Sounds of English

Topic 7

The acoustics of speech:

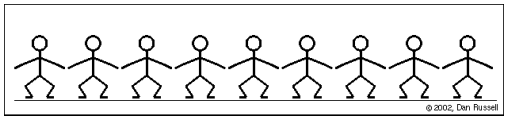
Sound Waves

About waves

- Lots of examples in the world around us!
- Can take all sorts of different forms
- Definition:
  - A disturbance that travels through a medium
  - where the "disturbance" is the oscillation of particles
  - and the "medium" is the material made up of those particles (air, water, steel are all examples)

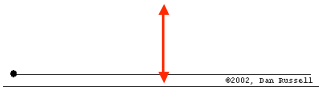
Ever done "the wave" ??

- At a stadium, a "people wave" travels through the crowd of spectators
- But the people don't move with the wave!



Different types of waves

- Transverse
  - particles "move" at right angles to direction of wave, as in waves at a beach or at a stadium



- Longitudinal
  - particles "move" in the same direction as the wave
  - sound waves are longitudinal waves

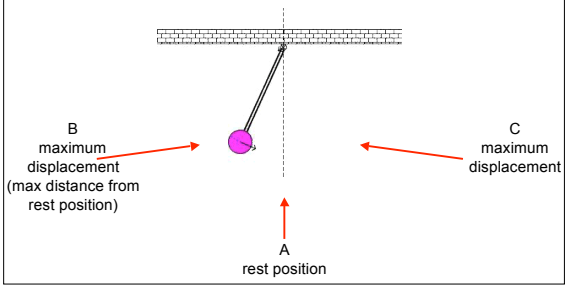
Why do we care?

- Linguistic forms are encoded in patterns of vibration (called waveforms)
- Vibrating patterns are the basis of **ALL** sound
- Obviously, it gets much more complicated than this, but we need to start somewhere!

So let's start with a tuning fork and a yo-yo.
(No, I'm not kidding.)

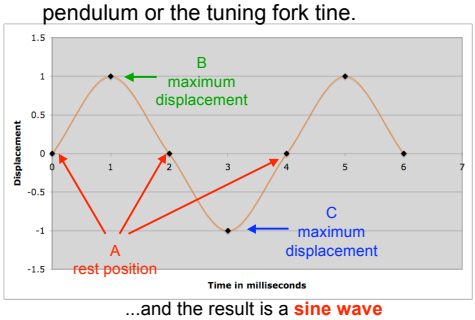
Tuning forks and pendulums

- Exhibit a very basic sort of movement called **Simple Harmonic Motion**



Remember making graphs?

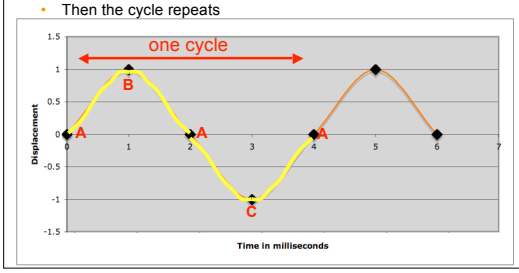
- We can graph the motion of the yo-yo pendulum or the tuning fork tine.



...and the result is a **sine wave**

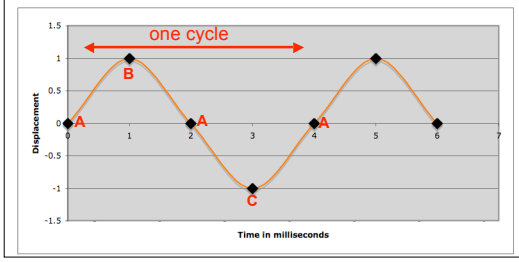
More about sine waves

- One **cycle** is the time it takes for a wave to go from
  - A to B
  - B to A
  - A to C
  - and back to A again
- Then the cycle repeats



Characteristics of waves

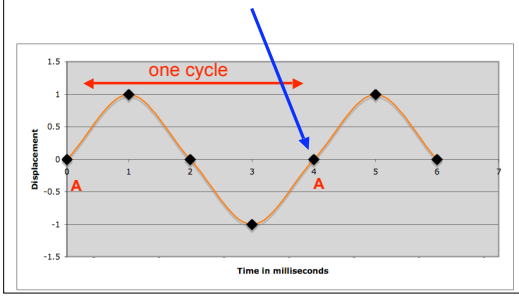
- **Frequency** is the number of cycles per second
- **Period** is the number of seconds needed to complete one cycle (1 / Freq)
- **Amplitude** is the maximum displacement



Measuring a wave's period

How long does it take to complete one cycle of this wave?

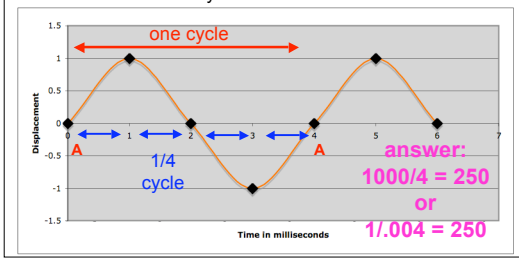
Answer: 4 milliseconds



Measuring a wave's frequency

How many cycles per second (Hz)?

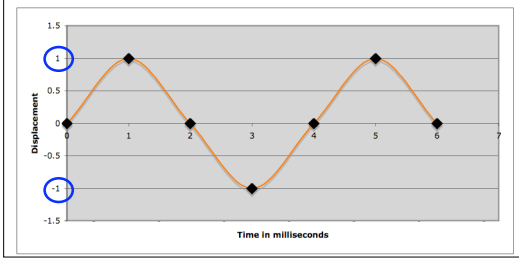
Answer: 1 cycle every 4 milliseconds
1000 milliseconds in 1 second
so how many times can we fit 4 into 1000?



Measuring a wave's amplitude

What is the amplitude of this wave?

Answer: 1



Frequency and amplitude

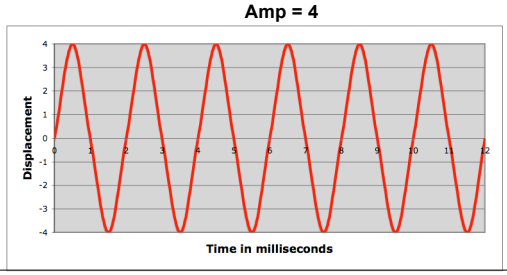
- Frequency
  - physical measurement of wave velocity
- =
- Pitch
  - *perception* of frequency

- Amplitude
  - physical measurement of maximum displacement
- =
- Volume (loudness)
  - *perception* of amplitude

Practice with sine waves

Calculate the period, frequency, and amplitude

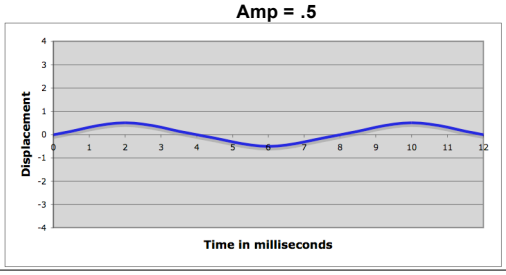
P = 2 ms
F = 1 cycle every 2 ms, so 1000 / 2 = 500 Hz
Amp = 4



Practice with sine waves

Calculate the frequency, period, and amplitude

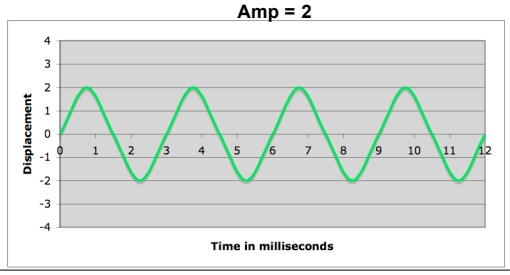
P = 8 ms
F = 1 cycle every 8 ms, so 1000 / 8 = 125 Hz
Amp = .5



Practice with sine waves

Calculate the frequency, period, and amplitude

P = 3 ms
F = 1 cycle every 3 ms, so 1000 / 3 = 333 Hz
Amp = 2



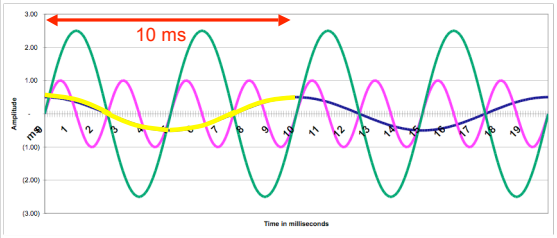
Simple versus complex waves

- So far all the waves we've looked at, even though they differ in frequency and amplitude, are SIMPLE:
  - produced by simple harmonic motion
  - result in a pure tone (such as A-440)
- But there are complex waves too!
  - produced by adding together two or more simple waves
  - Fourier: "every complex wave can be decomposed into some combination of simple waves"
  - these are the types of waves we will see in speech

Frequency of a complex wave will be the same as the LOWEST frequency of its component waves

Simple versus complex waves

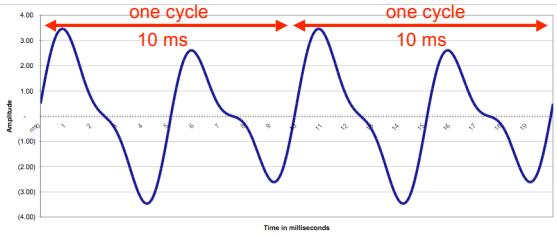
- 3 simple waves can combine (actually add together)...



Which wave has the LOWEST frequency?
The one where P=.010 s, so f = 1/.010 = 100 Hz

Simple versus complex waves

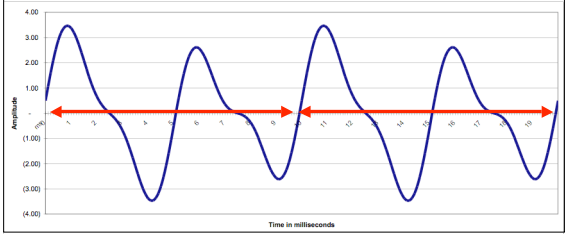
- ...to make this complex wave!
- pattern repeats: each cycle is more complicated than the simple patterns
- frequency is the same as lowest component frequency!



Frequency of complex waves

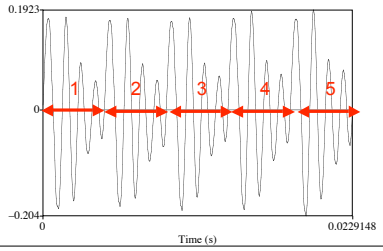
- If there's a repeating pattern, we can calculate the period and frequency the same way

P = 10 ms = .010 s
f = 1 / .010 s, so 1 / .010 = 100 Hz



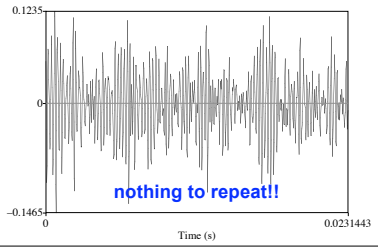
Periodic versus aperiodic

- If a pattern repeats, a sound wave is **periodic**
- This shows 5 cycles of me saying the vowel [a], a very "resonant" sound



Aperiodic = NOISY!

- If a pattern doesn't repeat, a sound wave is **aperiodic**
- This shows me saying the consonant [ʃ], a very "noisy" sound

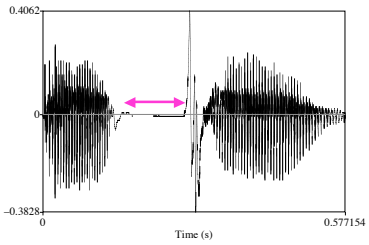


Waveforms in speech

- The different types of sounds we've learned about have different acoustic characteristics
- So waveforms will look different for..
  - Silence or closure during a voiceless plosive
  - Vowels, nasals, and approximants
  - Voiced fricatives
  - Voiceless fricatives
  - Release bursts after voiceless plosives

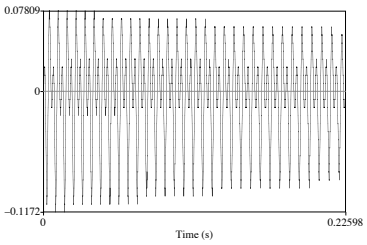
Voiceless plosives - closure

- This is a waveform of me saying /apa/
- Where is the closure during the /p/ ?



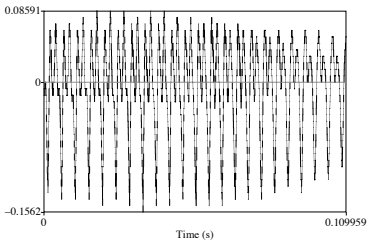
Periodic sounds - nasals

- This is a waveform of me saying /n/
- Notice the repeating pattern ?



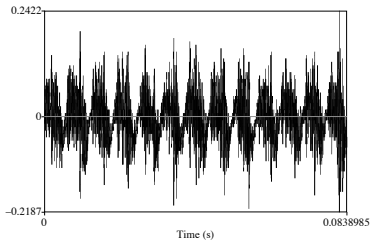
Periodic sounds - approximants

- This is a waveform of me saying /l/
- There's a repeating pattern here too



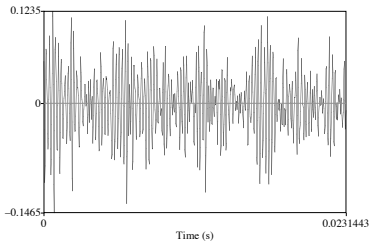
Voiced fricatives

- This is a waveform of me saying /z/
- It's periodic AND aperiodic!



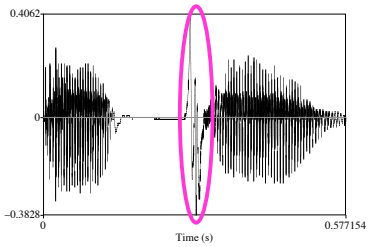
Voiceless fricatives

- This is a waveform of me saying /ʃ/
- There's NO repeating pattern



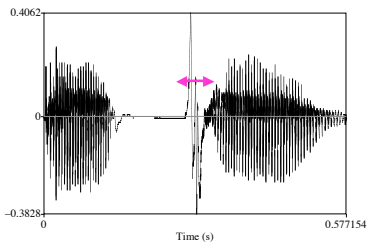
Voiceless plosives-release burst

- This is the same waveform of me saying /apa/
- Note the noisy "burst" after the closure period



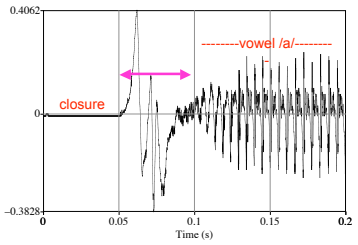
Burst duration = voice onset time

- We can measure this really precisely!!



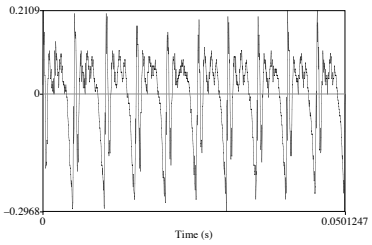
Measuring VOT

- Time between “release” and beginning of voicing for the vowel = .05 seconds, or 50 milliseconds



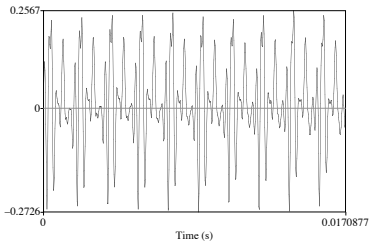
Measuring fundamental frequency

- 10 cycles of me saying the vowel /a/
- duration per cycle (period) = .005 seconds
- Frequency = 1/P = 1 / .005 = 200 Hz



Fundamental frequency

- Lowest component frequency of a complex wave
- # of times per second that vocal folds vibrate
- 110 Hz for men, 200 Hz for women, 300 Hz for children, and about 580 Hz for my cat Stoli:



Now it’s your turn...

- We’ll make recordings of each of your words for your phonetic notebook
- (I’ll upload these to WebCT later)

We’re done!!

See you all next week.

Same bat time.

Same bat channel.