An Analysis of Lenz's law

"The direction of an induced current is such as to oppose the cause producing it"

by

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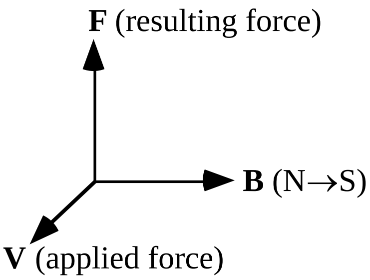
Introduction

Lenz's Law is a simplification of Faraday's law and unfortunately can be easily misinterpreted resulting in false conclusions being drawn about various interactions between permanent magnets and non-ferrous conductors.

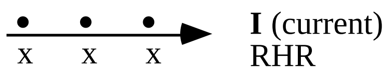
It is the intension of this paper to clarify this situation and reveal the potential benefits that can be obtained from the correct interpretation of these laws.

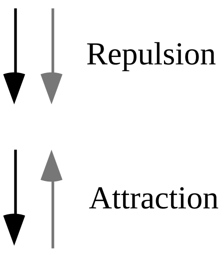
To start with, lets establish some conventions based on these laws. This will be followed by a series of simple experiments which can be repeated by anyone and that will clarify any confusion.



For a conductor carrying a current, **B** is the direction of an external magnetic field, **V** is the direction in which the conductor is pushed, the direction of motion, and **F** is the direction in which the electric current (positive charge) is induced. This is true for any conductor in relative motion perpendicular to the direction of any magnetic field.

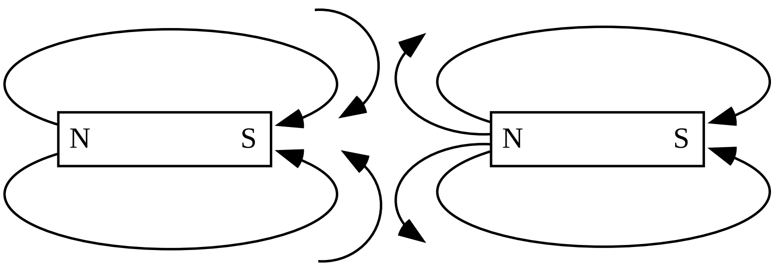
Any electric current has associated with it, a magnetic field. This is defined by the Right Hand Grip Rule. Where **I** is the direction of the electric current (positive charge), • is where the magnetic flux comes out of the page and **x** is where it disappears into the page.



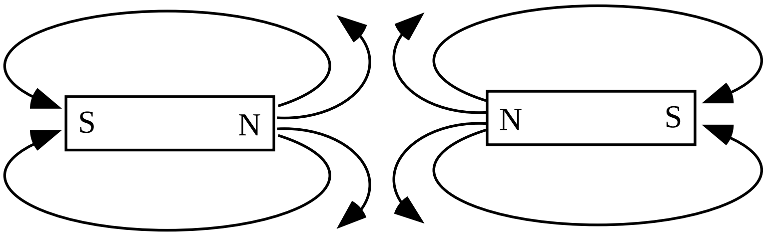


In diagrams showing magnetic flux lines, solid lines indicate a permanent magnetic field, while grey lines represent induced flux lines.

When considering standard magnets, attraction results when unlike poles are placed near each other, that is the flux lines are parallel and oppose each other. While like poles repel because the flux lines are parallel and in the same direction.



These diagrams are slightly unconventional as they show the flux lines of each magnet when, or just before, an interaction between two magnets takes place, rather then the more conventional flux pattern which results from the interaction of two magnets and which can be easily observed using iron filings and two bar magnets. These diagrams clearly show that opposing flux lines result in attraction, while unidirectional flux lines from different sources result in repulsion.



Remembering that an electric current is only induced when a conductor is placed in a changing magnetic field, or when there is relative motion between a conductor and a magnetic field (moving at right angles to each other).

Let us now consider Lenz's law which states that:

"The direction of an induced current is such as to oppose the cause producing it"

This law is sufficiently vague to allow for several interpretations, including the following:

1) *That the induced magnetic field opposes the permanent magnetic field.* This would result in an attraction between the conductor and the permanent magnet.

2) *That the forces which result from the interaction of the magnetic fields oppose each other.* This would mean that the conductor and the magnet would repel each other. It would also mean that the permanent and induced magnetic fields are unidirectional.

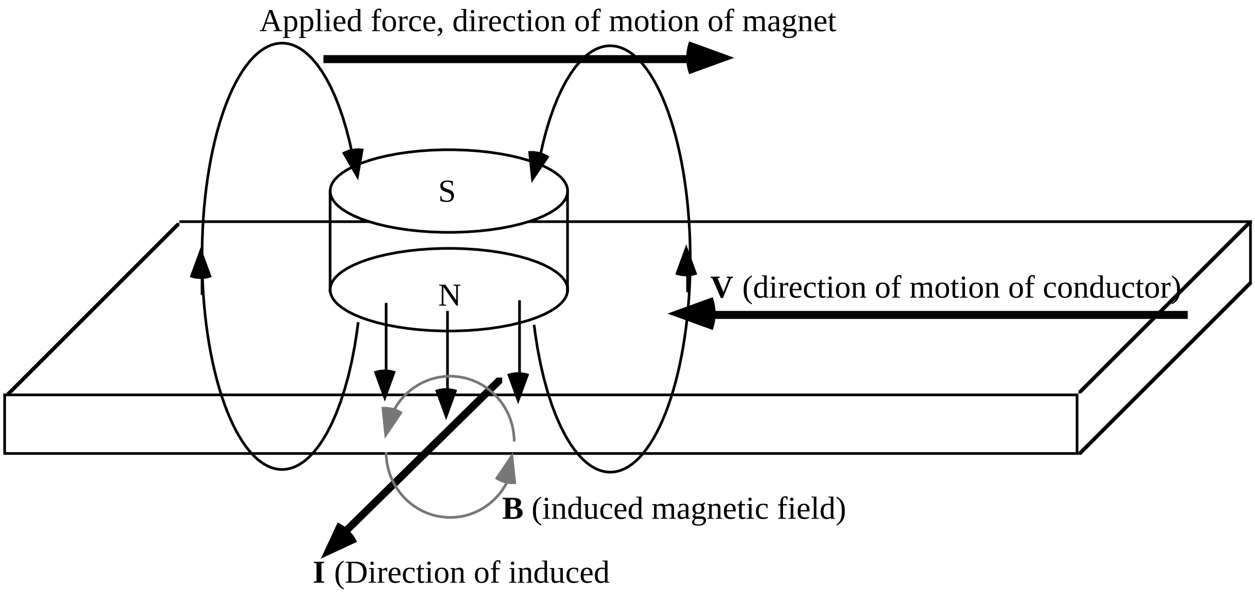
In the past it has been difficult to resolve this apparent confusion experimentally, as powerful magnets where too heavy, expensive and difficult to obtain, in order to carry out an experiment and "feel" the forces involved. However, with the recent (last 10 years) discovery of Neodymium, Boron, Iron magnets and their cheap and plentiful supply (last 2 years), it is now very easy to resolve this dilemma. As these magnets are 30 times more powerful then traditional ferrite magnets, it is now very easy to analyse permanent and induced magnetic forces.

Consider a flat conductor, such as a piece of aluminium, and a cylindrical magnet with its north and south poles located on its flat surfaces. If the magnet is moved along and just above the conductor, then the magnet will induce a current in the conductor, this current produces its own magnetic field which will interact with the permanent magnetic field resulting in forces of attraction and repulsion.

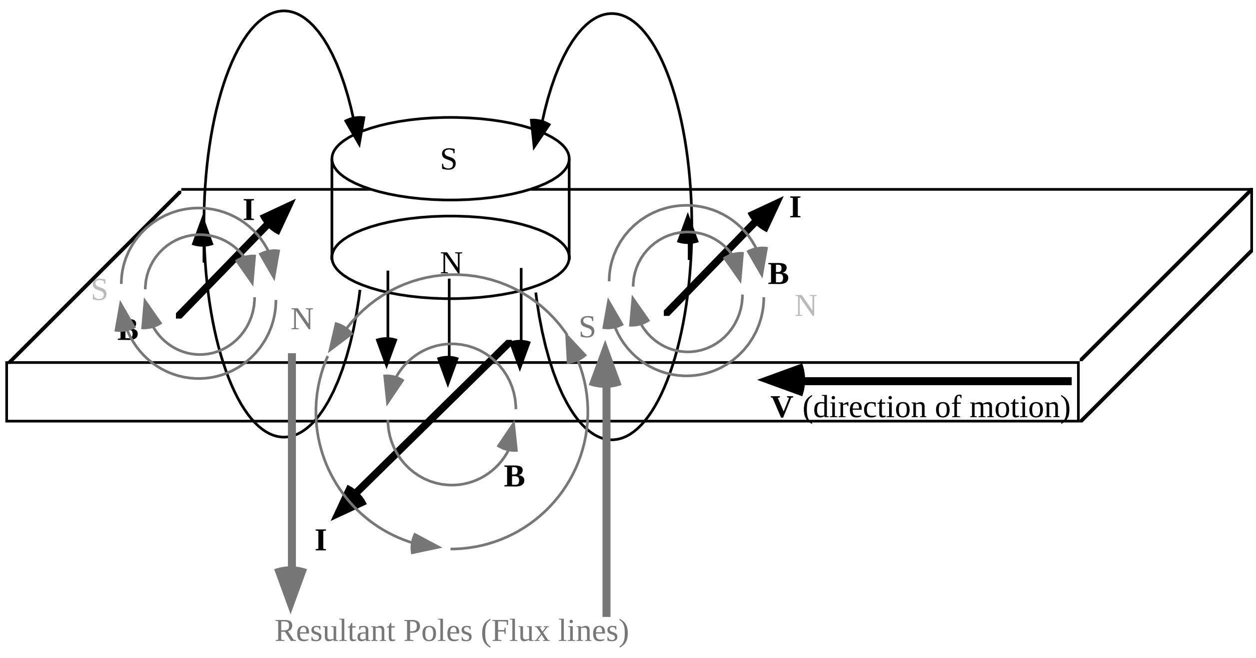
There are three fundamental ways in which the magnet can be held while moving it along the conductor. We shall consider each case, the associated currents, magnetic fields and forces separately in order to gain a better understanding of the concepts involved and to clarify the confusion caused by Lenz's law.

<u>Case 1:</u>

The cylindrical magnet is placed North (or South) face down, that is flat side down. It is than moved along the conductor, while being held just above its surface. If the magnet is moved left to right, then the lines of flux leave the magnet at right angles and intersect the conductor inducing a current which will flow towards the operator. Using the Right Hand Grip Rule, this current will induce a magnetic field which will cause opposing flux lines at the front or leading edge of the magnet, which in turn will result in an attractive force. While near the trailing or rear end of the magnet, the flux lines will approach unidirectionality and hence a force of repulsion will result. This visualisation reveals that Lenz's law is an oversimplification, as both forces of attraction and repulsion are involved.



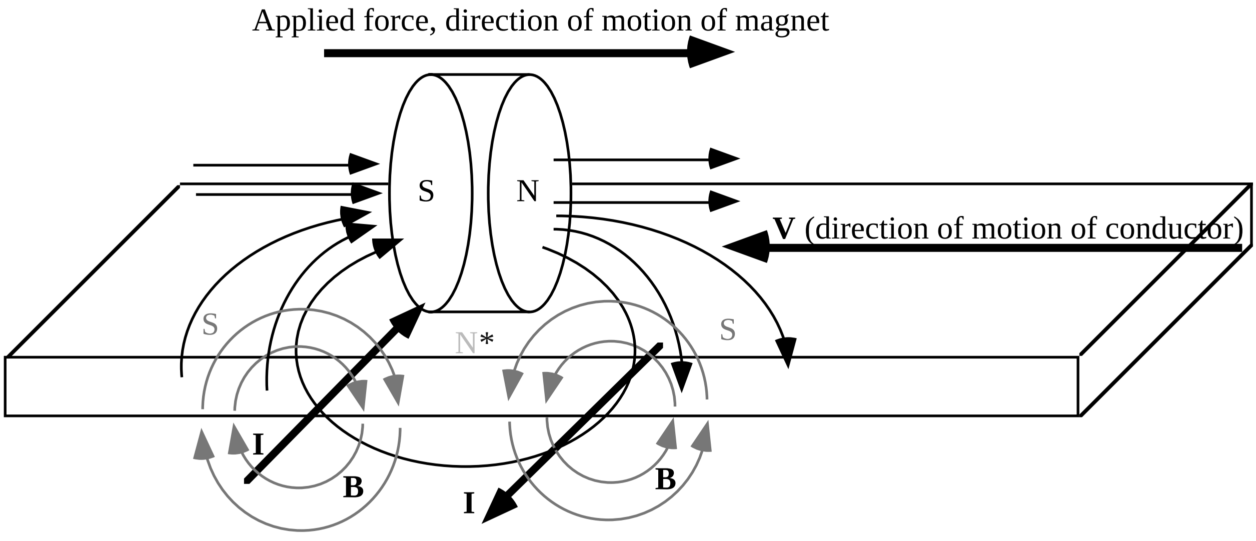
It is important to realise that the current is induced in the conductor and not in the magnet, therefore it is the relative direction of motion of the conductor which must be considered. An opposing (attracting pole) will form on the surface of the conductor near the leading edge of the magnet, relative to the direction of motion of the conductor, as shown in the diagram below.



It is important to note that if the magnet were placed upside down (South face down), all flux lines, poles and directions of currents would be reversed, but the resulting forces would be the same, that is attraction at the leading edge and repulsion at the trailing edge.

There are two more cases to consider, in each of these, the magnet has been rotated by 90˚ so as to change the direction of the flux lines. The resultant induced currents and associated flux lines are depicted and discussed below.

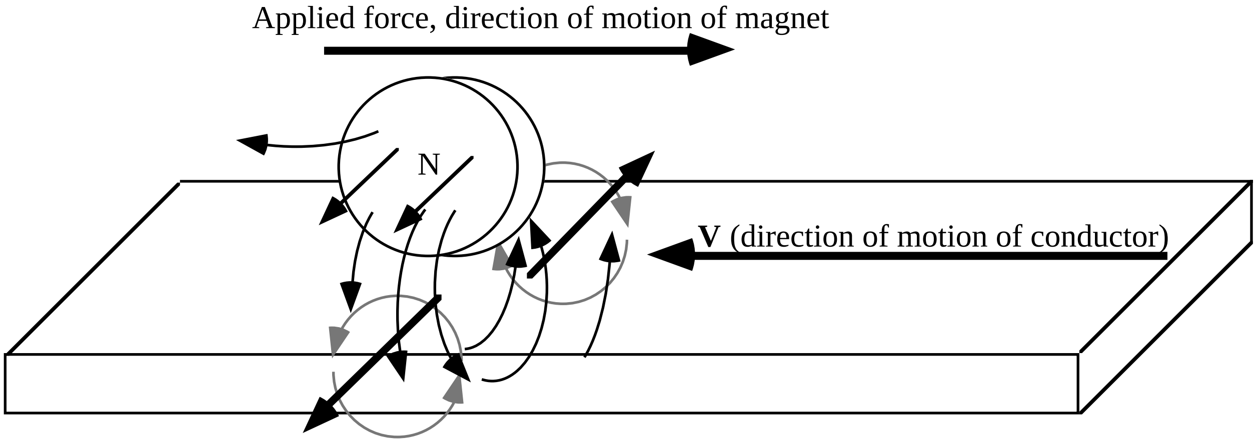
Case 2: A cylindrical magnet is placed on its side and moved along the conductor as shown, while being held just above the surface of that conductor. It is important to realise that only a small proportion of the magnetic flux actually intersects with the conductor. These flux lines still induce a current which has an associated "induced" magnetic flux. This can be seen in the diagram below.



Of the three induced poles, the N* is in an area where the magnet has no or very low flux density hence the induced N* pole will have no affect on the resulting forces experienced by the magnet held in this position and moved along the conductor. The two induced S (south) poles, have the affect of attracting the leading edge of the magnet and repelling the trailing edge of the magnet.

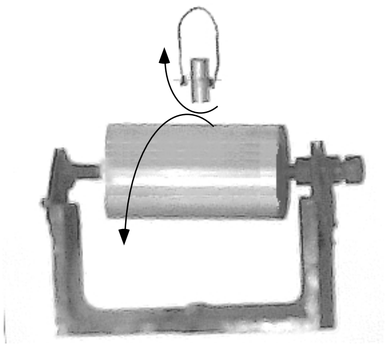
The opposing permanent and induced flux lines at the leading N (north) edge or face of the magnet also indicate an attraction, as does the presence of the induced S (south) and permanent N (north) poles. While at the rear (southern) end of the magnet, the induced S (south) pole and parallel flux lines which run in the same direction, indicate a repulsive force.

Case 3: The magnet in case 2 is spun around by 90˚ and then moved along the conductor as in the previous two cases. The resultant interactions are described in the following diagram.



Again it can be seen that there is an attraction at the leading edge of the magnet and a repulsion at the trailing edge. However, as only a very small proportion of the flux lines will interact with the conductor, the resulting forces from this interaction are minimal, as an experiment will confirm.

If the three cases discussed above are correct, then a magnet or other magnetic dipole should rotate when positioned near a moving conductor. The direction of motion of the magnet would be the same as that of a wheel or cog touching the conductor. In this case (the diagram on the left), the conductor is an Aluminium rod which can be freely rotated. The bar magnet above consists of two cylindrical magnets, pivoted in the middle on a sewing needle, this needle is suspended in a loop of insulated copper wire. As the Aluminium roller is rotated, the magnets start to rotate in the predicted direction. This confirms experimentally that the above described theory is in fact correct. This experiment can be easily reproduced to verify my claims and explanations.



The observations, realisations and explanations offered here seem to indicate that it may be possible to create a self perpetuating device which could potentially yield electrical energy from the interaction of permanent and electric fields. However, this would appear to violate the first and second law of thermodynamics.

Magnetodynamics

The term thermodynamics means and relates to devices (engines) which use heat (Thermo) to generate motion (Dynamics). If it were possible to create a permanent and induced magnet motor such as suggested by the above theory, then the first two laws of thermodynamics need to be considered. The first law of thermodynamics states:

"Energy can not be created or destroyed"

Scientists have proved over years that this law does not apply to every form of energy generation. For example in modern nuclear reactors, we break up heavy atoms to form lighter ones with a slight overall loss in mass, where the lost mass can be roughly equated to the energy liberated using the relationship $E = mc^2$. A similar mass to energy conversion is used in thermonuclear bombs, and in the continuous nuclear reaction which fires our Sun, here light atoms combine to form heavier ones with a slight loss of mass and a resulting conversion to energy.

Scientists have also shown that it is possible to convert energy into matter. It appears that this only occurs during supernova explosions, where there is sufficient energy released to created atoms heavier than iron.

To explain this apparent braking of the laws of physics some people have claimed that matter and energy are the same thing, that is that energy is a form of matter and visa versa. However, energy can be used to do work, matter can not!

It is clear from this that a precedent has been set for braking or defying the laws of thermodynamics. Accordingly it may be possible that there are some procedures or devices which defy the second law of thermodynamics, which states that:

"An engine cannot yield more than 100% output for a given input,
and usually yields much less"

As pointed out previously, conventional engines are ***Thermodynamic*** devices and require the use of heat to generate motion. Previous inventors of magnetically driven engines claim that the motion generated does not involve or require the use of heat (***Thermo***) but instead the interactions of magnetic forces. Hence it stands to reason that the laws of thermodynamics my not apply to these devices. Further, a new law, as jet undefined, may apply to the type of motion which results from the interaction of magnetic forces, and therefore should be called the law of ***Magnetodynamics***.

It may well turn out that these devices comply with the laws of thermodynamics (even though they do not necessarily apply) upon the completion of a full scientific investigation of this apparent anomaly.