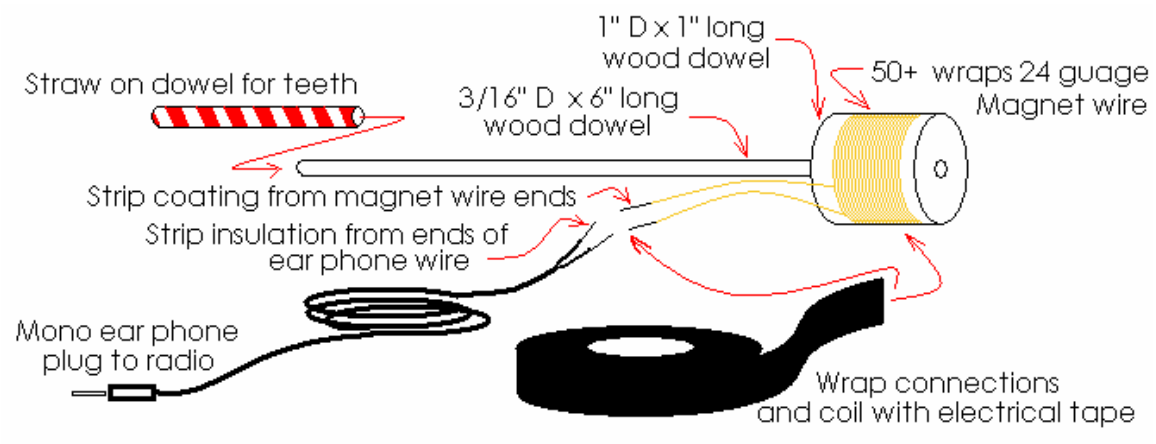
Ear Drum Speakers

Purpose: To make ear drums into speakers using opposing magnetic fields from a permanent magnet and an electromagnet.

Prerequisite Student Knowledge: This lab can be done as an inquiry activity with very little knowledge behind. Prerequisite knowledge or post lab discussion should include the following:

1) A current flowing through a coil induces a magnetic field in or out of the loop according to the right-hand rule (curled fingers on the right hand in the direction of the current, then the thumb points in the direction of the magnet field.)
2) Sound is traveling of mechanical energy through a medium and is produced by a vibration source.
3) The basic parts the ear and their function: drum, anvil and hammer.
4) The definition of efficiency as the ratio of energy or work out of a system compared to that which is put into a system.

Materials: 3/16" wood dowel, 1" wood dowel, flat toothpicks, wood glue, mono earphone with plug, straws, electrical tape and 24 gauge magnet wire, wire strippers.



Procedures:

Construction:

1) Cut 3/16" dowel about 6 inches long.
2) Cut 1" dowel about 1 inch long.
3) Drill a hole in the center of the 1-inch dowel to accept the 3/16" dowel.
4) Using wood glue, push the 3/16" dowel into the drilled hole of the 1" dowel. If it is not a snug fit, then use some small wood splinters or flat toothpicks to take up some space.
5) Use 24-gauge magnet wire to make the wire coil on the 1" dowel. Make sure that you use magnet wire because it has a thin plastic coating so that individual strands of wire cannot touch each other. Without the coating, there will not be a continuous coil. Wind the wire at least 50 times leaving several inches of free wire on each end. Make several wraps of electrical tape around the magnet wire to hold it in place on the dowel while leaving the ends exposed.
6) Using a fine piece of sandpaper or a utility blade scrape about ¾" of insulation off each end of the magnet wire. You can see that the wire looks different without insulation. Make sure that it is striped all the way around.

7) Cut the earpiece off the mono earphone so that the length of wire is still left on the plug end. The earpiece is not needed. You can purchase the earphone at Radio Shack. Try to get the kind that has a dual stranded outer insulation like a lamp cord. The single round looking insulation will work, but seem to have finer wires that are harder to work with.
8) Use wire stripers to strip about ¾" of insulation from the ends of the earphone wire.
9) Wipe both striped ends of the magnet wire and ear phone wire with a clean cloth to remove any skin oils and wind one magnet wire with one ear phone wire so that you have two separate connections. These can be soldiered, but is not necessary. Wrap the connections with a small amount of electrical tape so that no uninsulated parts are exposed. To take the strain off these connections, they may be taped to the 3/16" dowel next to the wire coil. This completes the construction of the apparatus.

Activity:

1) Cut a piece of drinking straw and slide it over the end of the 3/16" dowel. You will bite down on this with your teeth. Each user will use a fresh straw for good hygiene.
2) Find a boisterous radio station and plug in the earphone plug; turning the volume up high once plugged in.
3) Bite down on the end of the dowel with straw and bring two or three 1 1/8" donut shaped magnet (or the like) up close to the end of the coil, but not touching it. **Be sure that you are only holding the dowel with your teeth and not your lips or hand**. You should be able to feel vibration in your teeth and in the held magnets. You should be able to hear the music in your ears, and if someone puts their ear up next to yours' they can often hear the music as well. If you are not having success, then try one of the following:

   - Make sure that you used insulated magnet wire and that you remembered to completely strip the ends all the way around.
   - Check to be sure that there are no striped magnet wire sections touching each other.
   - If you have unsoldered connections disconnect and re-clean them so they make better contact.
   - The radio volume should be turned up.
   - Make sure that you are biting down with significant force onto the dowel to adequately transfer vibration onto your jaw.
4) Turn the magnet around and see that it works just as well with the magnetic field reversed.
5) Move a compass around the coil while plugged into an operating radio. Notice that the magnetic field is either is along the long axis of the dowel. Do the same with the donut magnet and notice that the field is in or out of the hole in the donut.

Analysis:

Students should attempt to explain how it is that they are able to hear the sound by drawing on previous skills involving induced magnetic fields and that sound is vibrations. It may be very helpful to have a dismantled speaker for the students to examine and one bare working speaker that is attached to a source. The flow of electrical signal from the radio through the wire coil induces a magnetic field surrounding the coil. According to the right hand rule, the field should be in or out of the coil along the long axis of the dowel rod. The interaction of the two magnetic fields produce vibrations that are transmitted by conduction through the dowel, to the teeth and jaw, to the hammer in the ear, anvil, then finally to the ear drum. The

frequency of vibration of the eardrum would be the same as that of attraction/repulsion of the magnetic field and of course the radio signal where it originated.

Students should identify that the any external source of support of the dowel will dampen the vibration while absorbing the mechanical sound energy, thereby reducing the amount of energy getting to the ears and hence the loudness or intensity of the sound heard. This damping is analogous to shocks absorbers on a car or machinery or friction within electrical conductors that causes resistance to the flow of electricity and reduces efficiency of the electrical system, that is, the delivery of current is diminished.

Students should attempt to explain how the magnetic fields interact. If the wire connections were reversed the field direction of the coil would be flipped 180° along the long axis of the dowel as measured by the compass, but the directions of the fields do not matter as the vibration that ultimately produces the sound could be propagated by attraction or repulsion of the two fields.

The use of a superconducting coil would have zero resistance to current flow and therefore produce more of an induced field in the coil. Stronger fields mean stronger forces between attracting or repelling fields that would produce louder (higher intensity) sound due to increased efficiency, that is, less loss of energy in the process. Adding more normal conducting copper coils would not have quite the same effect, because more wire means more resistance and energy losses.