THE SPEED OF SOUND IN A SOLID

REFERENCES

1.) The Signal Generator - Model 19, and *The Oscilloscope*. Both of these writeups are in the section entitled Commonly Used Instruments at the back of this lab manual.

INTRODUCTION

Everyone knows the old trick of putting your ear to a train track to get early warning of an approaching train. Sound can travel great distances in many solid materials, and moreover, it travels quickly. The speed of sound in an iron rail is roughly ten times that in air!

In this experiment we measure the speed of sound in a plastic rod. The technique we use is straightforward. We “tap” the rod at one end, and measure the time, t, it takes for the tap to be “heard” a distance d along the rod. If this is done for several distances, a plot of d vs. T will yield a straight line. The slope of this line is the speed of sound in the rod. Figure 1 shows the equipment used in the experiment.

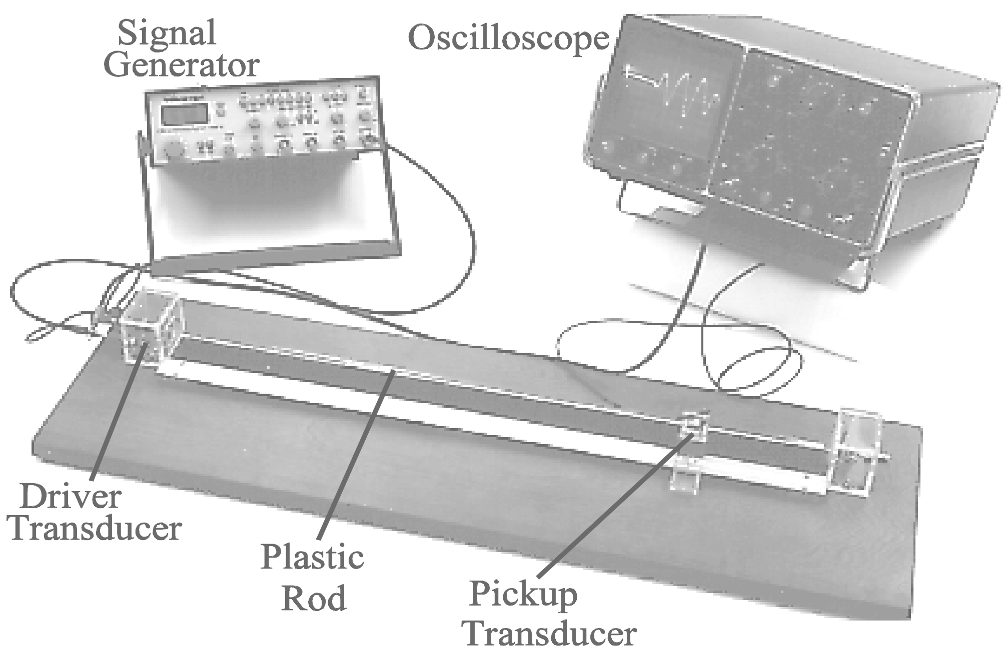

Figure 1: Equipment used to measure the speed of sound in a plastic rod. The signal generator supplies a voltage pulse to the driver transducer which converts the electrical pulse into a mechanical pulse. This mechanical pulse travels, as a sound wave, down the length of plastic rod and is detected by the pickup transducer. The pickup transducer converts the sound wave into an electrical signal. The oscilloscope is used to measure the time interval between the pulse supplied to the driver and the pulse detected by the pickup transducer.

THE EXPERIMENT

Connect the signal generator to the driver transducer and select a square wave output. Turn up the generator amplitude enough that you can start to hear a faint buzzing. The exact frequency you use is not important but it should be somewhere between 50 and 100Hz. Connect channel A of the scope to the driver's terminals, and adjust the scope as above, so that 2 or 3 stationary square waves are seen.

Now connect the pickup transducer to channel B of the scope, and adjust the channel B position and AMPL. controls so that the pickup signal is also seen. Make a sketch of what you see in your notebook and try to explain the main features qualitatively. Now increase the TIME/cm setting on the scope until the signal in channel B resembles that shown in Figure 2. Make a sketch of the signal you observe. Indicate on this sketch the point at which the pulse from the generator arrives at the driver, and the point at which the pickup transducer senses the sound wave. Calculate how long the time interval is between these two events. Does the time interval depend on the frequency of the signal generator's square wave? Could the time interval be measured accurately if this frequency was very large, say 1000Hz? Try it, and explain what happens.

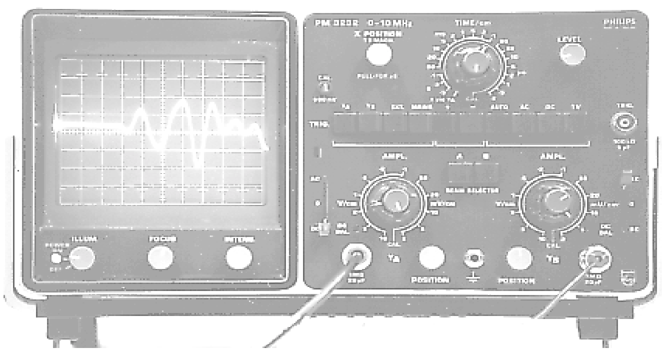

Figure 2. - A typical output signal from the pickup transducer.

Measure the time interval, t, as a function of the separation, d, between the driver and pickup transducers. Once you have 5 or 6 pairs of d and t values, plot d vs. t, and calculate the speed of sound in the rod. Compare the value you obtain with typical values for plastics (See the CRC handbook.).

Actually, there is not only one type of sound wave that can propagate through solid materials. In fact, there are at least three different types of sound waves, each with its own unique speed of propagation. Longitudinal waves (based on compression and rarefaction) are the fastest. Transverse waves (based on bending) and torsional waves (based on twisting) travel considerably more slowly. Of what type of wave does the present experiment measure the velocity - and how do you know?

RESONANCES

The apparatus for this experiment can also be used to study the phenomenon of resonance.
Once the sound wave generated by the driver has traveled the length of the rod it will be reflected back towards the pickup transducer. The wave may bounce back and forth several times before finally dying out. If the length of the rod happens to be an integral number of half wavelengths, then a wave reflected from an end will add constructively to the wave incident on that end, and large amplitudes will result.

Apply a **continuous sine** wave input to the driver transducer and search for resonances. (That is, find the frequencies for which the pickup transducer records especially large amplitudes; the signal from a cable attached to the ***end*** of the rod is often easier to see.) The wavelengths for which we expect a resonance are given by the condition

$$l = n\,\lambda/2, \qquad \ldots (1)$$

where n is an integer (=1, 2, 3, etc.) and l is the length of the rod. (You should make sure you understand how to derive this expression). Since wavelength and frequency are interrelated, the resonance condition may also be written $f = c/\lambda = n \cdot c/(2l)$, ... (2)
where f and c are the frequency and speed of sound respectively.

Using your measured value for c, calculate the expected three lowest resonance frequencies. Do you actually find resonances close to these frequencies? You may notice more resonances than are predicted by equation (2). Where might these additional resonances come from? Would resonances for the three different types of waves all occur at the same frequencies? In fact, due to these effects, you can probably expect only an approximate agreement between calculated and observed values.

(rs,tk,mf - 1997: tk - 1998)

VELOCITY OF SOUND IN A SOLID

Preparatory Questions.

Note: We hope that the following questions will guide you in your preparation for the experiment you are about to perform. They are not meant to be particularly testing, nor do they contain any “tricks”. Once you have answered them, you should be in a good position to embark on the experiment.

1. What is the algebraic relationship between the wavelength and the frequency of a sound wave?

2. The instructions for this experiment say to use a square wave to drive the transducer. Could a triangle or sine wave be used instead?

3. Should the time it takes for sound to travel from the driver to the pickup depend on the frequency of the signal generator? Explain.

4. How might you detect a resonant frequency of the plastic rod *without* using an oscilloscope?

5. What are the three lowest resonant frequencies in a rod of length 1 metre, if the speed of sound in the rod is 2000 m/s?