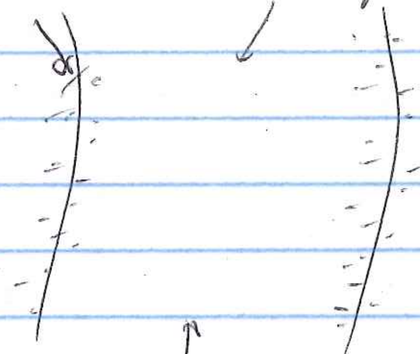
PHYS 107 - Week 15 - Wednesday

* Sound and hearing:

- longitudinal waves

higher pressure

lower pressure ("rarefaction")



motion of air molecules at nm scale

μm

- frequency ≈ pitch : $\lambda \sim \frac{1}{f}$ → long λ → low f
high f → short λ
(musical instruments)

constant v → $v = \lambda f$

* Audible range from 20 Hz to 20 kHz

infrasound

ultrasound

* Speed of sound:
$v_{air} = 331\ m/s$
$v_{water} = 1480\ m/s$
$v_{steel} = 5960\ m/s$
} at 0°C

in a gas: $v \sim \sqrt{T}$ → $v_{air} = 331\ m/s \sqrt{\frac{T}{273K}}$

$v(20°C) = v(293K) = 343\ m/s$

* Sound intensity:

$I_0 = 10^{-12}\ \frac{W}{m^2}$ → threshold of human hearing

up to $10^2\ \frac{W}{m^2}$

↳ threshold of pain/damage

sound level

$$\beta = 10\ {}^{10}\log\left(\frac{I}{I_0}\right)$$ in decibel (dB)

logarithmic response: - 10 times higher intensity
↳ only adds 10 in dB
- 100 times higher intensity
↳ adds 20 in dB

$\Delta\beta = 10 \rightarrow 10\times$ ~~louder~~ intensity

$\Delta\beta = 20 \rightarrow 100\times$

$\Delta\beta = 30 \rightarrow 1000\times$

* Properties of logarithms

if $A = 10^B$ then ${}^{10}\log A = B$

$$\log(A \cdot B) = \log A + \log B$$
$$\log\left(\frac{A}{B}\right) = \log A - \log B$$

What is the sound level of a sound with intensity $I = 1\ W/m^2$?

$$\beta = 10\ {}^{10}\log \frac{1\ W/m^2}{10^{-12}\ W/m^2} = 10\ {}^{10}\log(10^{12}) = 10 \cdot 12 = \underline{120\,dB}$$

(threshold of pain)

Decibels 1 and 2

* Loudness (how loud is sound perceived?)

1 phon = 1 dB at 1000 Hz

0 phon → threshold of hearing
125 phon → pain threshold

every 10 phon: twice as loud perceived

JND = just noticeable difference, depends on frequency

* Locating sounds:

ITD = intra-aural time difference

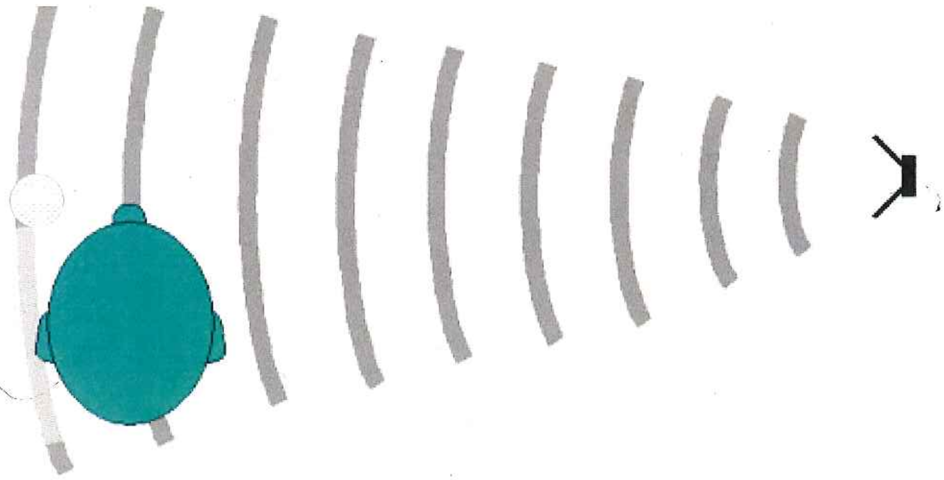
ILD = intra-aural level difference

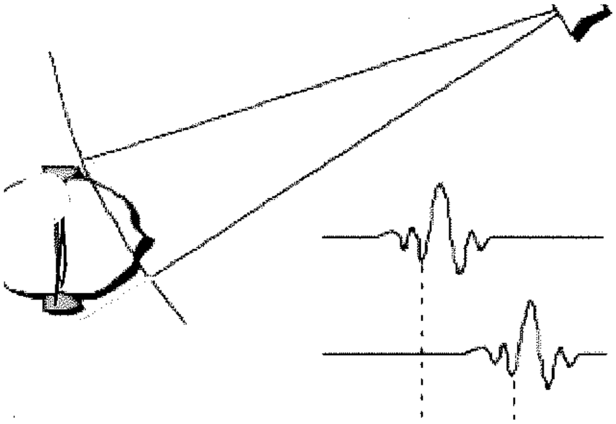
ITD fails when wavelength smaller than size of head

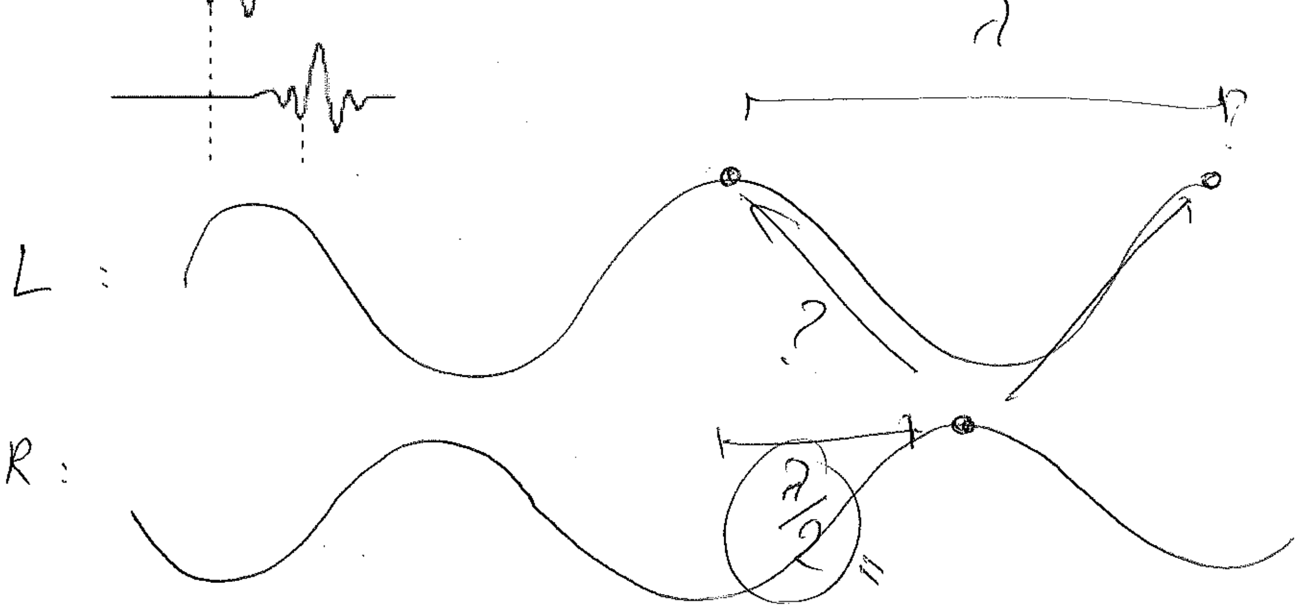
$\frac{\lambda}{2} = 17$ cm → $f = 1000$ Hz ≈ 1 kHz

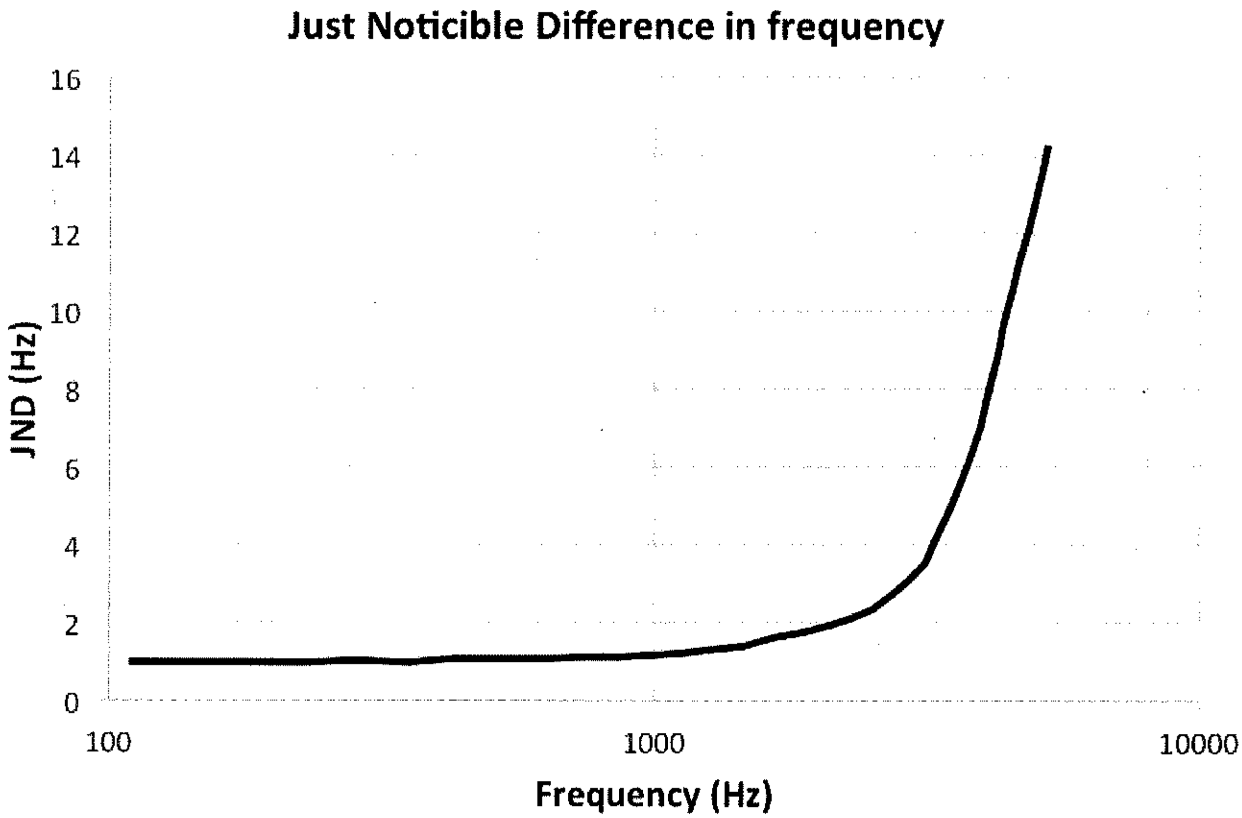
↓

$\lambda = 34$ cm



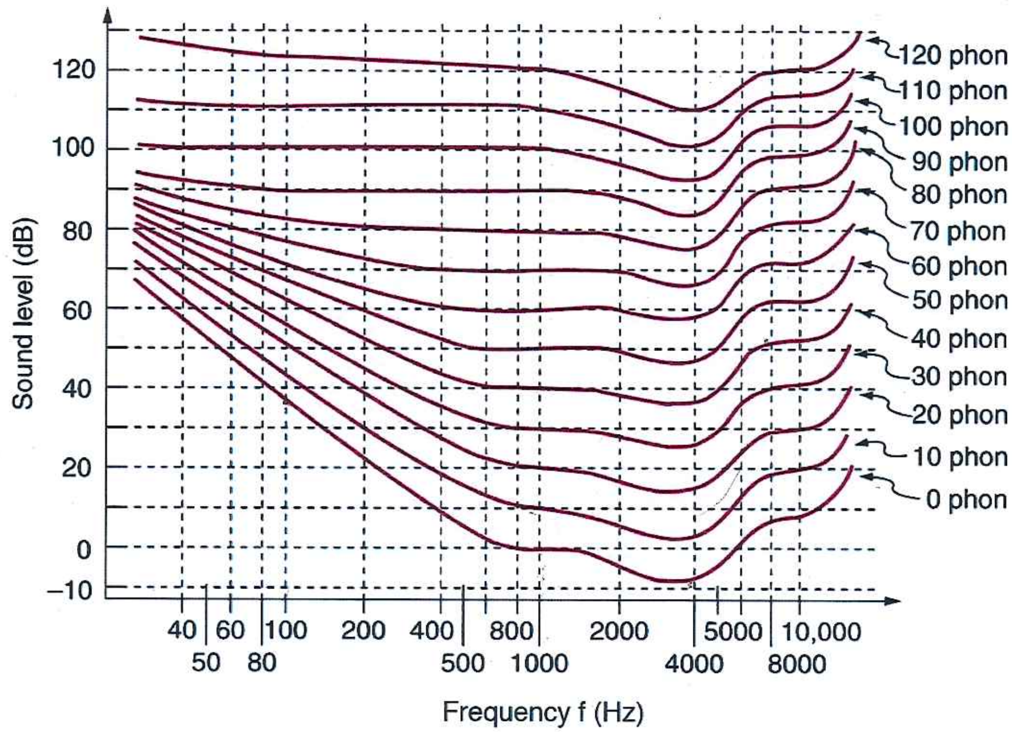



λ
L :
?
R :
λ/2



Just Noticible Difference in frequency
16
14
12
10
8
6
4
2
0
JND (Hz)
100
1000
10000
Frequency (Hz)

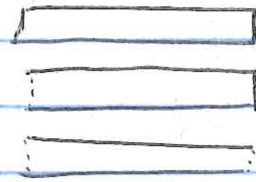
FIGURE 17.36



The relationship of loudness in phons to intensity level (in decibels) and intensity (in watts per meter squared) for persons with normal hearing. The curved lines are equal-loudness curves—all sounds on a given curve are perceived as equally loud. Phons and decibels are defined to be the same at 1000 Hz.

* Standing waves in air in a pipe

Demo: standing waves in auditorium

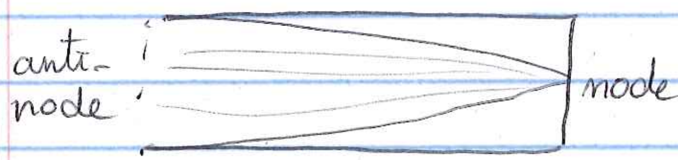
(closed / closed )

3 cases: open / closed

open / open

open end → large amplitude of longitudinal displacement
zero amplitude of pressure differences

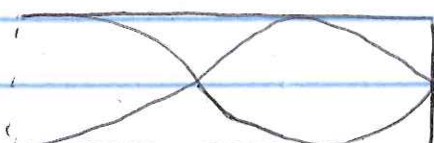
closed end → zero amplitude of displacements
large amplitude of pressure



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

open ↑ closed

fundamental, $n = 1$



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

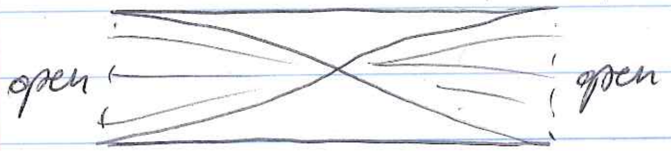
1st overtone, $n = 3$

$L = n\frac{\lambda}{4}$ or $f = \frac{nv}{4L}$

Demo

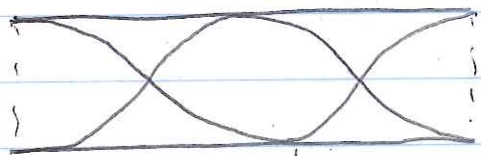
Oscillations 7

for $n = 1, 3, 5, \dots$
only odd



$n = 1$, fundamental

$\rightarrow L = \frac{\lambda}{2}$



$n = 2$, 1^{st} overtone

$\rightarrow L = 2\frac{\lambda}{2}$

$L = n\frac{\lambda}{2}$ or $f = \frac{nv}{2L}$

for $n = 1, 2, 3, \ldots$
(odd and even)

Open vs. closed pipes