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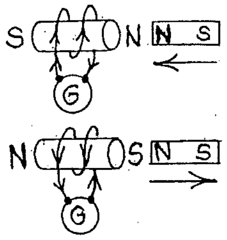
Lenz's law - is a brief, but vital, explanation of how work is done on the electrons in a wire during electromagnetic induction and thus, how energy is transferred to them. As such, the law is a key link between electromagnetic induction and the law of conservation of energy.

The historical time line goes as follows. In 1831, Faraday in London, Eng. and Henry in Albany, NY induced electric currents in wires via moving magnetic fields. At first glance, it appeared like they had produced electricity without effort (work). On second thought, they knew a necessary explanation was missing. It came in 1834 when Lenz in Germany discovered that an induced current always flows in a direction so that its magnetic field opposes the original motion (magnetic field) that induced (caused) it (1.). Eureka! It's an electromagnetic version of Newton's 3rd law, that equal and opposite magnetic forces are always present during induction. Lenz had found the missing link.

1.



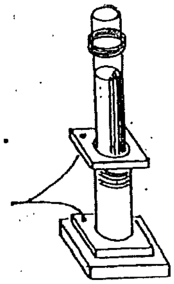
In 1842, Joule in Manchester, Eng. began his intensive study of electrical energy changing into heat energy via wires in water. His famous paddle wheel experiments soon followed. In 1847, Helmholtz in Germany suggested a law of conservation of energy. In 1849, Joule published the results of his extensive work on energy transformation (transfer). Soon after, Lord Kelvin of Glasgow, Scot. recognized Joule's work as conclusive proof for the establishment of the law of conservation of energy. Lenz's simple, but important, discovery was a major step toward the great law that specifies that there must be work in to get electrical energy out.

Lenz's law is a demonstrator's dream because we have so many dramatic demonstrations of its effect. Simply, whenever we have a conductor in the presence of a moving magnetic field, Lenz's law is involved, usually providing a retarding (opposition) effect. A few of the most popular demonstrations are described below.

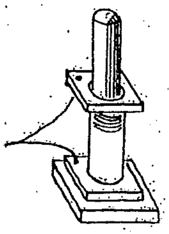
(a) The Ring Flinger - is a topic that is fully described elsewhere on this website. It is dramatic and has not lost its capacity to educate and entertain (2.).

(b) Self-inductance - is another topic that is fully described on this website. Lenz's law plays a major role in explaining this phenomenon (3.).

2.



3.

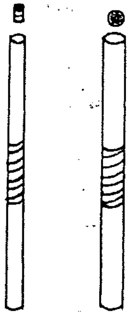


(c) Dropping nonmagnets and magnets through 2 ft. long, copper pipes (4.). Remove any "burrs" on the ends of the pipes. Select a pair of approximately ½" dia. neodymium magnets; wrap a little masking tape around them to increase their diameter to better fit inside the ½" I.D. copper pipe. Cut off a short piece of ½" solid iron rod to approximately match the size of the magnets. Wrap plastic electrical tape around the middle of the pipe as an insulator for your hand.

Warning: When dropping magnets, it is always good practice to have them land softly on a cushion of somekind.

Drop the nonmagnetic piece of iron through the pipe first; the result is nearly free-fall. Now drop the magnets through the pipe. The retardation due to the electromagnetic induction and according to Lenz's law is dramatic!

4.



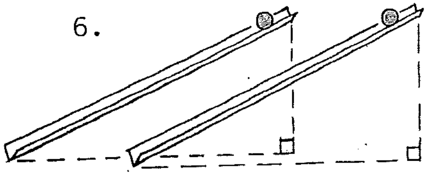
5.

An alternate demo with an identical theme uses a 3/4" I.D. copper pipe with a set of 3/4" (19mm) dia. spheres, one nonmagnetic steel and the other magnetic ceramic. (The ceramic sphere looks and feels like steel but will chip off if it strikes a hard surface - use with care!) Use the same dropping procedure as above. The retardation is very dramatic, also.

An additional demo may be performed with a special piece of copper pipe (5.). A milling machine may be required. Take another 2 ft. long pipe and cut a long, narrow slot down the side of the pipe. For strength, don't cut through the very ends. The falling magnets will nearly free-fall like the nonmagnetic iron. The slot interrupts the circulating currents in the pipe and thus, disrupts an opposing magnetic field. This can be presented as a puzzle with the "hidden" slot facing the presenter. Also tape (insulate) the middle of the pipe.

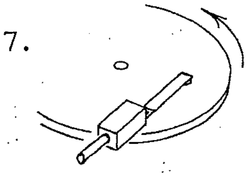
(d) "The Great Race" - is between two 3/4" (19mm) dia. spheres, one magnetic, the other nonmagnetic on an inclined track(s) 4 ft. long (6.). The track(s) is best made of 3/4" angle aluminum, 1/8" thick. A good hardware store sells this angle aluminum in 8 ft. lengths, enough for two tracks side by side. Remember that the magnetic sphere is ceramic and can chip; provide a soft (safe!) landing at the bottom of its track. You decide on the incline (angle) that you want and how to set it up. For a little drama, select two unsuspecting students to release the spheres on a signal. Again, the retardation is very dramatic.
If you already have a track on hand, don't buy more. Simply set it up with the two spheres several inches (cms) apart. Remember to place the nonmagnetic sphere ahead of the magnetic sphere, and watch the dramatic separation occur. Either way, the demonstration is very effective.

6.



(e) Students seem to like levitation demonstrations, and this one is not too difficult to perform and explain. It requires a rotator and variac, an aluminum disc or pot lid, and a neodymium, "floating" magnet. The alum. disc is rotated beneath a strong magnet (7.). When all adjustments have been made, i.e., speeds, location, etc., the magnet should levitate. A possible design for a magnet holder is provided (8.). A simpler design is always possible. The holder is attached to a right angle clamp on a ring stand. The full explanation for the levitation is rather complex. The simple explanation is that the motion of the aluminum electrons through the variable magnetic field of the neodymium induces the e's to swarm into small circles or eddy currents that oppose the magnetic field above with enough magnetic field strength upward to keep the magnet from falling due to gravity.

7.



8.