Sound waves and Perception of sound

Pre-reading: §16.3

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").

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):
• 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

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• Speed of sound:
  \[ v = \sqrt{\frac{B}{\rho}} \]
  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/r² (in 3-D)
• Human ears sensitive to enormous range in intensities (12 orders of magnitude!)
• Use a logarithmic scale to describe intensity
  \[ \beta = (10 \text{ dB}) \log \frac{I}{I_0} \]
  with reference intensity \( I_0 = 10^{-12} \text{ W m}^{-2} \)

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
2010 exam Q 6(b)

(i) 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 plucked 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