3.4.2.2: Longitudinal Wave Simulation

Longitudinal waves can be described mathematically by the same equation as transverse waves: $y(x,t) = A\sin(2\pi x/\lambda - 2\pi ft + \phi)$. Only now, $y(x,t)$ is the *horizontal* displacement at time t and location x of the material in the wave from equilibrium instead of the vertical displacement from equilibrium. As was the case for transverse waves the forward velocity of a longitudinal wave is given by $v = \lambda f$.

The following simulation shows a graph of the longitudinal motion of one row of molecules, the red dots, in a collection of molecules which has a longitudinal wave passing through it, much like sound passing through air. A vertical line marks the equilibrium location of the red circle. Random thermal motions are not shown.

Simulation Questions:

1. Click 'play'. Do any of the dots travel all the way across the simulation to the other side? Explain.
2. Left clicking (single click for Mac users) on the upper panel gives the time and displacement of points on the graph in the yellow box. Determine the amplitude (maximum displacement from equilibrium) and the period of oscillation from the graph.
3. Left clicking on the lower panel gives the x and y locations of points on the wave in a yellow box. Pause and step the animation until the red dots are at their equilibrium position. Find the wavelength of the wave using the mouse by finding the distance between one place where the circles are clumped together to the next location (or from two successive locations where the circles are furthest apart). What is the wavelength?
4. From the period and wavelength find the speed of this wave (Hint: The same equations work for both longitudinal and transverse waves).
5. For sound the wavelength (or frequency) tells us something about the ***pitch*** of the sound. There are other aspects of pitch perception which involve other physical features of the wave but the main component of pitch is the frequency. What is the frequency of the wave in the simulation?
6. Click the 'V' box and then 'play'. How does the top graph with displacement and transverse velocity compare to the graph for the transverse case?
7. Write an equation of the form $y(x,t) = A\sin(2\pi x/\lambda - 2\pi ft + \phi)$, filling in the values of A, f and λ for this wave assuming the phase angle is zero.

Advanced Questions

Notice that the circles in the simulation move back and forth with a variable speed around an equilibrium position while the wave moves only in one direction with a constant speed. The velocity of the individual particles is given as before by the derivative of the displacement: $v(x,t) = \partial y(x,t)/\partial t = -A\omega\cos(kx - \omega t + \phi)$ where k and ω are defined the same way as in the transverse wave case.

1. Click the 'V' box and then 'play'. The upper graph now gives the velocity of the red dots as a function of time. What is the maximum velocity (approximately) of the red dot according to the graph? How does this compare with the velocity of the wave which you found in 6.4? How does it compare with $v_{max} = A\omega$?
2. In your own words, explain the difference between wave speed and particle velocity for a longitudinal wave.
3. Where is the red dot relative to the vertical line when the maximum velocity occurs? Where is it when the velocity is approximately zero? What is the relationship between position and velocity?
4. How do your answers for the previous question compare with your answers for this question in the transverse wave case?
5. Take a derivative of velocity to find an expression for acceleration of particles in the material (the red dot). Show that the maximum acceleration is given by $a_{max} = A\omega^2$.
6. Calculate the maximum acceleration of the red dot using $a_{max} = A\omega^2$. If amplitude is in meters and angular frequency in radians per second, what are the units of this acceleration?