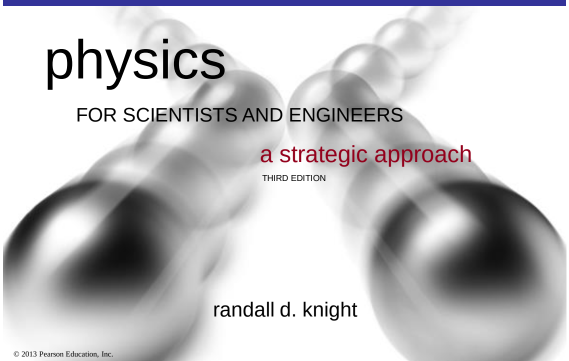
Class 1, Sections 20.1-20.3 Preclass Notes



physics

FOR SCIENTISTS AND ENGINEERS

a strategic approach

THIRD EDITION

randall d. knight

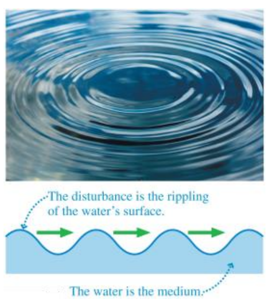
ALWAYS LEARNING PEARSON

Chapter 20 Traveling Waves

Chapter Goal: To learn the basic properties of traveling waves.

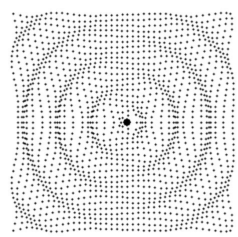
The Wave Model

- The wave model is built around the idea of a **traveling wave**, which is an organized disturbance traveling with a well-defined wave speed.
- The **medium** of a mechanical wave is the substance through or along which the wave moves.



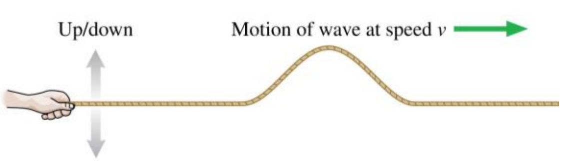
The Wave Model

- The wave propagates, but the particles of the medium don't.
- The particles in the medium oscillate up and down or back and forth as the ripples spread outward.



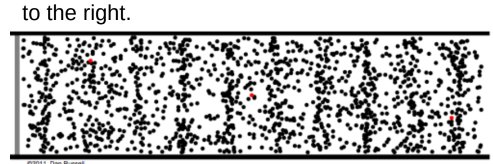
A Transverse Wave

- A **transverse wave** is a wave in which the displacement is *perpendicular* to the direction in which the wave travels.
- For example, a wave travels along a string in a horizontal direction while the particles that make up the string oscillate vertically.

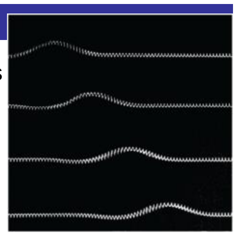


A Longitudinal Wave

- A **longitudinal wave** is a wave in which the displacement is *parallel* to the direction in which the wave travels.
- Here we see air molecules, with a disturbance produced by an oscillating wall on the left.
- Regions of compression and rarefaction propagate to the right.



Wave Speed



The speed of transverse waves on a string stretched with tension T_s is:

$$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$$

Where μ is the string's mass-to-length ratio, also called the **linear density**:

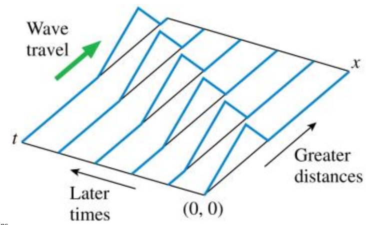
$$\mu = \frac{m}{L}$$

Units: [kg/m]

Graphing a Traveling Wave

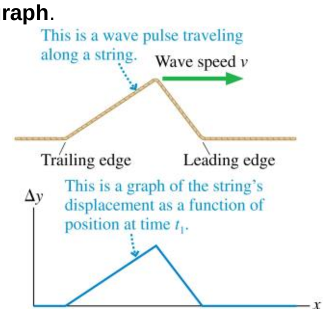
Three variables must be plotted to fully graph a one dimensional wave:

- **position** (x)
- **time** (t)
- the **displacement** of the medium (for example, Δy)



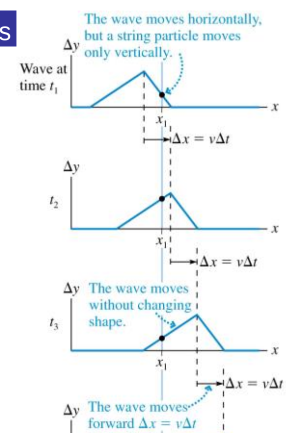
Snapshot Graph

- A graph that shows the wave's displacement as a function of position at a single instant of time is called a **snapshot graph**.
- For a wave on a string, a snapshot graph is literally a picture of the wave at this instant.



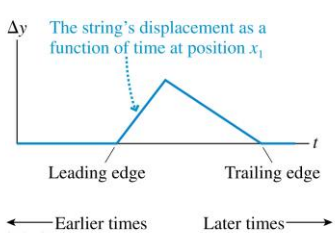
One-Dimensional Waves

- The figure shows a sequence of snapshot graphs as a wave pulse moves.
- These are like successive frames from a movie.
- Notice that the wave pulse moves forward distance $\Delta x = v\Delta t$ during the time interval Δt.
- That is, the wave moves with *constant speed.*

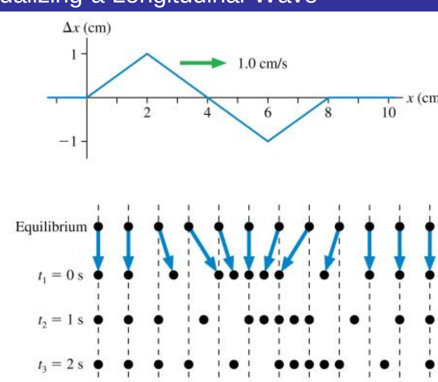


History Graph

- A graph that shows the wave's displacement as a function of time at a single **position** in space is called a **history graph.**
- This graph tells the history of that particular point in the medium.
- Note that for a wave moving from left to right, the shape of the history graph is *reversed* compared to the snapshot graph.



Visualizing a Longitudinal Wave

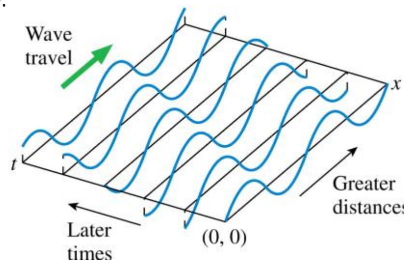


The Displacement

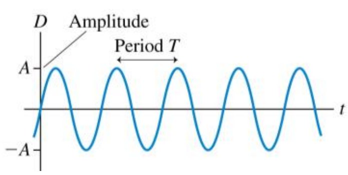
- In “the wave” at a sporting event, the wave moves around the stadium, but the particles (people) undergo small displacements from their equilibrium positions.
- When describing a wave mathematically, we’ll use the generic symbol D to stand for the *displacement* of a wave of any type.
- $D(x, t)$ = the displacement at time t of a particle at position x.

Sinusoidal Waves

A wave source at $x = 0$ that oscillates with simple harmonic motion (SHM) generates a **sinusoidal wave**.

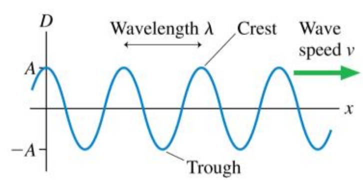


Sinusoidal Waves: History Graph

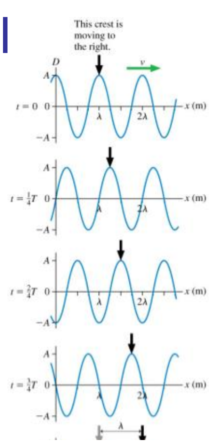


- Above is a history graph for a sinusoidal wave, showing the displacement of the medium at one point in space.
- Each particle in the medium undergoes simple harmonic motion with frequency f, where $f = 1/T$.
- The **amplitude** A of the wave is the maximum value of the displacement.

Sinusoidal Waves: Snapshot Graph



- Above is a snapshot graph for a sinusoidal wave, showing the wave stretched out in space, moving to the right with speed v.
- The distance spanned by one cycle of the motion is called the wavelength λ of the wave.



Sinusoidal Waves

- The distance spanned by one cycle of the motion is called the **wavelength** λ of the wave. Wavelength is measured in units of meters.
- During a time interval of exactly one period T, each crest of a sinusoidal wave travels forward a distance of exactly one wavelength λ.
- Because speed is distance divided by time, the **wave speed** must be:

$$v = \frac{\text{distance}}{\text{time}} = \frac{\lambda}{T}$$

or, in terms of frequency:

$$v = \lambda f$$

The Mathematics of Sinusoidal Waves

- Define the *angular frequency* of a wave:

$$\omega = 2\pi f = \frac{2\pi}{T}$$

- Define the *wave number* of a wave:

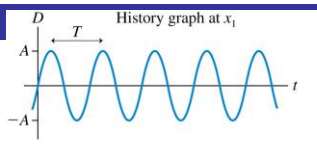
$$k = \frac{2\pi}{\lambda}$$

- The displacement caused by a traveling sinusoidal wave is:

$$D(x, t) = A\sin(kx - \omega t + \phi_0)$$

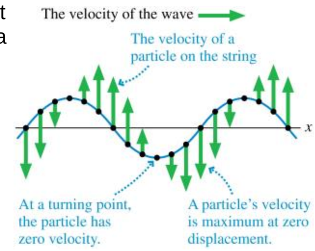
(sinusoidal wave traveling in the positive x-direction)

This wave travels at a speed $v = \omega/k$.



Wave Motion on a String

- Shown is a snapshot graph of a wave on a string with vectors showing the velocity of the string at various points.
- As the wave moves along x, the velocity of a particle on the string is in the y-direction.



$$v_y = \frac{dy}{dt} = -\omega A \cos(kx - \omega t + \phi_0)$$