Waves on a Wire

This lab involves investigating the velocity of a wave on a steel wire in two different ways. In the first method, discrete pulses are generated on the wire and the wave velocity is determined directly by measuring the "time of flight" between two detectors. In the second method the wire is driven continuously in one of its normal modes and the wave velocity is determined from the wavelength and frequency of the oscillation. The wave velocity can also be calculated from theory.

Before You Come to Lab:

Review your knowledge of wave velocity (HL 4.6). How does it depend on physical parameters? How is the velocity related to the normal mode frequencies (HL 6.2)?

I) Time of flight measurement

Set up the thinner of the two wires with a tension established by hanging up to 4 kg of mass from the end. (The amount you choose is not critical, as long as the wire does not snap.) Pulses are generated on the wire electromagnetically. A large (~1000 μF) capacitor is charged to 90 V and then suddenly discharged through the wire when a button is pressed. A strong magnet placed near the wire causes a sudden transverse force on a short segment of the wire when the current pulse passes by. This same electrical pulse can be used to trigger the dual-trace storage oscilloscope.

The detectors are electric guitar pickups which sense the motion of the steel wire. (Can you figure out how they work?) The signals from the detectors are displayed on the oscilloscope, allowing a determination of the time of flight. You will have to be careful about effects due to reflections of the pulses from the ends of the wire.

The toggle switch on the interconnection box must be in the "DC" position for this part of the experiment. You will observe the time of flight on a digital oscilloscope, which, unlike an analog oscilloscope, will record and continuously display data from a single trace. A short document, "The Tektronix 2430A Digital Storage Oscilloscope -- A Brief Introduction ," is available to help you get started. Two of this oscilloscope's features that you may want to use in this lab are on-screen measurement using cursors and hard copy plotting of the screen display.

II) Standing wave measurement

The wire can be driven in one of its normal modes (a standing wave) by using a variation of the magnet scheme described above. Alternating current is driven through the wire by a "bipolar operational power supply" which behaves like a powerful amplifier whose input is provided by a synthesized function generator. (WARNING: Keep the current below 350 mA for the thin wire, and below 600 mA for the heavy wire. The current limit screwdriver

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adjustment on the operational power supply should be set to about 600 mA.) The frequency of the signal can be determined with a frequency meter. When the magnet is placed near the wire, the wire will be driven at the driving frequency. The optimum magnet position depends on the mode you are trying to excite. (Why?) The display and controls of the synthesized function generator refer to the output frequency or amplitude as selected by pressing the FREQ or AMPL buttons. A frequency or amplitude can be entered by pressing the number keys, followed by (for example) the Hz or V_{pp} button. The value can also be raised or lowered by steps using the Δ or ∇ buttons, with a step size that can be adjusted using these same buttons after pressing the STEP SIZE button. This feature is particularly useful when searching for the frequency of a mode.

Measure the frequencies for several modes of both the lighter wire and the heavier wire. Calculate the wave velocities. Is there any evidence for dispersion (the dependence of wave velocity on frequency)? You may need to look at some high harmonics to answer this (note that once you know the frequency of the fundamental you can calculate the approximate frequency of a higher order mode). Careful error analysis will be needed to know if any apparent effects are significant.

III) Calculation of the wave velocity from theory

Do theoretical calculations of the wave velocity using the measured values of tension and linear mass density of the wires. Don't forget error analysis. How do the values of the wave velocity compare?

IV) Suggestions for further work

It could be fun to try to "terminate" the wire so it behaves as though it were infinitely long (no reflections). Can you think of any way to improve the results of this experiment? What suggestions do you have for investigations inspired by this work?

R.R.C.	1/21/83
S.J.H. rev.	1/14/91
R.R.C. rev.	2/15/93
C.E.C. rev.	1/19/96