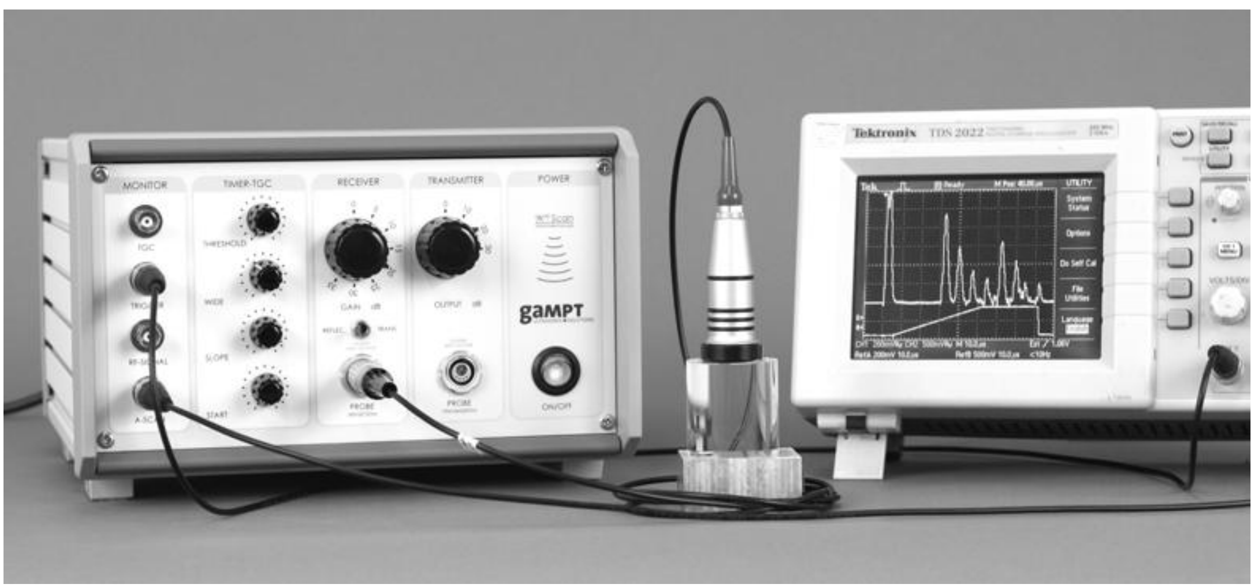
TeachSpin's UltraSonics
A Conceptual Introduction to the Experiment

Although, for most people, the first thing 'ultrasonics' brings to mind is medicine, the very techniques used to develop medical applications depend on an important area of physics that is often underrepresented in the upper division lab.

The parameters of interest in ultrasonic measurements are frequency, wavelength, propagation velocity, acoustic impedance and absorption coefficient. The frequency is determined by the electronic oscillator that drives piezoelectric transducers which, in turn, create an ultrasonic compression wave. But these transducers can also be used as ultrasonic receivers (or microphones), converting ultrasonic energy into electrical signals. The TeachSpin system includes various types of electronics, both pulsed and continuous-wave, which are customized for a variety of experiments.

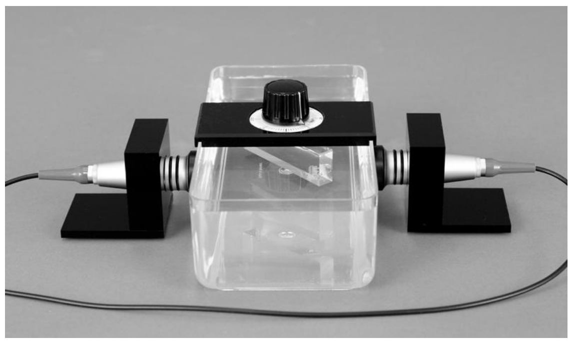
The Echoscope, a very versatile pulsed unit, is used in conjunction with 1, 2, and 4 MHz transducers that can act as both transmitter and receiver for a variety of explorations.

Ultrasonic waves, like electromagnetic waves (and light in transparent media) exhibit reflection as well as transmission when there is a discontinuity of the impedence at a boundary. The 'set-up' for a deceptively simple experiment is shown below.



The transducer is mounted on top of a stack consisting of an acrylic cylinder of height 41.3 mm on top of an aluminum block that is 24.2 mm high. The 1 MHz transducer being used for this experiment first creates a short ultrasonic driving pulse and then becomes a receiver to detect the time-delayed ultrasonic echoes. The sound waves encounter two significant boundaries, first at the acrylic-aluminum interface, and then at the aluminum-air end. The first impedance discontinuity encountered by the acoustic wave, the acrylic-aluminum interface, causes a reflected compression wave which travels back to the transducer. That reflection creates the first ‘echo‘ shown on the oscilloscope and the speed of the wave in this particular acrylic can be calculated from the time delay. The second echo is from the part of the wave that has gone through and reflected from the aluminum-air interface and can be used to calculate the speed of sound in the aluminum. Figuring out and verifying the source of the subsequent is a nice challenge!

Another interesting investigation demonstrates the difference between the behavior of sound in liquids and solids – specifically the difference between compression and shear waves. The sound pulse is sent into a water tank with a rectangular acrylic slab of 10 mm thickness obliquely immersed in it In this experiment, two transducers are used, one to inject an ultrasonic compression pulse into the tank and a second one to receive the ultrasonic waves that propagate to the opposite side.



Initially students are surprised that *two* pulses are received at the opposite end. The reason for the two signals is the creation, at the first water/acrylic interface, of two kinds of waves in the acrylic slab: a longitudinal (compression) wave, and a transverse (shear) wave. In the solid medium, this shear wave propagates at a significantly lower velocity than the compression. However, a shear wave will not propagate in a liquid. Thus, the shear wave in the solid, encountering the interface at an oblique angle, launches only a compression wave in the liquid, which then travels to the receiver. This set-up can also be used to determine the velocity of both the compression and shear waves in the solid, and the critical angle for total internal reflection, as well as the velocity of sound and the attenuation coefficient for compression waves propagating in the liquid. (In geophysics, compression and shear waves moving through the earth are called p-waves and s-waves.)

A very different set of experiments can be done with the Wave Generator SC 500 which produces a high-power continuous wave adjustable from 1 – 20 MHz. The electronics box includes a built-in power supply for operating the solid-state laser needed to observe the Debye-Sears effect. A special broadband ultrasonic transducer is mounted on top of a water-filled cell. Changes in the pressure in the water produce changes in the index of refraction. The standing waves create a 3-d grating. Shining the laser through the water gives an easily observed diffraction pattern. The experiment not only demonstrates the fascinating and highly applicable acousto-optic effect, but can also be used to measure the wavelength of sound in an optically transparent medium as a function of frequency.

This is only a beginning of what can be studied. Using additional apparatus to look at Doppler flow measurement introduces a whole other set of possibilities.