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Instruction Sheet for the PASCO Model MG-8600

Lenz's Law Demonstrator

The Model MG-8600 Lenz's Law Demonstrator provides a dramatic demonstration of Lenz's Law. A mass is dropped through a 1.5 meter long aluminum tube. It falls through the tube in about 0.5 seconds. Then an identical mass (actually a magnet) is dropped through the tube. The falling magnet produces a current in the tube, which in turn produces a magnetic field that opposes the field of the falling magnet. This opposing field slows the motion of the magnet, so it takes more than ten times as long to fall through.

The equipment and setup are shown in Figure 1. Two falling masses are included with the apparatus. They are seemingly identical, but one is a magnet, the other is not. A spring scale is included so you can show that the mass shown on the scale increases as the magnet falls through the tube, but not as the unmagnetized mass falls through.

To perform the demonstration:

1. Set up the equipment as shown in Figure 1.
2. Hold the unmagnetized mass over the opening in the tube, then drop it.
3. Now drop the magnet through the tube.
4. You may want to repeat the demonstration, allowing your students to observe the reading of the spring scale.

Theory

According to Faraday's Law of Induction, a changing magnetic field induces an electric field. According to Ampere's Law, a circulating current induces a magnetic field. So, if a magnetic field changes within a conductor, a current can be produced which in turn produces a secondary magnetic field. Lenz's Law states that this secondary magnetic field always opposes *the change* in the original field.

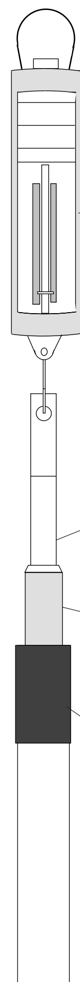

Figure 1 Equipment and Setup

Figure 2a shows a diagram of the magnet falling through the tube. The N-pole of the falling magnet is facing down. Three cross sections of the tube, A, B, and C, are shown. The magnetic field through all three cross sections points down. In cross section A, the magnetic field decreases as the magnet falls. Lenz's Law says that the induced field will therefore point down, reducing the rate at which the total field decreases. In section B, the field from the falling magnet is relatively constant. There is therefore no induced field in cross section B. In cross section C, the field from the falling magnet increases as the magnet falls. According to Lenz's Law, the induced field will point up, reducing the rate at which the total field increases.

An easy way to conceptualize the effect of these fields on the falling magnet is to imagine the fields as if they are produced by tiny magnets, as shown in Figure 2b. The direction of the field of the upper magnet is the same as that of the falling magnet, so the N-pole of the induced magnet is adjacent to the S-pole of the falling magnet. The falling magnet is attracted, which slows its motion. The field of the lower magnet is such that it repels the falling magnet, again, slowing its motion. Therefore, Lenz's Law predicts that the motion of the magnet will be slowed due to the induced fields. Experiment confirms this prediction.

Lenz's Law provides a simple way to determine the directions of induced currents and magnetic fields. However, the currents and fields can also be determined using more basic laws of electromagnetics.

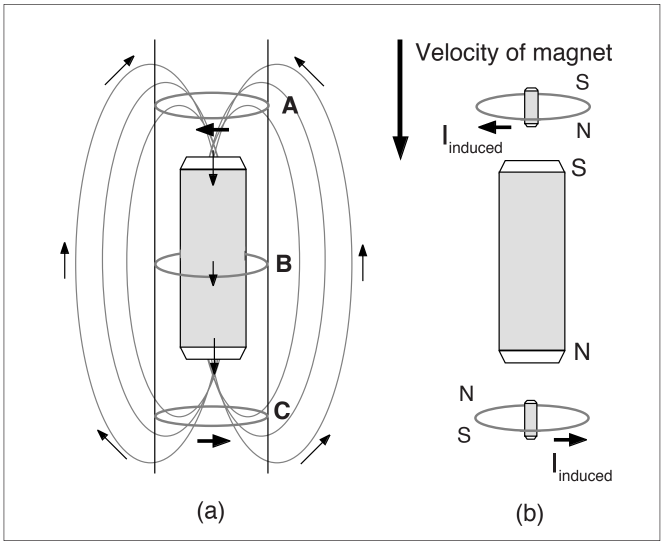

Figure 2 Diagram of the Falling Magnet

The direction of the induced currents in the tube can be determined using Faraday's law of induction, $\varepsilon = - d\text{Ø}/dt$; where $d\text{Ø}/dt$ is the rate of change of the magnetic flux through a selected cross section of the tube, and ε is the induced emf around that cross section. The right hand rule can be used to determine the direction of the current. If the magnetic flux through the tube is increasing, point your thumb in the direction opposite the magnetic field (because of the minus sign). If the magnetic flux through the tube is decreasing, point your thumb in the direction of the magnetic field. In each case, your fingers will curl in the direction that the current flows.

At cross section A, the magnetic field from the magnet is pointing down, but the field, and therefore the flux, is decreasing as the magnet descends. The current therefore flows clockwise (looking down from the top) in that cross section. At cross section B, the flux due to the field is constant, because the field near the middle of the magnet is constant. There are therefore no induced currents in cross section B. In cross section C, the field points down and the flux is increasing as the magnet descends. The current therefore flows counterclockwise.

The circulating currents at cross sections A and C produce magnetic fields. The magnitude and directions of these fields can be determined using Ampere's Law ($B\ dl = \mu_0 I$) and a different right hand rule. Curl the fingers of your right hand in the direction of current flow. Your thumb will point in the direction of the magnetic field. Using this rule, you can show that the predicted directions of the induced fields are the same as predicted by Lenz's Law.

Extending Lenz's Law

You can extend the length of your tube in 1.5 meter increments with the PASCO 1.5 Meter Extension Tube with Coupler (Model MG-8601). The extension tube and coupler attach to the Lenz's Law Tube as shown in Figure 3.

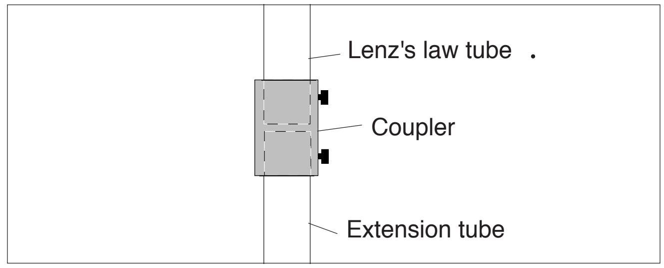

Figure 3 Attaching the Extension Tube

Limited Warranty

PASCO scientific warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment, after repair, will be paid by PASCO scientific.

Equipment Return

Should this product have to be returned to PASCO scientific, for whatever reason, notify PASCO scientific by letter or phone BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

NOTE: NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing.

To be certain the unit will not be damaged in shipment, observe the following rules:

1. The carton must be strong enough for the item shipped.
2. There should be at least two inches of packing material between any point on the apparatus and the inside of the carton.
3. Make certain that the packing material can not shift in the box, or become compressed, thus letting the instrument come in contact with the edge of the box.