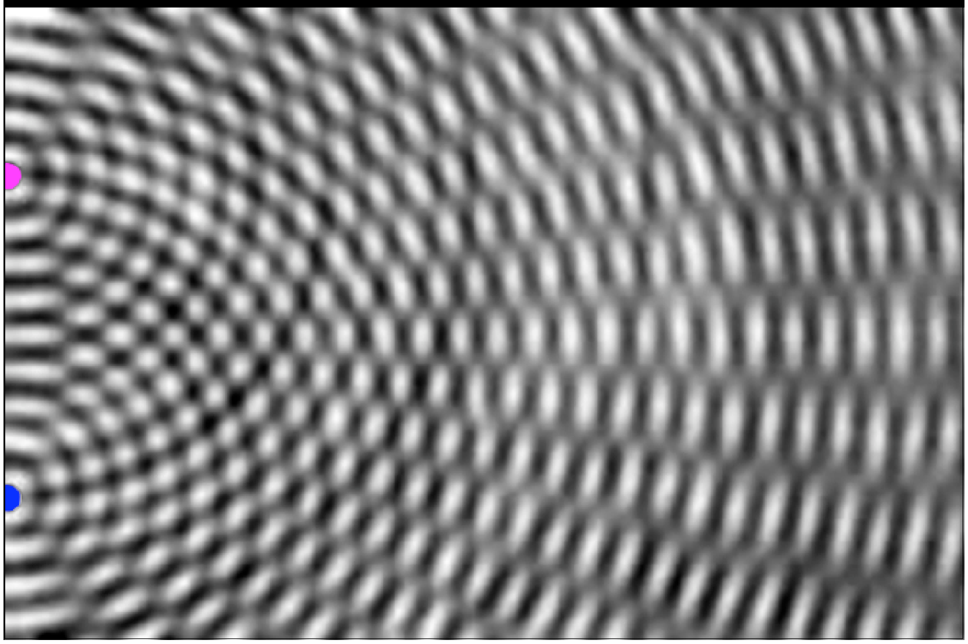
superposition

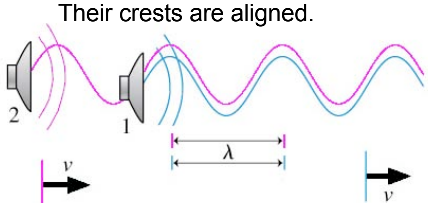


Principle of superposition

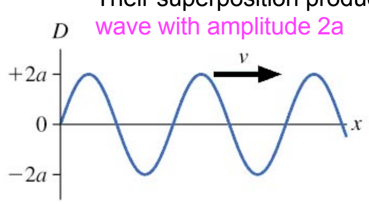
When more than one wave is present, the displacement of the medium is the sum of the displacements due to each individual wave.
Informal statement: waves add up

The superposition of 2 or more waves is called **interference**

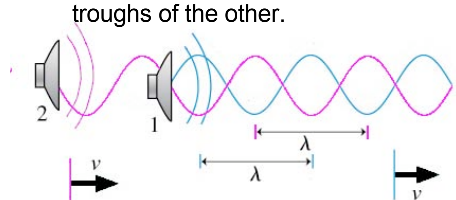
Constructive interference:
These two waves are in phase.
Their crests are aligned.



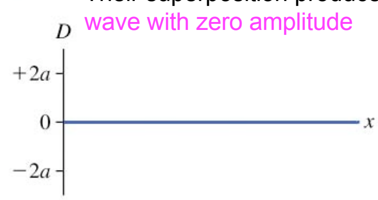
Their superposition produces a wave with amplitude 2a



Destructive interference:
These two waves are out of phase.
The crests of one are aligned with the troughs of the other.

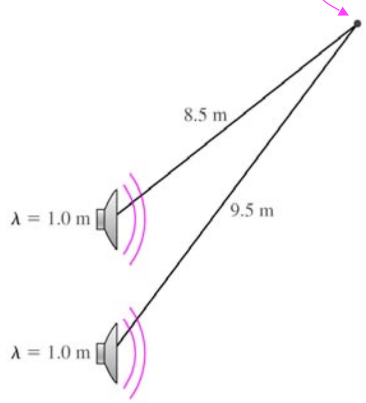


Their superposition produces a wave with zero amplitude

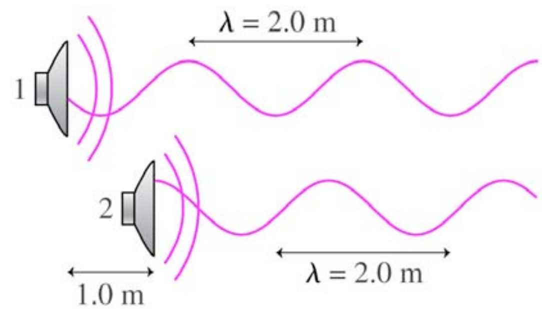


Interference: space and time

Is this a point of constructive or destructive interference?

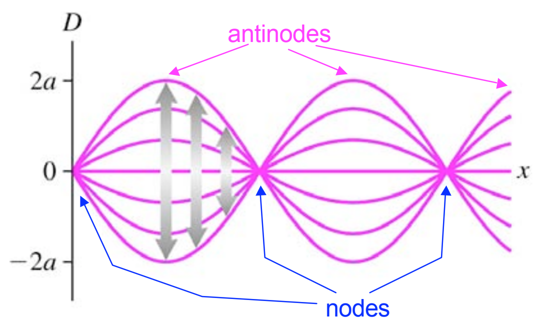


What do we need to do to make the sound from these two speakers interfere constructively?



standing waves

Two waves traveling in opposite direction interfere with each other.
<u>If the conditions are right</u>, their interference generates a standing wave.
A standing wave does not propagate in space, it "stands" in place
A standing wave has nodes and antinodes:



The amplitude of the oscillation A changes with position : *A(x)*

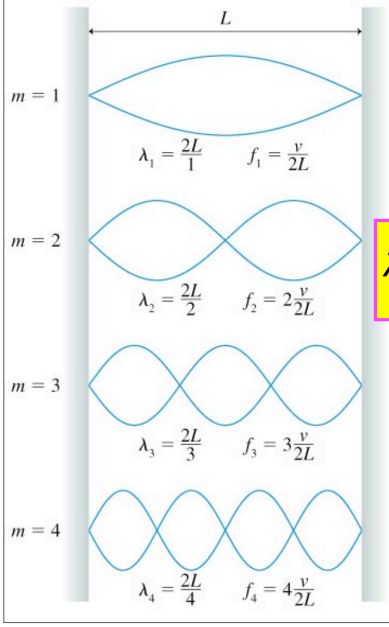
$D_R = a \sin(kx-\omega t)$

$D_L = a \sin(kx+\omega t)$

The outer curve is the amplitude function $A(x) = 2a\sin(kx)$

k = wave number = $2\pi/\lambda$

standing waves on a string



"….if the conditions are right"

Fundamental frequency $f_1 = \dfrac{v}{2L}$

A standing wave can exist on a string only if its frequency is one of the values given by:

$\lambda_m = \dfrac{2L}{m}$ $\quad f_m = m\dfrac{v}{2L} = mf_1$ $\quad m = 1, 2, 3, ...$

Remember that $v = \sqrt{\dfrac{T_s}{\mu_s}} = \sqrt{\dfrac{T_s L}{m_s}}$

thus $f_1 = \dfrac{1}{2}\sqrt{\dfrac{T_s L}{m_s L^2}} = \dfrac{1}{2}\sqrt{\dfrac{T_s}{m_s L}}$

demo guitar

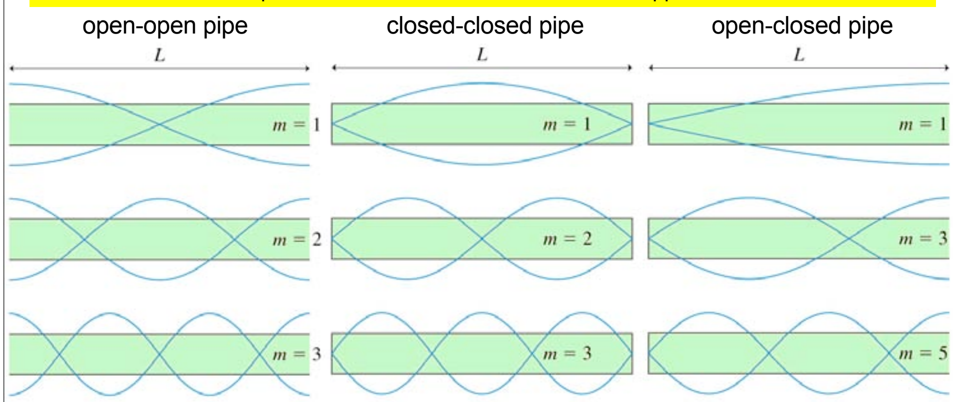
standing waves on strings

$$f_1 = \frac{v}{2L} = \frac{1}{2}\sqrt{\frac{T_s}{m_s L}}$$

standing waves in a pipe

An open end of a pipe ***must*** be an antinode, a clodes end a node.

The blue curves are displacement oscillations. Pressure makes opposite nodes and antinodes



Open-open and closed-closed pipes:

$$\lambda_m = \frac{2L}{m} \qquad f_m = m\frac{v}{2L} = mf_1$$

$m = 1, 2, 3, 4, \ldots.$

Open-closed pipe:

$$\lambda_m = \frac{4L}{m} \qquad f_m = m\frac{v}{4L} = mf_1$$

$m = 1, 3, 5, 7, \ldots$

standing waves in pipe instruments

pipe organ mostly open pipes

$$f_1 = \frac{v}{2L}$$

$$f_1 = \frac{v}{4L}$$

$$v = v(T)$$

→ warm up before tuning

beats

Beats are loud-soft-loud-soft modulations of intensity.
They occur when two waves of slightly different frequency are superimposed

The beats between waves of frequencies f_1 and f_2 have frequency $f_{beat} = f_1 - f_2$