Sound waves

Agenda today

1. The Speed of Sound Waves
2. Interference of sound waves
3. Doppler effect

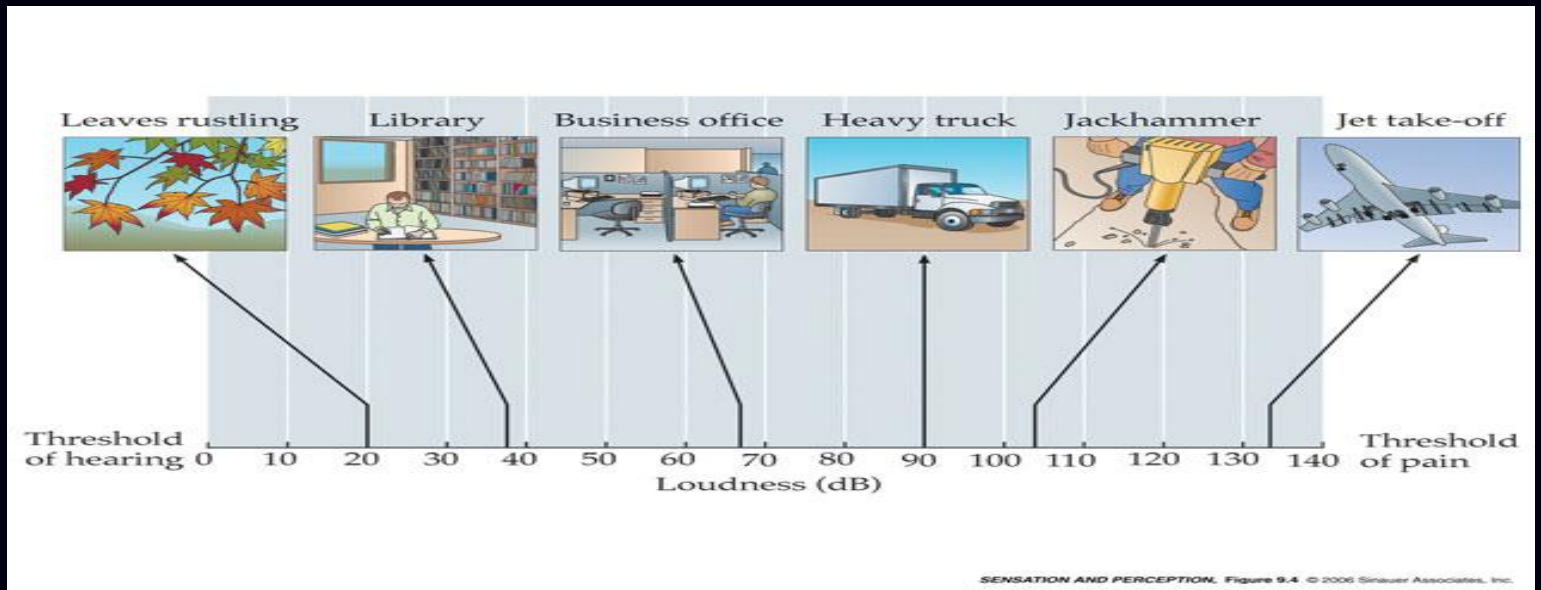
Sound waves:

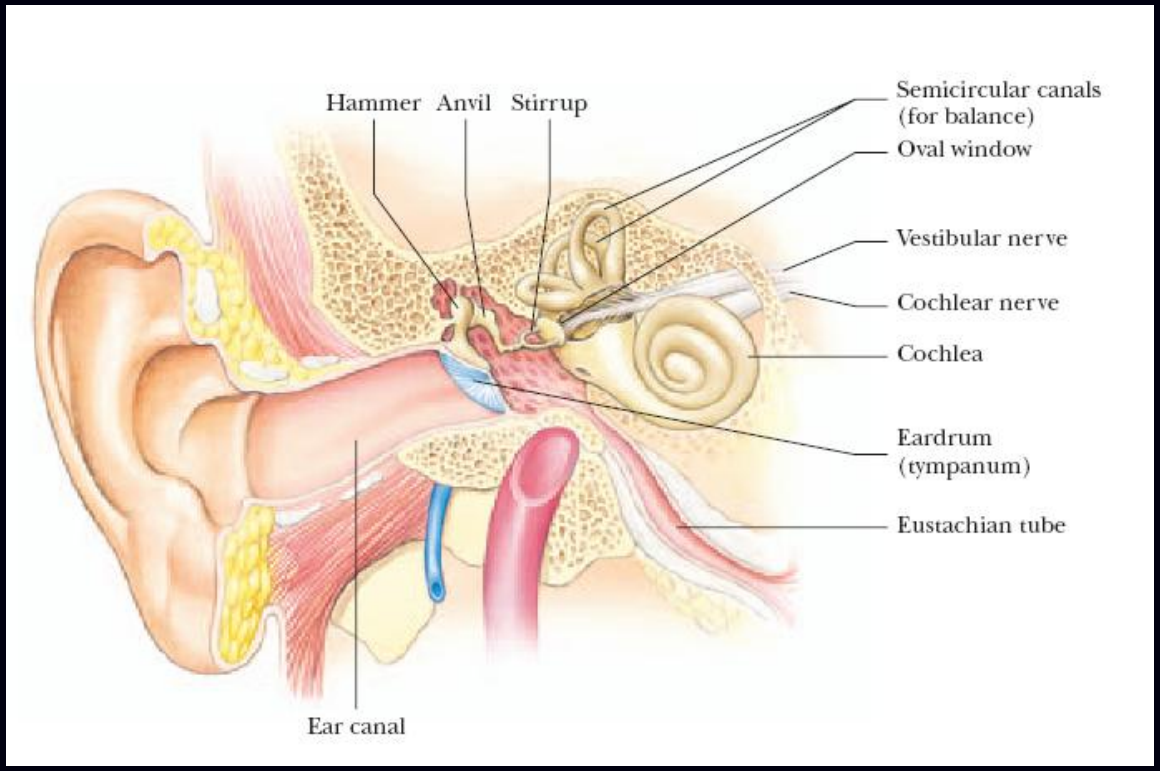
Frequency of sound waves(pitch): 20--25000 Hz

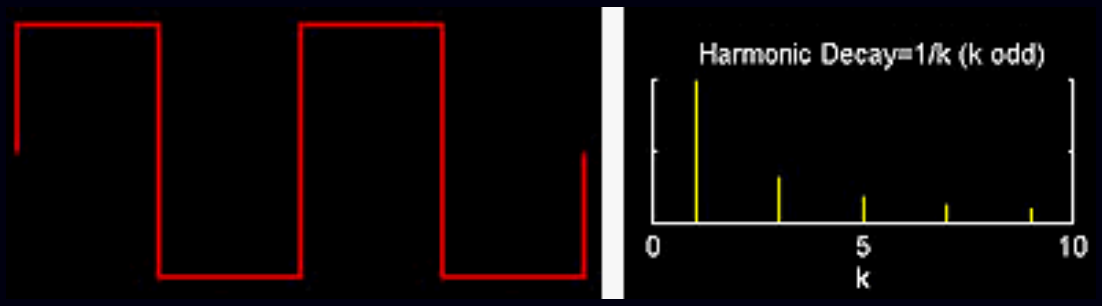
The intensity of sound waves: Decibel scale

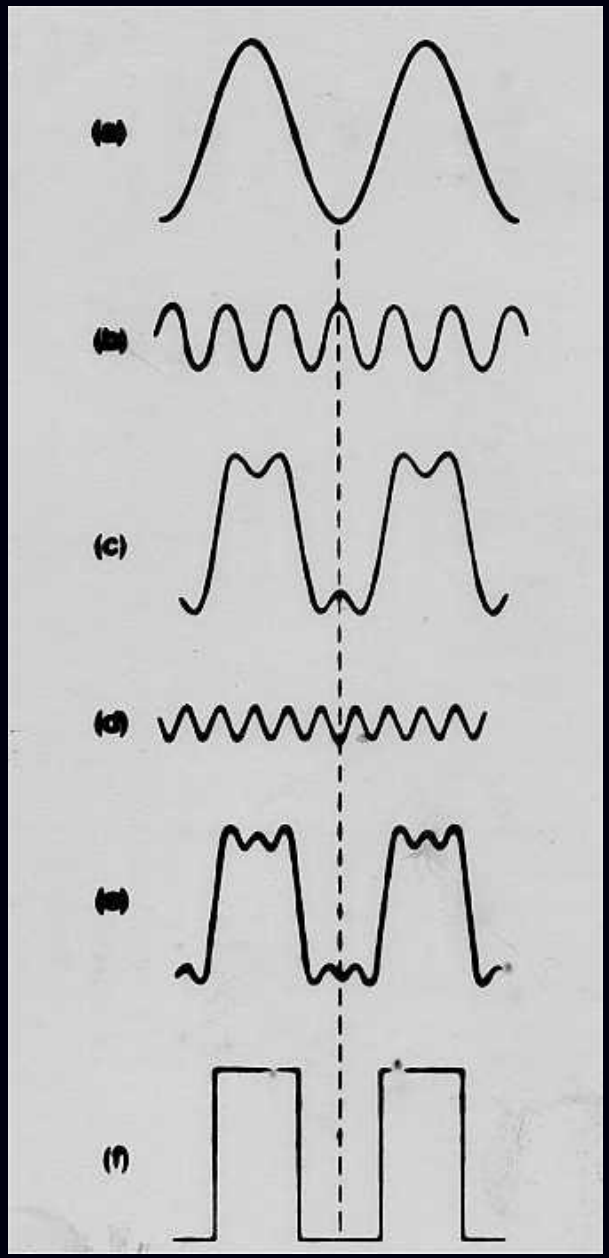
$$\beta = 10 \log \frac{I}{I_0} db$$

$I_0=10^{-12}$ W/m^2




Hammer
Anvil
Stirrup
Semicircular canals (for balance)
Oval window
Vestibular nerve
Cochlear nerve
Cochlea
Eardrum (tympanum)
Eustachian tube
Ear canal


Harmonic Decay=1/k (k odd)
0
5
10
k


(a)
(b)
(c)
(d)
(e)
(f)

white noise 

High pass 

Pink noise 

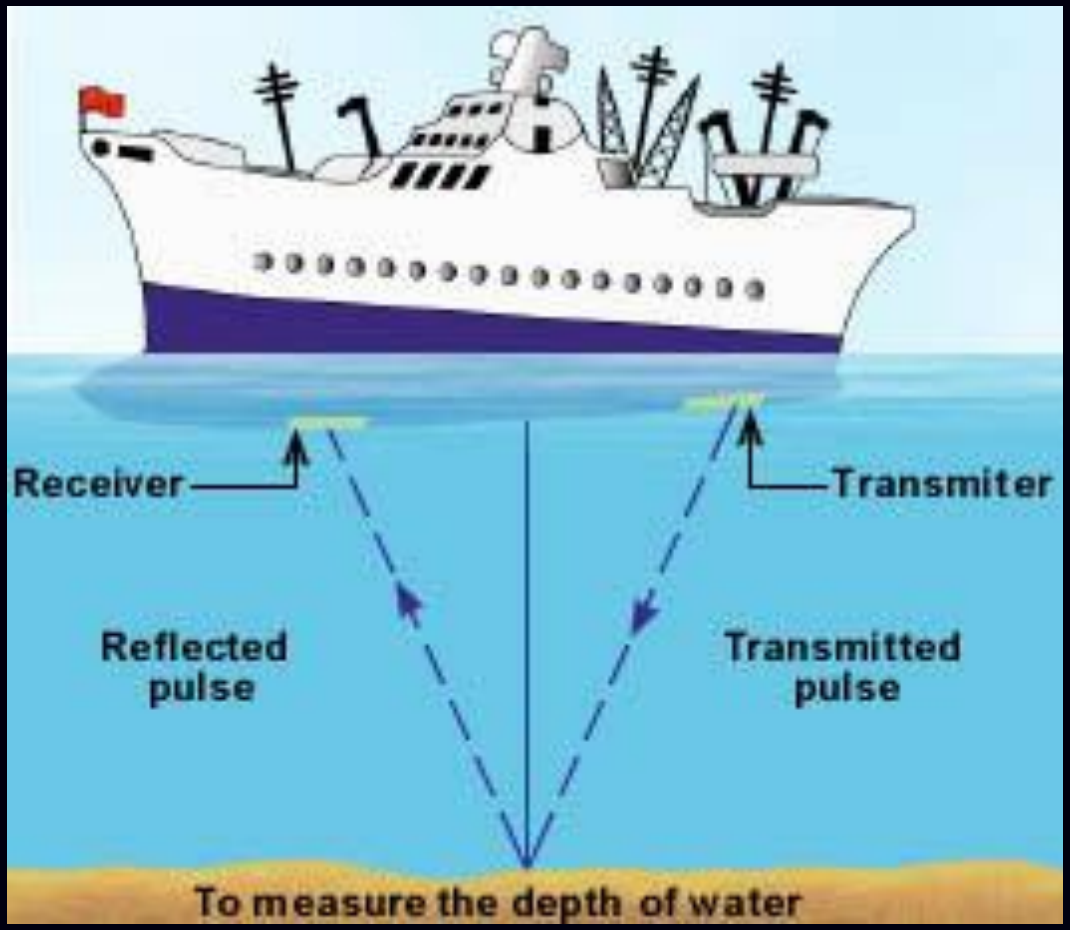
Low pass 

Band pass 

Attenuation of sound waves

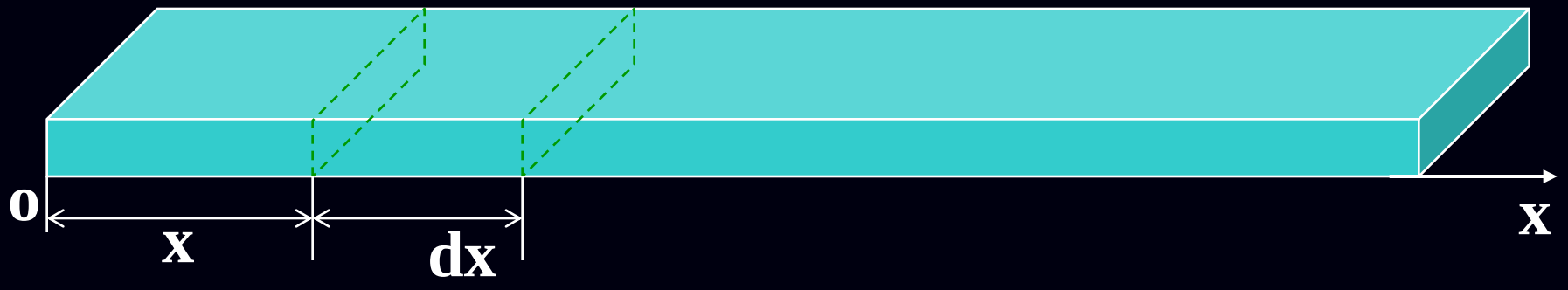
$$A = A_0 e^{-\alpha x}$$

$$I = I_0 e^{-2\alpha x}$$



Why is sonar used to measure the depth of water not radar?

The Speed of Sound Waves



$$F = pA - (p + \Delta p)A$$
$$= -\Delta pA$$

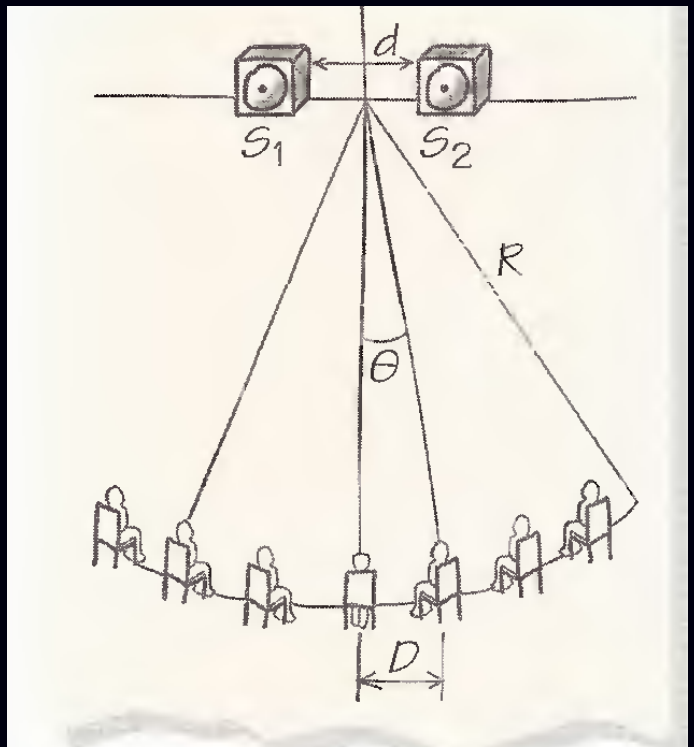
$$F = \Delta ma = \rho A \Delta x \frac{\Delta v}{\Delta t}$$

$$B = -\frac{\Delta P}{\Delta V / V} = -\frac{\Delta P}{\Delta V / V}$$

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

The interference of Sound Waves

Two loudspeakers, Sl and S2, are separated by 0.50 m. These speakers form sound waves of the same amplitude at a frequency of 4400 Hz. The amplifier emits the two waves 180 degrees out of phase. A set of chairs is arranged in a semicircle 30.0 m from the midpoint of the two speakers. Find the amplitude of the wave at the chair on the perpendicular bisector (center line) of the line between the speakers. At what distance to the right of this central chair is there a first maximum in sound intensity?



Beats

Period of beat: $T = \dfrac{2\pi}{\omega_2 - \omega_1}$

Frequency of beat: $\nu = \dfrac{\omega_2 - \omega_1}{2\pi} = \nu_2 - \nu_1$

$$x_1 = A_1 \cos \omega_1 t = A_1 \cos 2\pi \nu_1 t$$

$$x_2 = A_2 \cos \omega_2 t = A_2 \cos 2\pi \nu_2 t$$

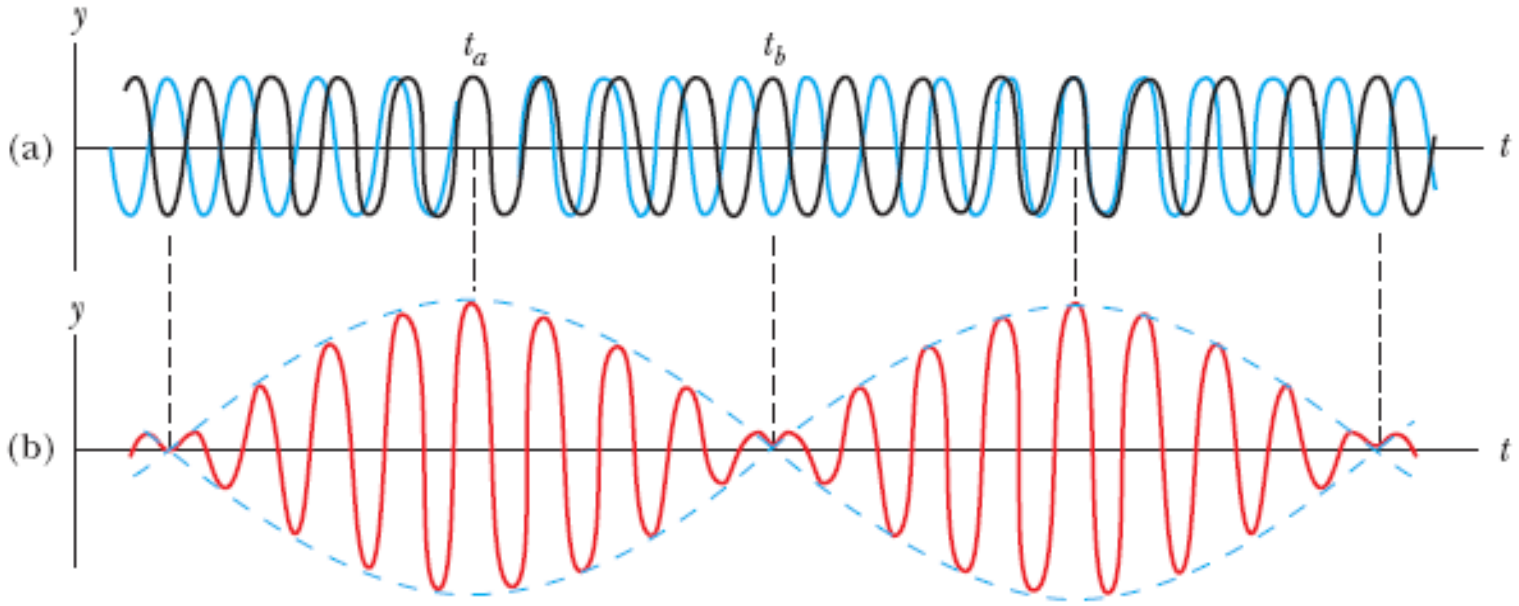
$$x = x_1 + x_2 = A_1 \cos 2\pi \nu_1 t + A_2 \cos 2\pi \nu_2 t$$

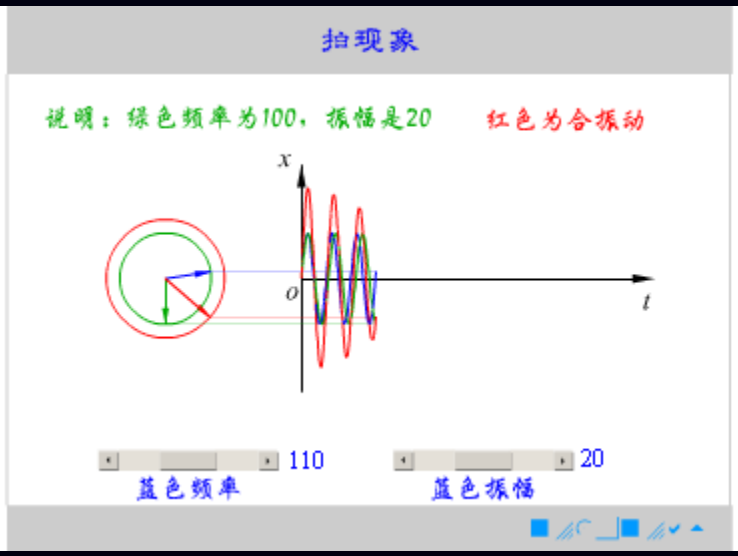
$$Let: \quad A_1 = A_2 = A$$

$$x = 2A\cos 2\pi \frac{\nu_2 - \nu_1}{2} t \cdot \cos 2\pi \frac{\nu_2 + \nu_1}{2} t$$

Amplitude: $\left| 2A\cos 2\pi \frac{\nu_2 - \nu_1}{2} t \right|$ **Is change with time slowly**

$\cos 2\pi \frac{\nu_2 + \nu_1}{2} t$ **Is oscillation factor**

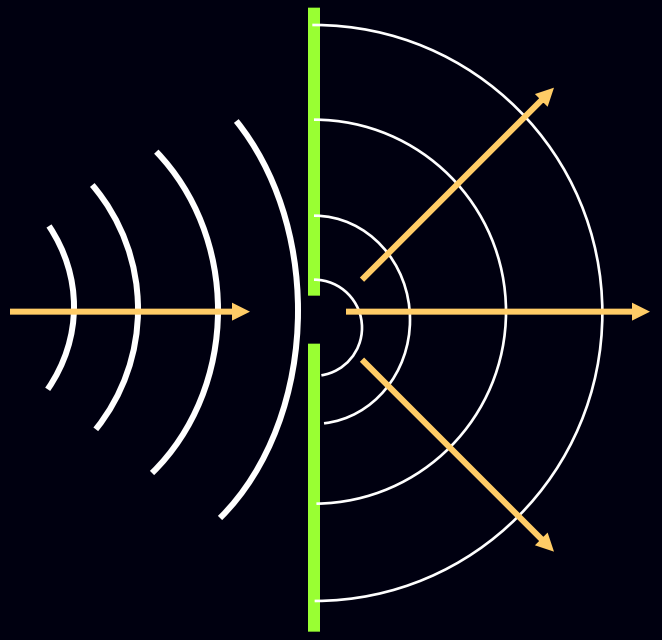

y
t_a
t_b
(a)
t
y
(b)
t

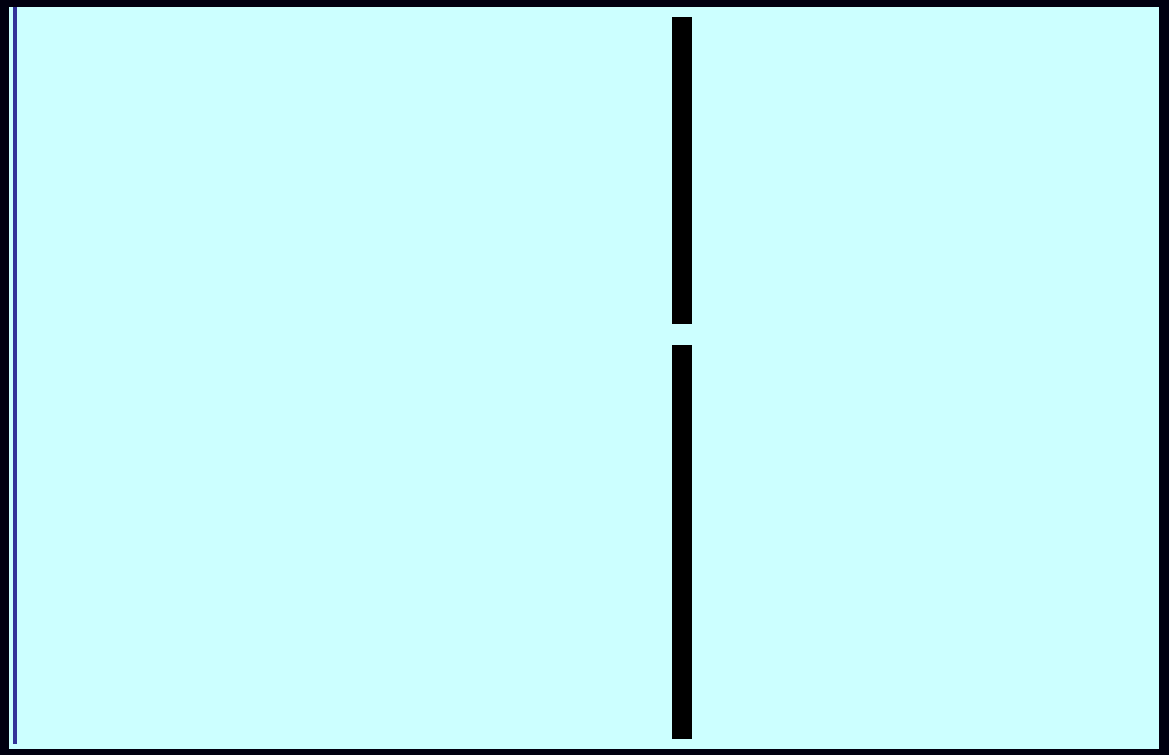

拍现象
说明：绿色频率为100，振幅是20
红色为合振动
x
o
t
110
20
蓝色频率
蓝色振幅

The diffraction of sound waves

diffraction

when wave meets small obstacle or slit, it will act as if it is generating from the edge of the obstacle or slit.

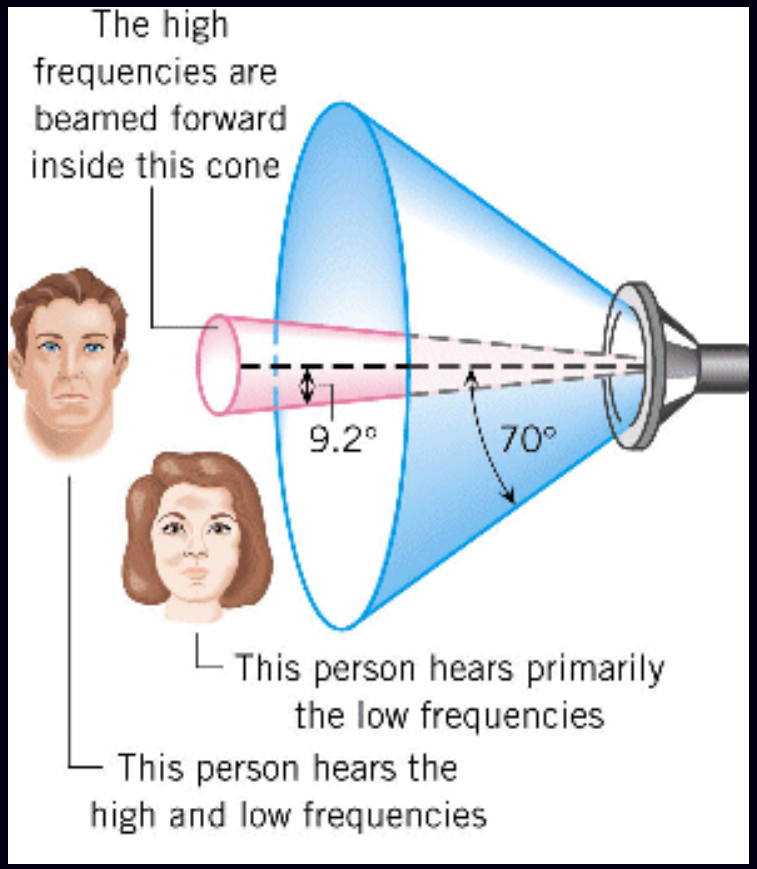




Diffraction with narrow slit

The diffraction becomes more significant when the obstacle is small or wavelength is large.

Which one is tweeter?



Doppler effect

When the source or the observer moves relative to the medium, the observer will find the frequency of sound different.

let v_o is the velocity of the observer, we assume it positive when the observer runs towards the source.

v_s is the velocity of the source, it is positive when it runs towards the observer.

When the source does not move, observer moves toward the source with v_o respect to the medium

The wave speed respect to observer:

$$u + v_o$$

The wavelength observed does not change :

$$\lambda = u/\nu$$

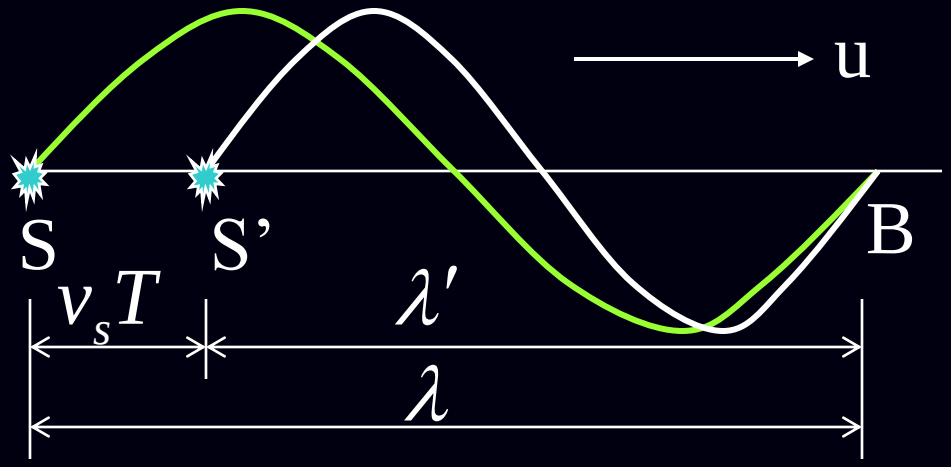
The frequency that the observer measured:

$$\nu' = \frac{u + v_o}{\lambda} = (1 + \frac{v_o}{u})\nu$$

$$\nu' = (1 \pm \frac{v_o}{u})\nu$$

The observe is at rest, but the source moves with velocity v_s

The wave length changes, but the speed of wave does not change



$$\lambda' = uT - v_sT = (u - v_s)T$$

$$\nu' = \frac{u}{\lambda'} = \frac{u}{(u - v_s)T}$$

$$= \frac{u}{u - v_s}\nu$$

$$\nu' = \frac{u}{u \mp v_s}\nu$$

When both the observer and the source move

$$\nu' = \frac{u \pm v_o}{u \mp v_s}\nu$$

The pitch that observer feels increases when observer and source come closer, and conversely.

Example: the train is moving with speed 20m/s, if its horn blows at frequency 500hz, Find the frequency a man at rest may observed before or behind the train.。

solution：

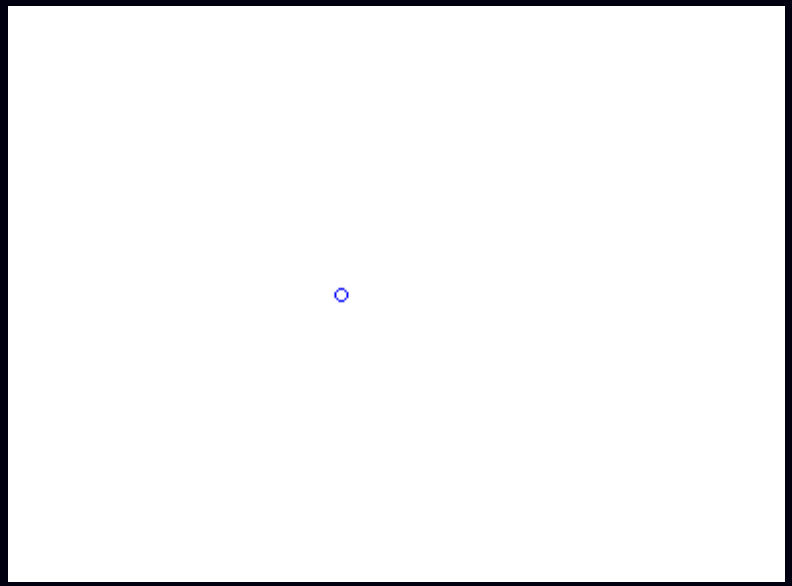
$$\nu_{前} = \frac{u}{u - v_s}\nu = \frac{340 \times 500}{340 - 20} = 531Hz$$

$$\nu_{后} = \frac{u}{u + v_s}\nu = \frac{340 \times 500}{340 + 20} = 472Hz$$

Quize: A bat flying toward an obstacle at 12 m/s emits brief, high-frequency sound pulses at a repetition frequency of 80 Hz. What is the time interval between the echo pulses heard by the bat?

How about the speed of source exceeds the speed of wave in medium when the source comes closer?

Shock waves:



Mach angle:

$$\sin\theta = \frac{u}{v_s}$$


你这身是扮谁?