I. INTRODUCTION

Transduction is the changing of energy (or information) from one form to another. Microphones transduce acoustical energy into electrical energy (voltage); loudspeakers transduce voltage back into sound. Tape deck record and playback heads transduce electrical signals into magnetized regions on magnetic tape, and vice versa. CD players transduce the information recorded on a CD back into electrical energy. Thus, transducers are a crucial part of the study of acoustics.

II. FARADAY’S LAW OF ELECTROMAGNETIC INDUCTION

The operation of most transducers is based on Faraday’s Law, which says that if you move a wire through a magnetic field (or vary the magnetic field strength through a coil of wire), a voltage will be produced in the wire. This physical fact is very useful in acoustics since sound is a mechanical vibration which can easily cause a small ribbon or membrane to move.

A. A SINGLE WIRE MOVING IN A MAGNETIC FIELD

1. Hook one of the long blue banana-banana wires directly from one of the scope inputs to scope ground. Set the scope to a sensitive setting, say 10 mV/div, and then move the wire back and forth between the jaws of your large horseshoe magnet. Try to keep the magnet as far away from the oscilloscope as possible, since its large magnetic field badly distorts the scope display. Notice that to generate a larger signal you need to move the wire faster. Also try moving the wire in different directions, for example back-and-forth between the jaws as opposed to parallel to the jaws.

2. Build a ribbon microphone.

   a. You will need:
      A strong horseshoe magnet
      A plastic frame
      Two clean 1/8 in. brass rods
      A strip of 1/2 mil aluminized (or copperized) mylar
      Masking tape

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b. Clean the brass rods with Emery-paper for better contact. Tape the rods onto the plastic frame so that they stick out from the frame on one side, which will allow for easy attachment of alligator clips. Stretch the mylar so that it runs through the central notch, over the rods (with the metallized side touching the brass rods), and tapes onto the back. The mylar should be as loose as possible, BUT IT MUST MAKE A GOOD CONNECTION WITH BOTH RODS. That’s it. Simply connect the microphone to the scope using a shielded cable with alligator clips at one end. It may be necessary to pull out the ×5 knob on the front of the Volts/Div knob to see the signal well.

c. Hold the frame so that the ribbon is close to the magnet, talk into your microphone and look at the output on the scope. How big is the signal if you make a loud (but not shouting) sound an inch from the microphone? Notice that the orientation of the ribbon with respect to the magnet is very important. Turning it 90° ruins the output.

d. Record yourself using your ribbon microphone; using an adaptor plug the end of the cable into the black cable that leads to the microphone input of the computer. Use the SoundScope program to record. Play back the recording: How does it sound?

e. Analyze the frequency spectrum of your recording (select a vowel) using the SoundScope program: what do you notice about the frequency response of your microphone?
B. A COIL OF WIRE MOVING IN A MAGNETIC FIELD

1. Repeat the first experiment, moving a wire through the magnetic field of your large horseshoe magnet. Now wrap one of your long banana wires into a loop and moving ONE SIDE of the loop between the jaws of the magnet. The more turns of wire in the coil, the bigger the signal. How much bigger is the signal from a coil compared to a single wire?

For this reason, many transducers use coils of wire having many, many turns. The most common example is the cone loudspeaker. In a microphone, the movement of the wire or coil causes a current to flow in the wire. In a speaker, a current is sent through the coil, which makes it move in the magnetic field.

2. In fact, a cone speaker is itself an excellent microphone. Hook your small speaker directly to your scope and talk into it. Notice the impressive signal generated with a relatively small magnet. How big is it?

This is possible because of the large number of turns in the coil. Your speaker is acting as a "moving-coil dynamic microphone", and this is also the principle used in moving-coil phone cartridges. Of course, it is also possible to hold the coil fixed and move the magnet. Such devices are called "moving-magnet" microphones and cartridges.
C. CHANGING THE MAGNETIC FIELD THROUGH A LOOP OF WIRE (DEMONSTRATION STATION)

Another manifestation of Faraday’s Law is that a current can be generated in a loop of wire by changing the strength of the magnetic field within the loop. This is the principle used in electric guitar pickups. In such a pickup, a wire is wrapped around a magnet (Once again, the more turns of the wire, the more signal). The “magnetic field lines” pass through the magnet and then out into the air, where they curve around and come back into the magnet at the other end.

Air has a high “reluctance”, which means that it resists the flow of magnetic field lines. Iron and steel have a very low reluctance, so the magnetic field will be stronger if a steel string is placed nearby. This change in the location of the field induces a current in the coil of wire. The effect of this current is displayed on the scope.

Use the pickup to detect the vibration of the vibrating steel string which has been set up.

Is the signal different for string vibrations in different directions (vertical, horizontal)?

How large can the signal get?

Which orientation of the pickup with respect to the wire gives the best signal?

How close does it have to be?
III. TRANSDUCTION USING CAPACITANCE

Magnets are bulky and heavy, and stray magnetic fields can cause problems in surrounding electrical equipment. A number of transduction devices use other techniques. Often these transducers are simple and durable but low in quality, such as the carbon microphone in a telephone or "piezo-electric" phono cartridges. An exception is the Condenser Microphone which is rather difficult to make but can have an excellent response. "Condenser" is an old-fashioned word for a capacitor, a pair of conducting plates separated by an insulator. The plates are charged. When they are then moved back and forth, charge is forced off and on the plates, creating a current.

Build a condenser microphone and see if you can get it to work! Your instructor will provide help. See the sample microphone at the demonstration station for hints.

1. Building a condensor microphone

You will need:
- Small aluminum plate
- 1 6-inch square 1 mil mylar sheet.
- a 3 to 4 inch square of 1/2 mil aluminized mylar
- masking tape

Instructions: Tape the plain mylar to aluminum plate. Put a layer of masking tape all around the edge. Place the aluminized mylar square on top of this and tape it down metal side up (it does not need to be taped all the way around, and should be only somewhat tight). Apply a piece of copper tape to the aluminized mylar to make your electrical connection. Connect the clips of your cable onto (a) the plate and (b) the copper tape attached to the diaphragm. Connect the inputs to the scope.

Try out your microphone. These should give signals large enough to distinguish between different vowel sounds on the oscilloscope. Do not try to record this signal with the computer – the impedances of the two devices do not much.

How big is the signal you can produce? Show your signal on the scope to your instructor.

In general, the frequency response is better for a condensor mike than a ribbon mike. How would you explain this fact?
In real condenser microphones, a battery is used to maintain a charge on the plates (here, a small amount of static charge is present), so it is important to TURN OFF real condenser microphones when you are done with them, or you run down the batteries.

It is possible to use a plate which has a permanent charge on one plate. This is called an Electret Microphone. A large condenser microphone run backwards is an Electrostatic Speaker.