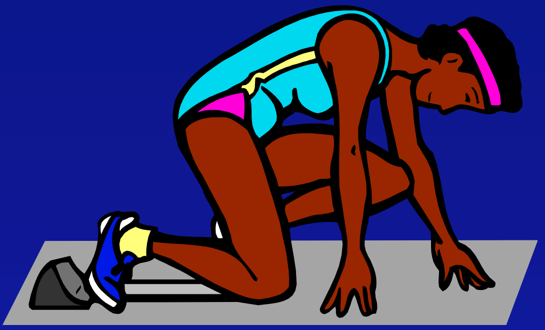
EXAM III

Physics 101: Lecture 22
Sound

Today's lecture will cover Textbook Chapter 12



Speed of Sound

- Recall for pulse on string: $v = \mathrm{sqrt}(T / \mu)$
- For fluids: $v = \mathrm{sqrt}(B/\rho)$

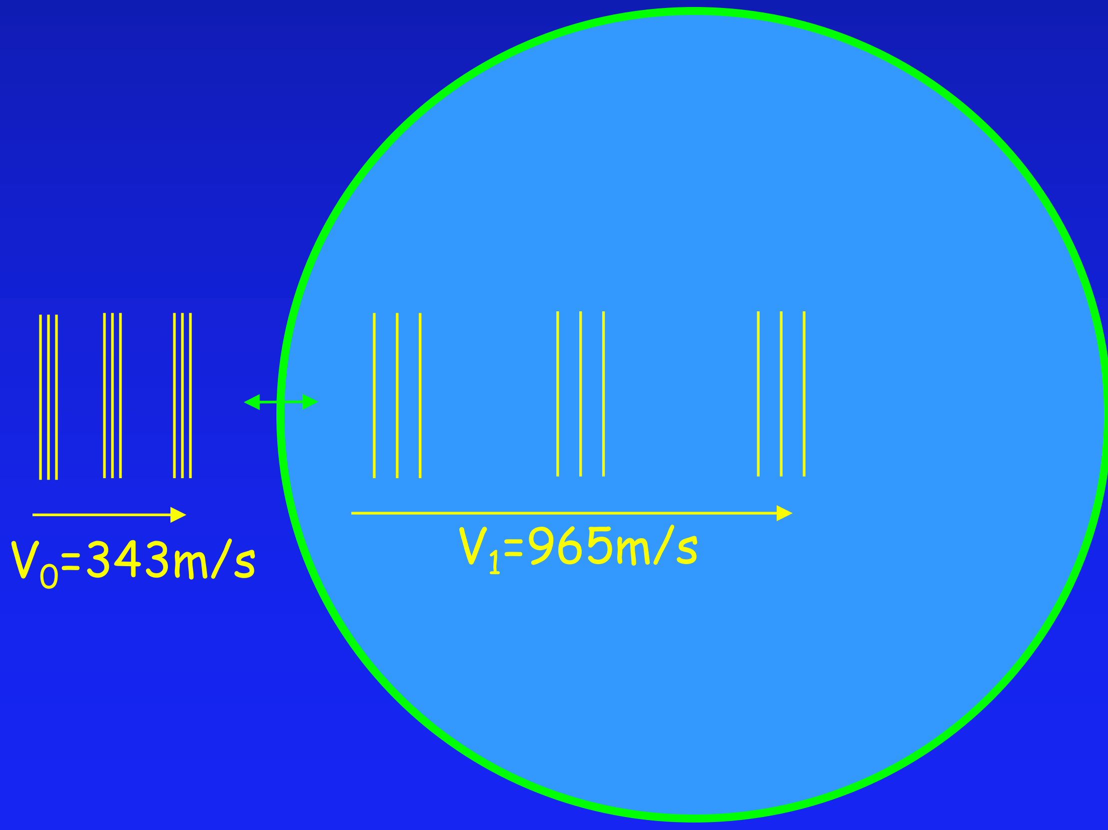
B = bulk modulus

Medium	Speed (m/s)
Air	343
Helium	972
Water	1500
Steel	5600

Velocity ACT

A sound wave having frequency f_0, speed v_0 and wavelength λ_0, is traveling through air when in encounters a large helium-filled balloon. Inside the balloon the frequency of the wave is f_1, its speed is v_1, and its wavelength is λ_1 Compare the speed of the sound wave inside and outside the balloon

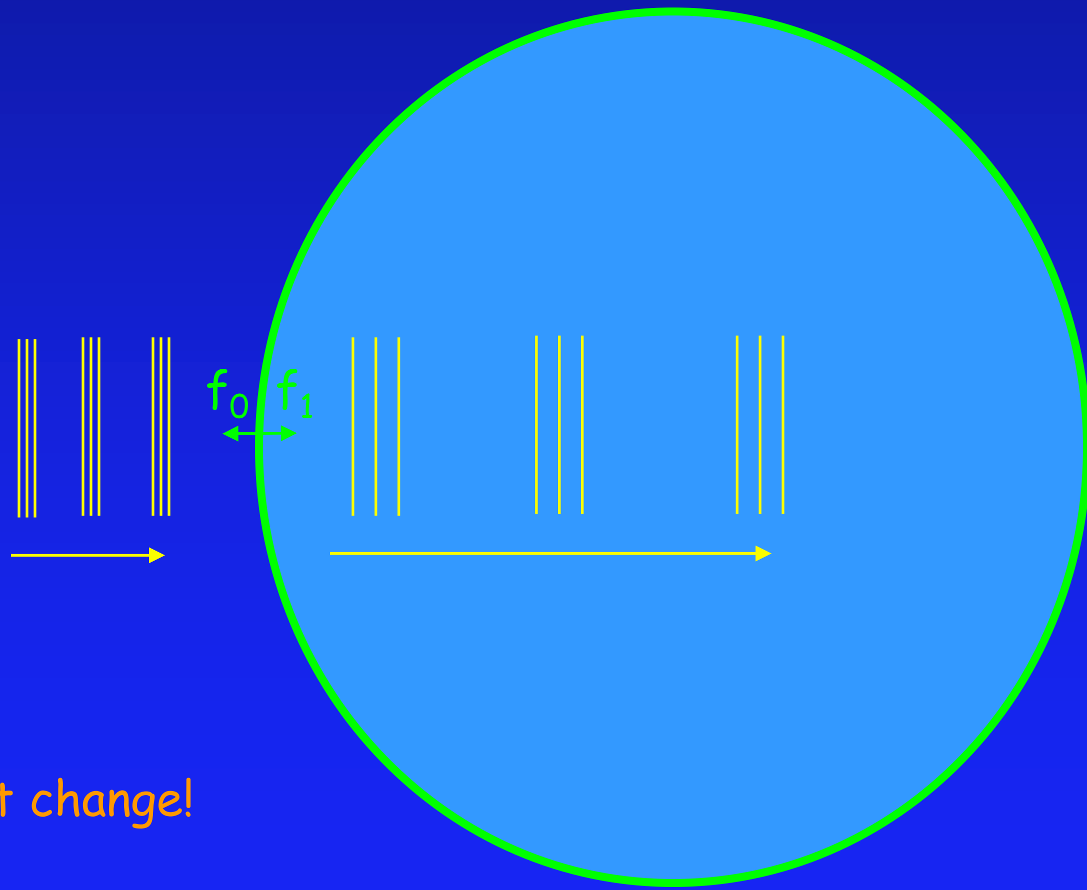
1. $v_1 < v_0$
2. $v_1 = v_0$
3. $v_1 > v_0$ ← correct



Frequency ACT

A sound wave having frequency f_0, speed v_0 and wavelength λ_0, is traveling through air when in encounters a large helium-filled balloon. Inside the balloon the frequency of the wave is f_1, its speed is v_1, and its wavelength is λ_1 Compare the frequency of the sound wave inside and outside the balloon

1. $f_1 < f_0$
2. $f_1 = f_0$ ← correct
3. $f_1 > f_0$

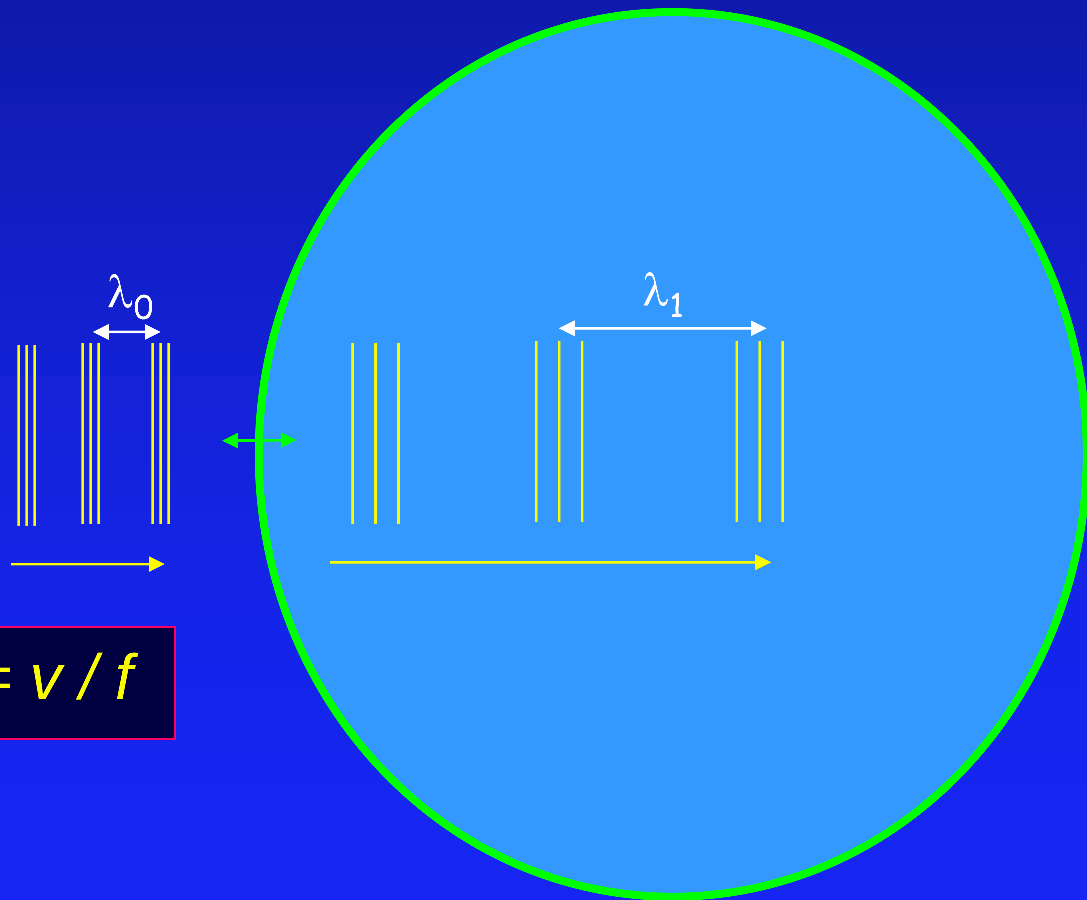


Time between wave peaks does not change!

Wavelength ACT

A sound wave having frequency f_0, speed v_0 and wavelength λ_0, is traveling through air when in encounters a large helium-filled balloon. Inside the balloon the frequency of the wave is f_1, its speed is v_1, and its wavelength is λ_1 Compare the wavelength of the sound wave inside and outside the balloon

1. $\lambda_1 < \lambda_0$
2. $\lambda_1 = \lambda_0$
3. $\lambda_1 > \lambda_0$ ← correct



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

Intensity and Loudness

- Intensity is the power per unit area.
  - ➔ $I = P / A$
  - ➔ Units: Watts/m^2

- For Sound Waves
  - ➔ $I = p_0{}^2 / (2\,\rho\, v)$ (p_o is the pressure *amplitude*)
  - ➔ Proportional to $p_0{}^2$ (note: Energy goes as A^2)
- Loudness (Decibels)
  - ➔ Loudness perception is logarithmic
  - ➔ Threshold for hearing $I_0 = 10^{-12}$ W/m^2
  - ➔ $\beta = (10\text{ dB}) \log_{10} (I / I_0)$
  - ➔ $\beta_2 - \beta_1 = (10\text{ dB}) \log_{10}(I_2/I_1)$

Log_{10} Review

- $\log_{10}(1) = 0$
- $\log_{10}(10) = 1$
- $\log_{10}(100) = 2$
- $\log_{10}(1{,}000) = 3$
- $\log_{10}(10{,}000{,}000{,}000) = 10$

$\beta = (10\ \text{dB}) \log_{10} (I / I_0)$

$\beta_2 - \beta_1 = (10\ \text{dB}) \log_{10}(I_2/I_1)$

- $\log(ab) = \log(a) + \log(b)$
- $\log_{10}(100) = \log_{10}(10) + \log_{10}(10) = 2$

Decibels ACT

- If 1 person can shout with loudness 50 dB. How loud will it be when 100 people shout?

1) 52 dB   2) 70 dB   3) 150 dB

$\beta_{100} - \beta_1 = (10\text{ dB}) \log_{10}(I_{100}/I_1)$

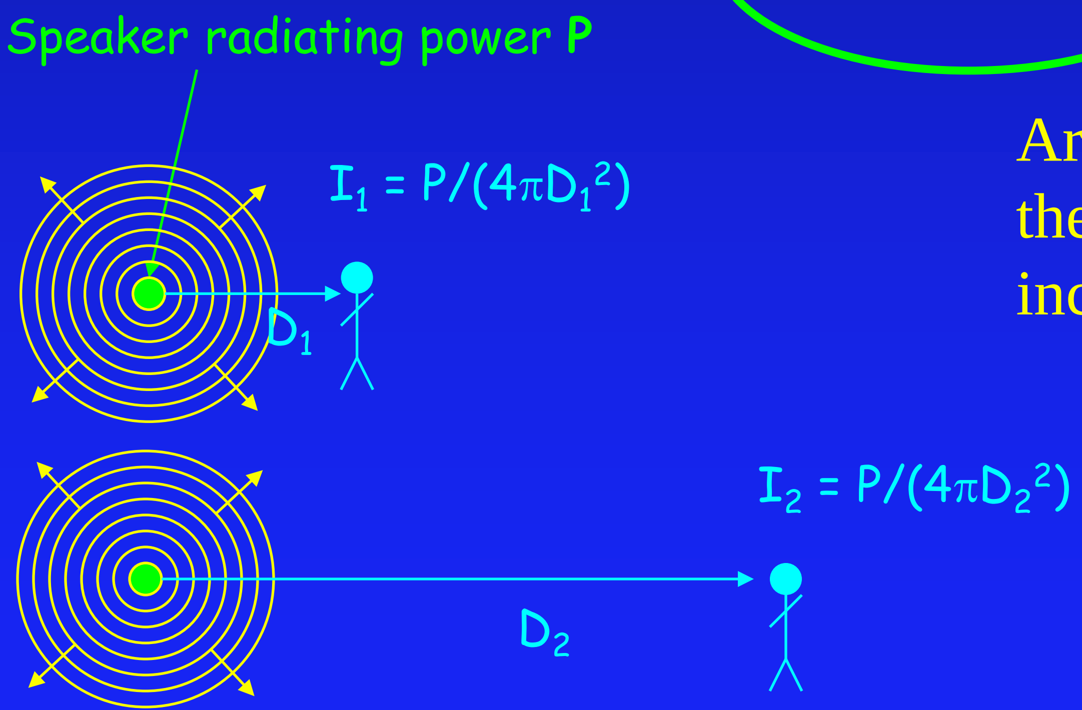
$\beta_{100} = 50 + (10\text{ dB}) \log_{10}(100/1)$

$\beta_{100} = 50 + 20$

Intensity ACT

- Recall Intensity = P/A. If you are standing 6 meters from a speaker, and you walk towards it until you are 3 meters away, by what factor has the intensity of the sound increased?

1) 2 2) 4 3) 8



Area goes as d^2 so if you are ½ the distance the intensity will increase by a factor of 4

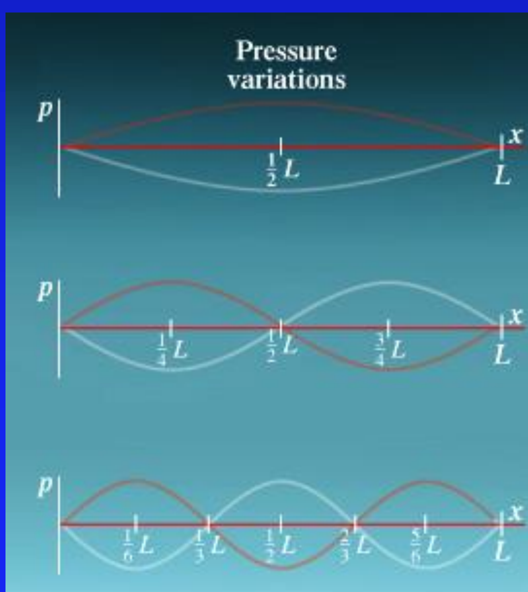
Standing Waves in Pipes

Nodes still! Nodes in pipes!

Open at both ends:

Pressure Node at end

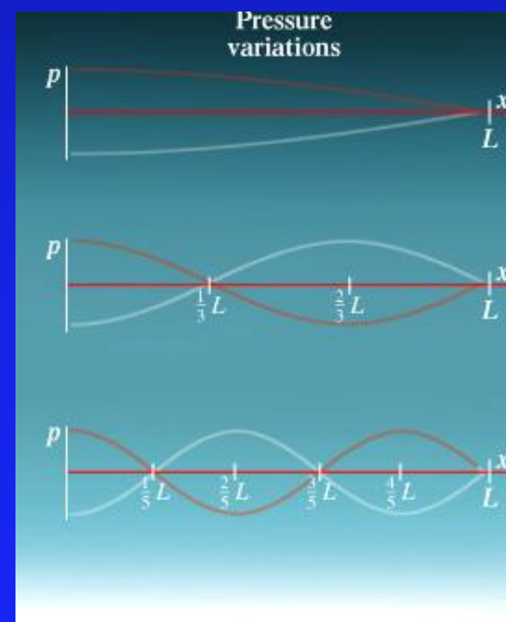
$\lambda = 2\,L\,/\,n$ n=1,2,3..



Open at one end:

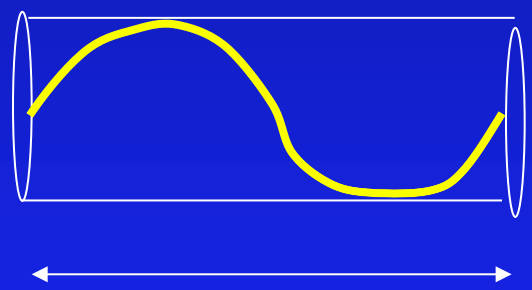
Pressure AntiNode at closed end : $\lambda = 4\,L\,/\,n$

n odd



Organ Pipe Example

A 0.9 m organ pipe (open at both ends) is measured to have its first harmonic at a frequency of 382 Hz. What is the speed of sound in the pipe?



Pressure Node at each end.

$\lambda = 2\ L\ /\ n \quad n=1,2,3..$

$\lambda = L$ for first harmonic (n=2)

$f = v\ /\ \lambda$

$v = f\ \lambda = (382\ s^{-1})\ (0.9\ m)$

$= 343\ m/s$

Resonance ACT

- What happens to the fundamental frequency of a pipe, if the air (v=343 m/s) is replaced by helium (v=972 m/s)?

1) Increases 2) Same 3) Decreases

$$f = v/\lambda$$

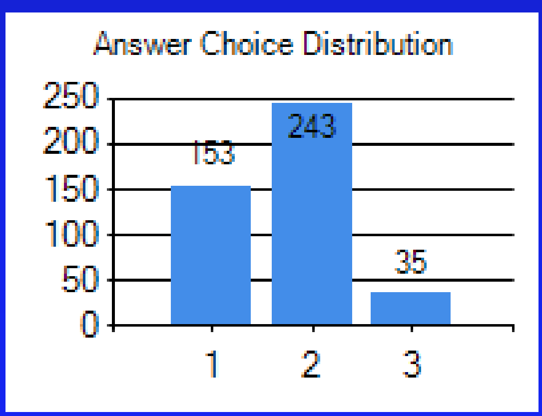
Preflight 1

- As a police car passes you with its siren on, the frequency of the sound you hear from its siren

Doppler Example Audio

Doppler Example Visual

1) Increases 2) Decreases 3) Same



When a source is going awaay from you then the distance between waves increases which causes the frequency to increase.

thats how it happens in the movies

Doppler Effect
moving source v_s

Knowing if Vo and Vs are negative or positive.

- When source is coming toward you ($v_s > 0$)
  - ➔ Distance between waves decreases
  - ➔ Frequency is higher
- When source is going away from you ($v_s < 0$)
  - ➔ Distance between waves increases
  - ➔ Frequency is lower
- $f_o = f_s / (1 - v_s/v)$

Doppler Effect moving observer (v_o)

- When moving toward source ($v_o < 0$)
  - ➔Time between waves peaks decreases
  - ➔Frequency is higher

- When away from source ($v_o > 0$)
  - ➔Time between waves peaks increases
  - ➔Frequency is lower

- $f_o = f_s\ (1- v_o/v)$

Combine: $f_o = f_s\,(1-v_o/v) / (1-v_s/v)$

Doppler ACT

A: You are driving along the highway at 65 mph, and behind you a police car, also traveling at 65 mph, has its siren turned on.

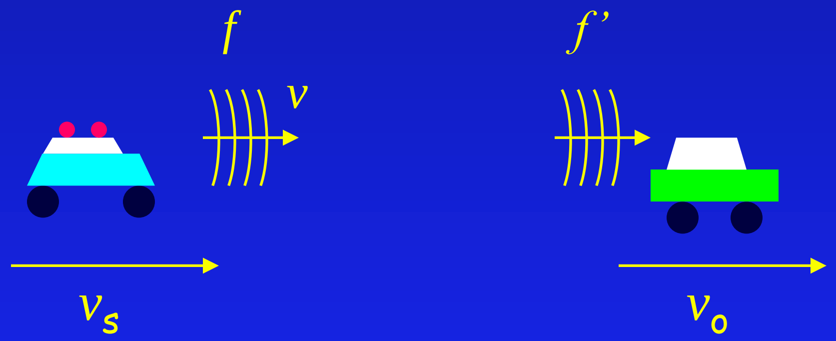
B: You and the police car have both pulled over to the side of the road, but the siren is still turned on.

In which case does the frequency of the siren seem higher to you?

A. Case A

B. Case B

C. same ⟵ correct



$$\frac{f'}{f} = \frac{1 - \frac{v_o}{v}}{1 - \frac{v_s}{v}} = \frac{1 - \frac{65\text{ mph}}{v}}{1 - \frac{65\text{ mph}}{v}} = 1$$

Doppler sign convention

Doppler shift: $f_o = f_s (1 - v_o/v) / (1 - v_s/v)$

$v_s = v(\text{source})$

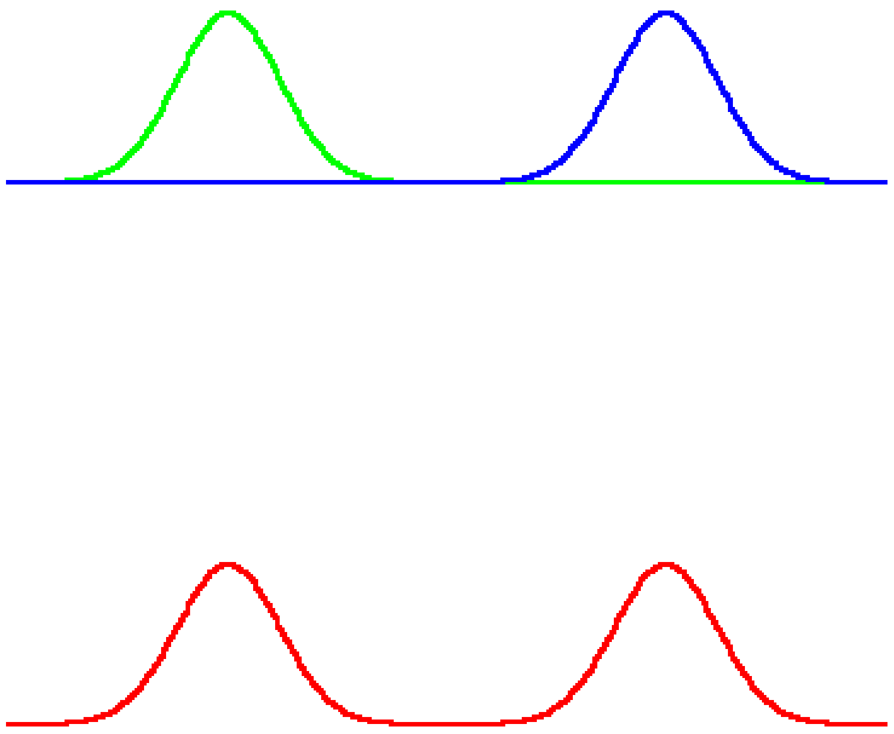
$v_o = v(\text{observer})$

$v = v(\text{wave})$

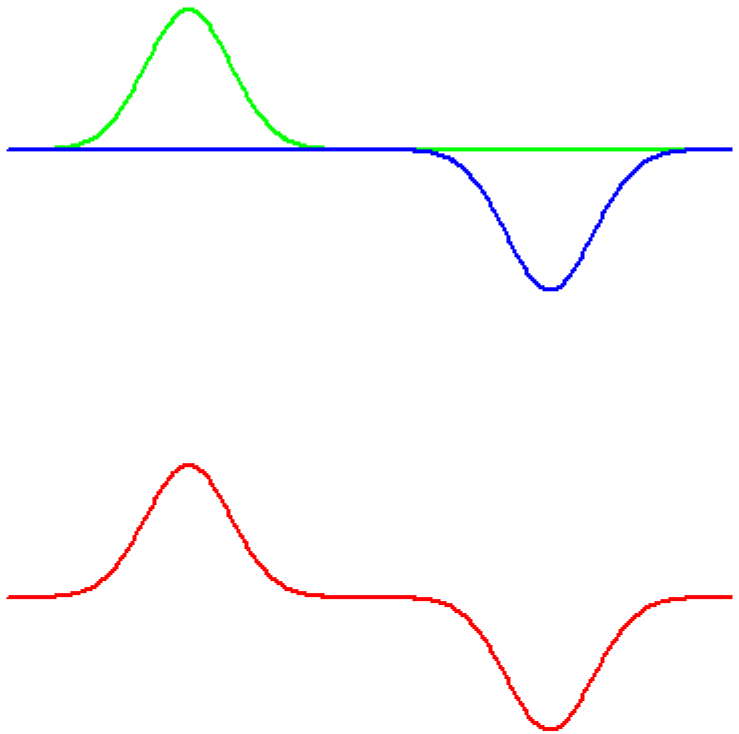
\+ If ***same*** direction as sound wave

\- If ***opposite*** direction to sound wave

Interference and Superposition



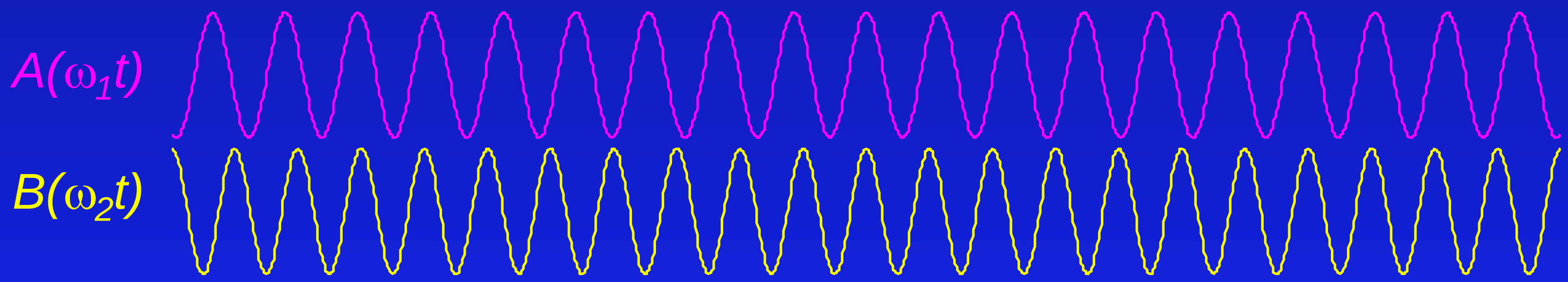
Constructive interference



Destructive interference

Superposition & Interference

- Consider two harmonic waves *A* and *B* meeting at $x=0$.
  - ➔ Same amplitudes, but $\omega_2 = 1.15 \times \omega_1$.
- The displacement versus time for each is shown below:



What does $C(t) = A(t) + B(t)$ look like??

Superposition & Interference

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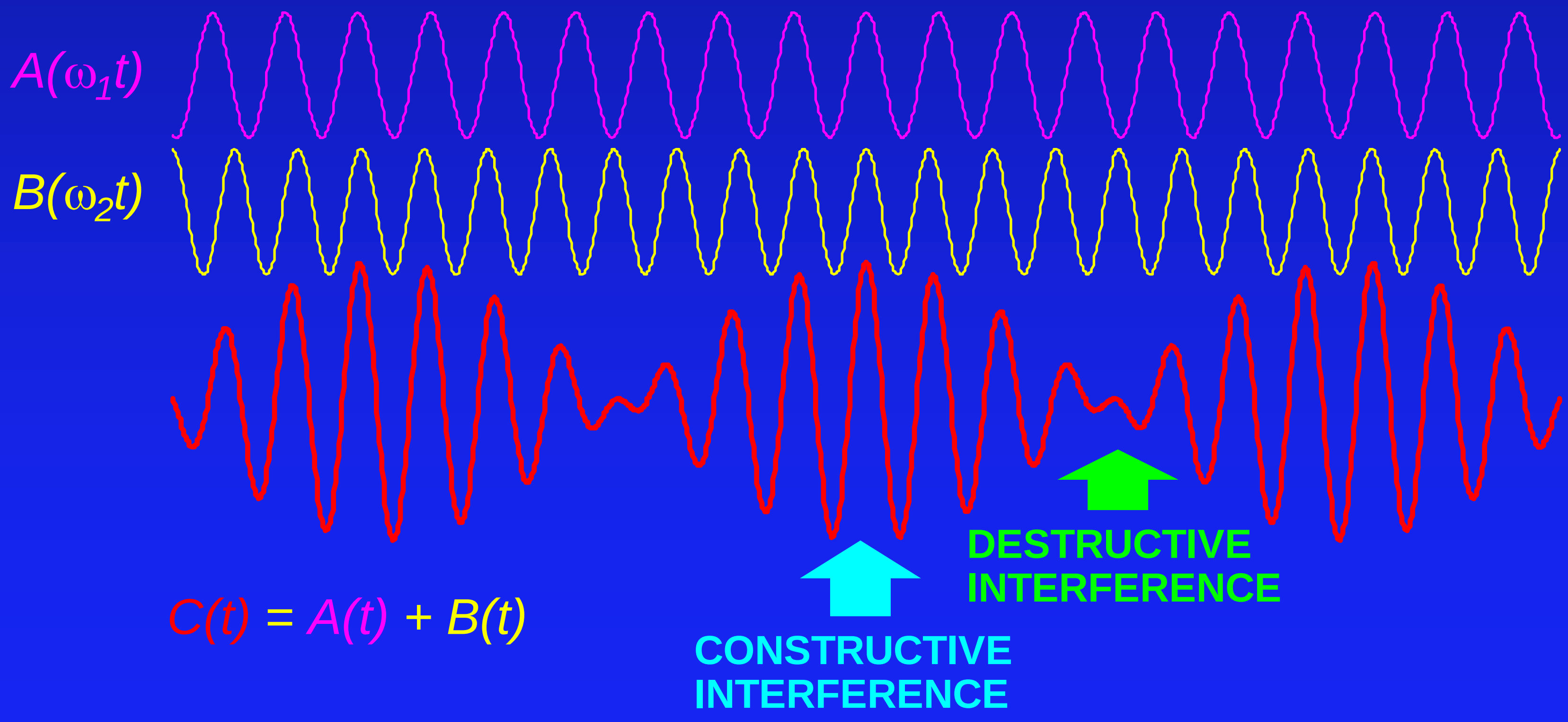
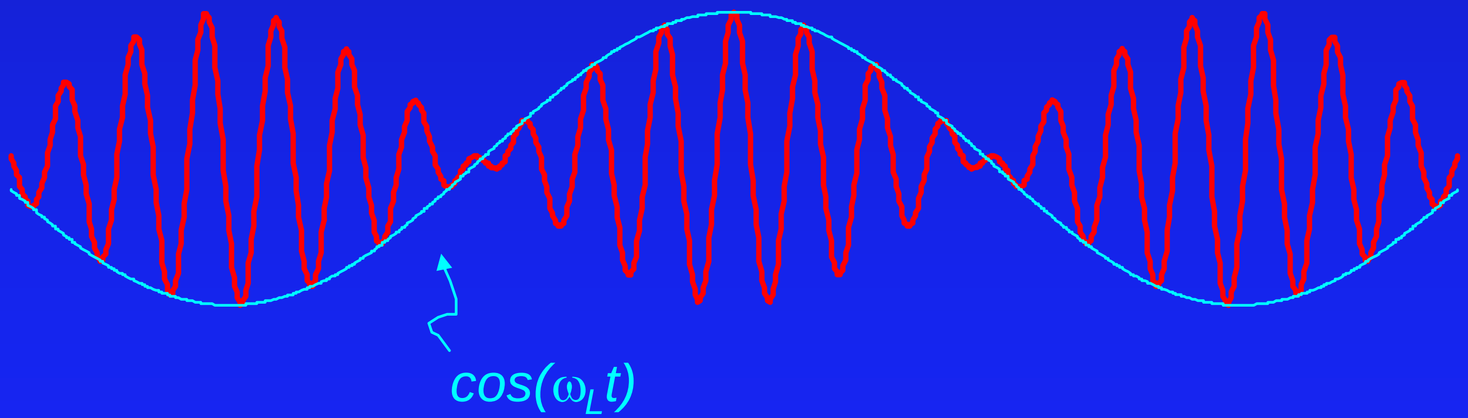


Beats

- Can we predict this pattern mathematically?
  - ➔ Of course!
- Just add two cosines and remember the identity:

$$A\cos(\omega_1 t) + A\cos(\omega_2 t) = 2A\cos(\omega_L t)\cos(\omega_H t)$$

where $\omega_L = \frac{1}{2}(\omega_1 - \omega_2)$ and $\omega_H = \frac{1}{2}(\omega_1 + \omega_2)$



Summary

- Speed of sound $v = \mathrm{sqrt}(B/\rho)$

- Intensity $\beta = (10\ \mathrm{dB}) \log_{10} (I / I_0)$

- Standing Waves
  - ➔ $f_n = n\, v/(2L)$ Open at both ends n=1,2,3…
  - ➔ $f_n = n\, v/(4L)$ Open at one end n=1,3,5…

- Doppler Effect $f_o = f_s\, (v-v_o) / (v-v_s)$

- Beats $\omega_L = \frac{1}{2}(\omega_1 - \omega_2)$