Physics 202, Lecture 20

Today's Topics

- Wave Motion
  - General Wave
    - Transverse And Longitudinal Waves
    - Wave speed on string
    - Reflection and Transmission of Waves
  - Wave Function
    - Sinusoidal Waves
    - Standing Waves

General Waves

- Wave:
  Propagation of a physical quantity in space over time
  $q = q(x, t)$
- Examples of waves:
  Water wave, wave on string, sound wave, electromagnetic wave, "light", quantum wave....
- Mechanical wave:
  Propagation of small motion ("disturbance") in a medium.
  ➔Physical quantity to be propagated: displacement.

  Recall: Displacement is a vector.

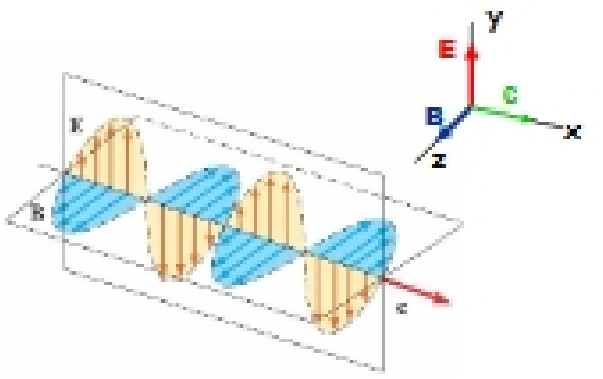
Transverse and Longitudinal Waves

- If the direction of mechanic disturbance (displacement) is perpendicular to the direction of wave motion, the wave is called transverse wave.
- If the direction of mechanic disturbance (displacement) is parallel to the direction of wave motion, the wave is called longitudinal wave.

➔see demos.

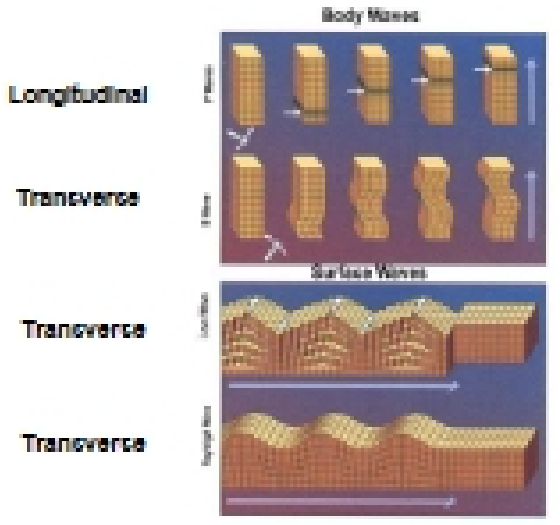
- In general, a wave can be a combination of the above modes.
- The definition can be extended to other (non-mechanical) waves.
  - e.g Electromagnetic waves are always transverse.

Electromagnetic Waves are Transverse



Two polarizations possible

Seismic Waves (motion in earthquakes)



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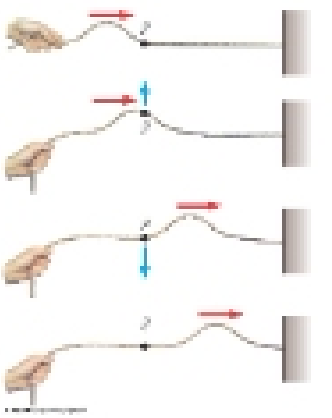
Wave On A Stretched Rope

- It is a transverse wave
  - ➔ See demos.
- The wave speed is determined by the tension and the linear density of the rope:

$$v = \sqrt{\frac{T}{\mu}} \; ; \qquad \mu \equiv \frac{\Delta m}{\Delta l}$$



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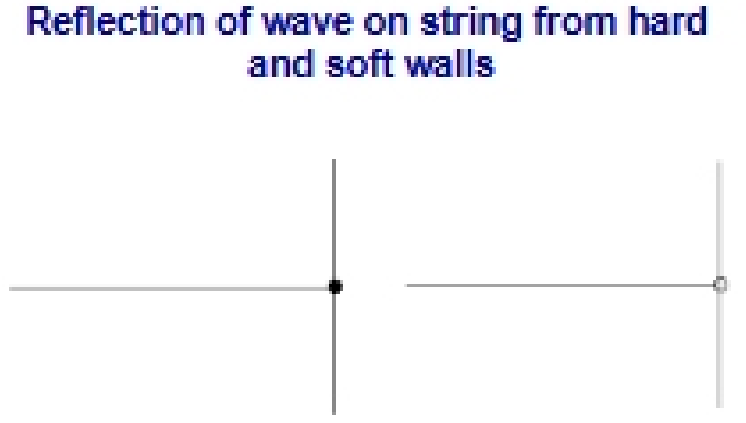
Reflection of wave on string from hard and soft walls



Hard wall
reflected wave is inverted

Soft wall
reflected wave is not inverted

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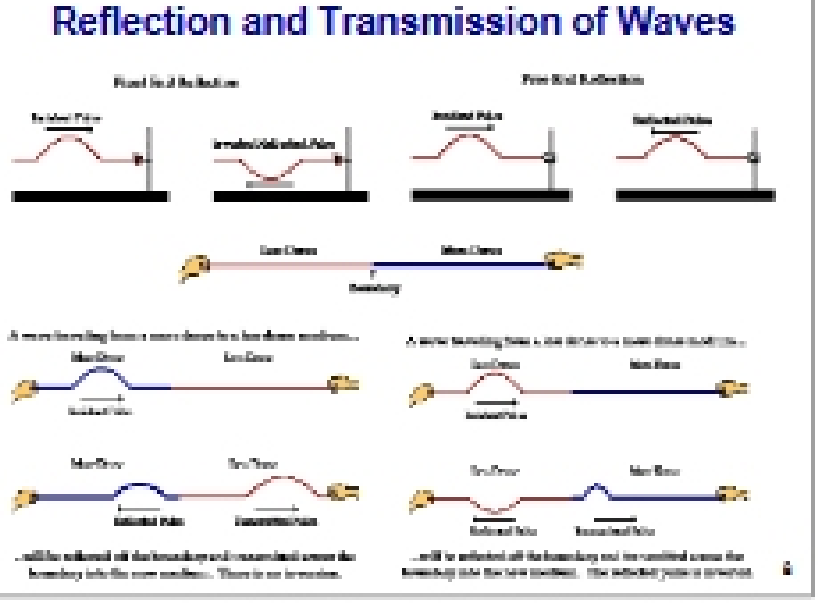
Reflection and Transmission of Waves



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Wave Function

- Waves are described by wave functions in the form:

y: A certain physical quantity e.g. displacement in y direction

f: Can have any form

$$y(x,t) = f(x-vt)$$

t: time. Its coefficient v is the wave speed
v>0 moving right
v<0 moving left

x: space position. Coefficient arranged to be 1

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An Exercise to Explain Wave Speed

- A wave is described by function y=f(x-vt).
  - At time t_1 in position x_1, how large is the quantity y?
    - $y = f(x_1-vt_1) = y_1$
  - At a later time $t_2=t_1+\Delta t$, what is y at position $x_2=x_1+v\Delta t$?
    - $y_2 = f(x_2-vt_2) = f(x_1+v\Delta t - v(t_1+\Delta t)) = f(x_1-vt_1) = y_1$
  - How to interpret the result?
    - Between t_1 and $t_1+\Delta t$, the value y_1 has transmitted from position x_1 to $x_1+v\Delta t$
    - → speed = $(x_1+v\Delta t - x_1)/(t_1+\Delta t - t_1) = v$
    - I.e v>0 ←→moving right; v<0 ←→moving left;

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Linear Wave Equation

- Linear wave equation

certain physical quantity

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

Wave speed

- Sinusoidal wave

f: frequency φ:Phase

$$y = A\sin\left(\frac{2\pi}{\lambda}x - 2\pi ft + \phi\right)$$

A:Amplitude λ:wavelength

v=λf
k=2π/λ
ω=2πf

General wave: superposition of sinusoidal waves

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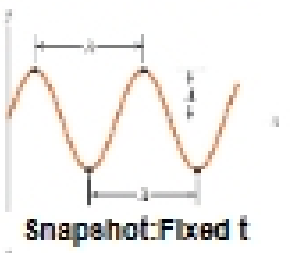
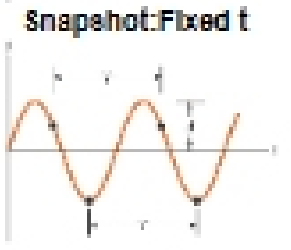
Parameters For A Sinusoidal Wave

- Snapshot with fixed t:
  wave length λ=2π/k
- Snapshot with fixed x:
  angular frequency = ω
  frequency f =ω/2π
  Period T=1/f
  Amplitude =A
- Wave Speed v=ω/k
  - → v=λf, or
  - → v=λ/T
- Phase angle difference between two positions
  Δφ =-kΔx



Snapshot:Fixed t



Snapshot:Fixed x

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