side of the coil, in an attempt to hold in the bar magnet in.

(b) The inducing magnetic field (bar magnet) is being put back into the coil. The induced current will produce a magnetic field in an attempt to oppose the motion of the bar magnet. Therefore, a north pole is induced at the right side of the coil, in an attempt to prevent in the bar magnet from moving in.

The induced magnetic field always opposes a change. This is the process that is used in electrical generation as illustrated in the simplified motor below.



(a) An external force, such as a water turbine, is turning the armature. As it turns within the external magnetic field, the induce current is attempting to prevent the armature from turning. As a result, the induced magnetic field creates opposite poles to prevent the counter clockwise rotation.

(b) As the armature continues to turn, the induced poles still work to attempt to stop the clockwise rotation.

(c) However in this position, the induced field suddenly switches in order to switch the magnetic poles in the armature, so the that the induced field and the magnetic field are always configured to oppose the rotation.
(d) The induced current constantly switches direction producing **alternating current** (AC)