MUS 7: Sound Waves

Instructor: Jingwei Liu

S124 UC San Diego

Phonograph (1877) and Vinyl (1948)

- Until the invention of phonograph, notation was the only way to record music other than through memory.
- Thomas Edison invented phonograph, a device that records sound vibration waveforms by physical cutting in 1877.
- Vinyl records, which was firstly released in 1948, works in the same principle as phonograph, only with cylinder replaced by flat disc.


No Electricity
to Play Music
How ?

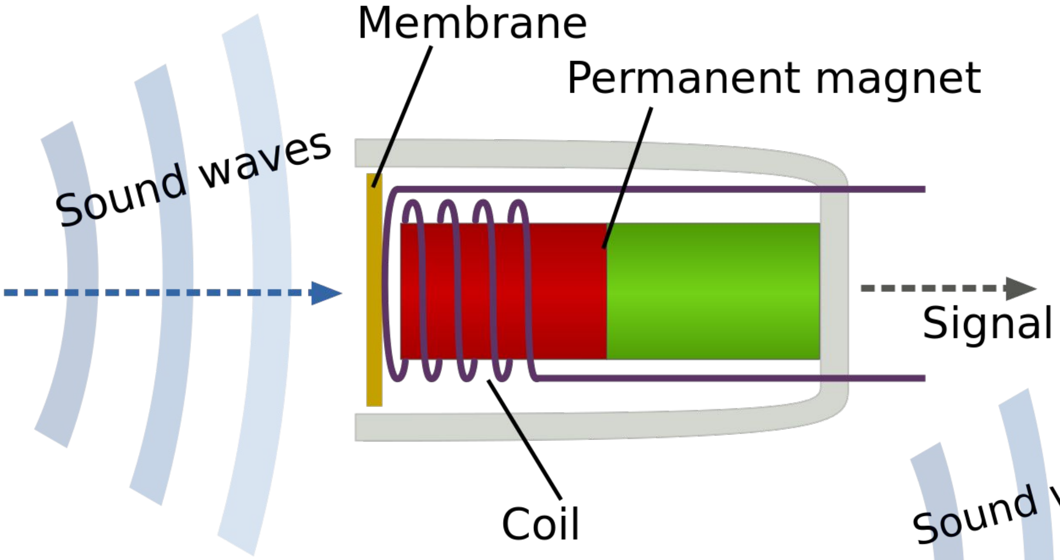

REAL
ENGINEERING
THE
TRUTH
ABOUT VINYL


HOW SPEAKERS
MAKE SOUND
IN FULL
3D
ANIMAGRAFFS

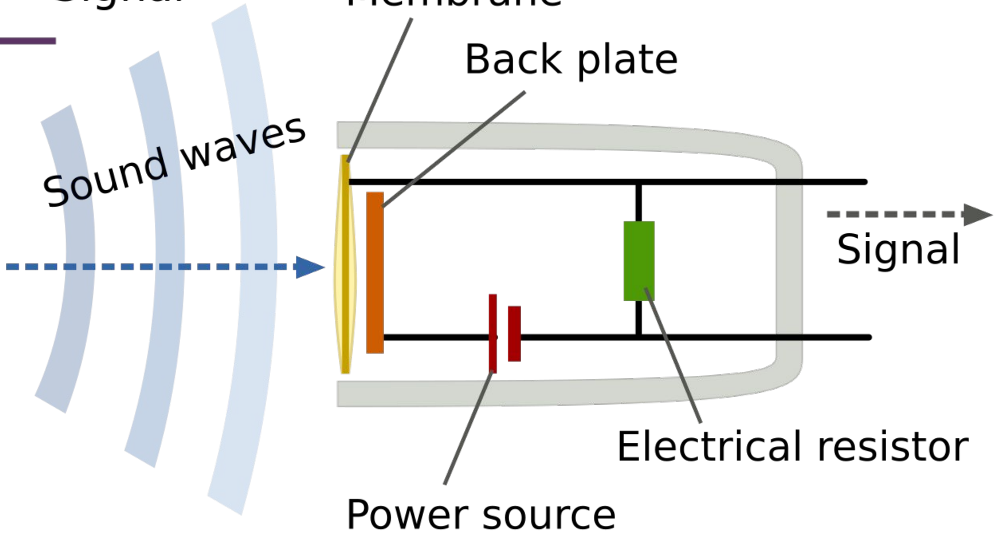
Microphone

- The **dynamic microphone** (also known as the moving-coil microphone) works via electromagnetic induction. They are robust, relatively inexpensive and resistant to moisture. This, coupled with their potentially high gain before feedback, makes them ideal for onstage use.
- The **condenser microphone**, is also called a capacitor microphone or electrostatic microphone. The diaphragm acts as one plate of a capacitor, and audio vibrations produce changes in the distance between the plates. Because the capacitance of the plates is inversely proportional to the distance between them, the vibrations produce changes in capacitance. These changes in capacitance are used to measure the audio signal.


HOW DO
MICS
WORK
DYNAMIC || CONDENSER



Inner workings of the dynamic microphone



Inner workings of the condenser microphone

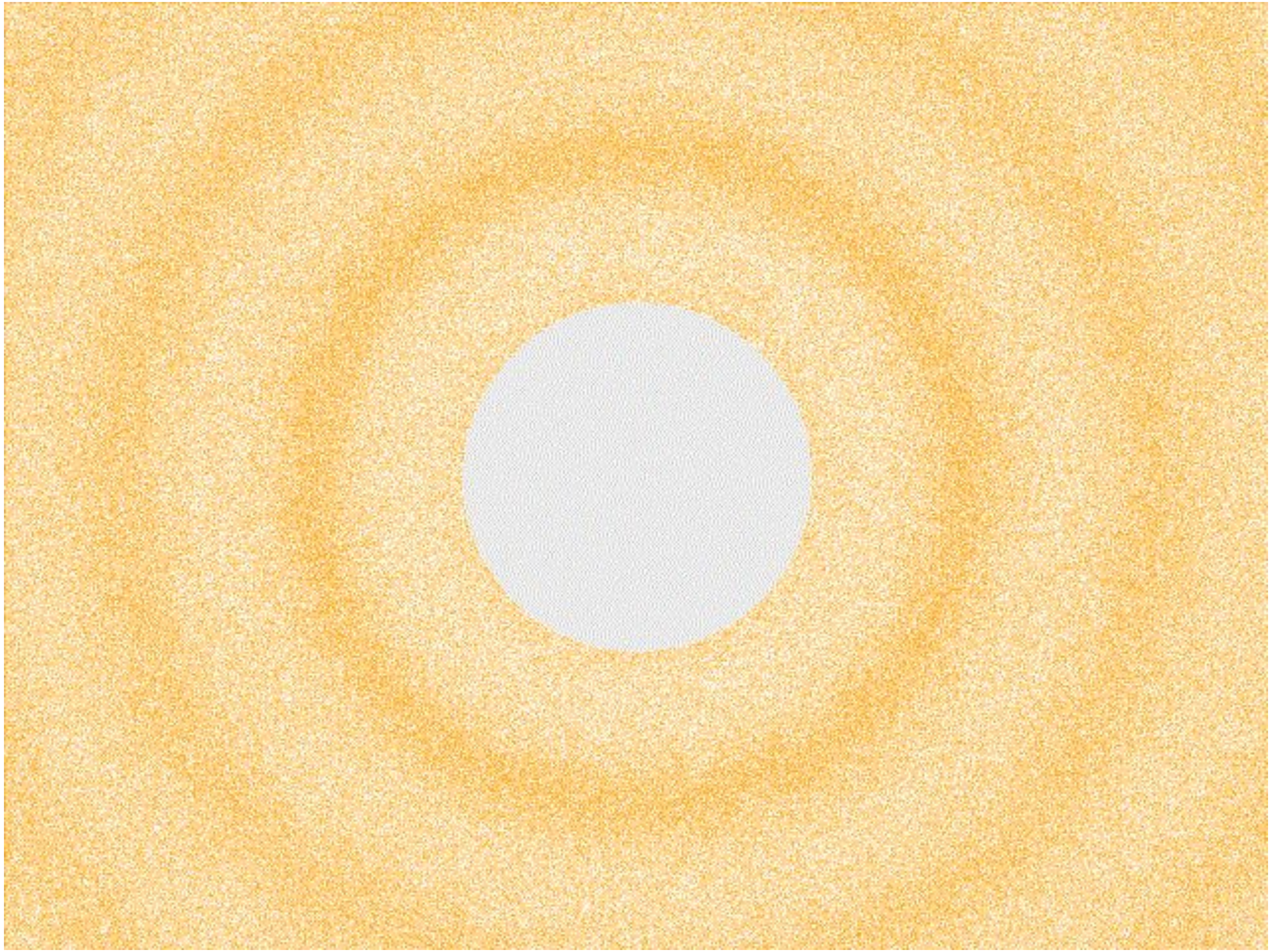

What is
Sound?

Sound as Mechanical Waves

- In physics, sound is a vibration that propagates as an acoustic wave through a transmission medium such as a gas, liquid or solid.
- In physics, a mechanical wave is a wave that is an oscillation of matter, and therefore transfers energy through a material medium
- Mechanical waves can be produced only in media which possess *elasticity* and *inertia*:
  - Elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed.
  - Inertia is the tendency of objects in motion to stay in motion and objects at rest to stay at rest, unless a force causes its speed or direction to change.

Physics of Sound

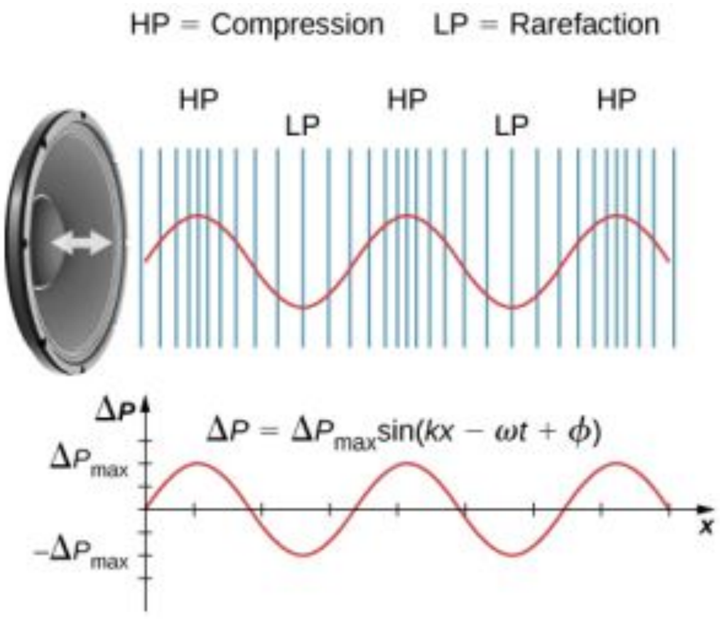
- Sound can propagate through a medium such as air, water and solids as longitudinal waves and also as a transverse wave in solids.
- The sound waves are generated by a **sound source**, such as the vibrating diaphragm of a stereo speaker.
- The sound source creates vibrations in the surrounding medium. As the source continues to vibrate the medium, the vibrations propagate away from the source at the speed of sound, thus forming the sound wave.



Spherical Compression (Longitudinal) Waves

Physics of Sound Cont.

- At a fixed distance from the source, the pressure, velocity, and displacement of the medium vary in time.
- At an instant in time, the pressure, velocity, and displacement vary in space.
- The particles of the medium do not travel with the sound wave.
- During propagation, waves can be reflected, refracted, or attenuated by the medium.

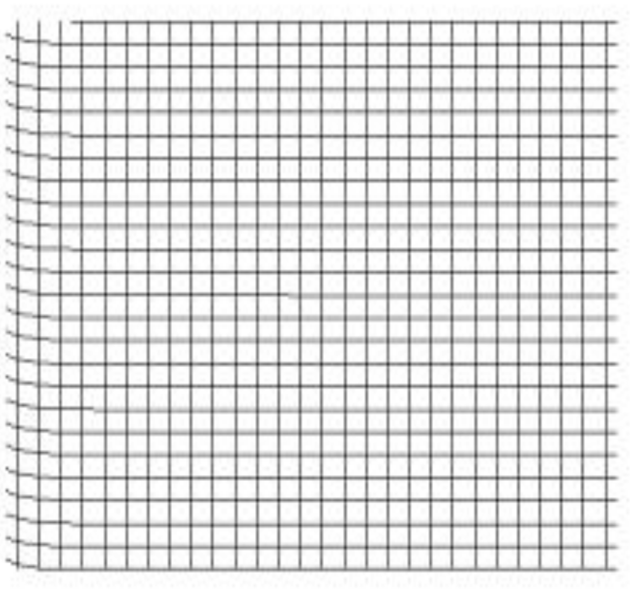


Longitudinal Sound Wave in the Air

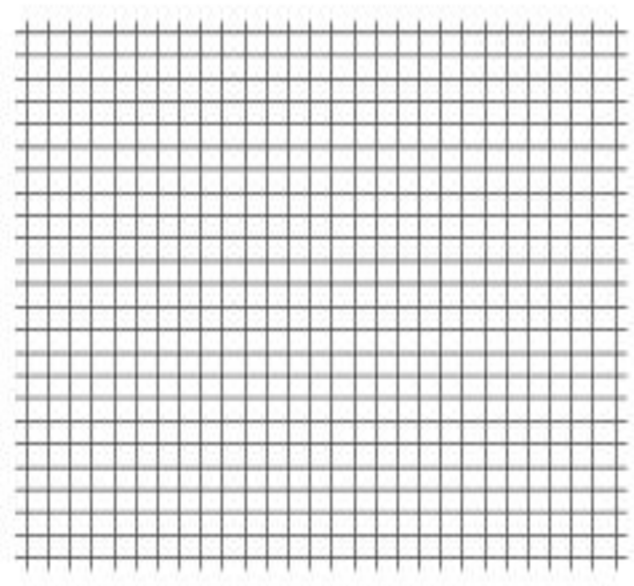

How does
Sound Travel?

Longitudinal and Transverse Waves

- Sound is transmitted through gases, plasma, and liquids as longitudinal waves, also called compression waves.
- Longitudinal sound waves are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of *compression* and *rarefaction*.
- Through solids, sound can be transmitted as both longitudinal waves and transverse waves.
- Transverse waves (in solids) are waves of alternating shear stress at right angle to the direction of propagation.



Transverse Plane Wave



Longitudinal Plane Wave

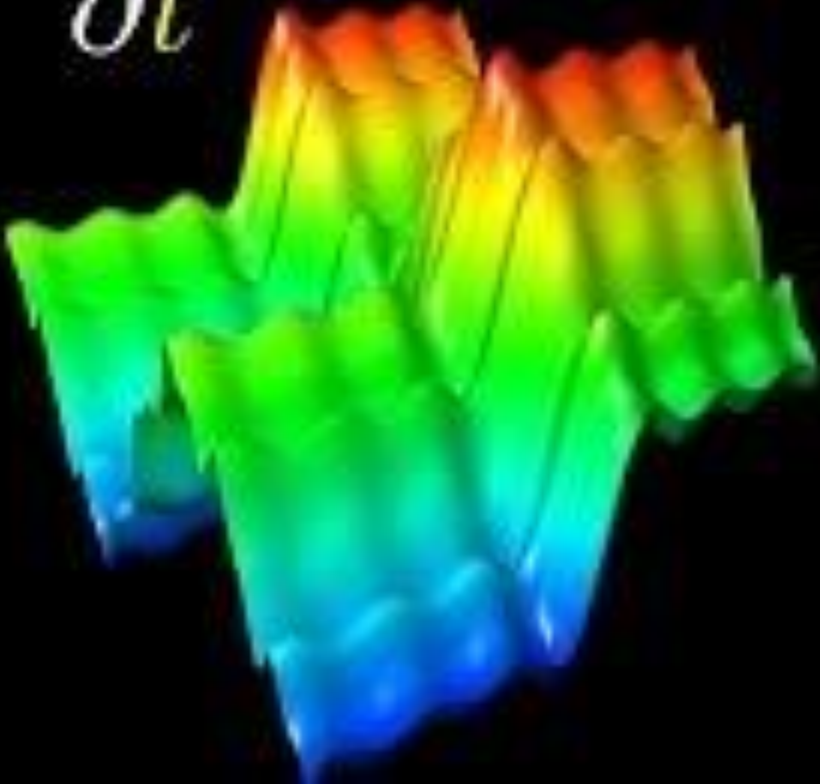
Longitudinal (<u>transverse</u>) waves are waves in which the vibration of the medium is parallel (<u>perpendicular</u>) to the direction the wave travels and displacement of the medium is in the same direction of (<u>at right angles to</u>) the wave propagation.


Sound properties
Khan Academy

The Physics of Sound Waves

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T$$

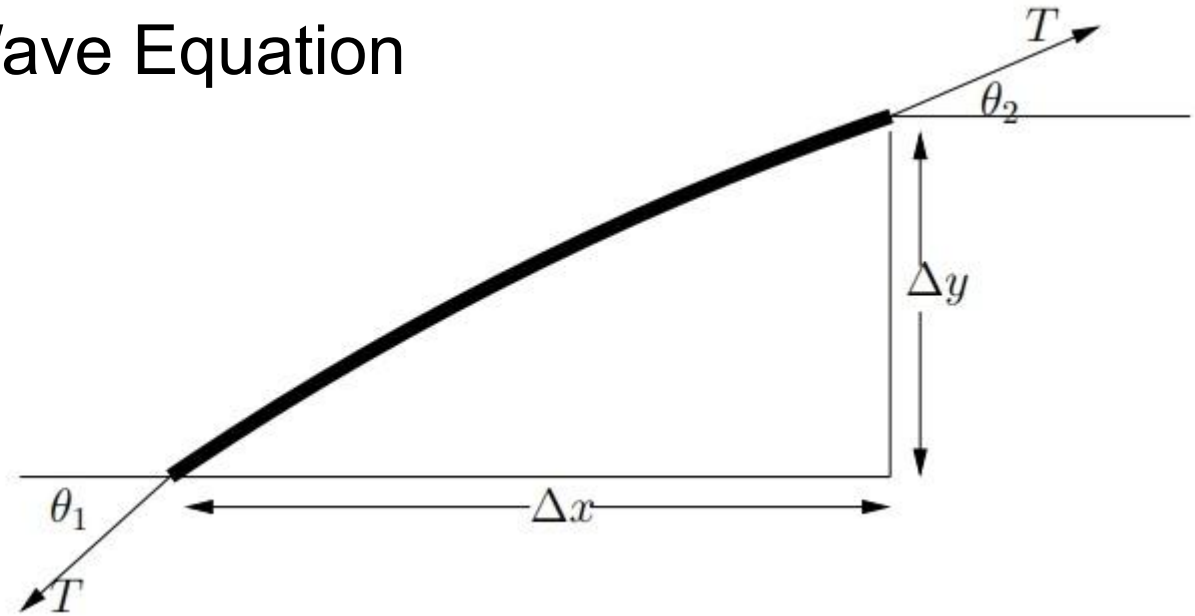
What is this?

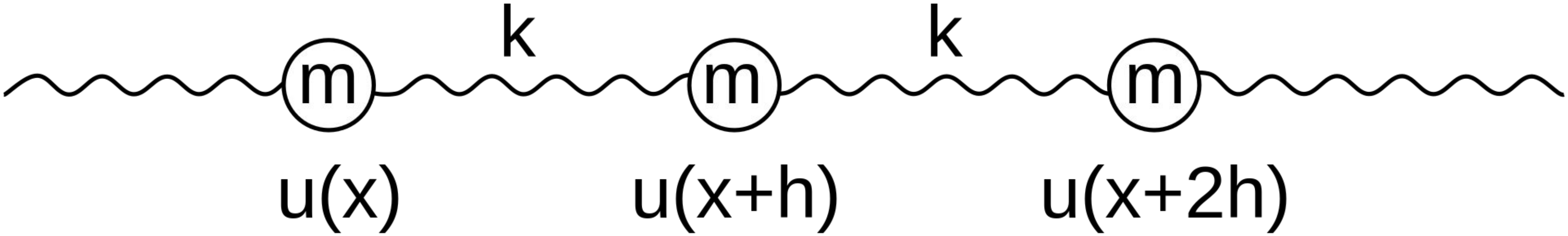


Derivation of the Wave Equation

- [The String Model]
- [The Spring Model]

$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$$





Linear Acoustics

- Small-amplitude phenomena can be described to a good approximation in terms of linear algebraic and linear differential equations.
- **Superposition Principle**: the net displacement caused by two or more waves is the sum of the displacements which would have been caused by each wave individually. In addition, the behavior of a wave can be analyzed by breaking up the wave into components, e.g. the *Fourier transform* breaks up a wave into sinusoidal components.

Wave Equation

$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$$

General Solution

$$u(x,t) = F(x - ct) + G(x + ct)$$

Initial Value Problem

$$u(x,0) = f(x), u_t(x,0) = g(x)$$

d'Alembert's formula:

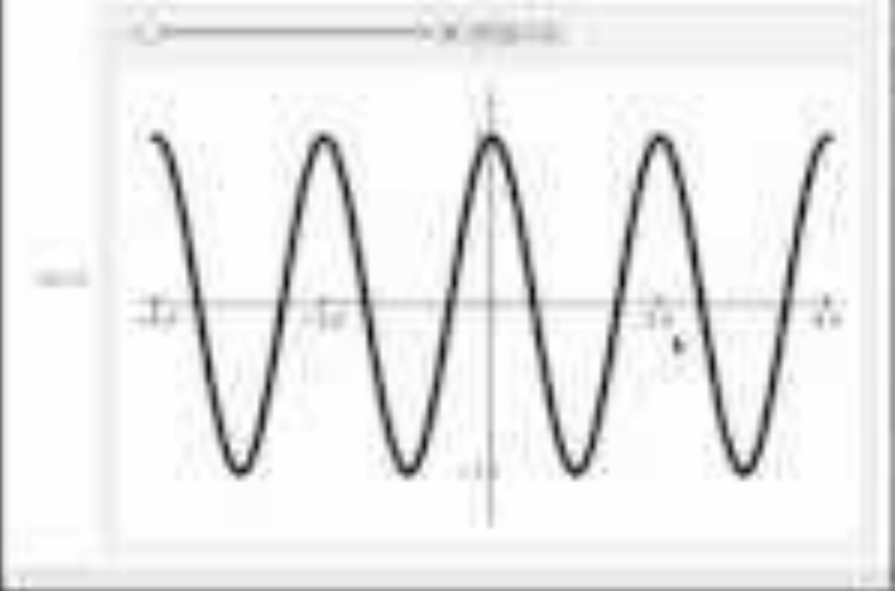
$$u(x,t) = \frac{f(x-ct) + f(x+ct)}{2} + \frac{1}{2c}\int_{x-ct}^{x+ct} g(s)\, ds.$$

Initial value problem:

$$\begin{cases} u_{tt} = c^2 u_{xx} \\ u(x,0) = f(x) \\ u_t(x,0) = g(x) \end{cases}$$

d'Alembert formula:

$$u(x,t) = \frac{1}{2}\left[f(x+ct) + f(x-ct)\right] + \frac{1}{2c}\int_{x-ct}^{x+ct} g(s)\,ds$$



$f(x) = \cos x$

$u(x,t) = \frac{1}{2}\cos(x+t) + \frac{1}{2}\cos(x-t)$

$g(x) = 0$

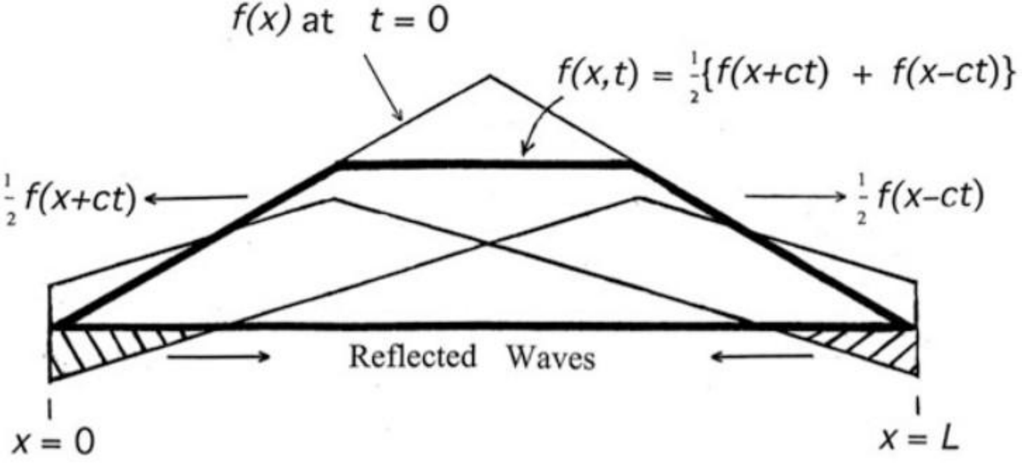
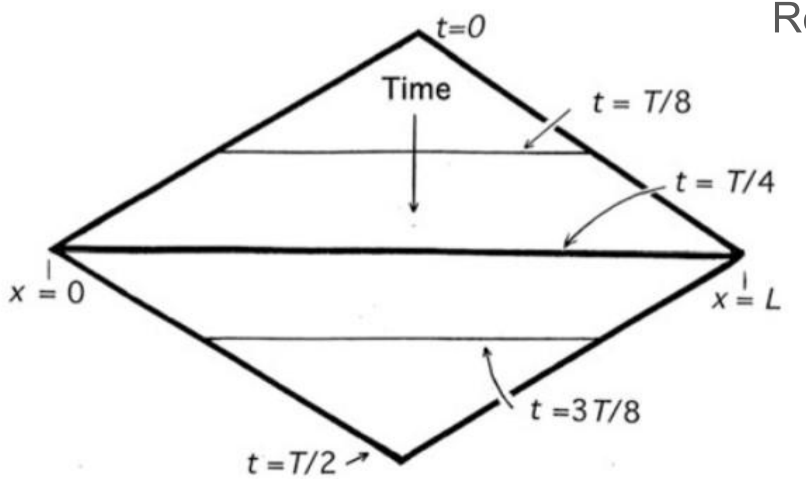
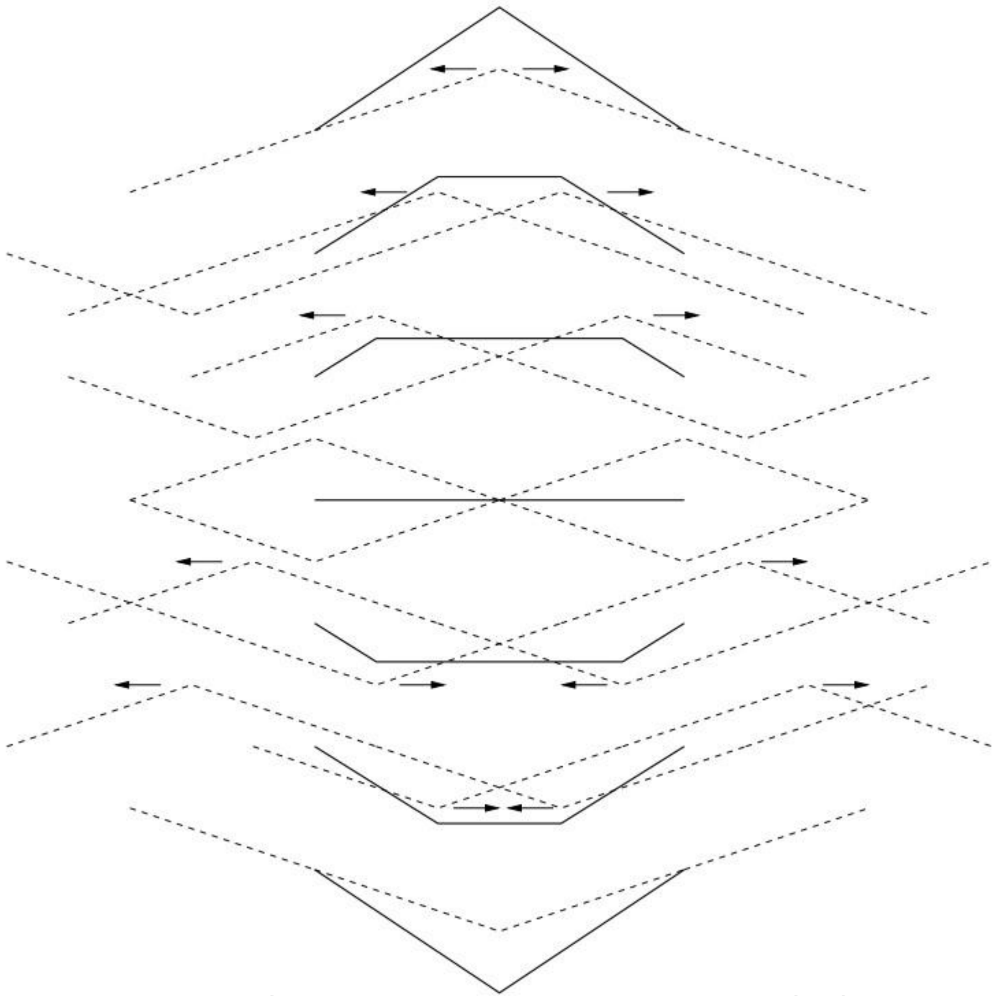


Fig. 3.4 Graphical illustration of d'Alembert's solution to the vibrating string problem. Here, the string is plucked in the middle at $t = 0$

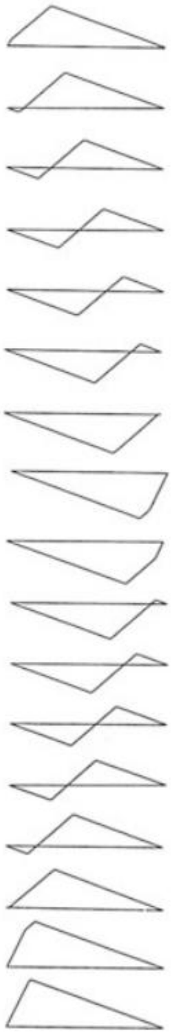
Reflection at a Fixed End of String

Fig. 3.5 Motion of the string plucked at the midpoint after release at $t = 0$



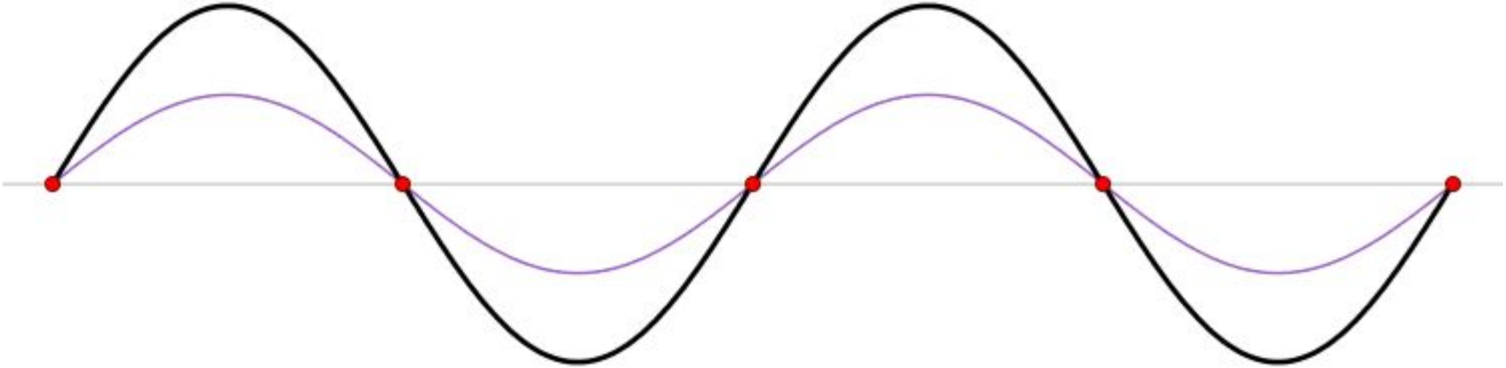


The motion of a string plucked at one-half of its length



The motion of a string plucked at 1/7th of its length

Standing Wave



$$u(x,t) = A\cos(\omega t)\sin(\frac{2\pi}{\lambda}x)$$

Physical Modeling