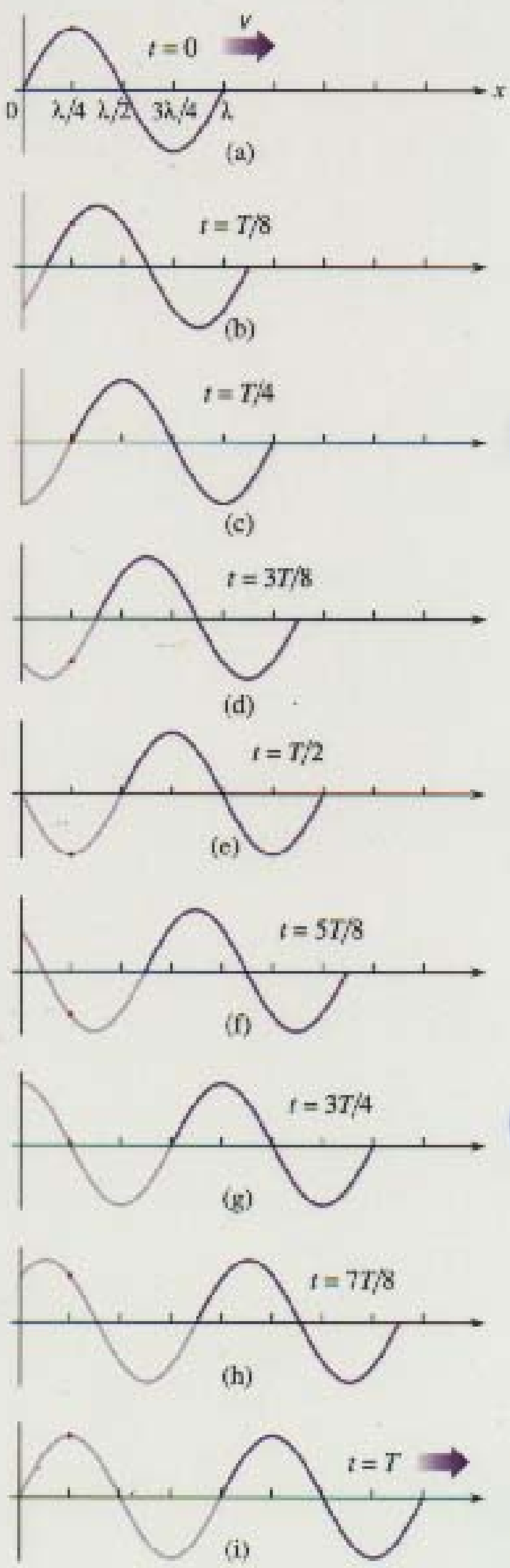
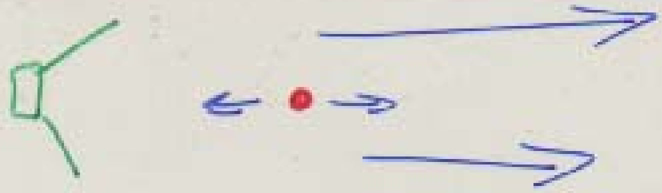
Figure 11.11

Harmonic wave moving along the x-axis



Sound as a Compression Wave



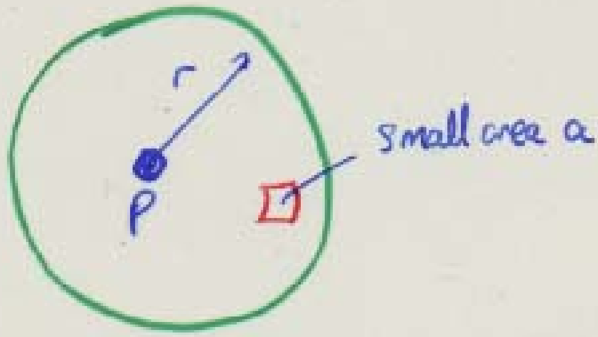
As speaker vibrates air molecules displaced longitudinally

For typical sounds, amplitude $A \sim$ few mm (not related to λ)

For harmonic waves, molecules execute SHM with energy $\propto A^2$

Sound Intensity

If sound wave expands from source power P [W]
At distance r, power spreads over area $4\pi r^2$



Define Intensity = Power/Area $I = \frac{P}{4\pi r^2}$ [W/m²]

$\therefore$ for detector area a, power received $= \frac{P.a}{4\pi r^2}$

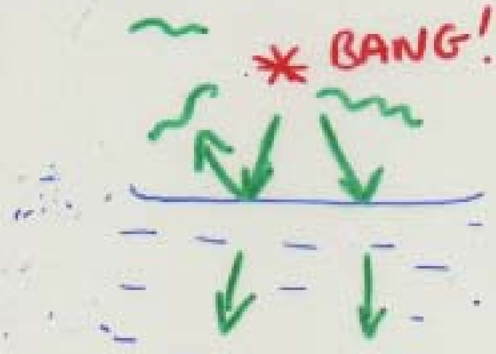
$\propto \frac{1}{r^2}$: "inverse square law"

Sound Waves (Acoustics)

General Wave Properties

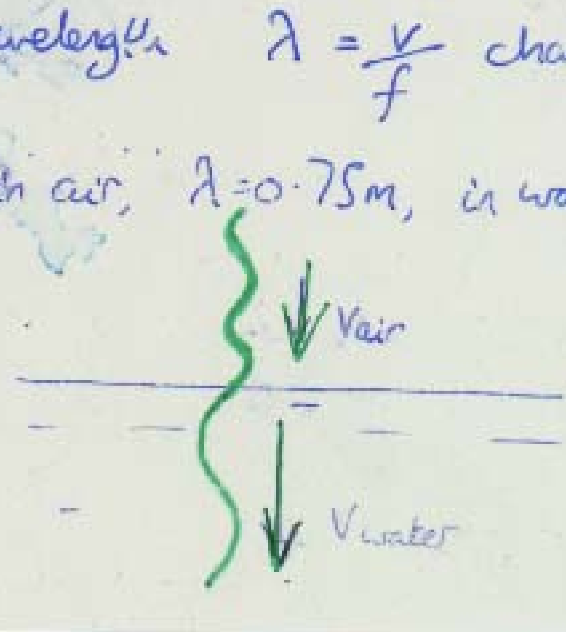
- Absorption - oscillation can be damped ⇒ dissipates energy
- Reflection -- when wave hits discontinuity in medium (e.g. echoes, sonar, ultrasound imaging)
- Transmission - wave energy transfers into another medium.

e.g.

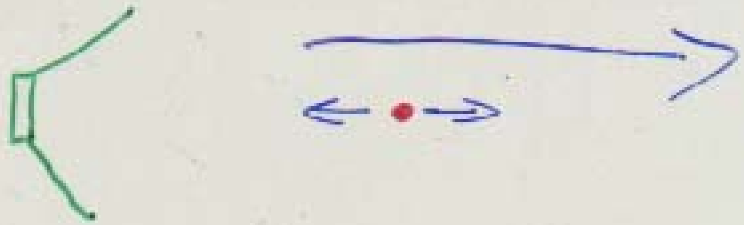


Note: Wave frequency f is the same in any medium (so we hear the same "note"), so if speed v changes, wavelength $\lambda = \frac{v}{f}$ changes

e.g. $f = 440\,Hz$: in air, $\lambda = 0.75\,m$, in water: $\lambda = 2.25\,m$



Sound as a Compression Wave



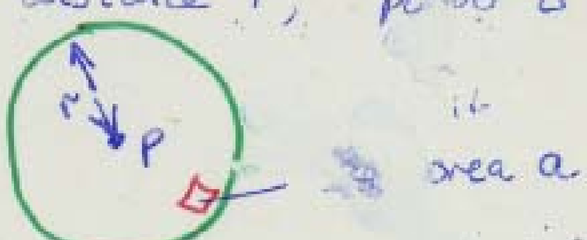
Speaker vibrates
→ air molecules
displaced along
direction of wave

For typical sounds, amplitude $A \sim$ few mm, related to energy of wave (not wavelength λ).

For harmonic waves, molecules execute SHM
with $E \propto A^2$ (c.f. mass on spring)
so wave energy $\propto A^2$

Sound Intensity:

If sound wave expands from a source of power P [W]
At distance r, power is spread over sphere area $4\pi r^2$:



Define Intensity = Power/Area i.e. $I = \dfrac{P}{4\pi r^2}$

e.g. For 100W speaker, how much power impinges on ear (area $\sim 5\times10^{-4}\,m^2$) at (a) 5m, (b) 50m ?

Figure 11.21

Waves from a loudspeaker

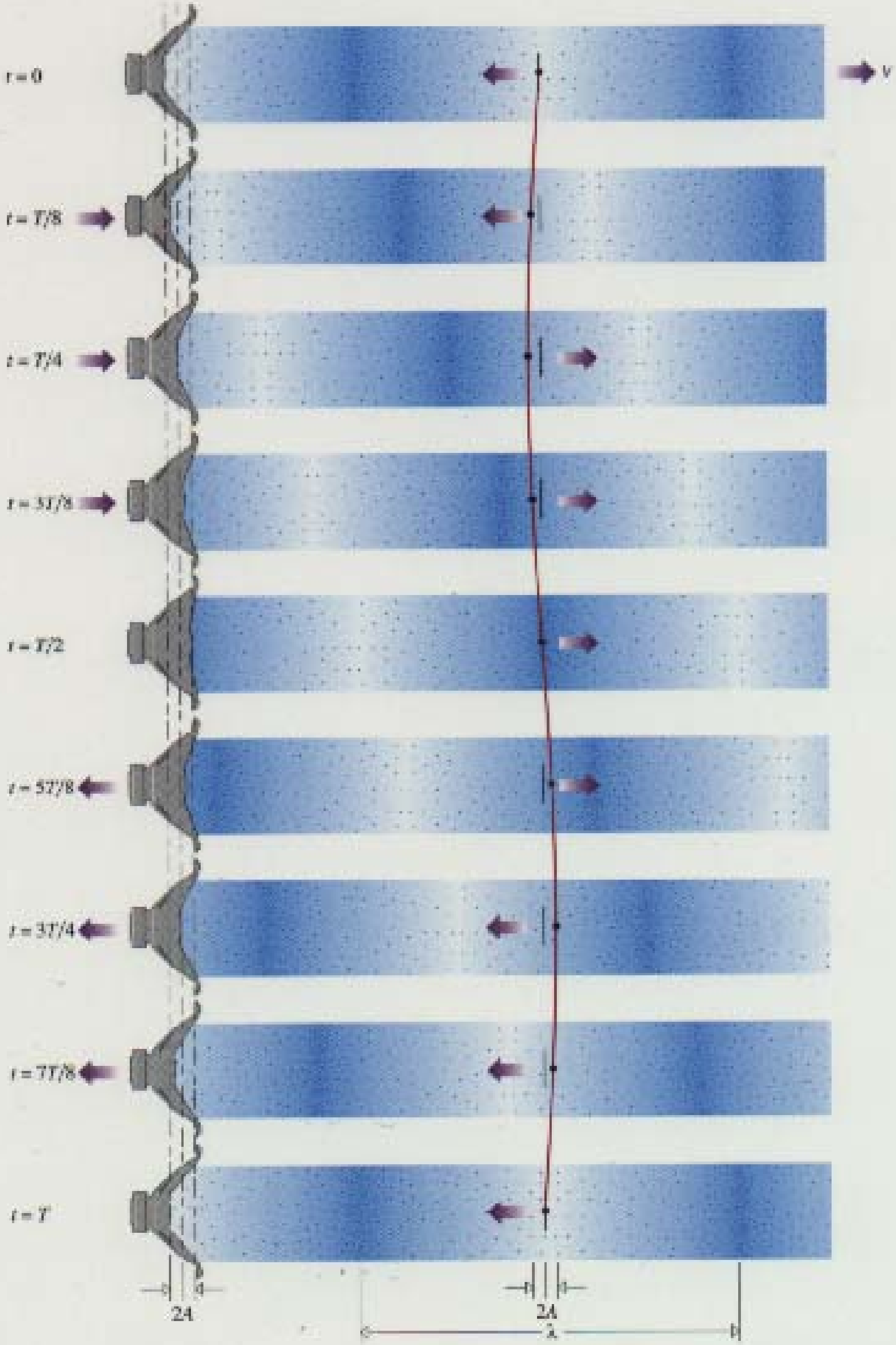


Figure 11.22
Sinusoidal sound wave

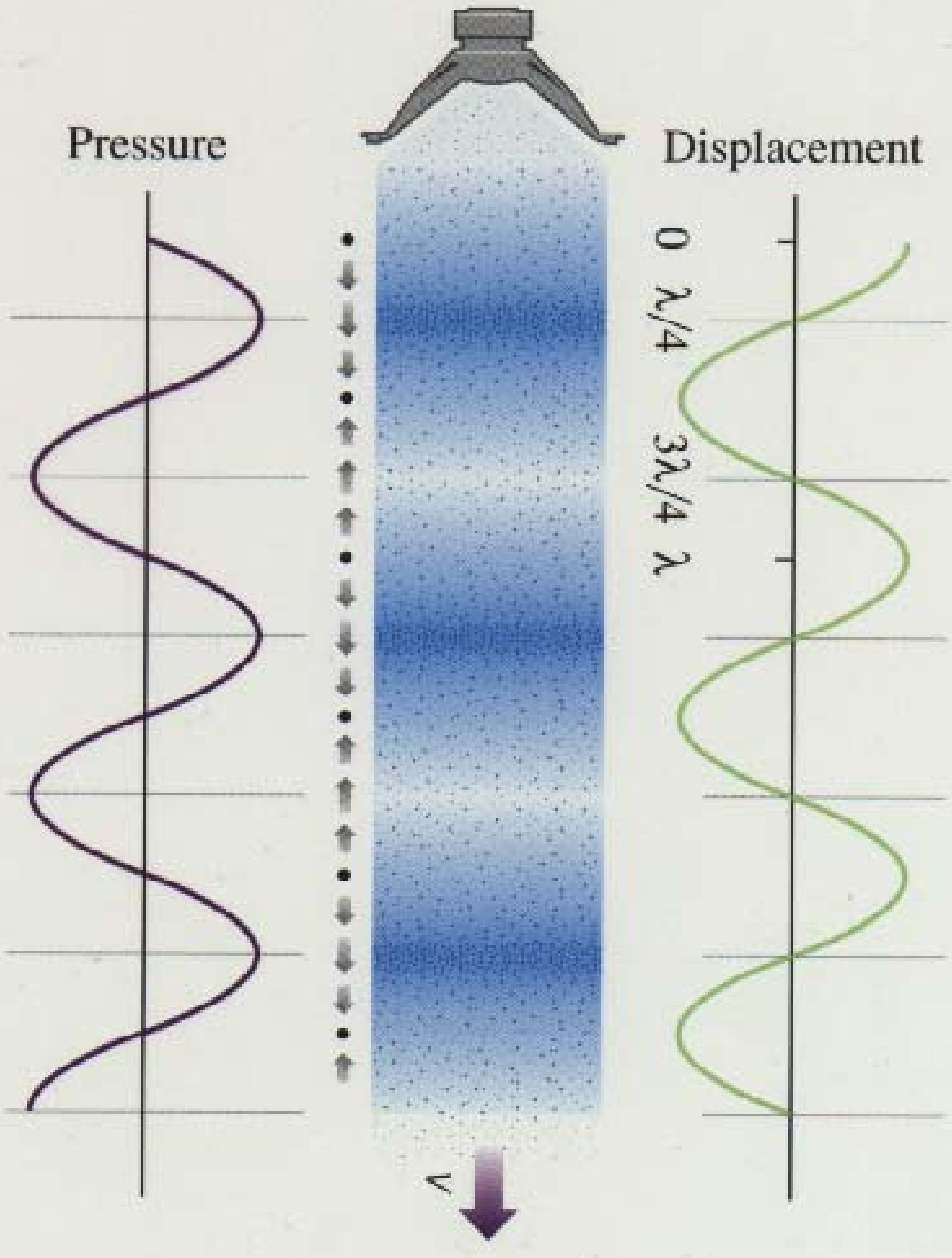
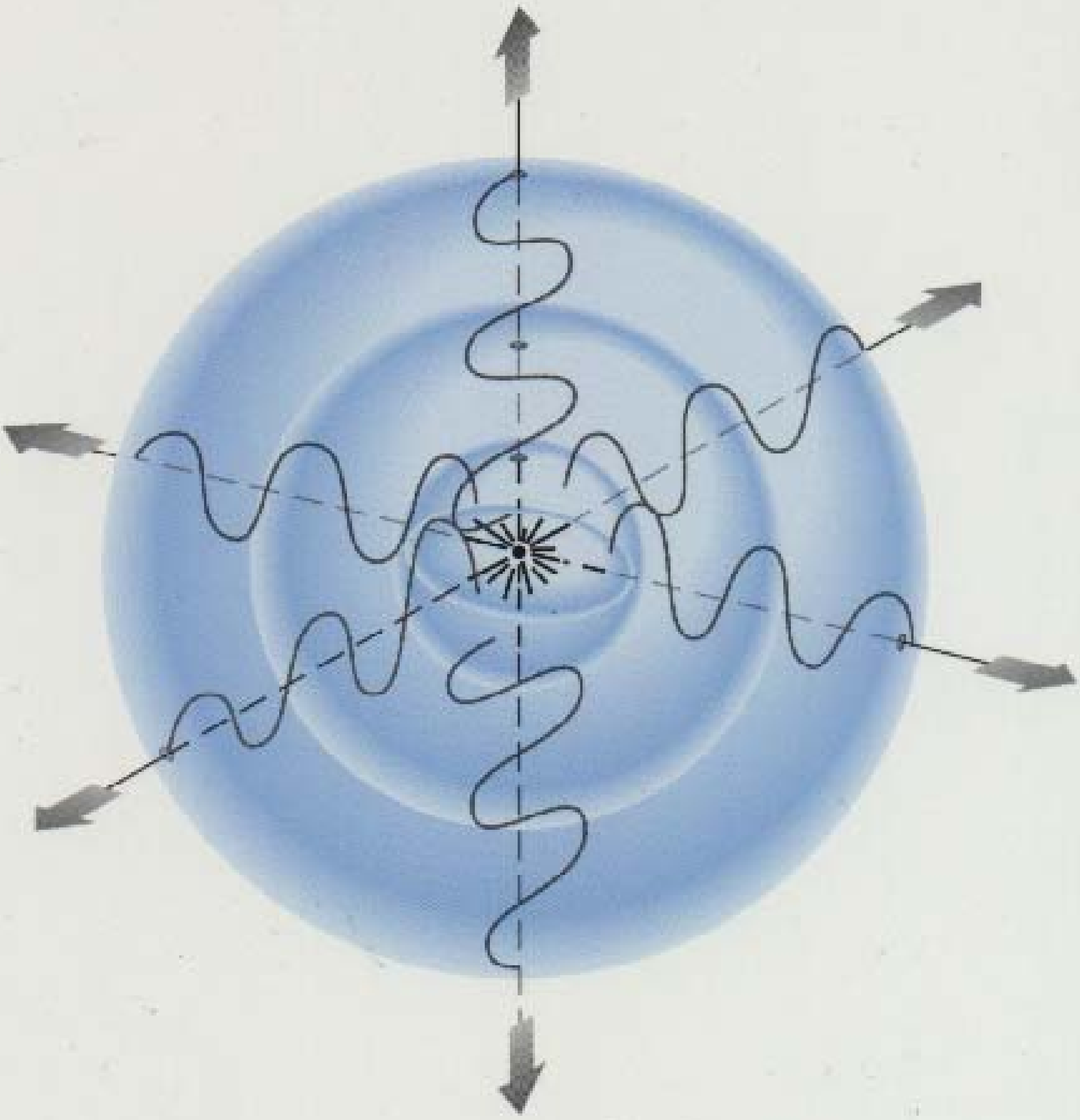


Figure 11.32

Wave from a point source



Basic Properties of a Continuous Sound Wave

(e.g. musical note, vowel in speech)

- Intensity ("loudness") = power/unit area

$$\propto [\text{amplitude}]^2$$

$$\propto \frac{1}{[\text{distance}]^2}$$

- Pitch = freq. of fundamental tone f_0

(Why not give λ? (i) λ depends on the medium $\lambda = v/f$

(ii) ears measure frequency, not λ).

- "Timbre" = the particular superposition of harmonics $2f_0$, $3f_0$, ... required to produce the waveform.

So $f = 440$ Hz on piano sound different to $f = 440$ Hz on flute, violin etc.

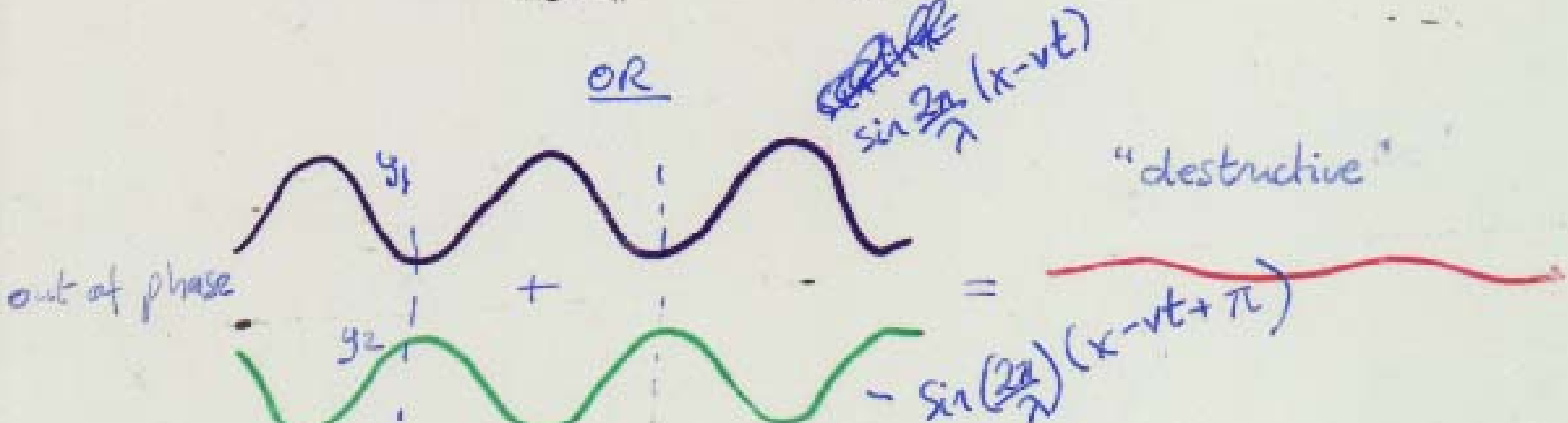
Superposition of Waves

When 2 waves in medium meet, resulting displacement $y(x,t) = y_1(x,t) + y_2(x,t)$

- just add them, no "collision" or energy/momentum transfer between waves.

We say waves INTERFERE.

OR

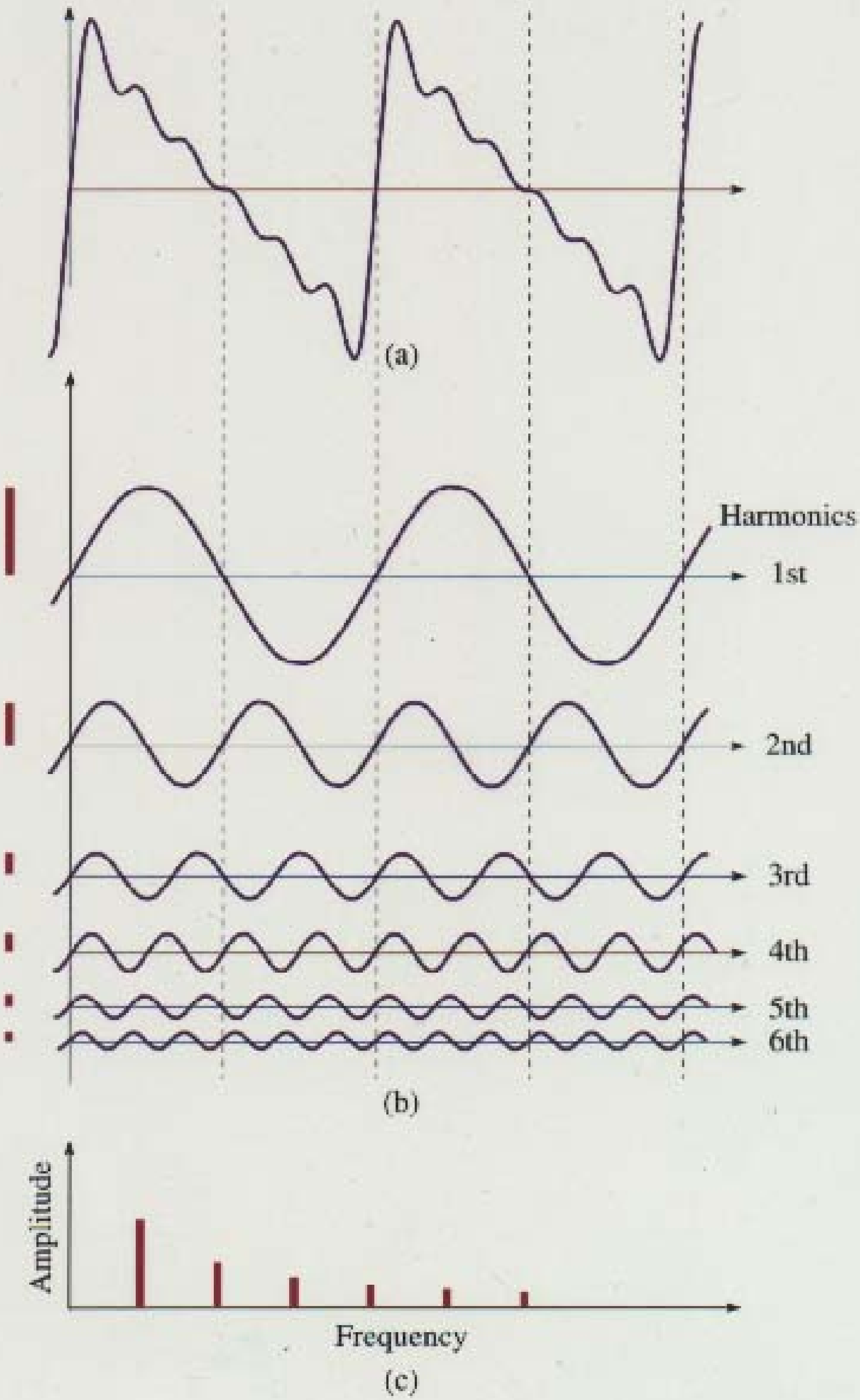


Interference is a purely wave phenomenon: two energetic waves can "cancel out" to give ~ nothing!

(Waves are non-local - energy is conserved overall but not at specific locations)

Figure 11.28

Synthesis of a sawtooth wave



Superposition cont/d : Fourier Synthesis

Every periodic wave has fundamental (lowest) freq. f_0

Fourier (1807) showed: Any periodic waveform can be synthesized by adding harmonic waves together with frequencies $f_0, 2f_0, 3f_0, 4f_0, 5f_0, \ldots$ by choosing correct amplitudes and phases

e.g. Fig. 11.28, or: