Magnetic Fields

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Moving electric charges produce magnetic fields. Since an electric current is many moving charges, a current in a wire will produce a magnetic field.

This magnetic field is present *as well as* the electric field produced by existence of the charges. They are not the same thing. If the charges stop moving, then the magnetic field will no longer exist, but the electric field will remain.

A magnetic field can be represented by field lines such that the direction of the field is at a tangent to each line, and the magnitude of the field at any point is represented by the number of lines crossing a unit area perpendicular to the field in the vicinity of the point.

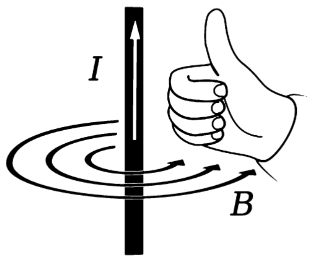
The direction of the magnetic field is the direction in which the north pole of a small compass needle points. That is, the field lines at any point will be in the same direction as the force felt by the north pole of a magnet placed there.

Direction of Current

Where the direction of the electric current is referred to, it is the *conventional current*. Before electrons were discovered, people thought that positive charges flowed and so conventional current is the direction that positive charges would flow if they did (from positive to negative). Now that we know it is actually electrons flowing, we think of conventional current as the opposite direction to electron flow.

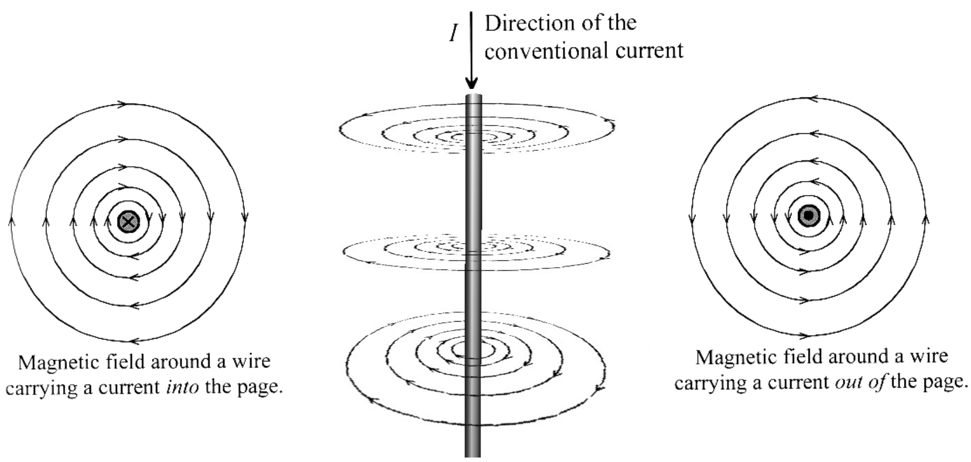
Right Hand Curl Rule

If the right hand is curled as if to grasp a current-carrying conductor with the thumb pointing along the direction of the current, the curled fingers show the direction of the magnetic field.



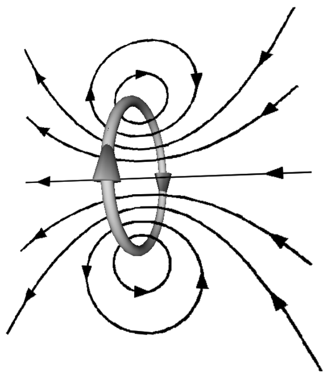
Straight Current-carrying Conductor

Electric current flowing in a conductor will produce a magnetic field according to the right hand curl rule. It is important to note that the distance between the field lines increases as they get further out from the conductor, because the field becomes weaker.



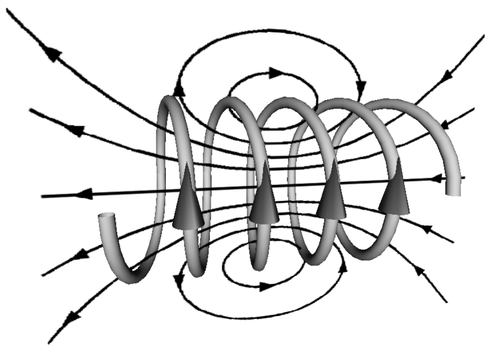
Single Current-carrying Loop

If the direction of the magnetic field is found at various points on a loop following the right hand curl rule, it will be noticed that the field curls around the loop and goes in the same direction on the inside of the loop. The effect of this is a strong field in the centre, as shown below:



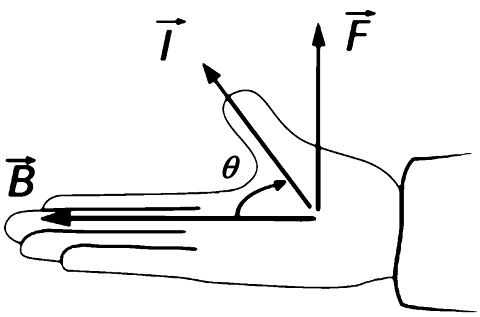
Solenoid

A solenoid (coil) acts like a series of the loops shown above. Their magnetic fields combine to give a strong field running through the centre, as shown below:



Right Hand Palm Rule

An electric charge moving through a magnetic field will experience a force. Therefore a current-carrying conductor (lots of moving charges) placed in a magnetic field will also experience a force. If the conductor is straight and the magnetic field is uniform, then the force experienced will follow the right-hand palm rule where the fingers point in the direction of the magnetic field, the thumb points in the direction of the current, and the palm 'slaps' in the direction of the force.

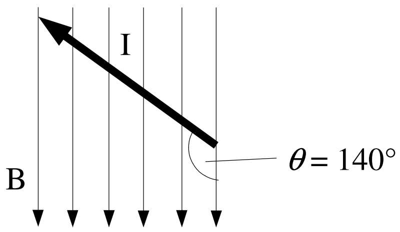


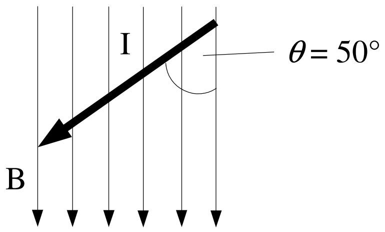
Magnitude of the Force on a Current in a Magnetic Field

The magnitude of the force on a current element in a uniform magnetic field is given by $F = I\Delta lB\sin\theta$

I is the current, Δl is the length of wire in the field, B is the strength of the field

θ is the angle of the current to the field measured with the arrows pointing away from each other, as below:





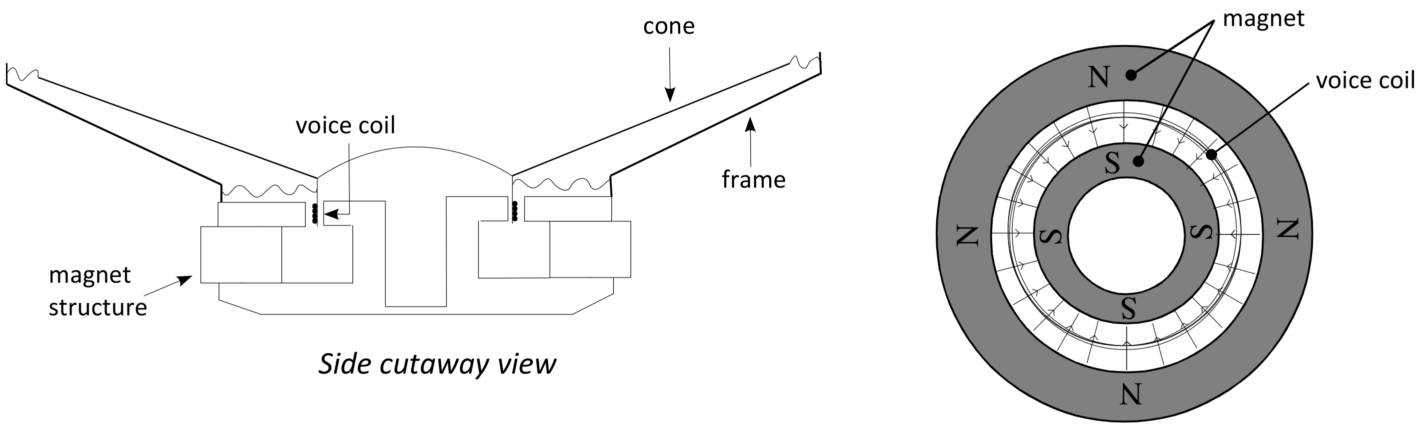
Note that the force on a current element that is parallel to a magnetic field is zero, since sin(0) = 0, and on a current element perpendicular is $I\Delta lB$ since sin(90°) = 1.

The unit for magnetic field strength is tesla (T) and is equivalent to N A^{-1} m^{-1} .

The Moving-coil Loudspeaker

A moving-coil loudspeaker consists of:

- a cone (a conical surface made from light, rigid material that sets the air vibrating by moving in and out)
- a magnet structure (fixed permanent magnet, forming a kind of 'magnetic circuit')
- a voice coil (a coil of wire that passes through the gap in the magnet structure and is attached to the cone)
- and a supporting frame (usually an open metal frame connecting the cone to the magnet structure)



Side cutaway view

Top-down cutaway view

In the top-down view the magnetic field lines are shown; this means when the current is clockwise the force on the voice coil will be into the page.

The electrical source for the speaker provides a potential difference for the voice coil. This potential difference means that current is flowing through the voice coil in the magnet structure gap. Since this means moving charges in a magnetic field, the voice coil experiences a force, pushing the cone in or out. The signal provided by the source will be oscillating in some fashion meaning that the cone is pushed in and out, producing sound waves.

The force on the voice coil is proportional to the current, since $F = I\Delta lB\ sin\theta$, and if we assume resistance in the voice coil is constant then force is also proportional to ΔV since Ohm's Law states that $I = \dfrac{\Delta V}{R}$.