Course announcement

- Homework set 4 will be posted on eLearn on 11/25. It will be due on 12/2 Friday at 5PM.
- The second midterm will on 12/6 (Tuesday). Range: from chapter 9 to chapter 15 of Wolfson (skip chapter 12). Exam will be started 8:00AM. Please bring student ID and calculator. You can bring one A4 information sheet for the exam.

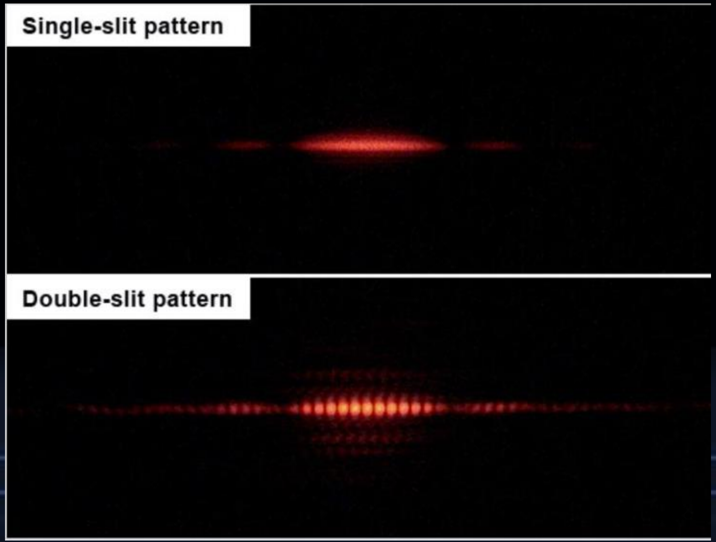
11	11/22(Tue.)	**Oscillation and Waves:** propagation of waves
11	11/25(Fri.)	**Fluid Motion:** Density, Pressure, and Hydrostatic Equilibrium (Homework4)
12	11/29(Tue.)	**Fluid Motion:** Fluid Dynamics and Application
12	12/2(Fri.)	**Review II**
13	12/6(Tue.)	Mid Term 2

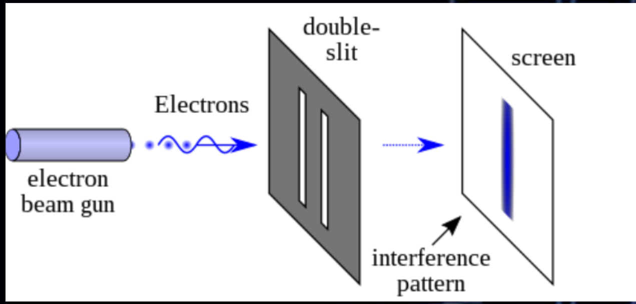
GENERAL PHYSICS B1
OSCILLATION & WAVE

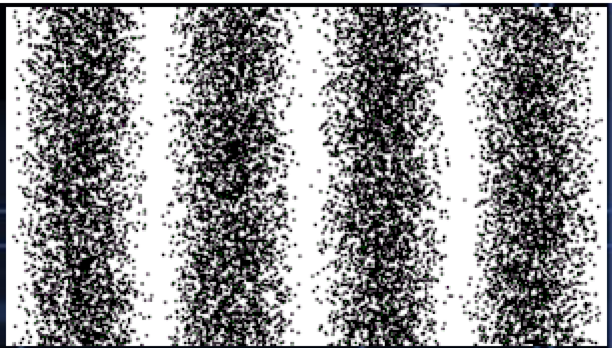
Propagation of Waves
2022/11/11

Interference of wave

- It often happens that two or more waves pass simultaneously through the same region and have interference to each others







https://gfycat.com/gifs/search/destructive+waves

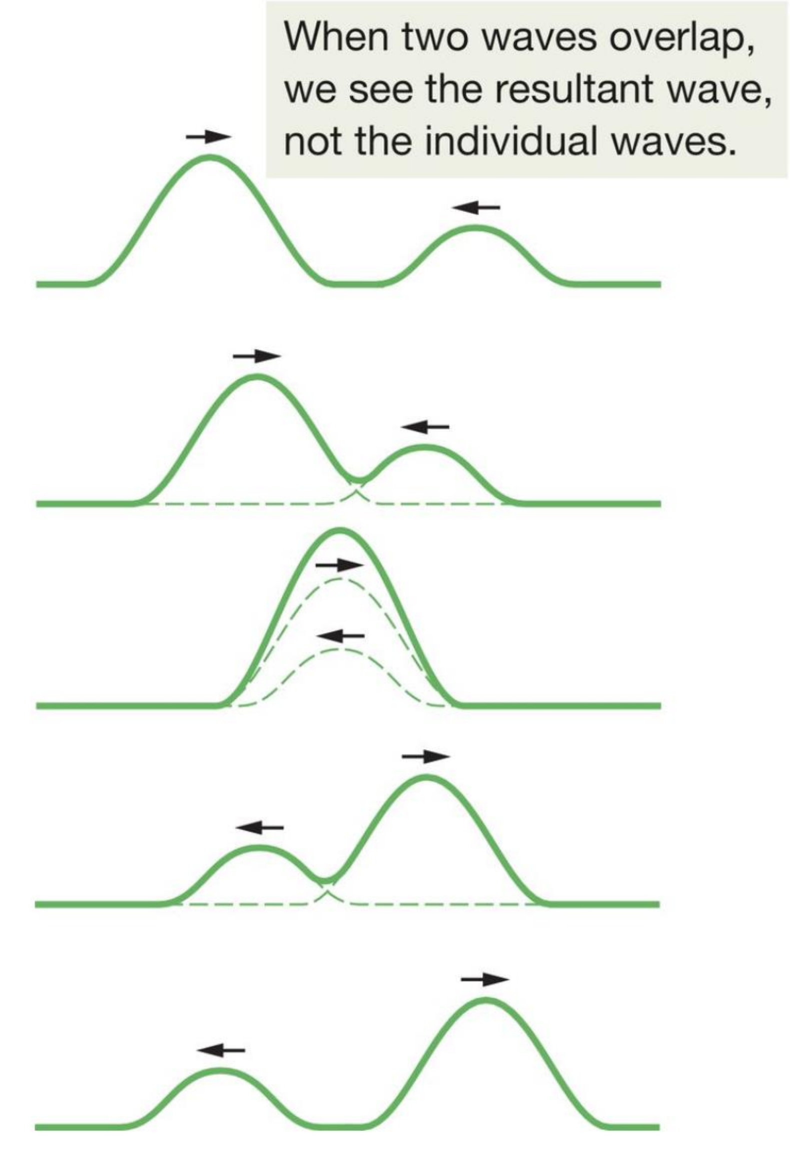
https://en.wikipedia.org/wiki/Double-slit_experiment

Principle of superposition

Principle of superposition: when several effects occur simultaneously, their net effect is the sum of the individual effects:

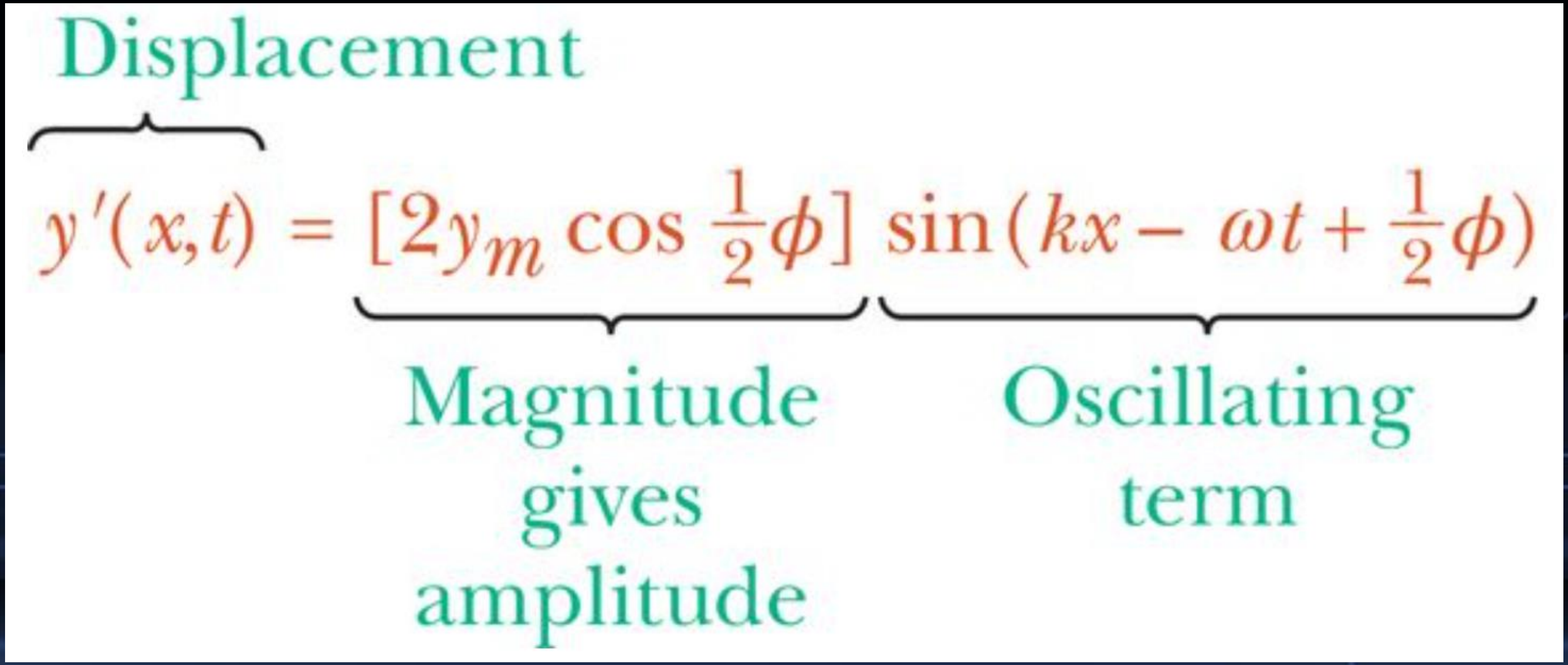
$$y'(x,t) = y_1(x,t) + y_2(x,t)$$

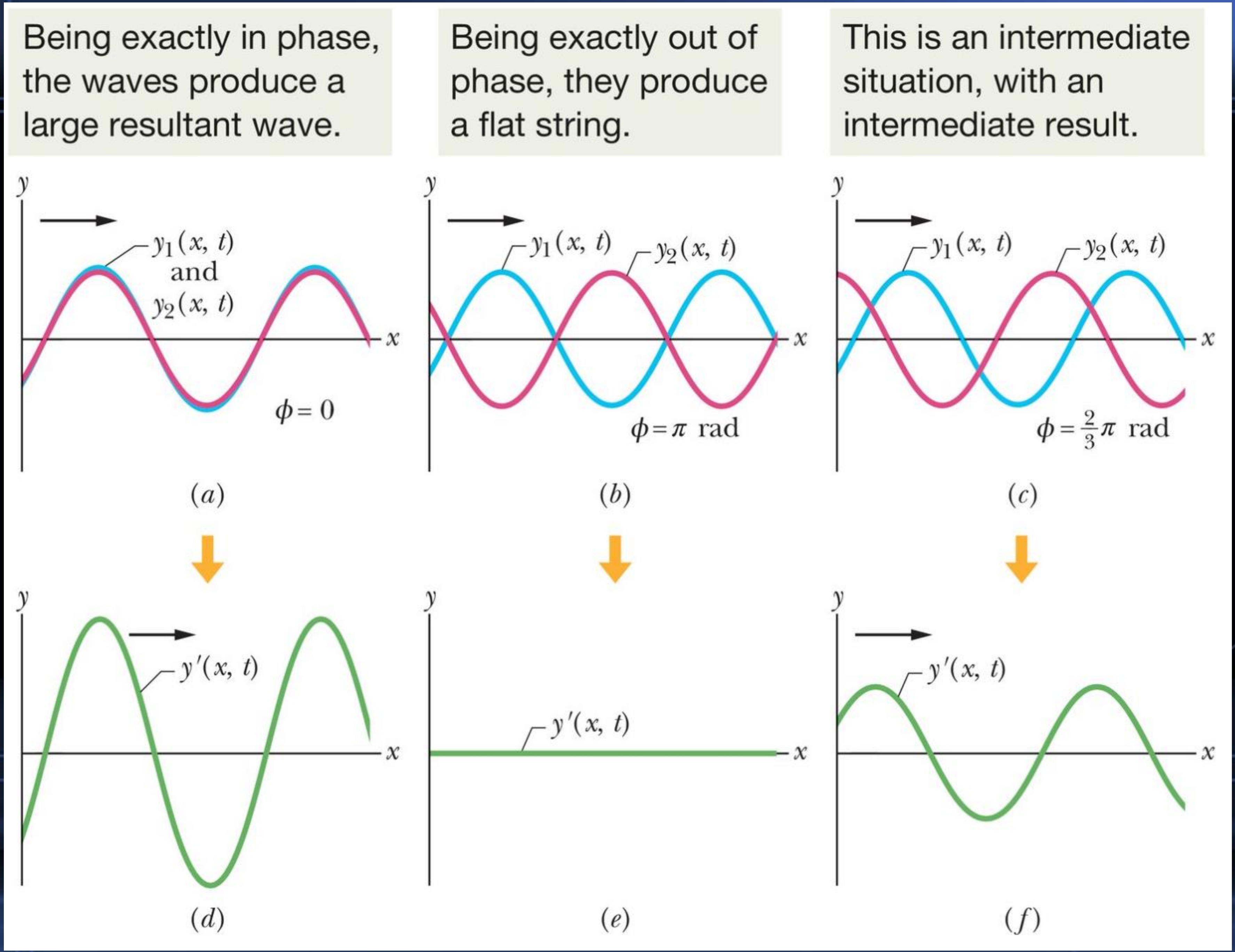
- Overlapping waves algebraically add to produce a resultant wave (or net wave).



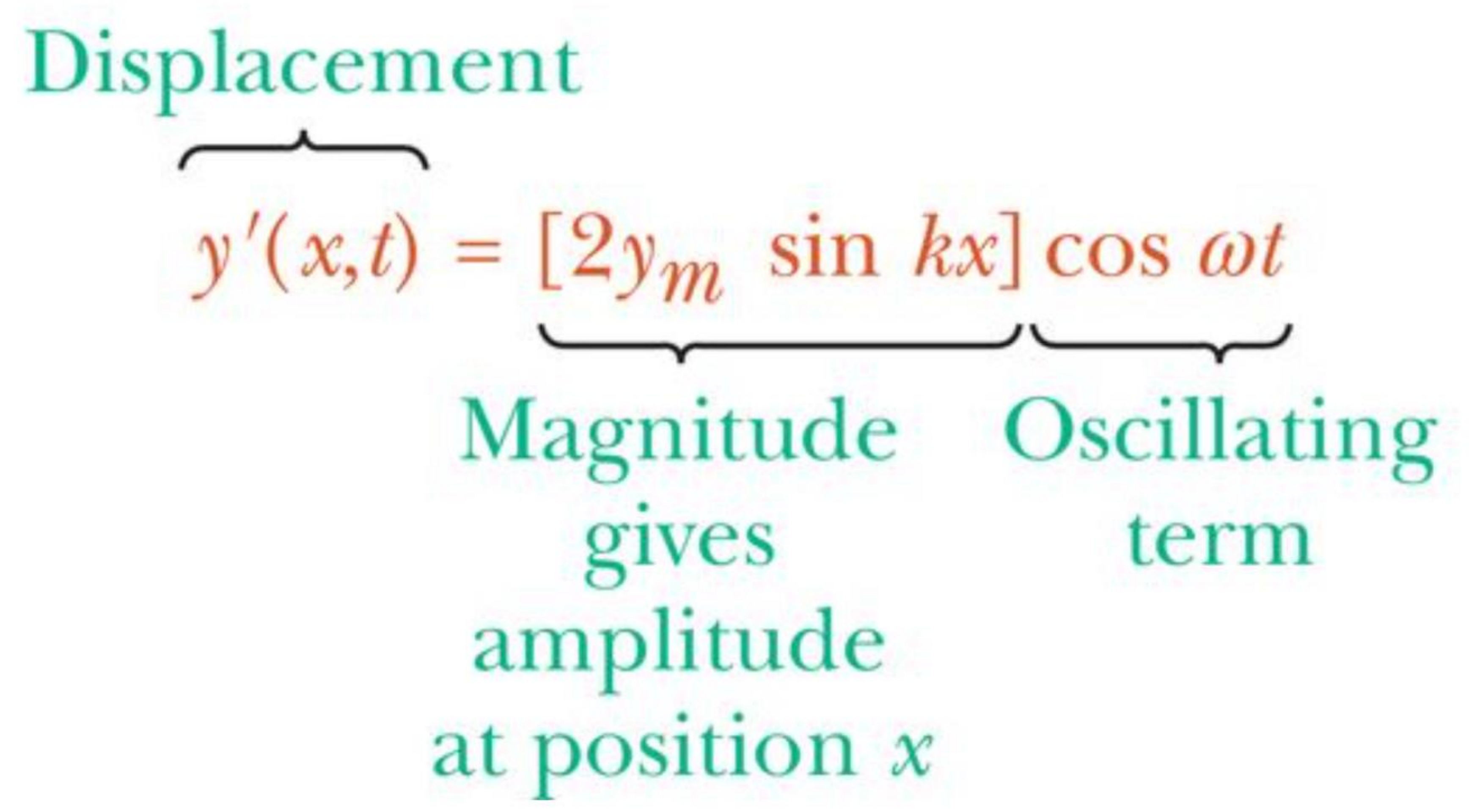
Math description: interference of waves in the same directions

- The resultant wave: $y'(x,t) = y_1(x,t) + y_2(x,t) = y_m \sin(kx - \omega t) + y_m \sin(kx - \omega t + \phi)$

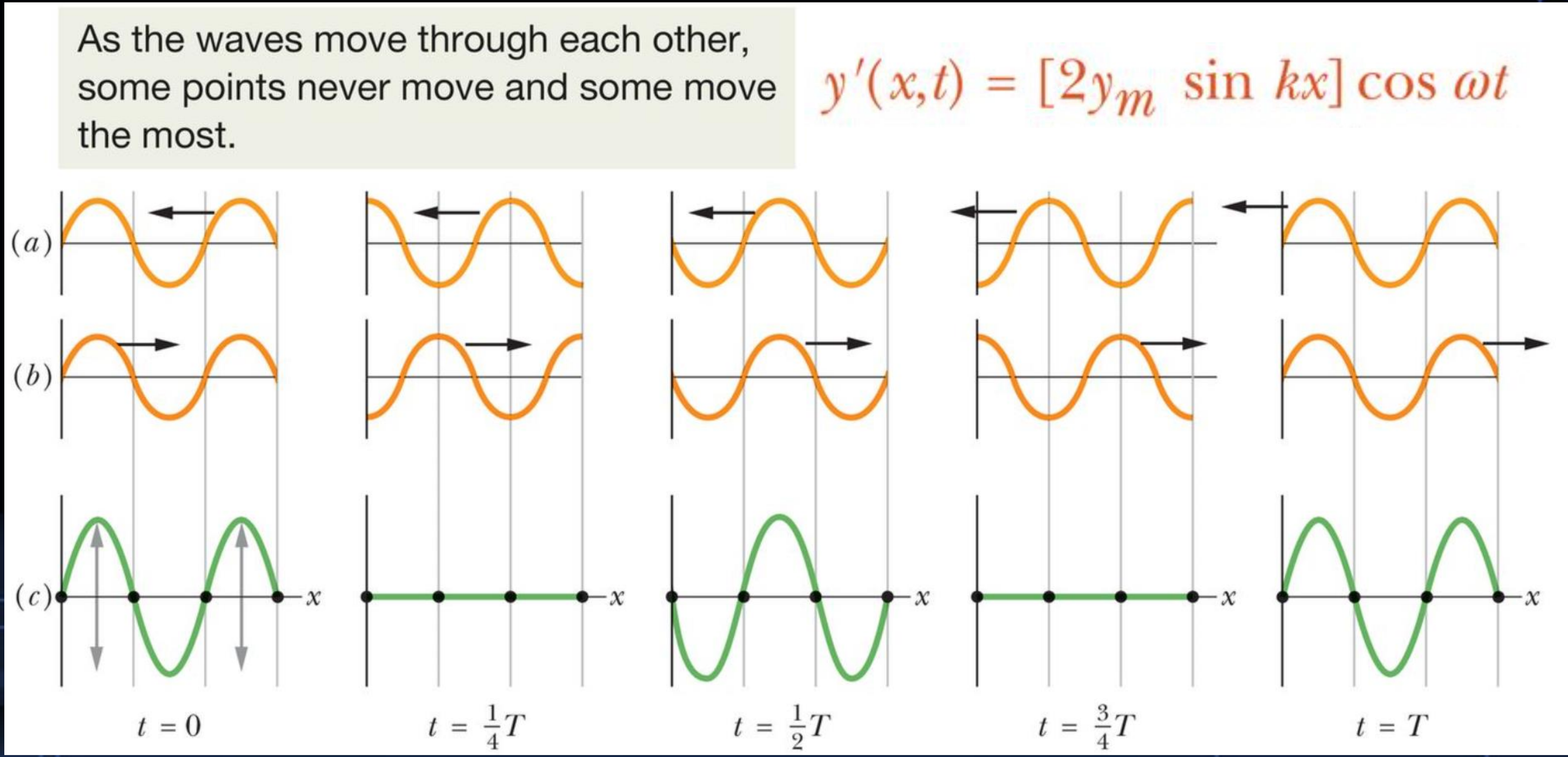



Being exactly in phase, the waves produce a large resultant wave.
Being exactly out of phase, they produce a flat string.
This is an intermediate situation, with an intermediate result.
y
$y_1(x, t)$ and $y_2(x, t)$
x
$\phi = 0$
(a)
$y_1(x, t)$
$y_2(x, t)$
$\phi = \pi$ rad
(b)
$\phi = \frac{2}{3}\pi$ rad
(c)
$y'(x, t)$
(d)
(e)
(f)

Mathematical form of standing wave



Visualization of standing wave

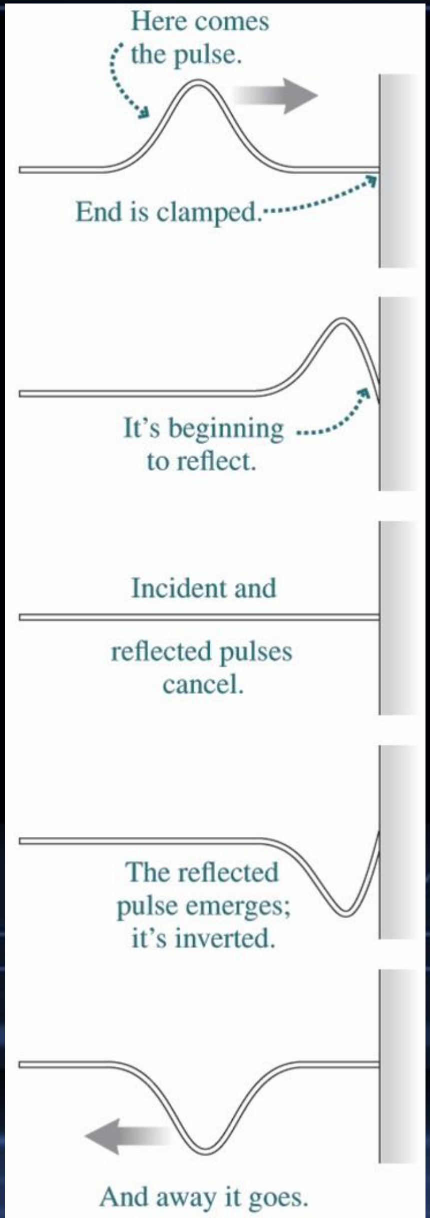


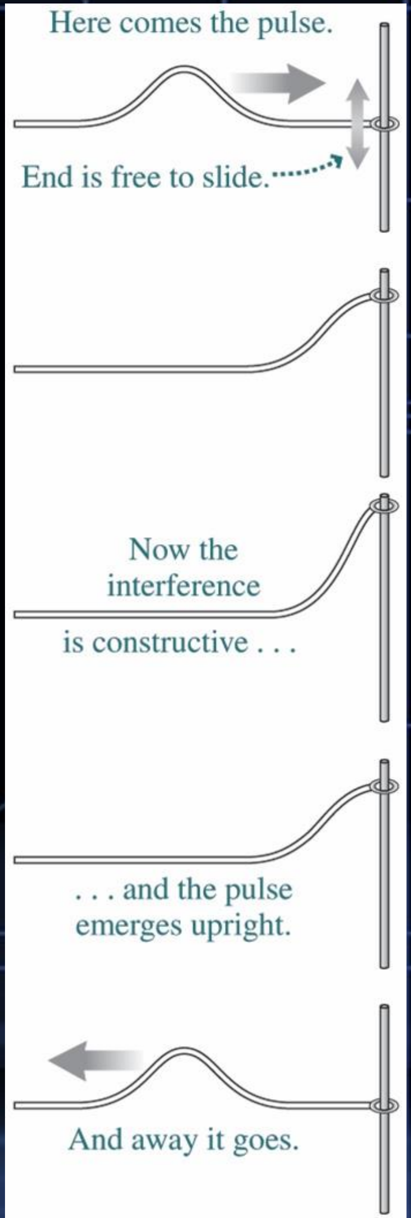
Today’s topic

- reflection, beat, and refraction
- sound wave
- Doppler effect and shock wave

Reflect on the boundary

- There are two ways of pulse can reflect from the end of the string:
- (a) hard end: the reflected pulse is inverted from the incident pulse.
- (b) soft end: the pulse is not inverted by the reflection.

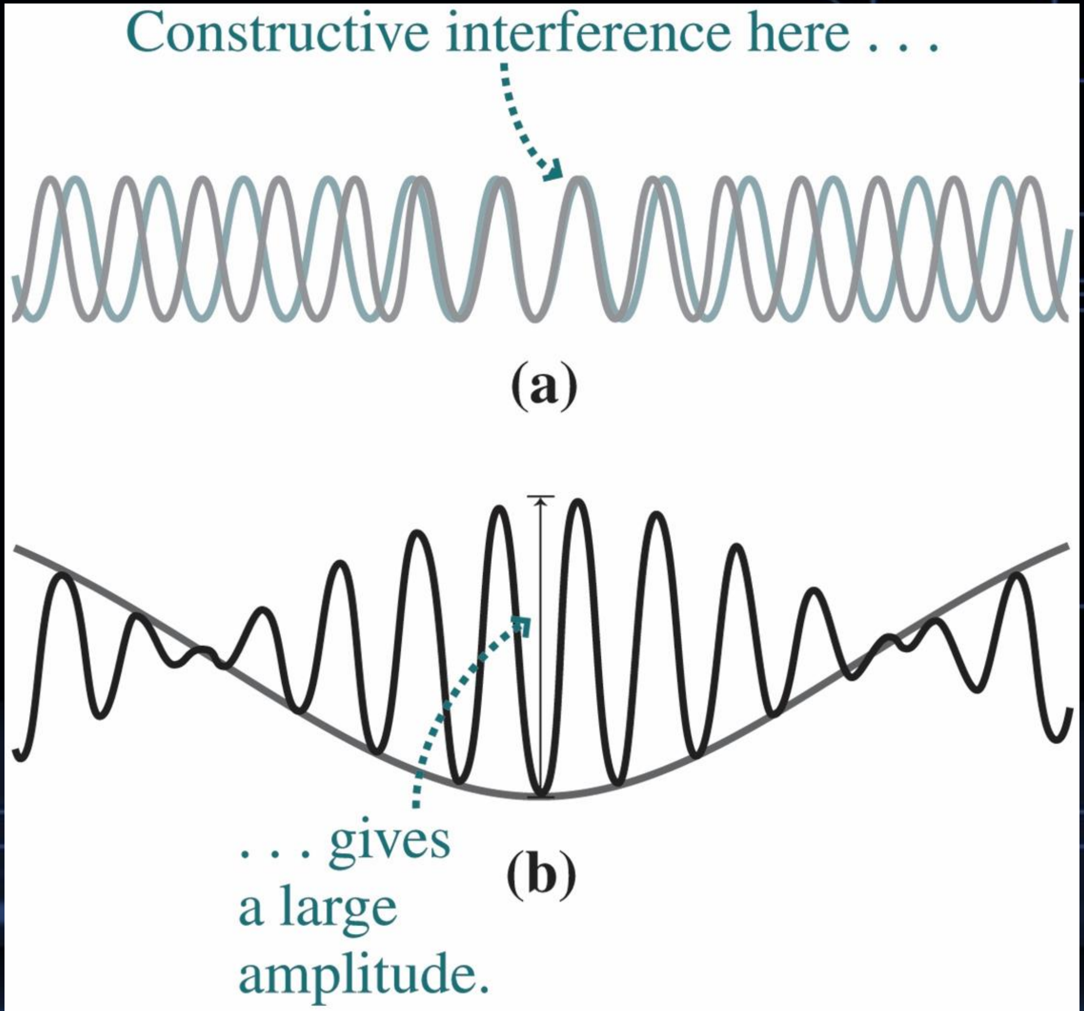




Beat

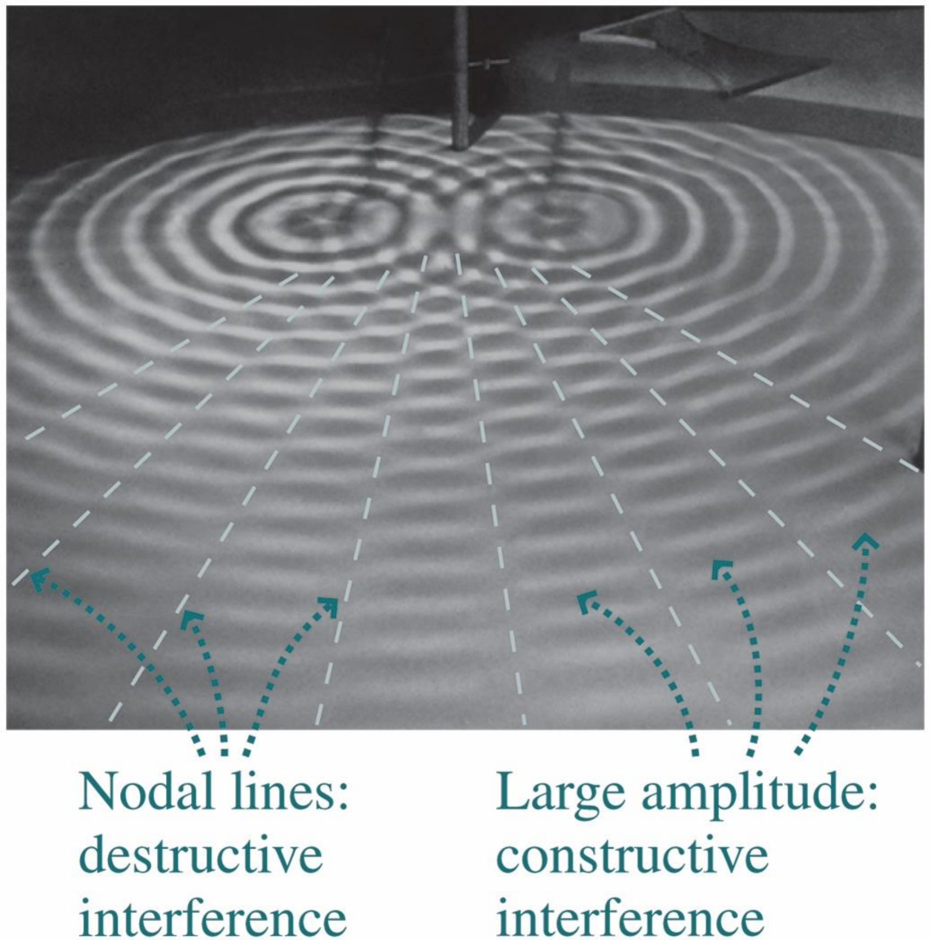
- When waves of slightly different frequencies interfere, they alternate between constructive and destructive interference:
  - This results in a periodic intensity variation known as **beats**.
  - The beat frequency is equal to the difference of the frequencies of the two interfering waves.

$$\omega_{\text{beats}} = \left|\omega_1 - \omega_2\right|$$



Interference in 2D

- Interference from two closely spaced sources results in patterns of high- and low-amplitude waves.



Example: Interference in 2D

- Ocean wave pass through two small openings, 20m apart, in a breakwater. You’re in a boat 75m from the breakwater and initially midway between the openings, but the water is rough. You row 33m parallel to the breakwater and, for the first time, find yourself in relatively calm water. What’s the wavelength of the waves?

Example: Interference in 2D

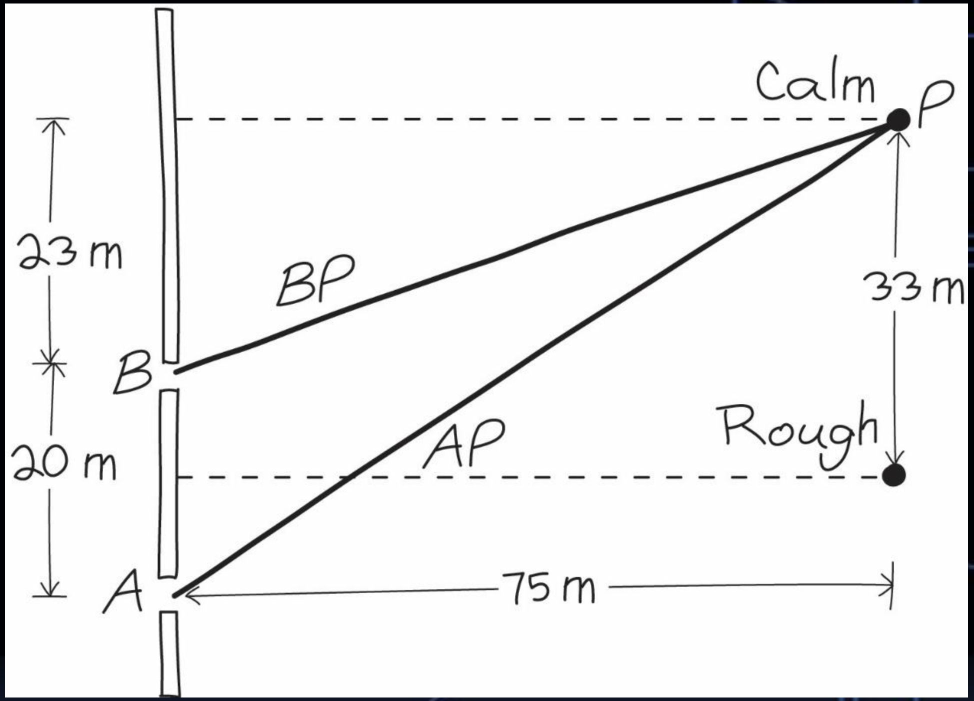
- Completely constructive interference: rough
- Completely destructive interference: calm

$$AP = \sqrt{75^2 + 43^2} = 86.5m$$

$$\mathrm{B}P = \sqrt{75^2 + 23^2} = 78.4m$$

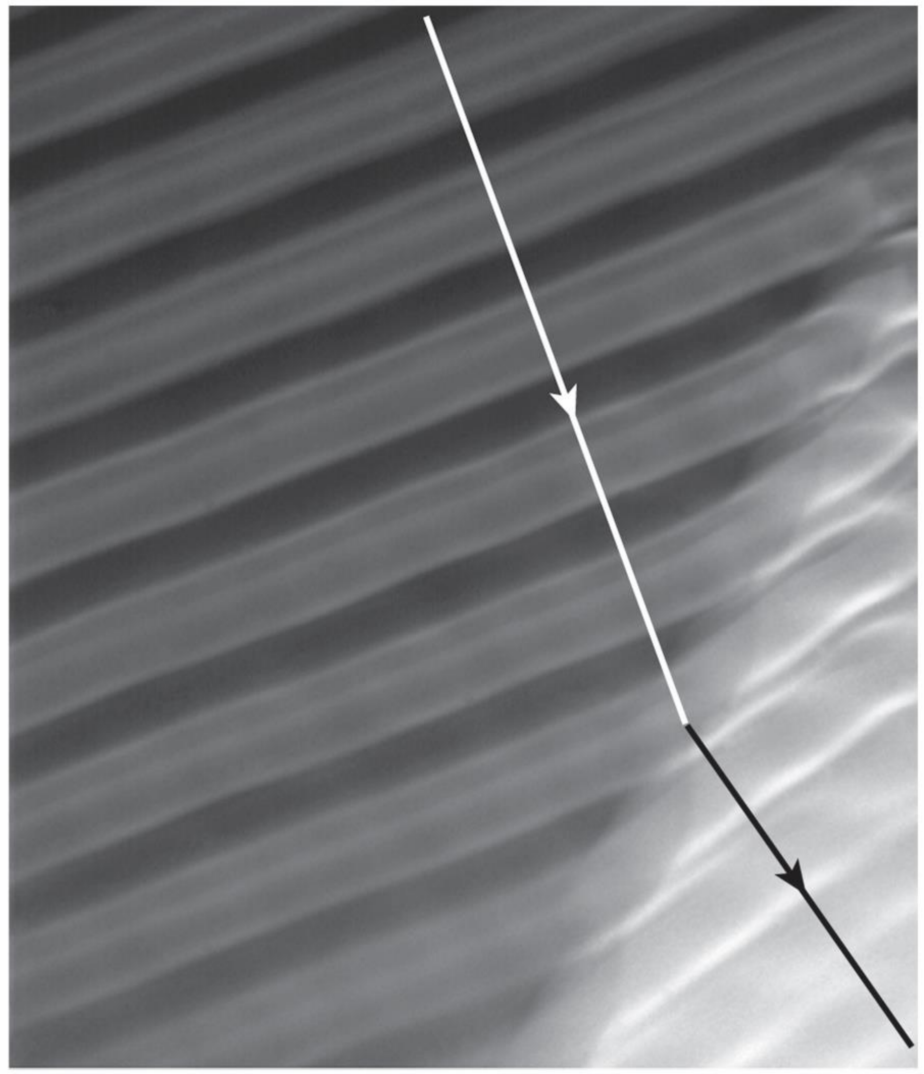
The wavelength is twice difference between these lengths:

$$\lambda = 2(AP - BP) = 16.2m$$

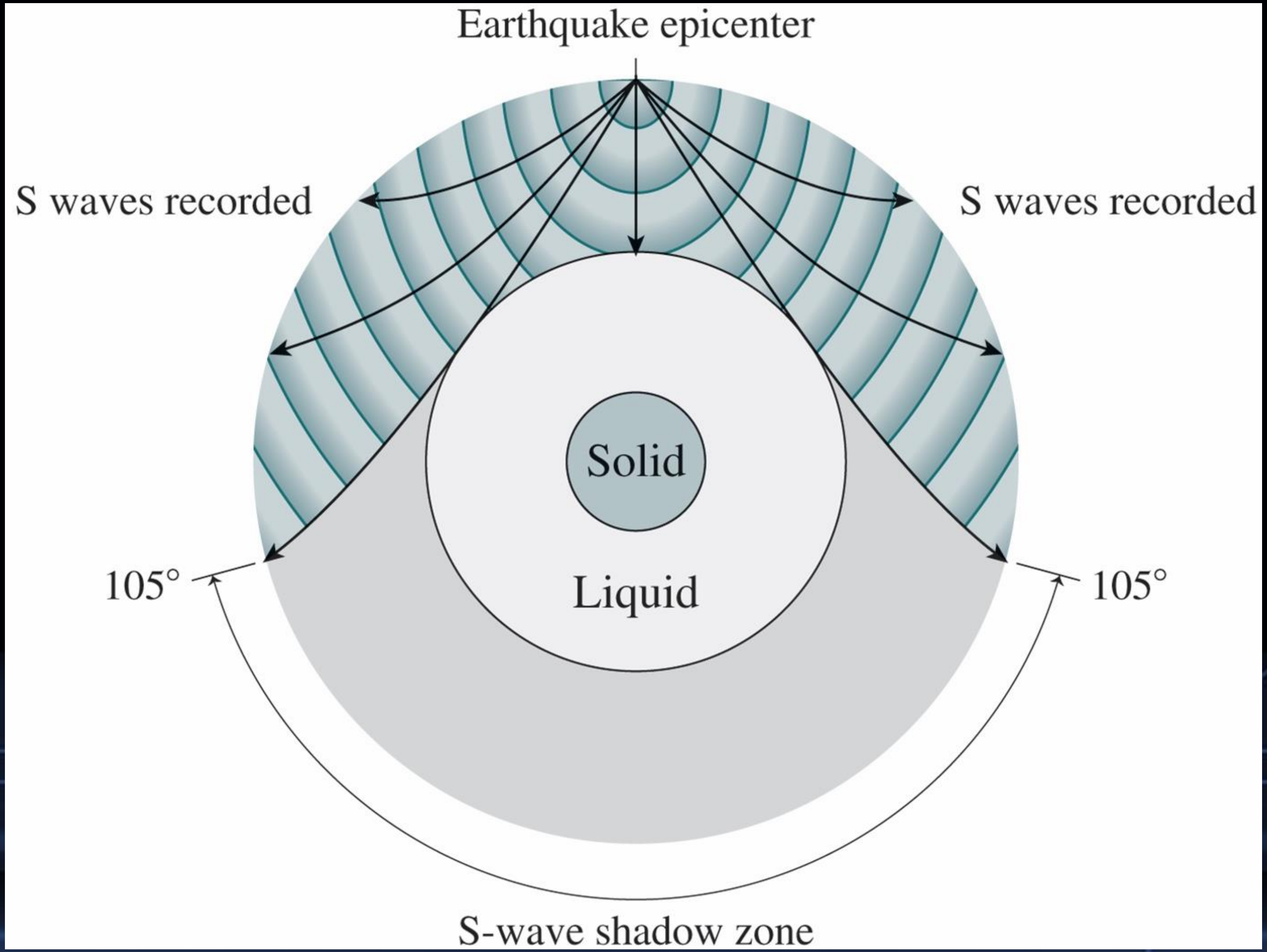


Reflection and Refraction

- When a wave strikes the interface between two different media, it may be partially reflected and partially transmitted.
- If the wave strikes the interface at an oblique angle, the transmitted wave may change its direction of propagation. In this case, we say that the wave is **refracted**.



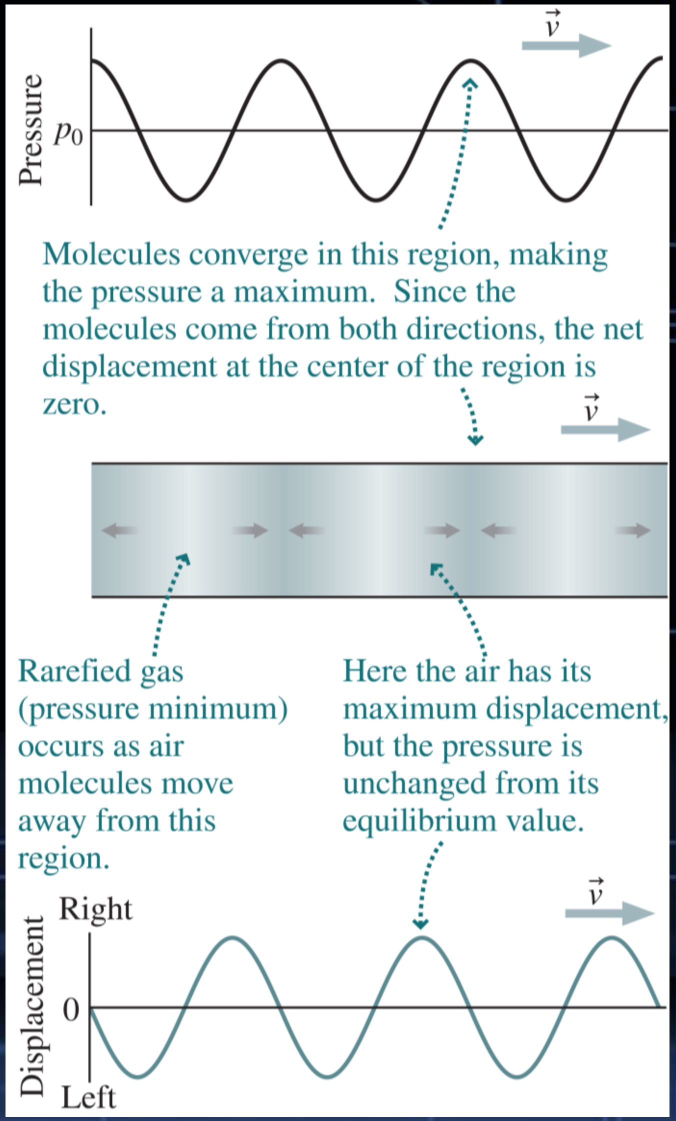
Examples of wave propagation

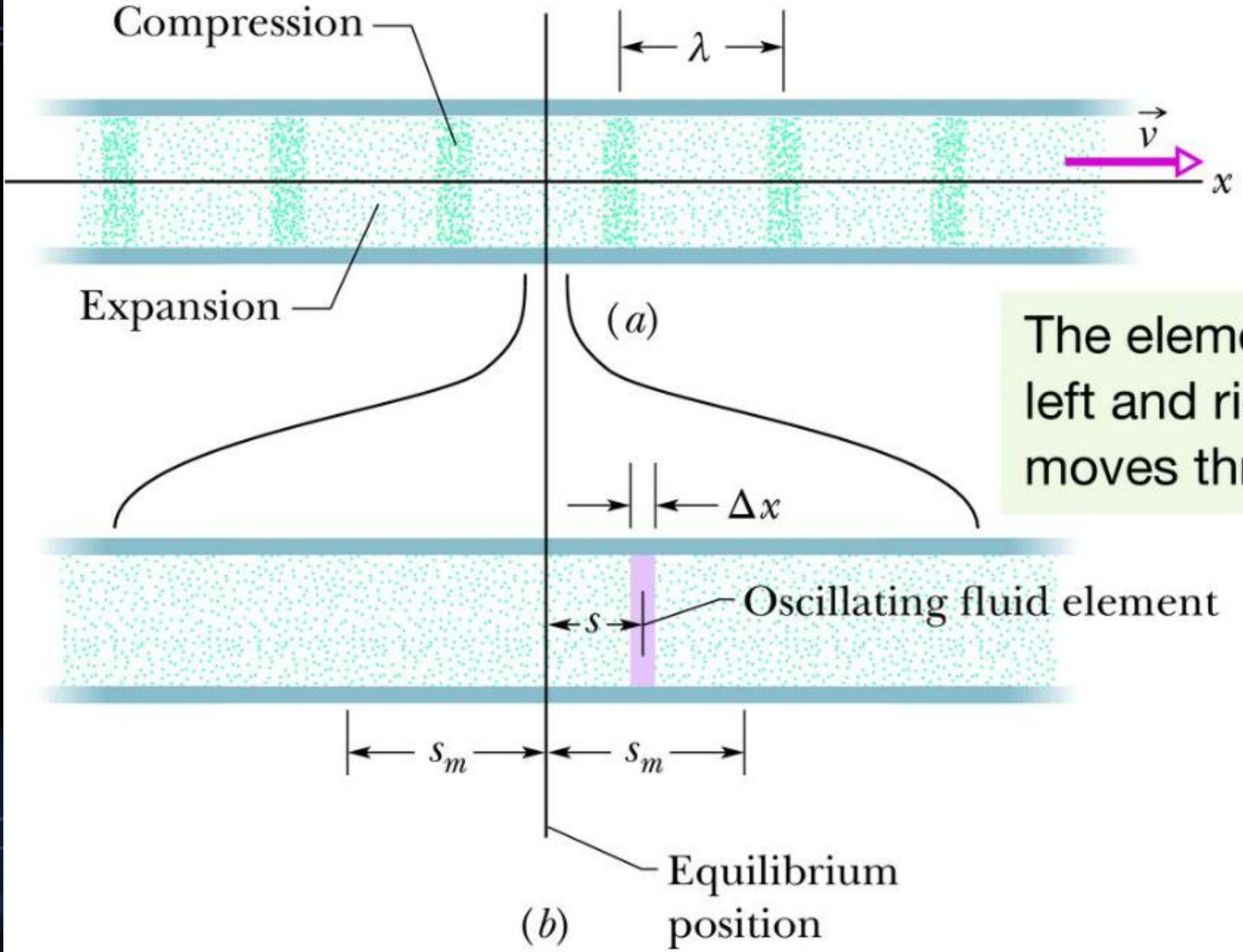


Sound Wave

- Sound waves are longitudinal mechanical waves that propagate through gases, liquids, and solids:
  - Sound waves in air involve small changes in air pressure and density, associated with back-and-forth motion of the air as the wave passes.
  - The speed of sound in a gas depends on the background pressure *P*, density ρ, and a factor γ that is determined by the number of atoms that form a typical gas molecule:

$$V = \sqrt{\frac{\gamma P}{\rho}}$$





The element oscillates left and right as the wave moves through it.

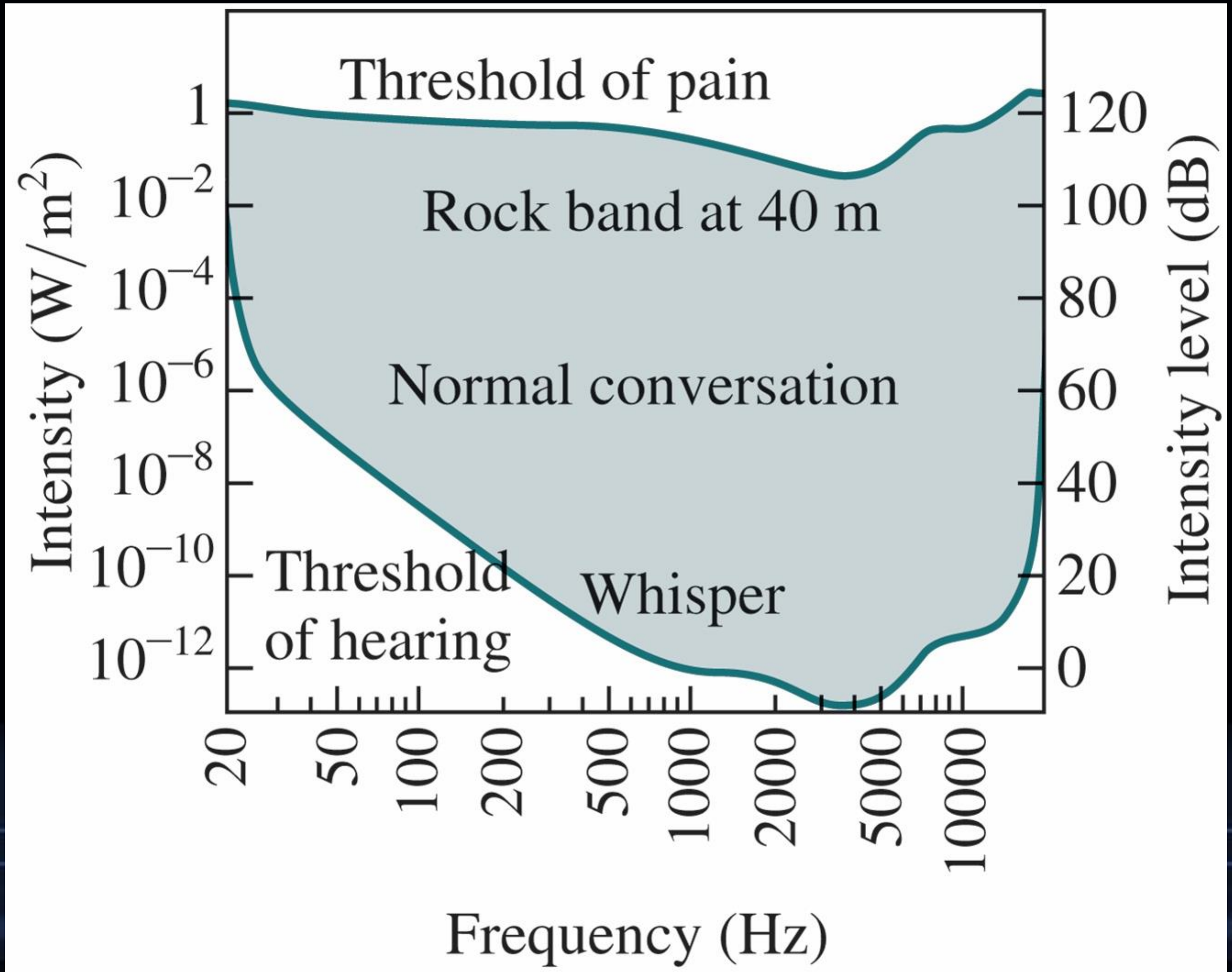
Sound wave speed in different materials

Medium	Speed (m/s)
Gases	
Air (0°C)	331
Air (20°C)	343
Helium	965
Hydrogen	1284
Liquids	
Water (0°C)	1402
Water (20°C)	1482
Seawater*b*	1522
Solids	
Aluminum	6420
Steel	5941
Granite	6000

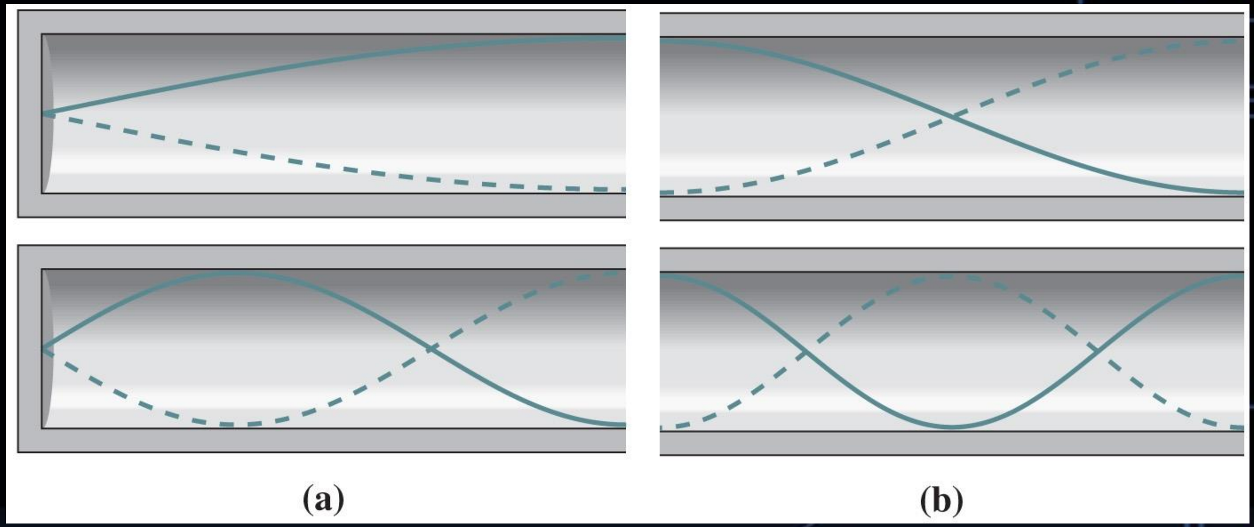
Sound and the Human Ear: The Decibel

- The human ear responds to a broad range of sound intensities and frequencies:
  - The audible range extends from about 20Hz to 20kHz in frequency and over 12 orders of magnitude in intensity.
  - The **sound intensity level β** is measured in **decibels**: $\beta = 10 \log(I/I_0)$

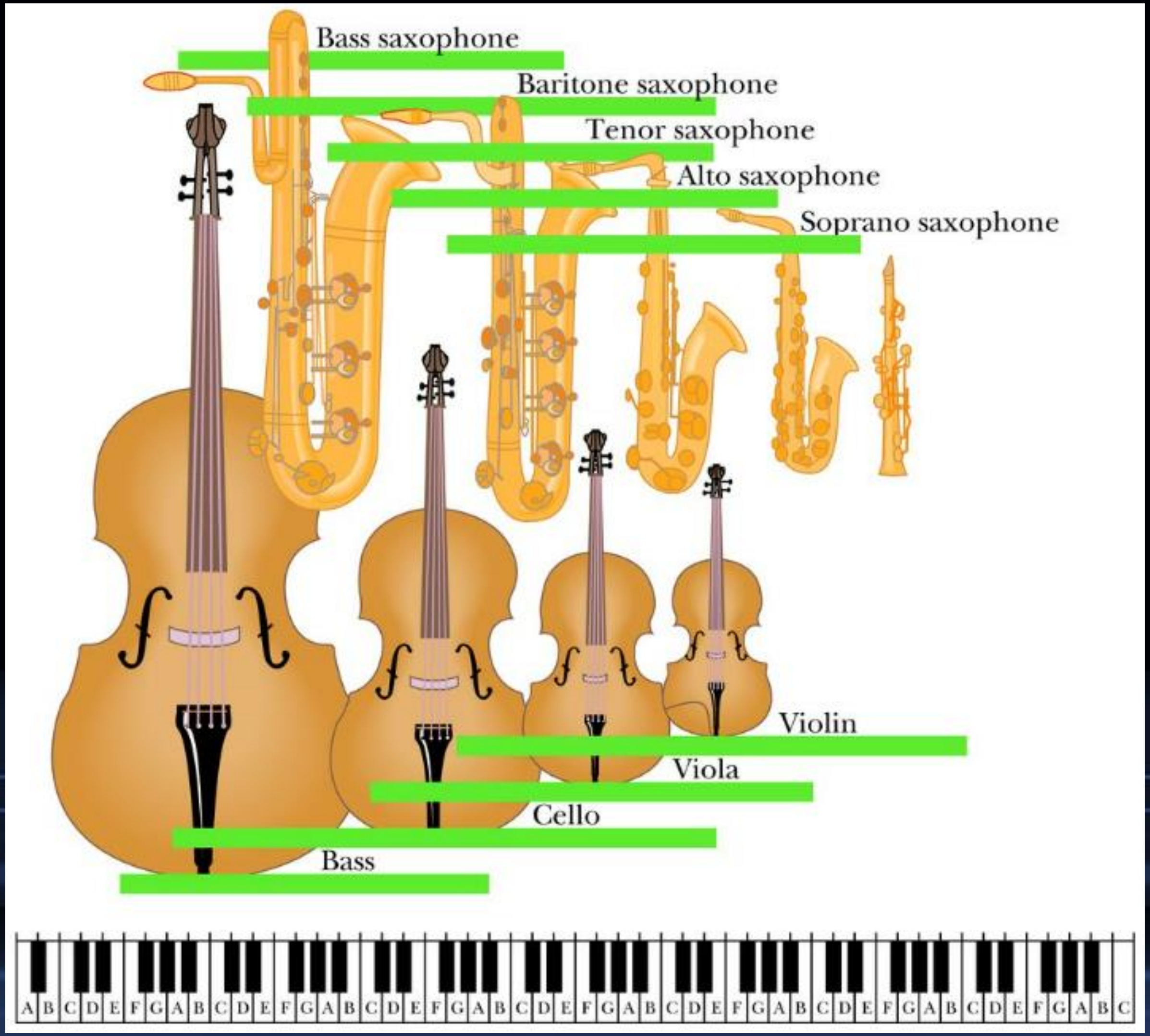
Sound and the Human Ear: The Decibel



Standing sound waves of instruments



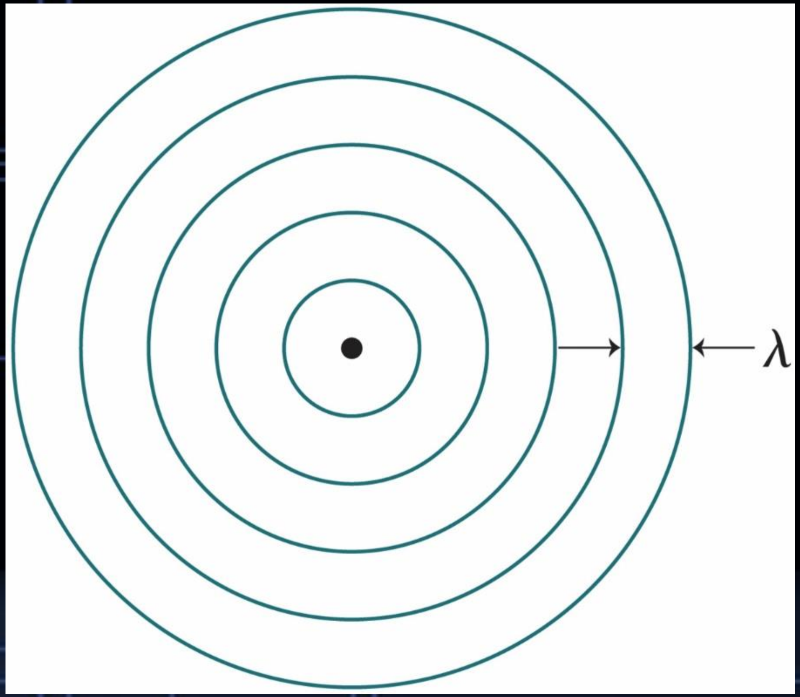
Standing sound waves of instruments

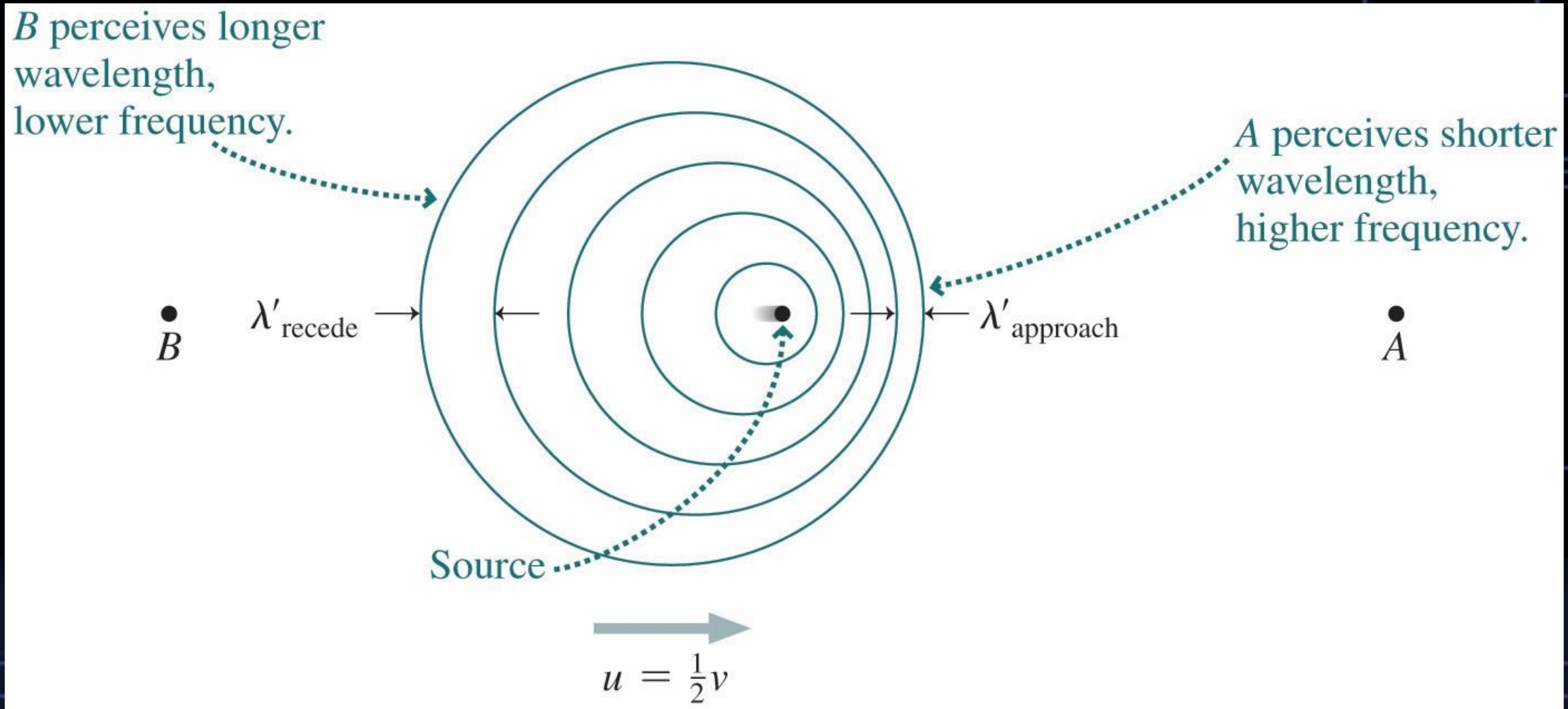


The Doppler Effect: Moving Source

- When a wave source moves through the wave medium, a stationary observer experiences a shift in wavelength and frequency:
  - If the wave moves with a speed *v* and the source moves with a speed *u*, the shifted frequency is: $f' = f/(1 \pm u/v)$
    - The frequency decreases for a receding source.
    - The frequency increases for an approaching source.

The Doppler Effect: Moving Source





The Doppler Effect: Moving Observers

- When the wave source is stationary, an observer moving with a speed *u* will experience a Doppler shift in frequency (but no shift in wavelength) that is given by:

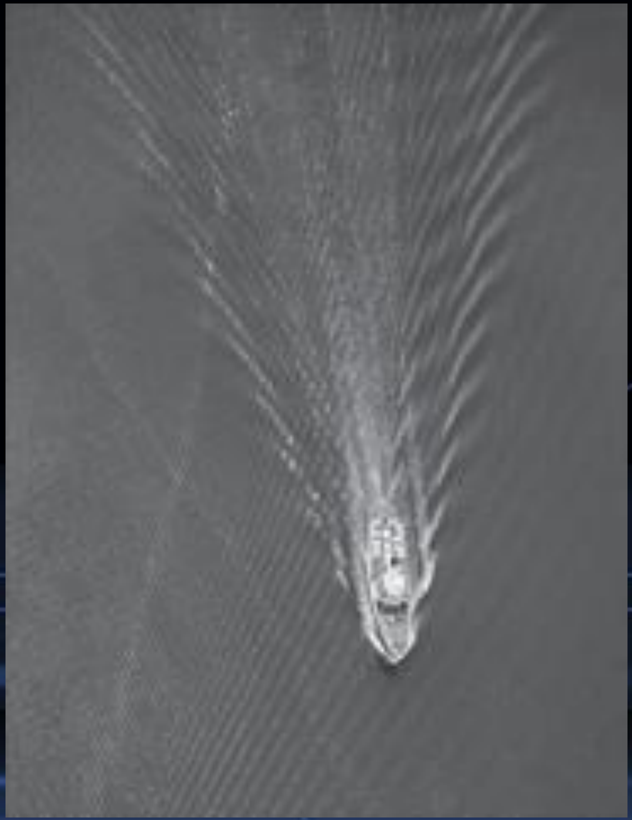
$$f' = f\left(1 \pm u/v\right)$$

- At low speeds (*u* is small compared to *v*), the formula for a source moving with a speed *u* gives nearly the same result as the formula for an observer moving with a speed *u*.

Shock waves

- **Shock waves** occur when a wave source moves through the medium at a speed u greater than the wave speed v:

https://qph.cf2.quoracdn.net/main-qimg-ab7a30704e51218f1853a0fe5e9598e0



Shock waves

The ratio u/v is called the **Mach number**.

The **Mach angle** θ is defined by $\sin\theta = v/u$