22400 Longitudinal Wave Model

Purpose:

To demonstrate the action of traveling longitudinal waves.

Discussion:

The propagation speed of longitudinal (or compression) waves is determined by the mechanical properties of the medium through which it travels. Although a traveling wave of alternating compressions and rarefactions is observed, the individual particles in the material only exhibit simple harmonic motion (oscillation) about their equilibrium positions. The traveling motion of the longitudinal wave is a result of the 'phase' difference of the oscillation between neighboring particles.

When the driving knob on the right side of the model is rotated in a clockwise direction, an endless train of compressions is seen to travel from left to right across the model. However, upon closer inspection, it will be seen that the individual particles do not 'travel' but simply oscillate about an equilibrium position. Why do we observe a bulk traveling wave of alternating compressions and rarefaction if the particles remain in a confined space?

Each particle on the model is oscillating with the same frequency and an identical amplitude, however, the phase of each particle's oscillation lags behind the phase of its left hand neighbor by 30 degrees. This may sound a little mysterious but it is simply a consequence of the individual particles 'reaction time'.

As an example, if 10 students were lined up in front of the class, single file, facing from left to right, and were asked to tap the student in front of them on the shoulder when they felt a tap from behind on theirs, we would have a simple model of 'phase lag'. When the instructor sets the experiment in motion by tapping the left most student on the shoulder, the tapping will proceed from left to right with a 'time lag' between each tap. This 'time lag' or 'phase lag' is a measure of each student's reaction time.

This same type of phenomena is occurring between neighboring particles, however, since each particle is undergoing cyclic motion and one complete cycle is 360 degrees, the 'time lag' is termed a 'phase lag' and measured in degrees (remember $\theta = 2\pi ft$ radians for simple harmonic motion).

Each 'particle' on the wave model has a 30 degree phase lag with respect to its left neighbor. This produces a gradual phase change as we move along from left to right. Every twelfth particle is in phase (a phase difference of 360 degrees is one complete cycle) and every sixth particle is out of phase (180 degree phase difference).

The model is provided with black markers to label individual particles and to help clarify any discussion of phase differences. By attaching markers to any two particles separated by one wavelength (λ) one can illustrate the formula $V = \nu \cdot \lambda$ by timing the vibrations/second (ν) for the individual particles. After the calculation has been made, the actual speed of the wavefront can be timed to provide a direct comparison.

Although the passing of compressions and rarefaction is commonly explained as being a direct consequence of the gradual phase change of the individual particles as we move away from the source, the longitudinal wave model allows a more complete explanation to be given which should appeal to all advanced level physics teachers. By running the model slowly, the air movements in a sound wave and the forces that cause them can be studied in more detail than is customary such as the fact that the motion of any particular air layer is controlled entirely by the pressure difference between its two sides and by its own inertia, as well as the fact that in a compression, the air is always advancing whereas in a rarefaction it is always receding.

Time Allocation:

To prepare this product for a typical demonstration should take less than two minutes. Actual demonstration times will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.