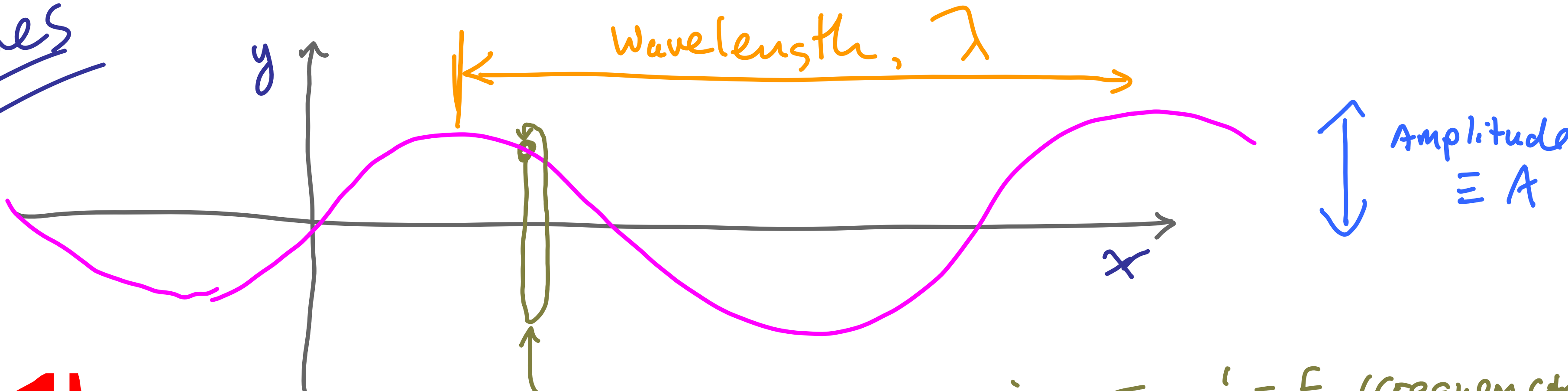
Physics 113 - December 12, 2013

Last Day of class

- All regrade requests to date are done
  Pick up here if you want
- Exam 3 graded - Pick up here After class
- Expect "material coverage since Exam 3" email
  after today's lecture - Fine tune endgame
- Q+A TBA

Waves



Executes SHO with period, T, $\frac{1}{T} \equiv f$ (frequency)

$$\boxed{v = \lambda f}$$

$$y(x,t) = A \sin(kx - \omega t + \varphi)$$

Wave traveling to $+x$ right

initial phase

$$y(x,t) = A \sin(kx + \omega t + \varphi)$$

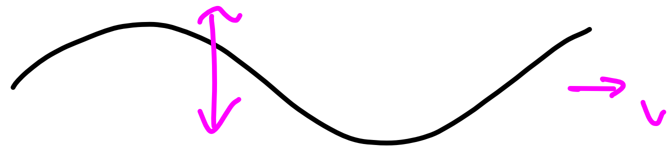
wave traveling to left

Toward $-x$

$2\pi/\lambda$

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

Transverse waves



string

Longitudinal waves

sound in air or Slinky

v depends on what is vibrating

For Transverse wave on String

$$v = \sqrt{\frac{T}{\mu}}$$

Tension (NOT period in this case)

Mass/length

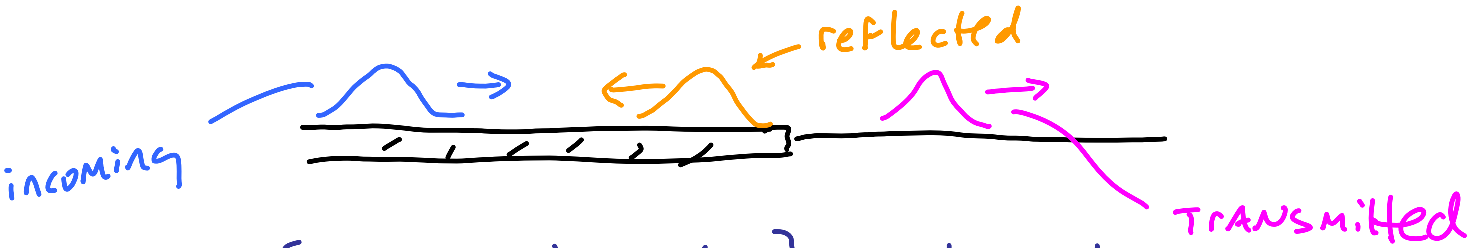
longitudinal vibrations in Material (sound)

$$v = \sqrt{\frac{B}{\rho}}$$

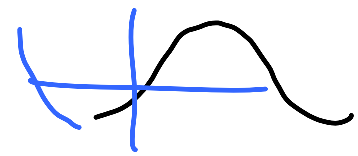
Bulk Modulus

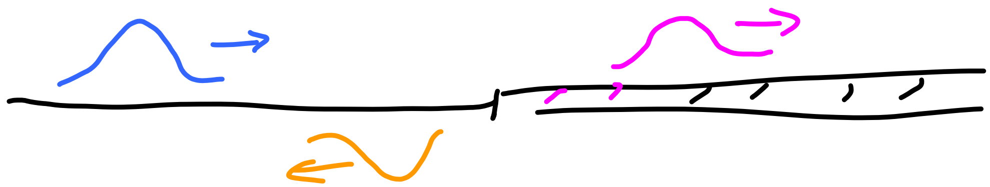
mass/volume

What happens at Boundary between Media?



Heavy to light } No phase change
Slow to fast



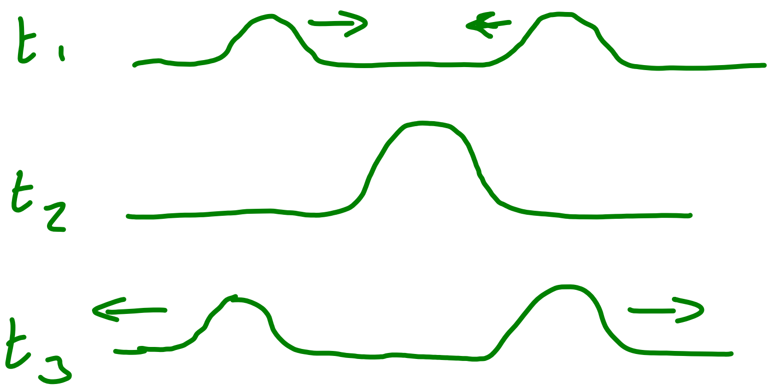


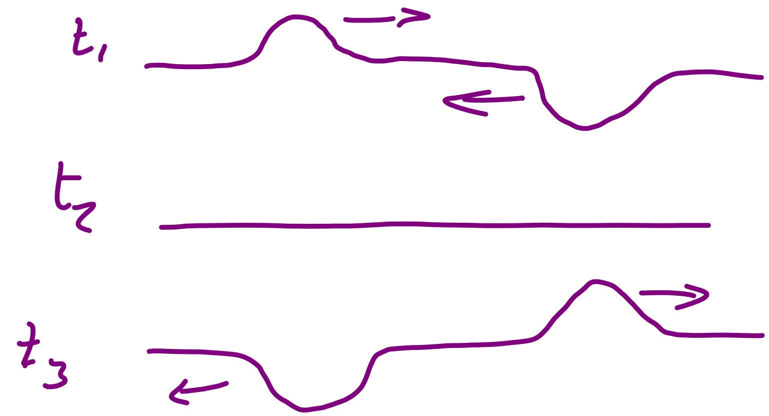
light to heavy } No phase change for Transmitted wave
fast to slow } 180° phase change for reflected wave

Waves exhibit superposition

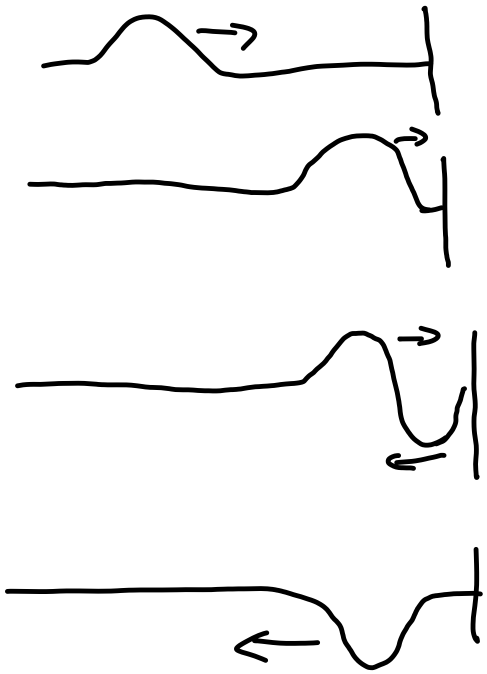
... Total is the sum of the parts

Interference

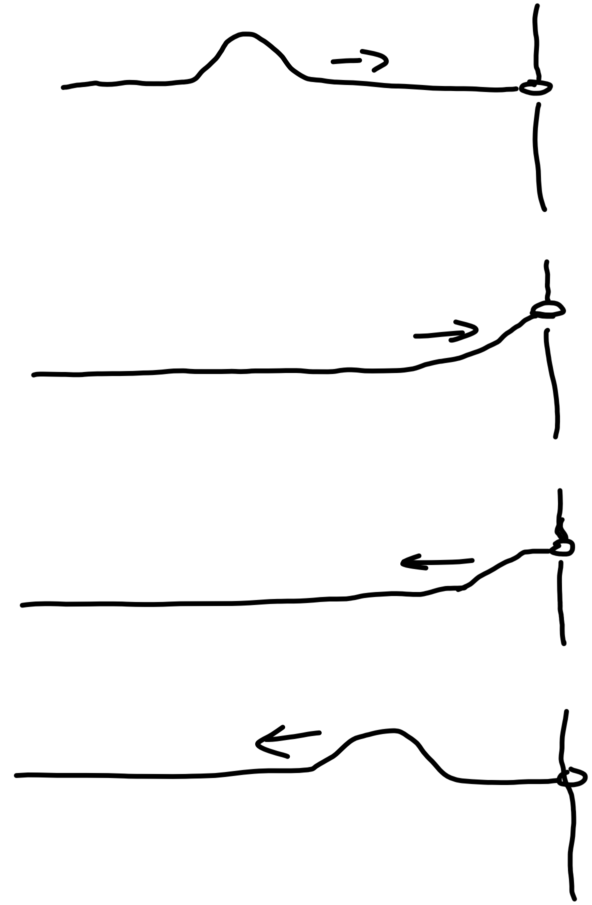




Waves on string – reflections



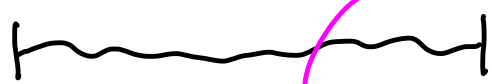
Fixed end ~ 180° phase change



loose end

No phase change

consider



string fixed at both ends

wave traveling to right

+

reflected wave traveling to left

both have same frequency and amplitude

$$y_1(x,t) = A\sin(kx - \omega t)$$

$$y_2(x,t) = A\sin(kx + \omega t + \varphi)$$

We want this to be a reflected wave from fixed end so $\varphi = \pi$

$$y_2(x,t) = -A\sin(kx + \omega t)$$

$A\sin(x+\pi) = -A\sin(x)$

use Principle of Superposition

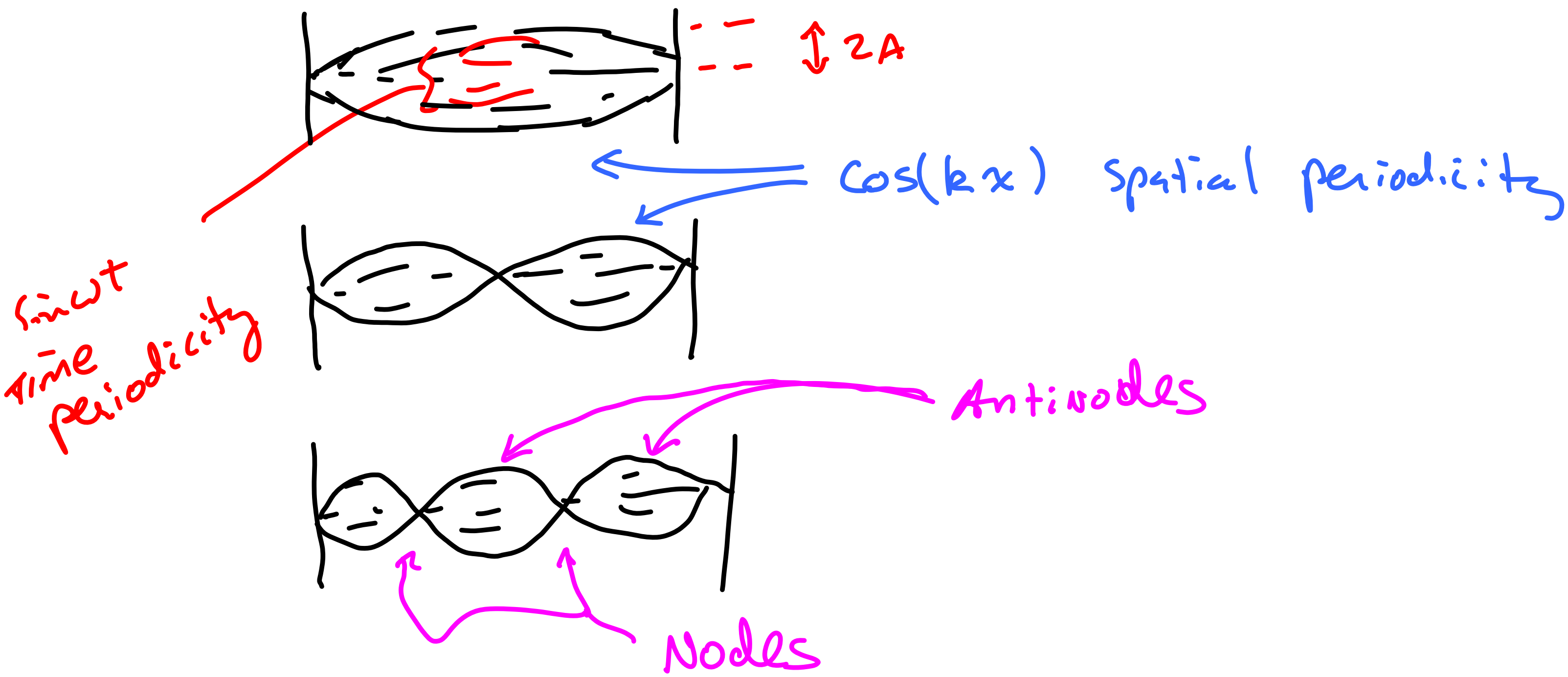
$$y(x,t) = y_1(x,t) + y_2(x,t) = A\sin(kx - \omega t) \underbrace{- A\sin(kx + \omega t)}_{+A\sin(-kx-\omega t)}$$

use Trig identity $\rightsquigarrow$ $\sin C + \sin B = 2\sin\left[\frac{1}{2}(C+B)\right]\cos\left[\frac{1}{2}(C-B)\right]$

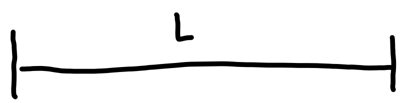
where $C \equiv kx - \omega t$ and $B = -kx - \omega t$

$$y(x,t) = \underbrace{(-2A)}_{2A\,=\,\text{Amplitude of Superposition}}\underbrace{\sin(\omega t)}_{\text{Time Variation}}\underbrace{\cos(kx)}_{\text{fixed form in space, periodic in }\lambda}$$

$\boxed{\text{Standing Waves}}$



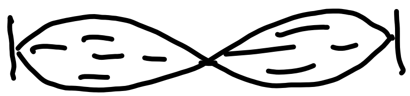
2A
cos(kx) spatial periodicity
sin ωt
time periodicity
Antinodes
Nodes



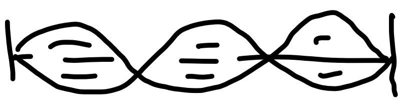
Tension, T

Mass/Length, μ

Fundamental $L = \lambda/2$ 1^{st} harmonic



2^{nd} harmonic $L = 2\frac{\lambda}{2} = \lambda$



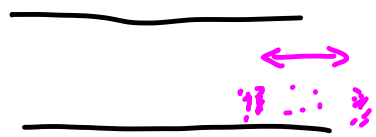
3^{rd} harmonic $L = \frac{3\lambda}{2}$

⋮ higher harmonics ⟶ $L = n\frac{\lambda}{2}$ $n = 1, 2, 3 \ldots$

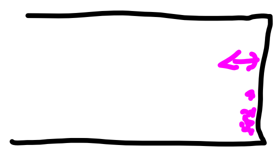
$v = f_n \lambda_n$ $v = \sqrt{T/\mu}$ on string

$f_n = v/\lambda_n$ $f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ are frequences that "resonate" on string

For Tubes/sound (wind instruments)

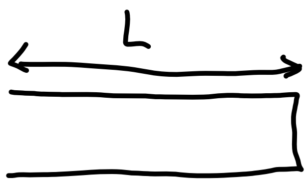


open end
Displacement Antinode
(pressure Node)

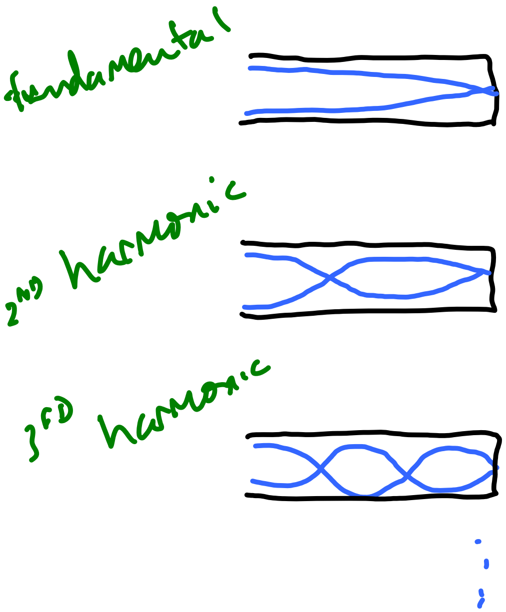


closed end

displacement node
(pressure Antinode)



what are frequencies that resonate in Tube of length L that is closed at 1 end?



$L = \frac{\lambda}{4}$

$L = \frac{3}{4}\lambda$

$L = \frac{5}{4}\lambda$

$L = \frac{n}{4}\lambda_n$

where $n = 1, 3, 5 \ldots$

$v = f\lambda$

$v_{sound} = 343 \text{ m/s}$ at $20°C$

$v = f_n \lambda_n$

$L = \frac{n}{4}\frac{v}{f_n}$

$f_n = \frac{nv}{4L}$ $n = 1, 3, 5$

frequencies that resonate on this instrument

⟶ Tune + Warm up musical instruments

$$f_n = \frac{n v}{4L} \qquad n = 1, 3, 5$$

Beats

Two waves passing a fixed point $(x=0)$
Differ slightly in frequency
Equal amplitudes

Wave 1 $\quad x_1(x,t) = A\sin(k_1 x - \omega_1 t) = A\sin(\omega_1 t)$

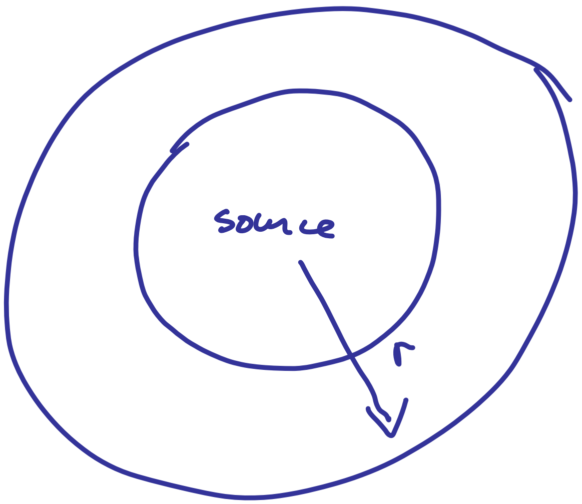
Wave 2 $\quad x_2(x,t) = A\sin(\omega_2 t)$

$$x(t) = \underbrace{2A \cos\left[\left(\frac{\omega_1-\omega_2}{2}\right)t\right]}_{\text{Amplitude modulated by frequency difference}} \;\underbrace{\sin\left[\left(\frac{\omega_1+\omega_2}{2}\right)t\right]}_{\text{Hear this sound at average frequency}}$$

Intensity $\propto$ (Amplitude)^2

Energy flow in waves $\boxed{\frac{dE}{dt} \sim A^2 v}$

This is why I say intensity $\sim A^2$



same Energy

larger Area $\rightarrow 4\pi r^2$

$\frac{\text{Energy flow}}{\text{Area}}$ (intensity)

drops as r^2

True for light, sound . . .

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}} \qquad \frac{\text{Watts}}{m^2}$$

Intensity of sound

define I_0 as reference intensity

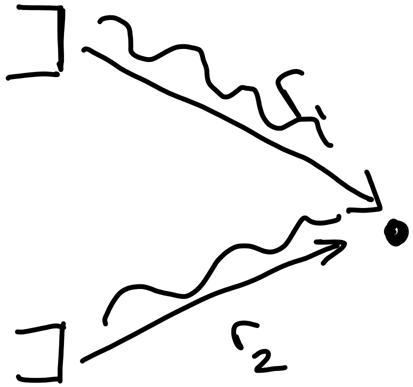
1×10^{-12} W/m^2

Threshold of hearing for average person

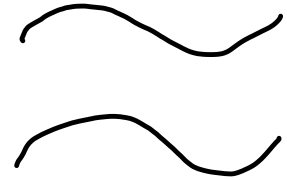
$$\beta \text{ (decibel)} = 10 \log \frac{I}{I_0}$$

dB

	dB
threshold	0
whisper	~20
street traffic	~70
Siren @ 30 m	~100
Rock concert at pain Threshold	~120
Jet engine at 30 m	~140

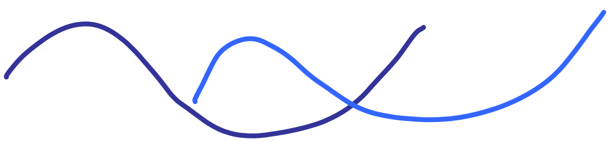


if $r_1 = r_2$



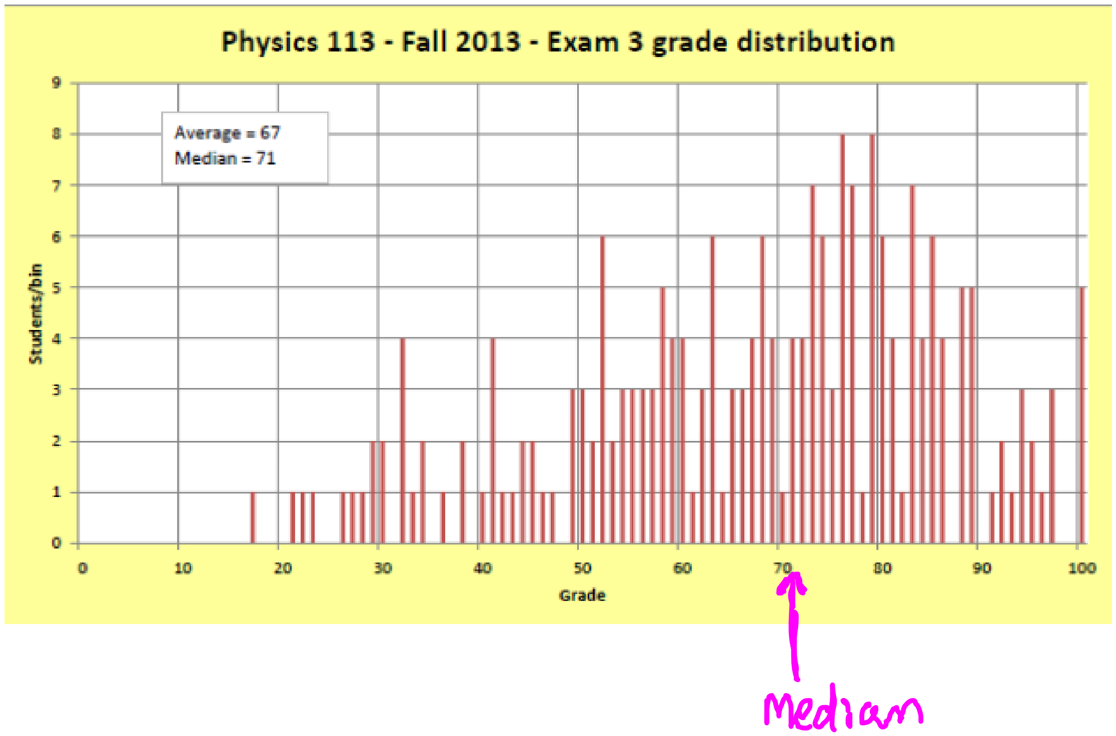
constructive interference

$r_1 - r_2 = n\lambda$



if $r_1 - r_2 = \cancel{n\lambda - \frac{1}{2}}\ (n - \frac{1}{2})\lambda$

Destructive



Physics 113 - Fall 2013 - Exam 3 grade distribution
Average = 67
Median = 71
Students/bin
Grade
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
Median