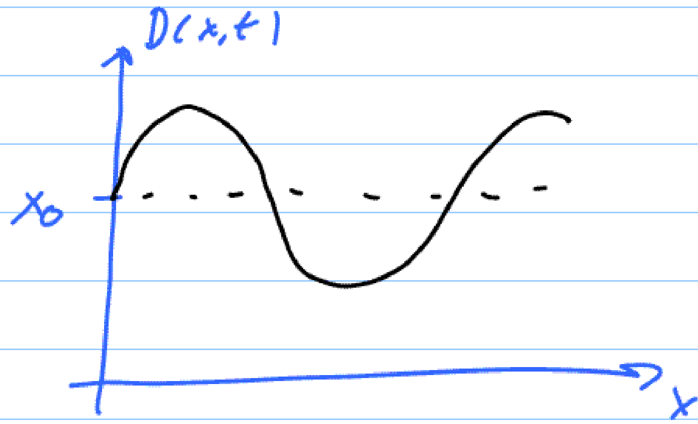
PHY132 - Class 4 - January 14, 2008

§21.4 - Standing Waves & Musical Acoustics

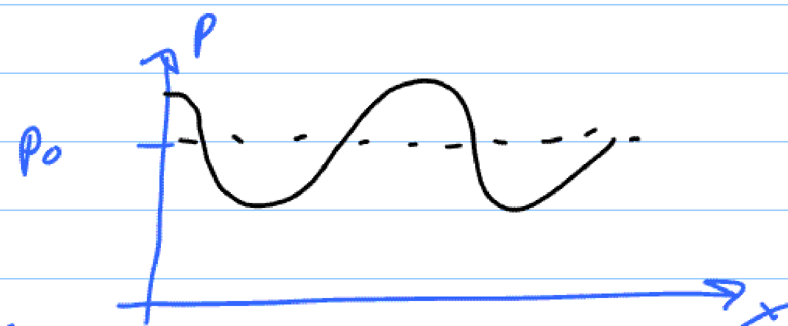
Sound waves

Displacement wave



x_0 = equilibrium position

Pressure wave



p_0 = atmospheric pressure

Text (pg 642-643) & a coming Practical!

displacement and pressure waves are $\pi/2$ out of phase

Node in displacement wave,
anti-node in pressure wave
and vize versa.

Standing Waves on a String

Given m: increase $T_s \Rightarrow$ increase v
$\Rightarrow$ increase f_m
increase $\mu \Rightarrow$ decrease v
$\Rightarrow$ decrease f_m

Adjust T_s & μ:

$m = 1$ $f_1 = 440 Hz$
"concert A" $= A_4$

$m = 1$ fundamental

note string is tuned to

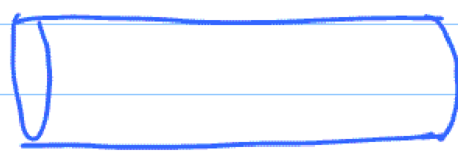
$m > 1$ overtones

real string - all these modes happening simultaneously

Relative amount of overtones determines timbre of note

e.g. violin & guitar both play A_4 sound different, different amounts of overtones

Sound Waves

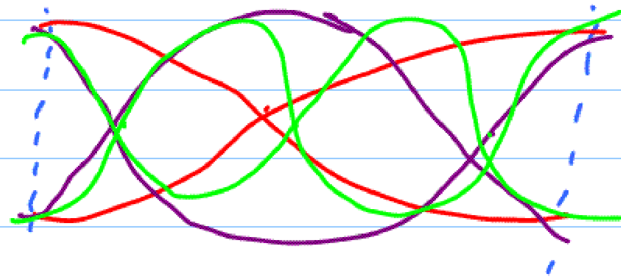


fixed on both ends "closed"

Set up standing wave.

Displacement wave! nodes at end

Pressure wave: anti-nodes at ends



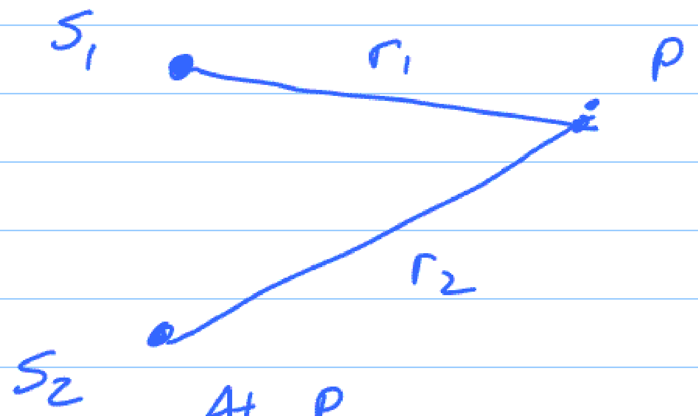
open at both ends

displacement wave: anti-nodes @ ends
pressure wave: nodes @ ends

§21.5, §21.6, §21.7 COMBINE

text: easy to miss the big picture
me: give big picture

2 source! same λ & f



At P

$$D_1(r_1, t) = a_1 \sin(kr_1 - \omega t + \phi_{10})$$

ϕ_{10} = phase of source at $t=0$

$$D_2(r_2, t) = a_2 \sin(kr_2 - \omega t + \phi_{20})$$

In general $a_1 \neq a_2$

$$a_2 = a_1 + \delta a$$

$$D_2' = a_1 \sin(kr_2 - \omega t + \phi_{20})$$

$$D_1 = a_1 \sin(\phi_1)$$

phase of wave at P

$$D_2' = a_1 \sin(\phi_2)$$

$$\phi_2 - \phi_1 = k(r_2 - r_1) - (\phi_{20} - \phi_{10})$$

$$\Delta\phi = 2\pi \frac{(r_2 - r_1)}{\lambda} + \Delta\phi_0$$

$$\Delta\phi = m \times 2\pi \qquad m = 0, 1, 2, \ldots$$

2 waves in phase

Superposition constructive interference

$$\Delta\phi = (m + \tfrac{1}{2}) \times 2\pi \qquad m = 0, 1, 2, \ldots$$

out of phase

destructive interference

$$\delta a \sin(k r_2 - \omega t + \phi_{20})$$

always left over

If $\Delta\phi_0 = 0$ sources are in phase

Constructive / Destructive interference depends only on $\underline{(r_2 - r_1)}$

difference in path length

§21.8 - Beats

$$\begin{bmatrix} D_1(x,t) = a_1 \sin(k_1 x - \omega_1 t + \phi_{10}) \\ D_2(x,t) = a_2 \sin(k_2 x - \omega_2 t + \phi_{20}) \end{bmatrix}$$

<u>Assume</u> $\underline{a_1 = a_2 \equiv a}$

For math convenience:

Detector, (Position P), (ear)

$x = 0$

$\phi_{10} = \phi_{20} = \pi$ radians

$D_1 = a \sin(-\omega_1 t + \pi)$
$= a \sin(\omega_1 t)$

$D_2 = a \sin(-\omega_2 t + \pi)$
$= a \sin(\omega_2 t)$

$D_1 + D_2 = a \sin(\omega_1 t) + a \sin(\omega_2 t)$

trig identity: $\Rightarrow$

$$= 2a \cos\left[\underbrace{\tfrac{1}{2}(\omega_1 - \omega_2)}\, t\right] \sin\left[\underbrace{\tfrac{1}{2}(\omega_1 + \omega_2)}_{\omega_{avg}}\, t\right]$$

$\omega_{mod} \equiv \frac{1}{2}(\omega_1 - \omega_2) t$

$$= \underbrace{\left[2a \cos(\omega_{mod} t)\right]}_{\text{amplitude of this}} \sin(\underline{\underline{\omega_{avg}}}\, t)$$

Hear as twice the modulation frequency