32520 LENZ'S LAW APPARATUS

Purpose:

A strong magnet accelerates normally in a tubular non-conductor, but falls at a low and constant velocity in a tubular conductor in this visible application of Lenz's Law.

Background:

It is well known that moving a magnet through a loop of wire will induce an electric current in that loop, while the magnet is moving. Reversing the direction of motion reverses the direction of the induced electric current. Similarly, it is well know that an electric current running through the loop of wire will create a magnetic field around that loop, and reversing the direction of the electric current will reverse the polarity of the magnetic field.

Lenz's Law states that an induced current will flow in such a direction that the magnetic field it produces will oppose the magnetic field whose motion produced it. Therefore, if we move a magnet through a coil of wire, according to Lenz's Law, the newly created magnetic field will oppose the magnetic field of the magnet (the cause that produced it). Since only the change in the magnetic field is being resisted, we must do work to push or pull the magnet through the coil of wire. As the magnet is moved toward a turn of wire in the coil, the induced current produces a magnetic force that pushes against the entering magnet.

As the magnet is moved away from a turn of wire, the wire's magnetic field will attract the magnet and try to keep if from exiting that turn of wire. This is a continuous process. As the magnet is moved through the coil, each end of the magnet feels a force resisting its movement. It is only the change in the magnetic field being resisted. No force tries to stop the center of the magnet from moving because the magnetic field is constant along the length of the magnet away from the ends. This concept also holds true if the coil of wire were a non-magnetic conducting tube.

As a result, we must do work to push the magnet through the coil of wire or tube. If the conducting tube is held vertically, the force able to do the work is the weight of the falling magnet. A stable condition exists, while the falling magnet is in the tube, where the force of the opposing magnetic field just equals the weight of the magnet so the net force is zero and the magnet falls at a low, constant velocity, its terminal velocity. Current flows around the tube, much as one's fingers curl around the tube, so the analysis is the same as if the tube were a solenoid made from a coil of wire.

If the tube were made of a non-magnetic and non-conducting material, then no electric currents would be induced by the magnet's field. Thus there would be no magnetic fields from the tube to oppose the magnet, and it would accelerate as in free fall. The size and direction of the relevant forces can be deduced by hanging the tubes from a simple spring balance of appropriate range.

Experiment:

For the purpose of this experiment we are going to use the force of gravity as our force to move the samples through the tubes. The force created when the magnet sample is dropped through the copper tube can be shown by a change in weight of the tube assembly.

1. Remove any protective paper from both plastic Plates.

2. Form a loop in the end of the apparatus suspension cord at least 8 inches from the Plate.

3. Install the Plastic Tube through both Plates, with the suspension cord pointed away from the other plate, leaving about 1 centimeter protruding from each plate.

4. Install the Copper Tube through both Plates, parallel and aligned with the Plastic Tube.

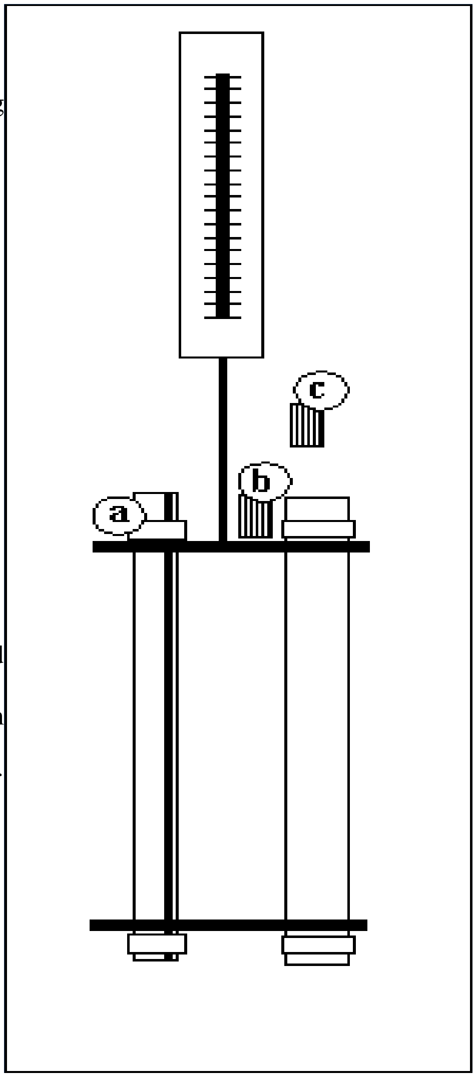
5. Gently force a plastic clip on the extremities of each tube, as in **Figure 1a**. This completes the tube assembly, which is accomplished without adhesives.

6. Using the suspension cord, attach the tube assembly to the spring balance. Then hang the assembly so that nothing will interfere with it.

7. Drop the Non-magnetic Sample through each of the tubes. The sample will accelerate at the same rate through both tubes (there is no significant resistance), and there will be no change in weight of the tubes.

8. Set the Magnet Sample on the upper plate, as in **Figure 1b**, and notice the new combined weight.

9. Drop the Magnet Sample through each of the tubes, as in **Figure 1c**. The Magnet Sample will fall with no resistance through the acrylic tube. However, the Magnet Sample falls at a slower and constant rate through the copper tube. Compare the weight from Step 8 with the reading of the Spring Balance while the Magnet Sample is falling but is still inside of each tube. When the Magnet Sample is falling inside of the Copper Tube, the tube assembly weighs more by exactly the weight of the Magnet Sample.



To further visualize the magnetic field set-up by an induced current, use the **Right-Hand Rule**. Pointing the thumb in the direction of the current, your fingers will wrap in the direction of the circular magnetic field created by that current. If you use this rule to run your hand along the wires of a coil or a tube, you would see that the magnetic line of force exits one end of the coil or tube, like a north pole of a magnet, and enters the other end of the coil or tube, like a south pole of a magnet.

Time Allocation:

To prepare this product for an experimental trial should take less than five minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.