Lecture 8

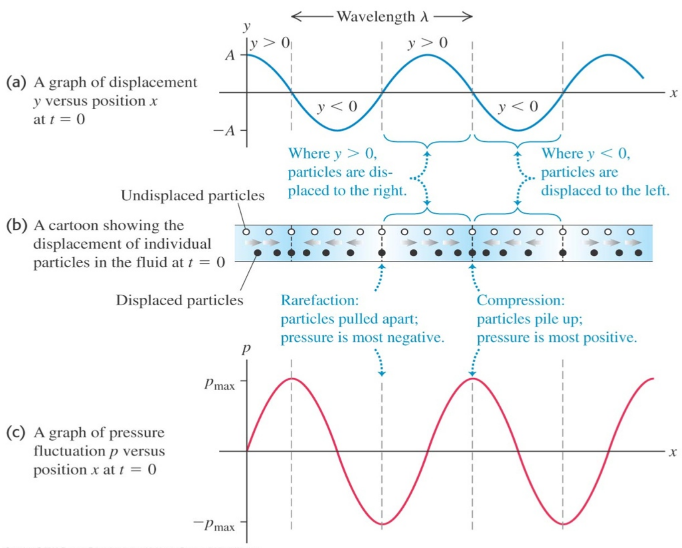
Sound waves

and

Perception of sound

Pre-reading: §16.3

Sound as Pressure Wave



Three ways to describe sound waves

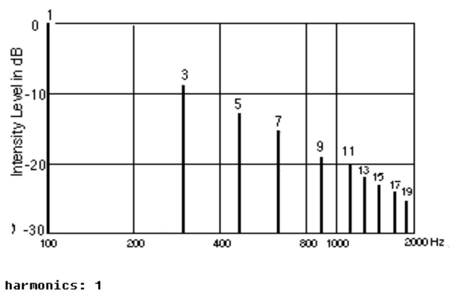
Pressure is 90° out of phase with displacement!

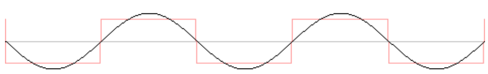
Fourier Series

- Every periodic wave can be represented as a sum of sinusoidal waves ("harmonics" or "overtones") with frequencies which are multiples of the fundamental frequency of the periodic wave.
- To recreate the original wave, analyse which overtone frequencies are present, their amplitudes and phase shifts ("**Fourier analysis**").
- Add up all these sinusoidal waves to copy the original wave ("**Fourier synthesis**").

§15.8

Fourier analysis:
analysing which frequencies are present ("harmonic content")



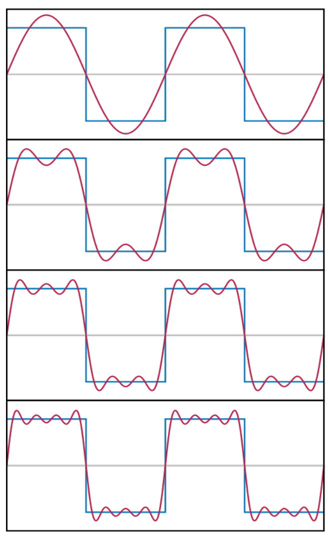


$\sin \omega t$

$+(\sin 3\omega t)/3$

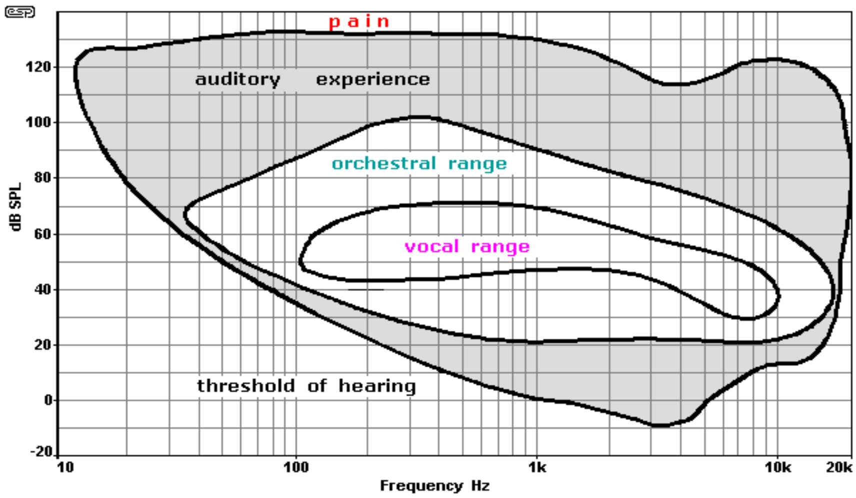
$+(\sin 5\omega t)/5$

$+(\sin 7\omega t)/7$



Properties of Sound Waves

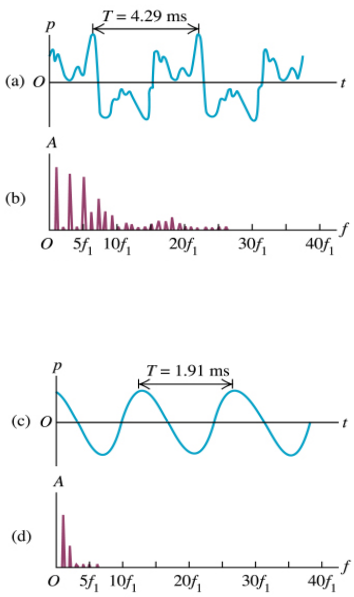
- Sound is a longitudinal wave
- Perception of sound affected by:
  Loudness = Amplitude
  Pitch = Frequency
  Tone/timbre = Mix of fundamental/overtones
  Noise = Mix of random frequencies



- Audible frequencies are 20–20,000 Hz (more for young people, less for older)

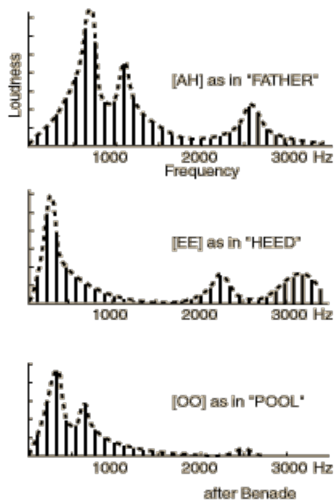
- Timbre: harmonic content (*ear measures Fourier spectrum*):

clarinet



alto recorder

- Different *vowel sounds* are produced by varying the harmonic content of the sound



- Harmonic content is different for various musical instruments *(Tuvan throat singers!)*
- Other situations have very unusual harmonic content (not musical), *i.e. harmonics not simple ratios of fundamental*

§16.1

Properties of Sound Waves

- Sound is a longitudinal wave
- Perception of sound affected by:
  Loudness = Amplitude
  Pitch = Frequency
  Tone/timbre = Mix of fundamental/overtones
  Noise = Mix of random frequencies
- Speed of sound:
  $v = \sqrt{(\text{Incompressibility / Density})} = \sqrt{(B/\rho)}$
  Air: 340 m/s Water: 1440 m/s
  Helium: 1000 m/s Aluminium: 6400 m/s

Sound Intensity

- Intensity is Power per unit Area (W m^{-2})
- From conservation of energy, intensity falls off as 1/r (in 2-D) or $1/r^2$ (in 3-D)
- Human ears sensitive to enormous range in intensities (12 orders of magnitude!)
- Use a logarithmic scale to describe intensity

$$\beta = (10\ \mathrm{dB}) \log \frac{I}{I_0}$$

with reference intensity $I_0 = 10^{-12}$ W m^{-2}

Units are decibels (dB)

§16.3

Sound and Resonance

- Standing waves can be thought of as oscillations
  - particles oscillate in phase with one another
- Recall damped + forced oscillations
- A system exhibiting standing waves (e.g. string, tube, metal plate) has many 'natural frequencies' (normal modes)
- Resonance: If oscillation is driven near 'natural frequency', amplitude grows quickly

§16.5

2010 exam Q 6(b)

b) The string of a guitar with fundamental frequency, 256 Hz, is plucked while two tuning forks (two-pronged forks which can vibrate with a pure musical tone, see picture below) are on a table nearby. The natural frequencies of the two tuning forks are 512 Hz and 384 Hz, respectively, and they are silent before the string is plucked. Discuss whether you think either of the tuning forks will start to vibrate and why.

(5 marks)

Next lecture

Interference

and

Beats

Read §16.6–16.7