Wave Fundamentals

Objective: Understand three basic waves: transverse waves, longitudinal waves, and circular waves.

Background: A **wave** is a disturbance that propagates in space. A one-dimensional wave traveling in the positive *x* direction can be represented by a **wave function** of space and time:

$$g(x,t) = g(x - vt)$$

where the function g can take any **waveform** (wave profile) and is dependent on time t and space coordinate x; v is the speed of the wave. It can be shown that g satisfies the **wave equation**,

$$\frac{\partial^2 g}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 g}{\partial t^2}$$

A very important class of waveforms is the sine or cosine functions which can be represented by

$$g(x,t) = A\sin(\beta x - \omega t + \varphi_0)$$

where A is the **amplitude**, β is the **angular wavenumber** (or **phase constant**), ω is the **angular frequency**, and φ_0 is the **initial phase**. For **frequency** f, **period** T, **spatial frequency** ν (not the velocity v), and **wavelength** λ, we have the following relations:

$$f = \frac{1}{T},\ \omega = 2\pi f = \frac{2\pi}{T} \text{ (time related)}$$

$$\nu = \frac{1}{\lambda},\ \beta = 2\pi\nu = \frac{2\pi}{\lambda} \text{ (space related)}$$

Note the symmetry between time and space reflected in the above two sets of equations.

A wave is the propagation of a disturbance which can be caused by the vibration of some particles (such as molecules in the air for sound waves). When some particles are vibrating, they affect the neighboring particles and cause them to vibrate subsequently. This chain effect leads to the propagation of the disturbance (vibration) from one place to another. Most importantly, the particles themselves are not necessarily propagating together with the disturbance they caused, i.e., the propagation of the disturbance does not mean the propagation of the particles.

When the direction of the vibration of particles is the same as the propagation direction of the disturbance, we have a **longitudinal wave**; when the direction of the vibration of particles is perpendicular to the propagation direction of the disturbance, we have a **transverse wave**. We can have more complicated waves that are the combination of longitudinal and transverse waves.

Lab Description: In this lab we observe a collection of particles while they are vibrating. When these particles are observed as a whole, we see waves propagating in one direction; while we look at one particular particle, we can see the particle is vibrating in a certain way and it does not travel with the wave (the disturbance).

Fig. 1 shows a screen shot of one of the waves.

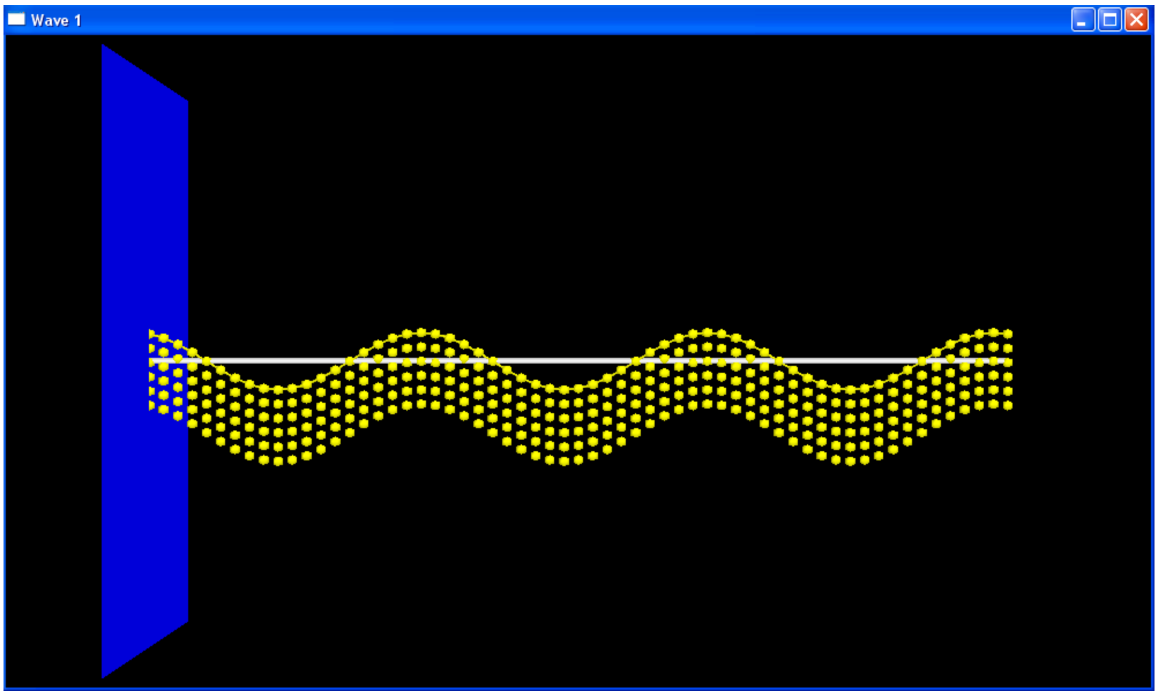

Fig. 1. A snap shot of the particles and the wave

The operations you can use to explore the software:

- When the program is running, you can click the left button of the mouse in the animation window to start/stop/continue the wave motion.
- Press key 's' to assume the 'stepping mode' in which each mouse click (left button) will cause the program run one step. Press key 'c' to quit the stepping mode.
- You can click the right mouse button to change the color of a particle under the cursor (at the same time other particles are dimmed). It is recommended to do so when the wave is not in motion (otherwise it's not easy to click on the particle you want to change its color). Note that in the stepping mode, this function does not work.

Exercises

For each of the three waves, answer the following questions:

1. Which direction is the disturbance (wave) traveling?
2. In which direction are the particles vibrating?
3. Is this wave longitudinal, transverse, or circular?
4. Does any particle travel with the wave?
5. What does the green curve (the wave form) represent?
6. Can you give a real life example similar to this wave? Explain why they are similar.