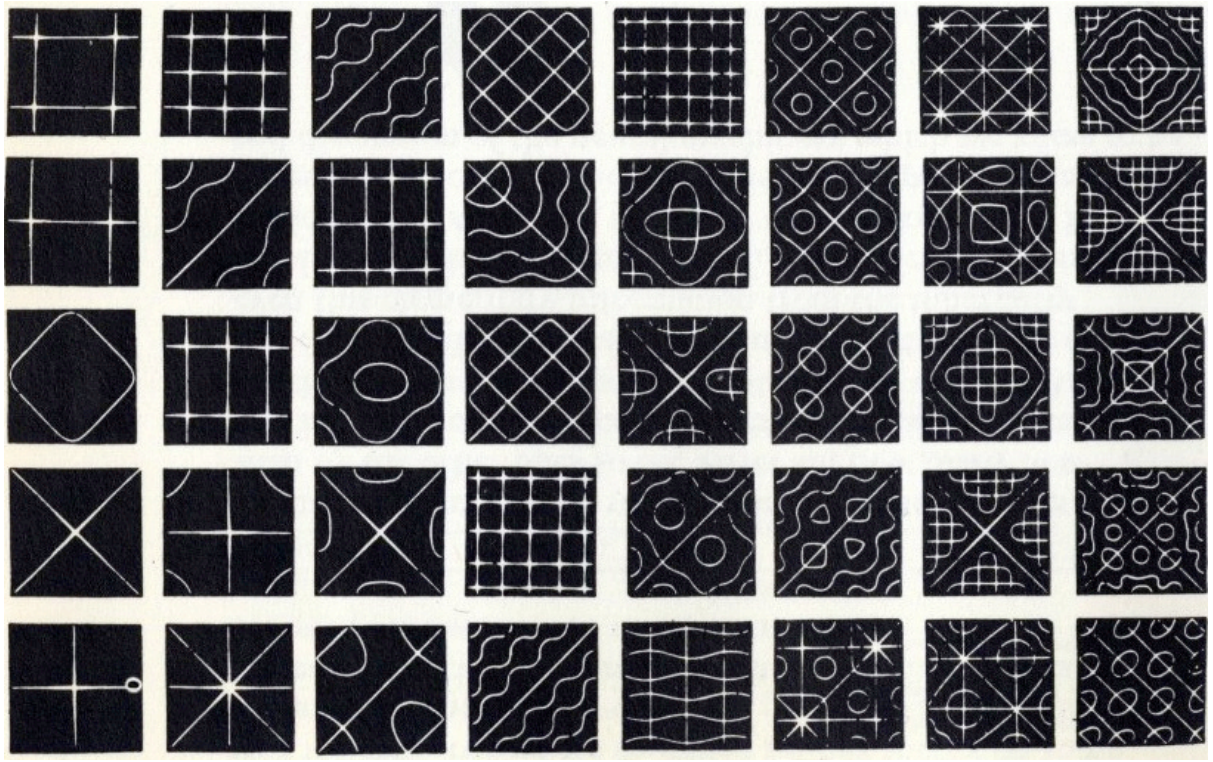
Physics 1240: Sound and Music

Today (8/8/19): Review for Final

Next time: Final Exam



Online FCQs

(Faculty Course Questionnaires)

colorado.campuslabs.com/courseeval

(we will begin the review session at 11:10 AM)

Final exam tomorrow

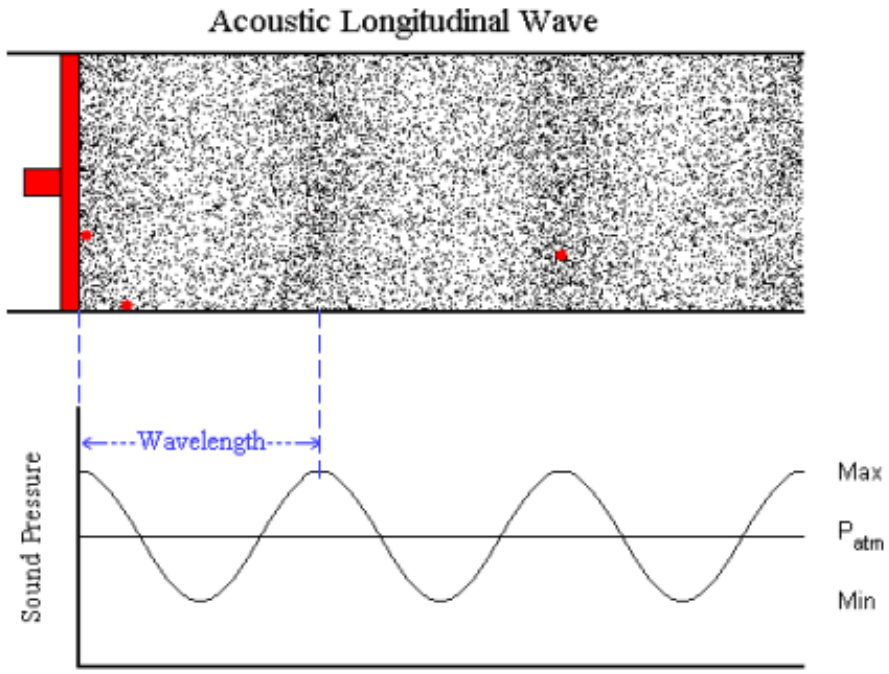
Friday, August 9th
11:00 AM – 12:35 PM
Duane G1B31 (this lecture hall)

Materials to bring:

- pencil or pen
- calculator
- one 8.5”x11” equation sheet
  (anything written on BOTH sides)

Sound Basics

- Sound: a mechanical disturbance of the **pressure** in a **medium** that travels in the form of a **longitudinal wave**
- Speed = Wavelength × Frequency $(v = \lambda f)$
- Frequency = 1 / Period



BA

Clicker Question 22.1

As you walk along the edge of a pond, you notice a duck bobbing up and down in the waves. It takes 2 seconds for the duck to go from one wave peak to the next. You guess that the duck moves vertically 0.5 meters from peak to trough. What is the wave's amplitude?

A) 2 sec
B) 0.5 Hz
C) 0.5 m
D) 0.25 m/s
E) None of the above

BA

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BA

Clicker Question 22.2

As you walk along the edge of a pond, you notice a duck bobbing up and down in the waves. It takes 2 seconds for the duck to go from one wave peak to the next. You guess that the duck moves vertically 0.5 meters from peak to trough. What is the wave's frequency?

A) 2 Hz
B) 1 Hz
C) 0.5 Hz
D) 0.25 Hz
E) None of the above

BA

Clicker Question 22.2

As you walk along the edge of a pond, you notice a duck bobbing up and down in the waves. It takes 2 seconds for the duck to go from one wave peak to the next. You guess that the duck moves vertically 0.5 meters from peak to trough. What is the wave's frequency?

A) 2 Hz
B) 1 Hz
C) 0.5 Hz
D) 0.25 Hz
E) None of the above

BA

Clicker Question 22.3

As you walk along the edge of a pond, you notice a duck bobbing up and down in the waves. It takes 2 seconds for the duck to go from one wave peak to the next. You guess that the duck moves vertically 0.5 meters from peak to trough. At the duck's peak, the next peak is 8 meters away. What is the wave's speed?

A) 2 m/s
B) 4 m/s
C) 8 m/s
D) 16 m/s
E) None of the above

BA

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A) 2 m/s
B) 4 m/s
C) 8 m/s
D) 16 m/s
E) None of the above

Sound Basics

- Simple harmonic motion:
  - Higher elasticity (stiffness) means _____ frequency
  - Higher inertia (mass) means _____ frequency

- Resonance: amplifying a system's natural frequency
- Damping: decrease in amplitude of oscillating system

Sound Propagation

- Speed of sound increases with temperature:

$$v[\mathrm{m/s}] = 331 + 0.6\,T[^{\circ}\mathrm{C}]$$

  - Reflection (diffuse or spectral)
  - Absorption (greater for softer surfaces)
  - Refraction (when speed of sound changes)
  - Diffraction (greater for larger wavelengths)

  - Sonic boom (shock wave when going over Mach 1)
  - Doppler effect (frequency increases when sources travels towards you):

$$\%\ \text{change in}\ f \cong \frac{\Delta v}{v_{\text{sound}}}$$

  - Two-source interference (waves cancel when separated by half a wavelength)

BA

Clicker Question 22.4

If you are in a room with two speakers each producing sine waves with a wavelength of 0.5 meters, where should you stand if you don't want to hear any sound?

A) 1 meter from one speaker and 2 meters from the other
B) 1 meter from one speaker and 1 meter from the other
C) 1 meter from one speaker and 1.125 meters from the other
D) 1 meter from one speaker and 0.5 meters from the other
E) 1 meter from one speaker and 0.25 meters from the other

BA

Clicker Question 22.4

If you are in a room with two speakers each producing sine waves with a wavelength of 0.5 meters, where should you stand if you don't want to hear any sound?

A) 1 meter from one speaker and 2 meters from the other
B) 1 meter from one speaker and 1 meter from the other
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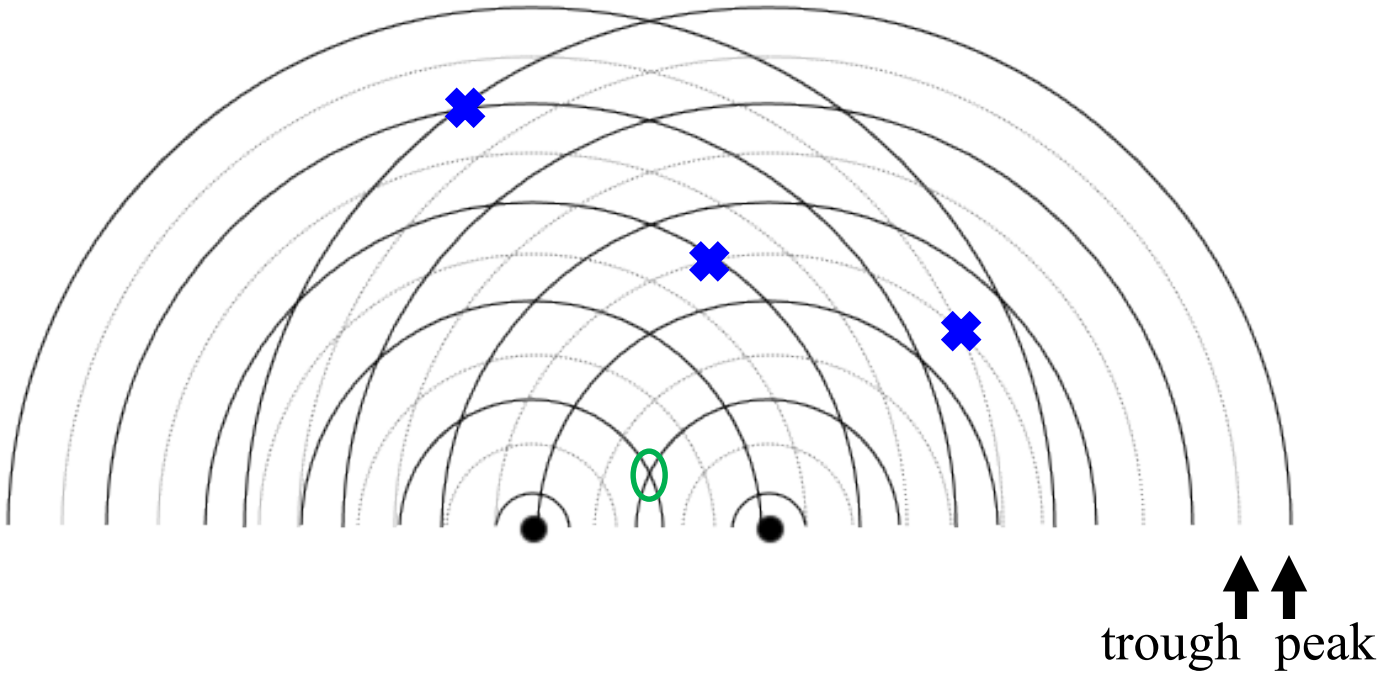
E) 1 meter from one speaker and 0.25 meters from the other


trough
peak

Amplitude/Loudness

- Intensity: energy flow per unit area (W/m^2)
  - proportional to the pressure amplitude squared

- SIL: logarithmic version of intensity, relative to reference value $I_0 = 10^{-12}\ \mathrm{W/m^2}$, measured in decibels

$$SIL\ [\mathrm{dB}] = 10 \log\left(\frac{I}{10^{-12}\ \mathrm{W/m^2}}\right)$$

$$SIL_1 - SIL_2 = 10 \log\left(\frac{I_1}{I_2}\right)$$

- Two sounds playing together ⇒ add their intensities

BA

Clicker Question 22.5

If a room full of a hundred babies crying has an ambient sound intensity level of 110 dB, how many babies would you need to take out to reduce the SIL to 90 dB?

A) 20
B) 50
C) 80
D) 99
E) 100

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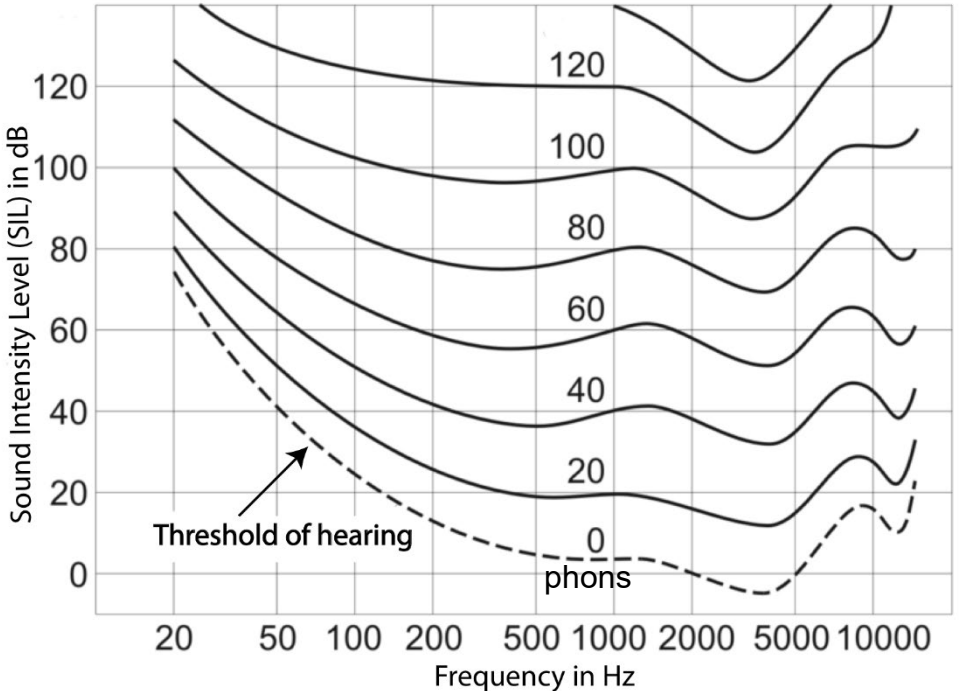
Loudness and Hearing

Pressure amplitude [N/m^2]
Intensity [W/m^2]
Sound Intensity Level [dB]
Loudness Level [phon]

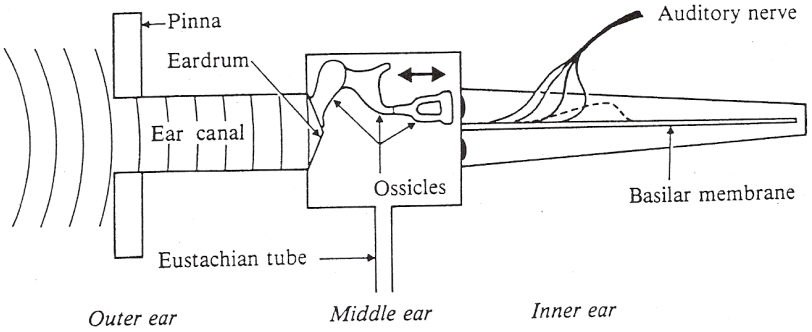


Outer ear: pinna, auditory canal

Middle ear: ear drum, ossicles: malleus, incus, stapes; Eustachian tube

Inner ear: cochlea, oval window, circular window, basilar membrane, hair cells, auditory nerve

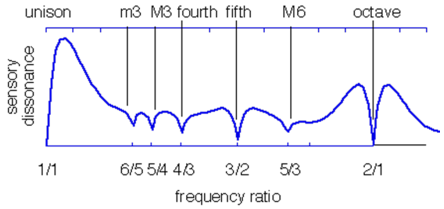
cochlea = “mechanical spectrum analyzer”



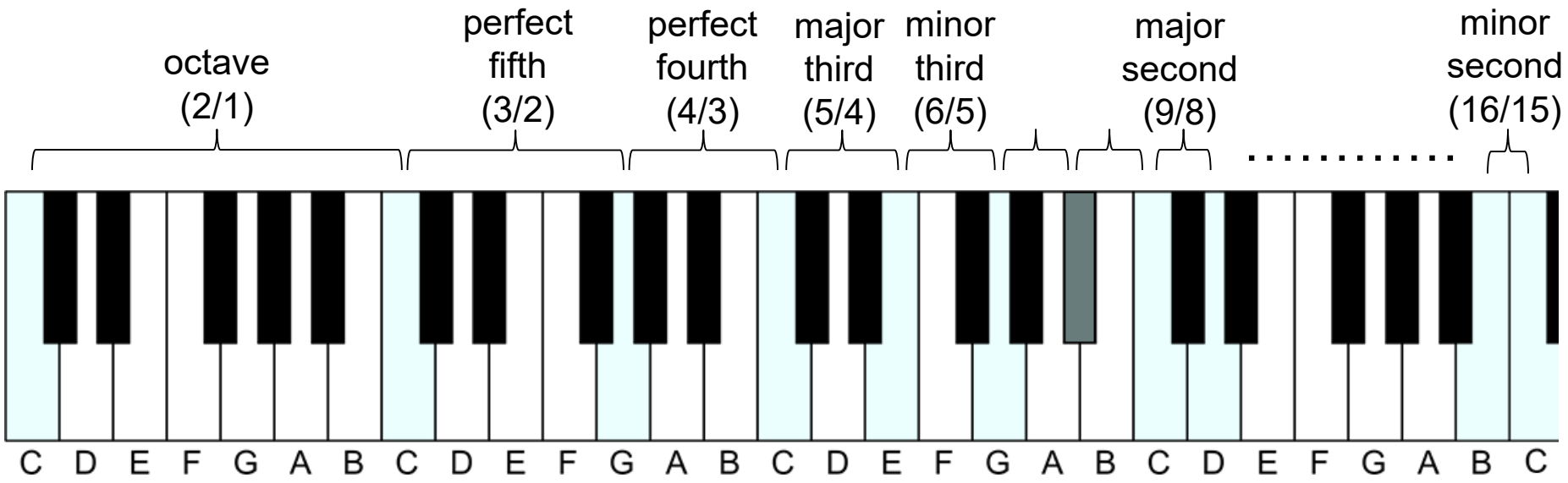
Psychoacoustics

- Octave equivalence, Missing fundamental

- Dissonance: harsh sound when 2 tones (or upper harmonics) produce beats within the same critical band
- Consonance: Pythagorean hypothesis



- Harmonic series → Pythagorean intervals



Tuning systems

- Just Tuning: uses only pure, harmonic intervals
  - Pros: all pure consonances for intervals from same note
  - Cons: can only play in one key
- Pythagorean Tuning: makes all fifths in any key pure (3/2)
  - Pros: all pure consonances for fifths
  - Cons: thirds are dissonant; Pythagorean comma
- Equal Temperament: same interval for all adjacent notes
  - Pros: can play in any key
  - Cons: all intervals are very slightly dissonant

	Note name:	C	D	E	F	G	A	B	C
Just	Frequency ratio to C:	$\frac{1}{1}$	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	$\frac{2}{1}$
Pythagorean		$\frac{1}{1}$	$\frac{9}{8}$	$\frac{81}{64}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{27}{16}$	$\frac{243}{128}$	$\frac{2.03?}{1}$
Equal-Tempered		$\frac{1}{1}$	$\left(2^{\frac{1}{12}}\right)^2$	$\left(2^{\frac{1}{12}}\right)^4$	$\left(2^{\frac{1}{12}}\right)^5$	$\left(2^{\frac{1}{12}}\right)^7$	$\left(2^{\frac{1}{12}}\right)^9$	$\left(2^{\frac{1}{12}}\right)^{11}$	$\frac{2}{1}$

BA

Clicker Question 22.6

What is the frequency ratio of an interval of a perfect fifth in a just tuning system? What about using equal temperament?

A) 1.5 and 1.333
B) 1.5 and 1.5
C) 1.5 and 1.414
D) 1.333 and 1.327
E) None of the above

BA

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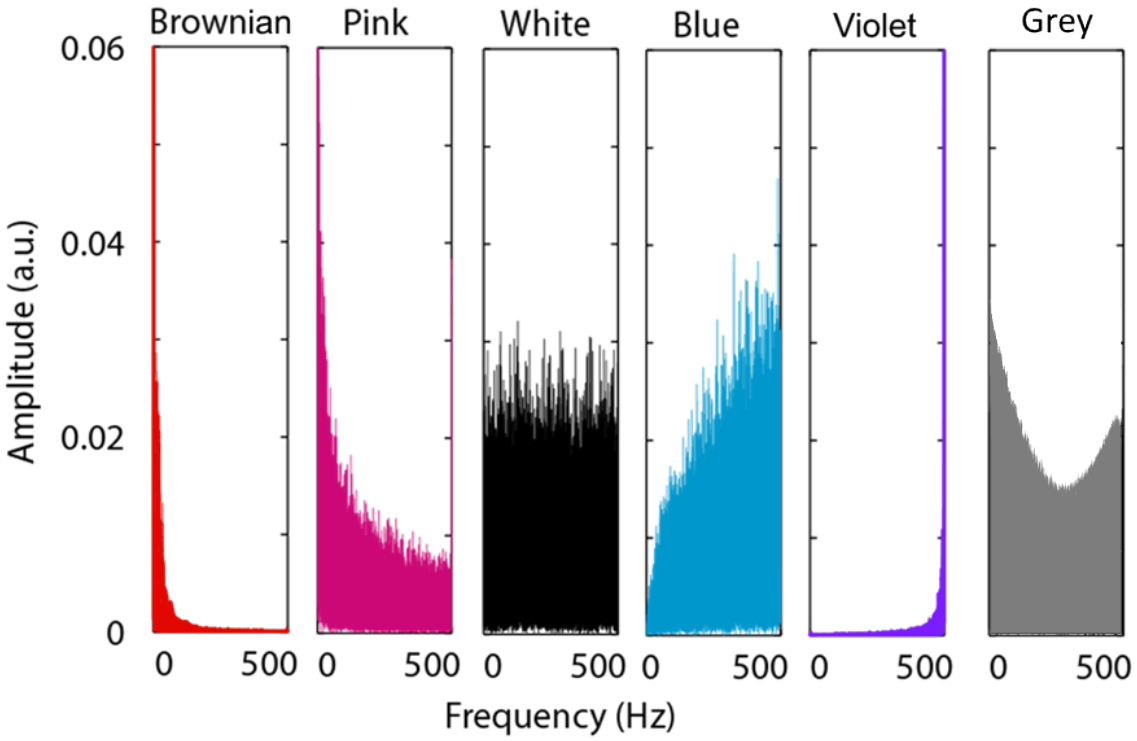
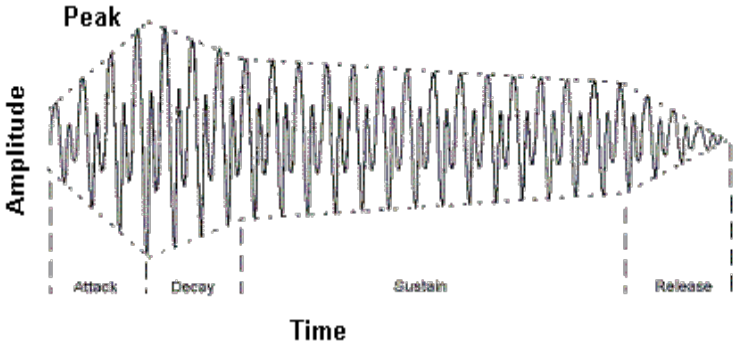
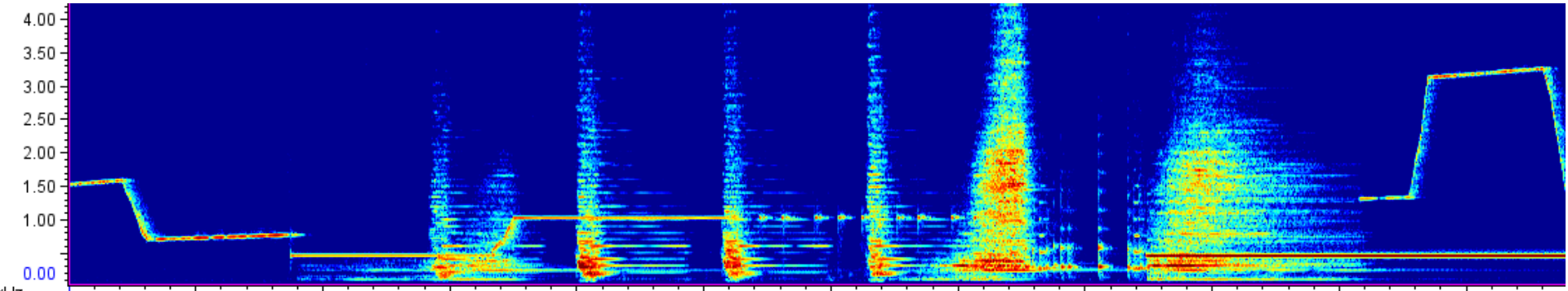
Noise, Sound Envelopes







BA

Clicker Question 22.7

What's the difference between white and grey noise?

A) White noise has equal intensity of all frequencies and grey noise has stronger middle frequencies
B) White noise has inharmonic frequencies and grey noise has harmonic frequencies
C) White noise has a greater intensity than grey noise
D) White noise has equal intensity of all frequencies and grey noise has equal loudness of all frequencies
E) None of the above

BA

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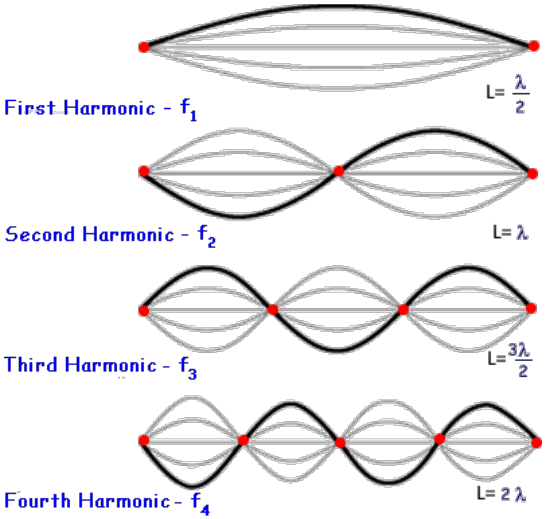
E) None of the above

Types of Instruments

(Hornbostel–Sachs classification)

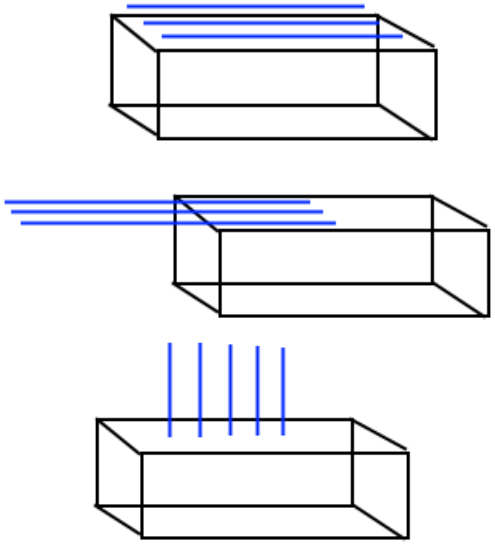
- Chordophones: vibrating strings
- Aerophones: vibrating columns of air
- Idiophones: vibrating the whole instrument
- Membranophones: vibrating membrane/skin
- Electrophones: vibrating loudspeaker

Chordophones



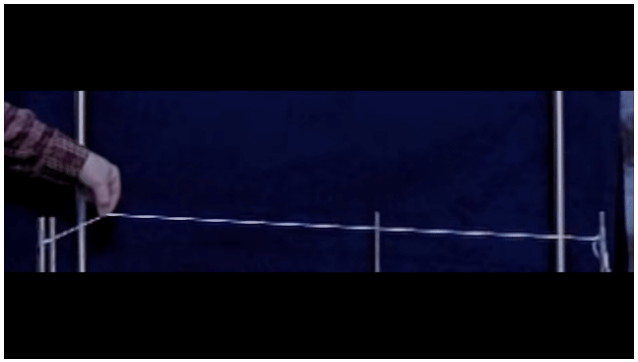
Types:

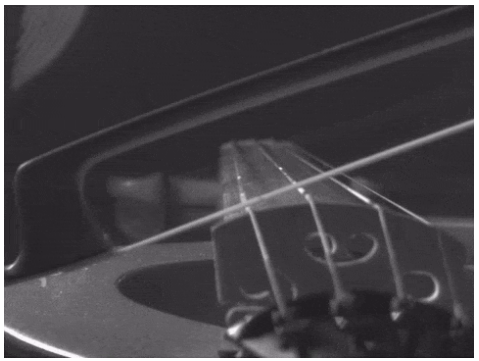
- Zithers
- Lutes
- Harps



$$f_n = \frac{n}{2L}\sqrt{\frac{T}{m/L}}$$

- How to create waves: initial displacement, velocity, or both



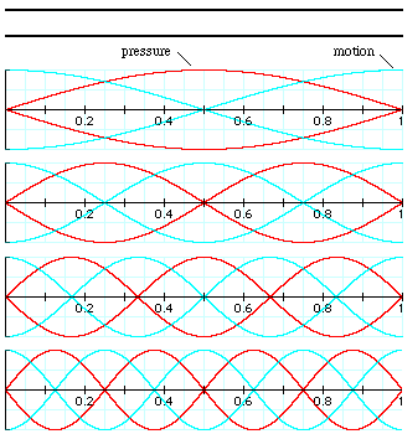


Aerophones

Types:

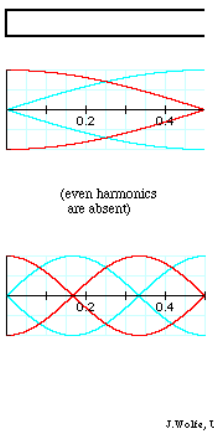
- Free
  (no standing waves)
- Flute-type
  (edge tones)
- Reed-type
  (vibrating reed/lips)

e.g. flute, recorder



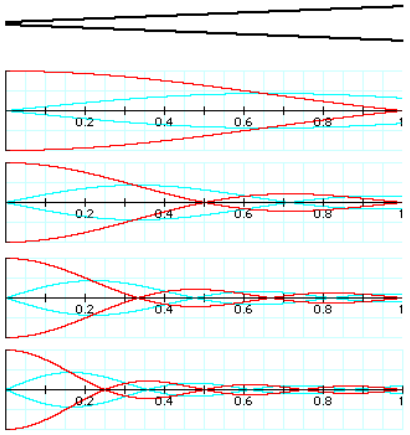
$$f_n = n\frac{v}{2L}$$

e.g. clarinet



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

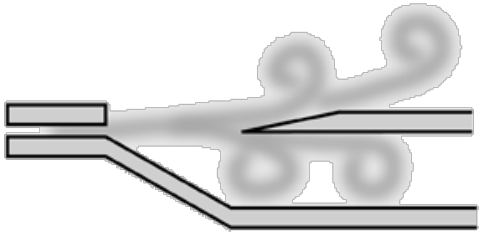
e.g. saxophone, oboe, bassoon



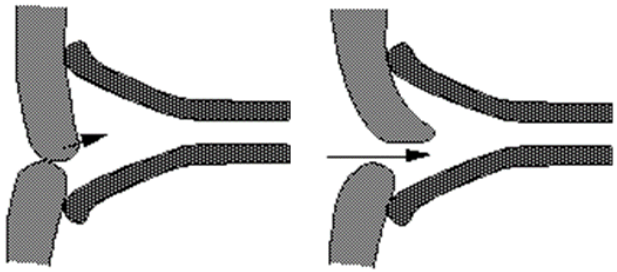
$$f_n = nf_1$$

- How to create waves:

Edge tones



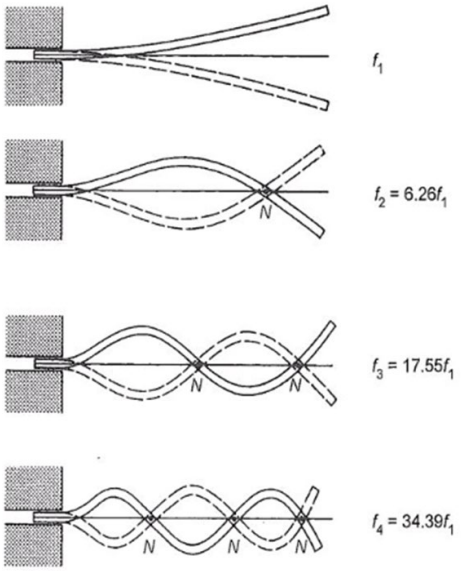
Bernoulli effect



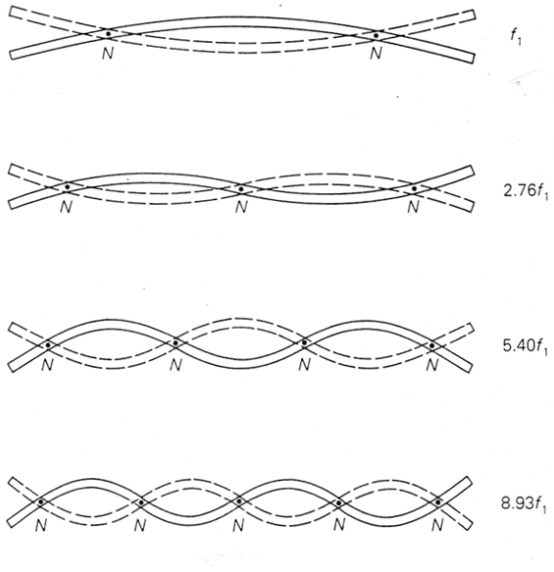
Idiophones

Types:

Clamped-free beam



Free-free beam

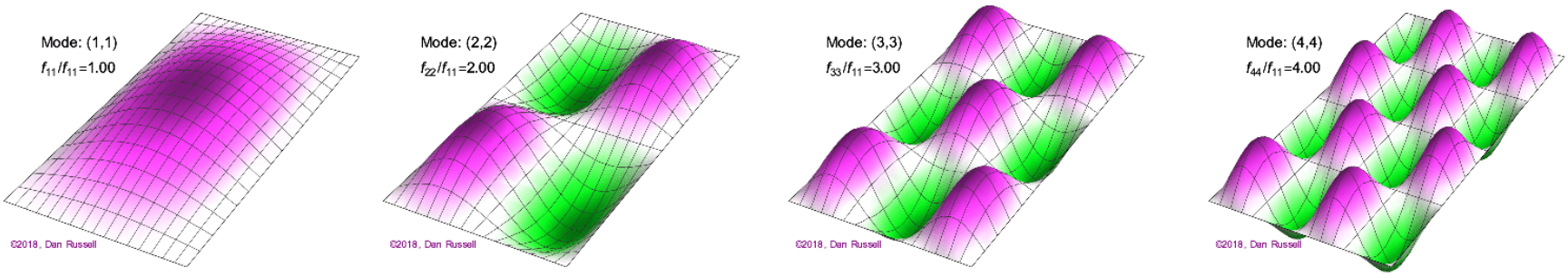


- Striking an object at any given point will sound each natural mode in proportion to how much that mode involves motion of that point
- Fixing an object to any given point will sound each natural mode that has a node at that point

Membranophones

Types:

- Unpitched (inharmonic spectrum)
- Pitched (certain modes damped out due to instrument's shape or striking point)

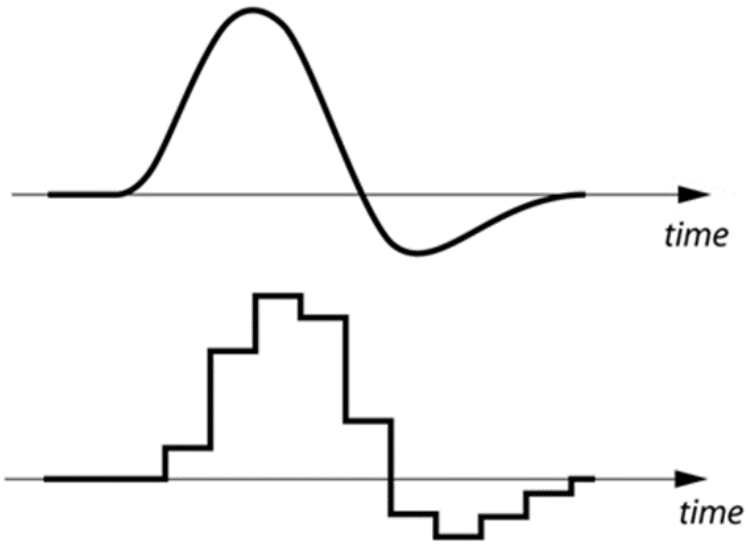


- Natural modes in 2D: nodes are lines instead of points
- Drums: have circular node around outer edge

Electrophones

Types:

- Analog (continuous signal)
- Digital (sampling rate, bit depth)



How to create waves:

- Loudspeaker (type of transducer)
- Combination of MIDI data, sound envelope, high/low pass filters

BA

Clicker Question 22.8

What's one difference between a clarinet and an oboe?

A) A clarinet has a reed and an oboe has a brass mouthpiece
B) A clarinet uses the Bernoulli effect and an oboe uses edge tones
C) A clarinet has odd harmonics and an oboe has all harmonics
D) A clarinet is like a closed-open tube and an oboe is like an open-open tube
E) The oboe sounds better

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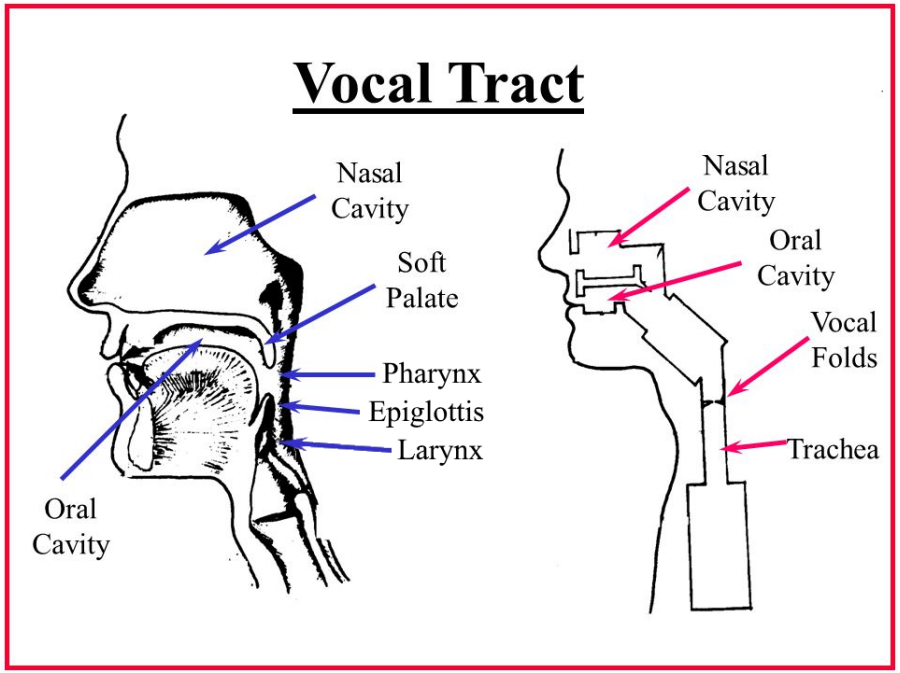
Instruments

- What class of instruments?
- How is sound produced on the instrument?
- How to change the instrument's pitch?
- Sound envelope?

https://www.youtube.com/watch?v=oCYHMVlQezA

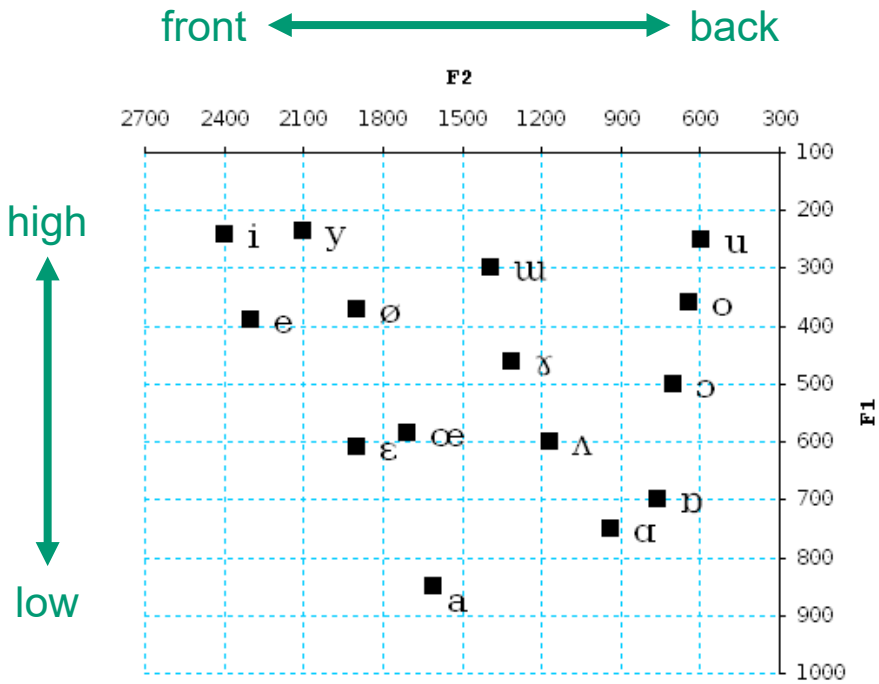
Human Voice

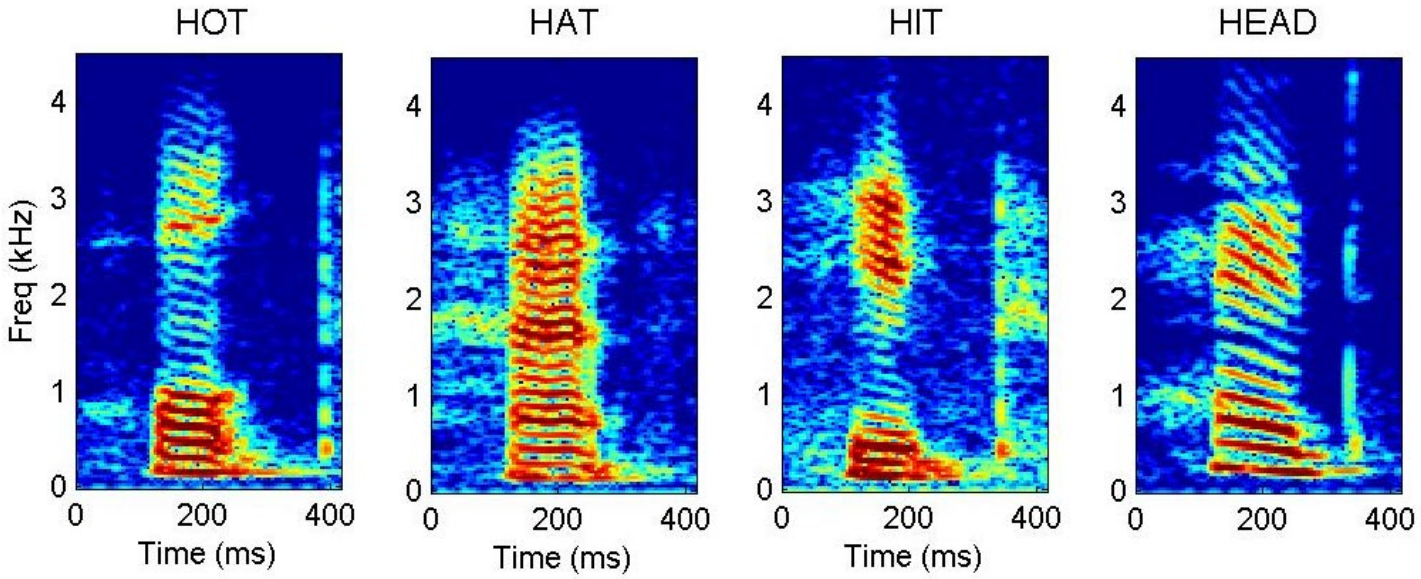
- Vocal cords: produce sound by the Bernoulli effect (determines pitch)
- Vocal tract: can be modelled as tube closed on one end, 14-17 cm long (determines timbre (vowels))
- Types of phonemes:
  - *Vowels* (vocal tract completely open)
  - *Plosives* (burst of air through initially closed vocal cords)
  - *Fricatives* (sustained sound by forcing air through turbulent passageways)

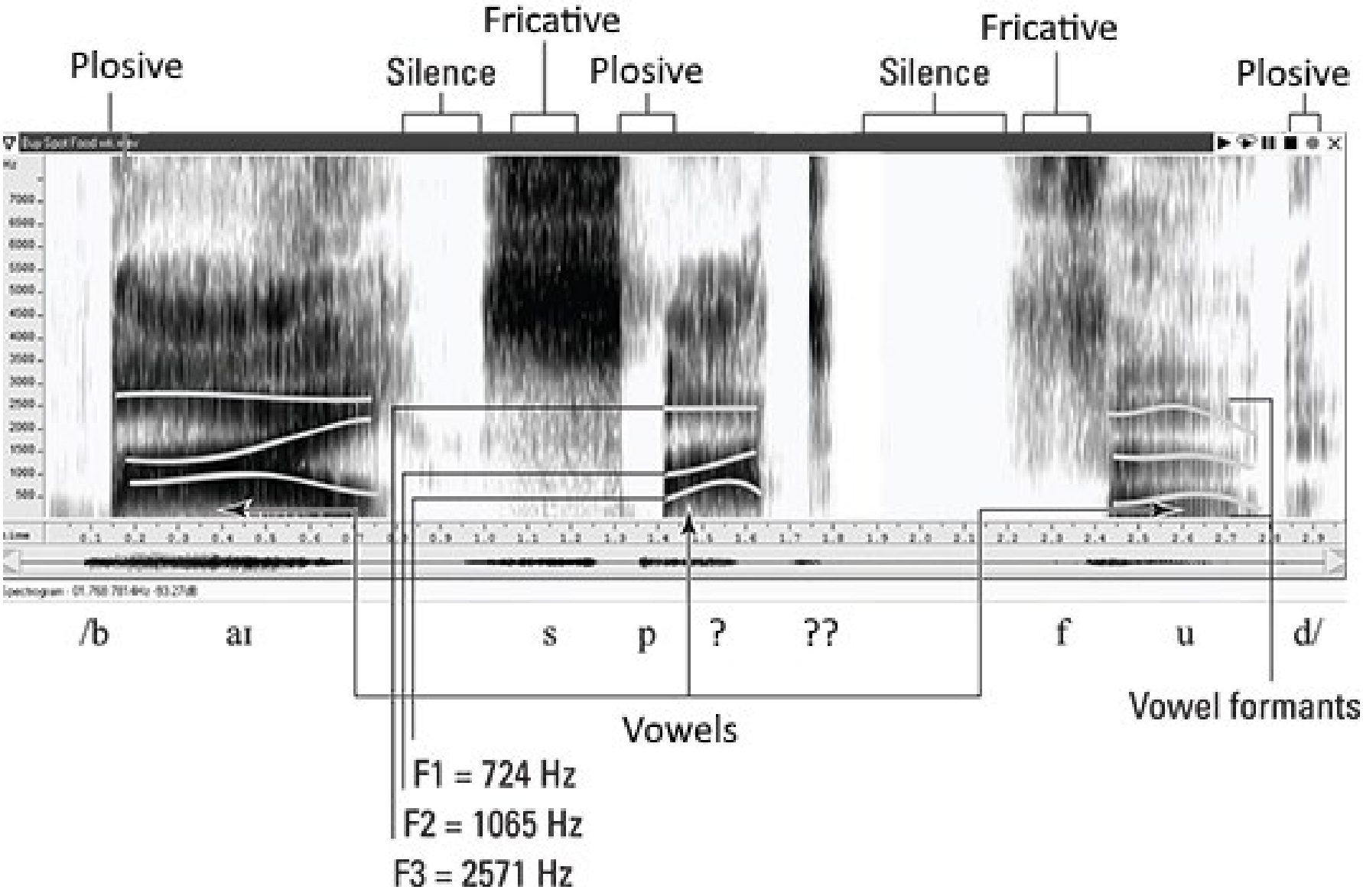


Human Voice

- Formant: band of enhanced frequencies corresponding to a resonant frequency in the vocal tract



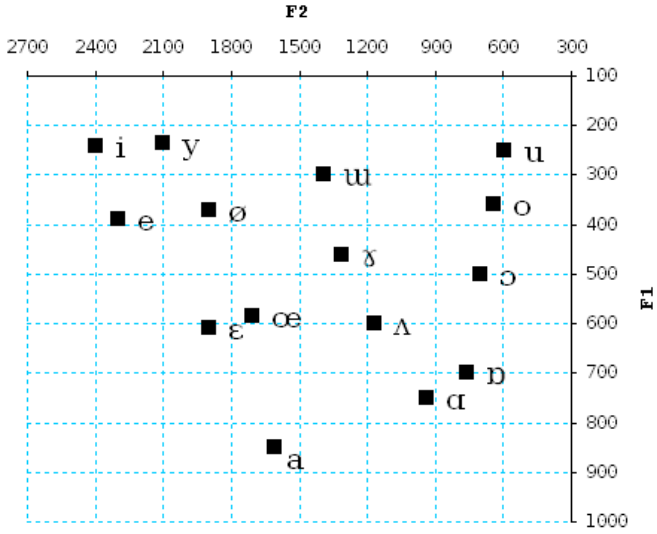


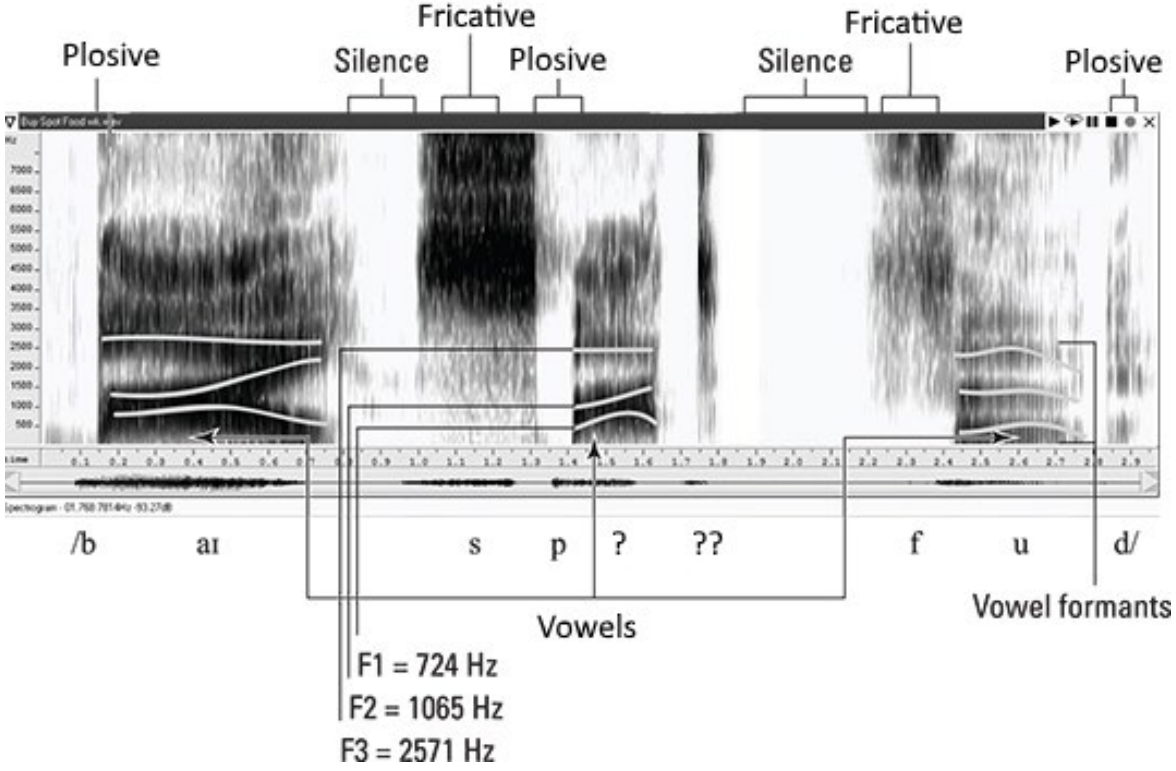

Plosive
Silence
Fricative
Plosive
Silence
Fricative
Plosive
/b
aɪ
s
p
?
??
f
u
d/
Vowels
Vowel formants
F1 = 724 Hz
F2 = 1065 Hz
F3 = 2571 Hz

Clicker Question 22.9

What letter could “??” represent?

A) a (vowel)
B) t (plosive)
C) s (fricative)
D) oi (diphthong)





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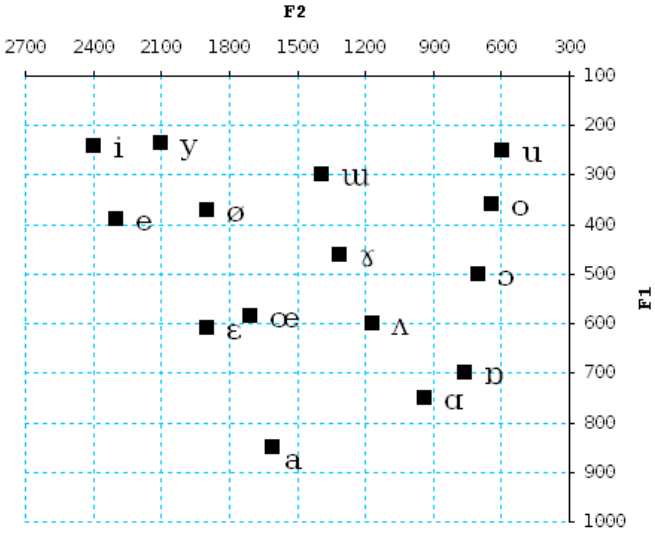
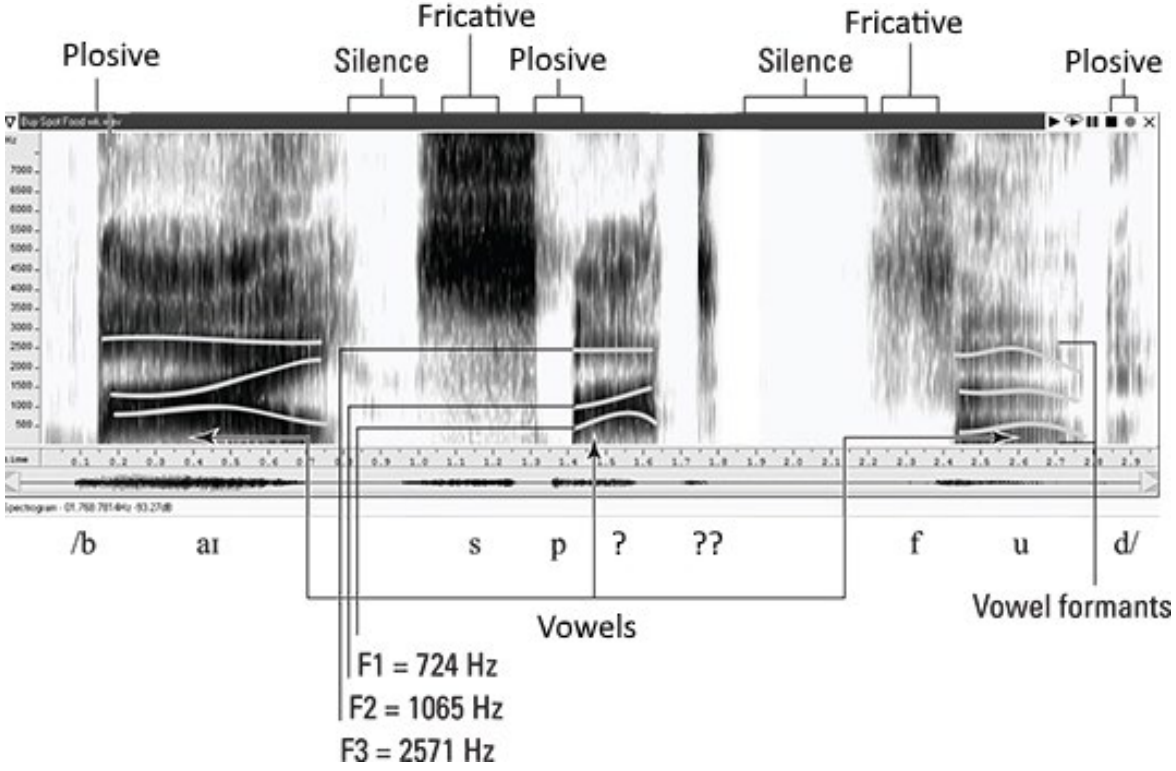
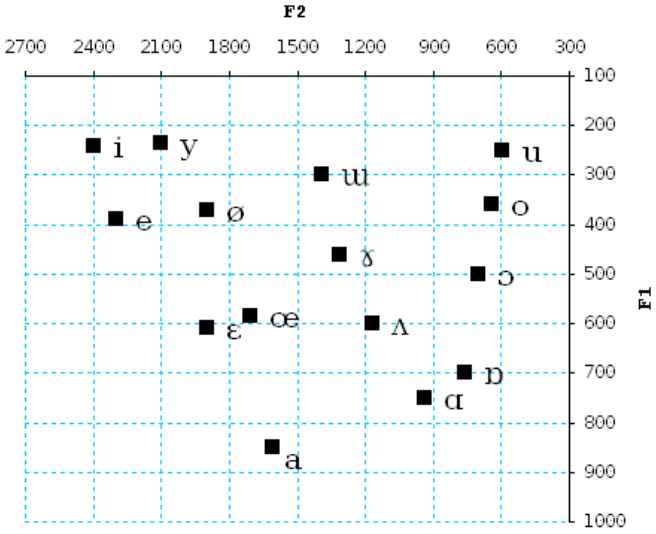


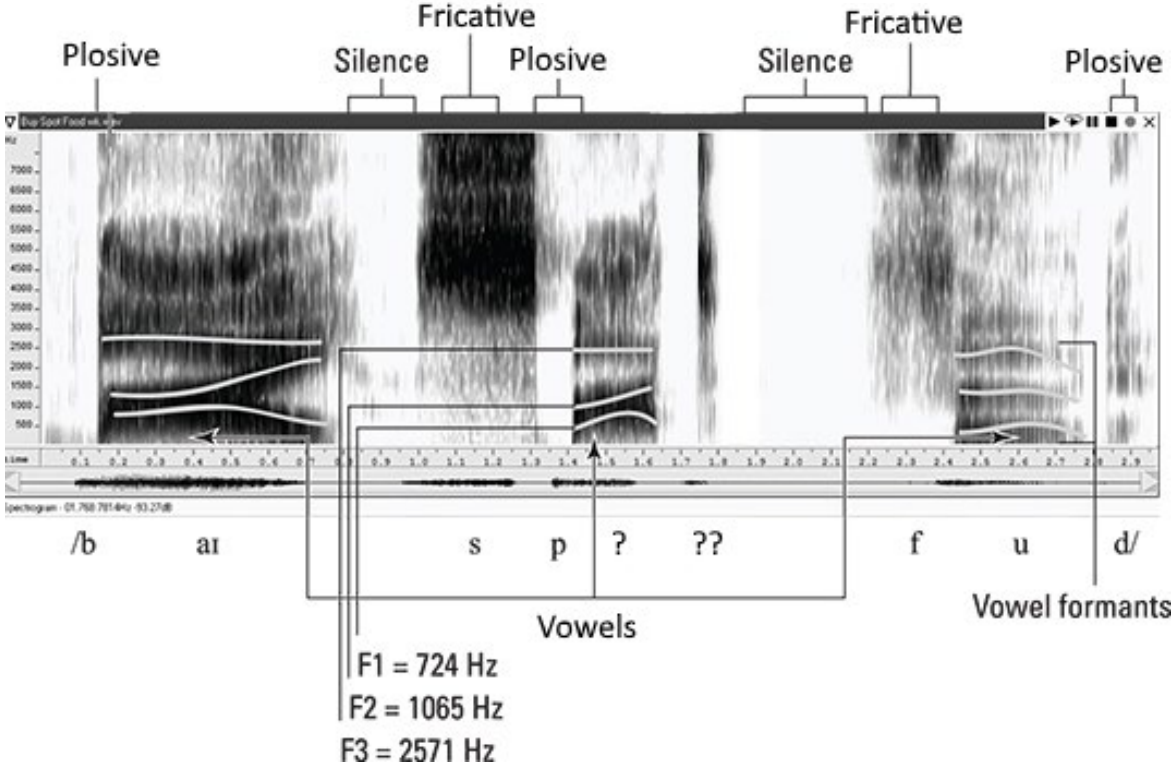


Clicker Question 22.9

What is the middle word?

A) spot [spɑt]
B) spit [spɪt]
C) speed [sp:id]
D) spoon [sp:un]





Clicker Question 22.9

What is the middle word?

A) spot [spɑt]
B) spit [spɪt]
C) speed [sp:id]
D) spoon [sp:un]