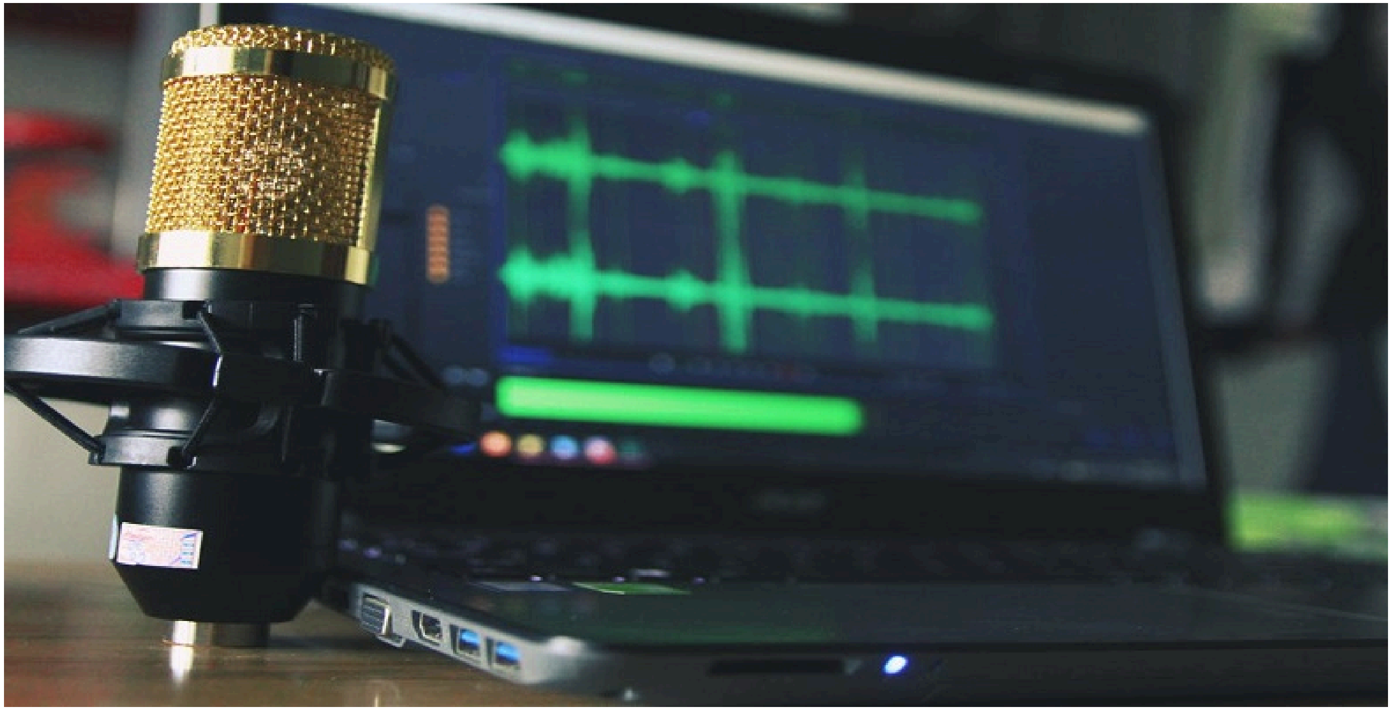
Physics 1240: Sound and Music

<u>Today (8/5/19)</u>: Electronic Sound: Recording

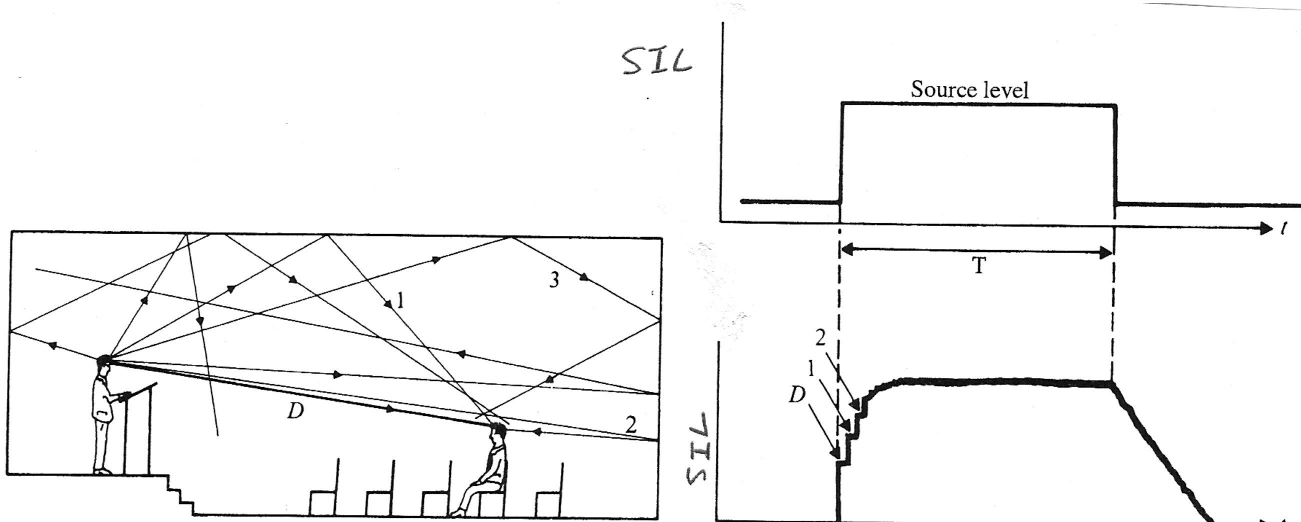
<u>Next time</u>: Electronic Sound: Instruments, Editing



<u>Review</u>

- <u>Reverberation</u>: the buildup and decay of a sound in a room after it is produced

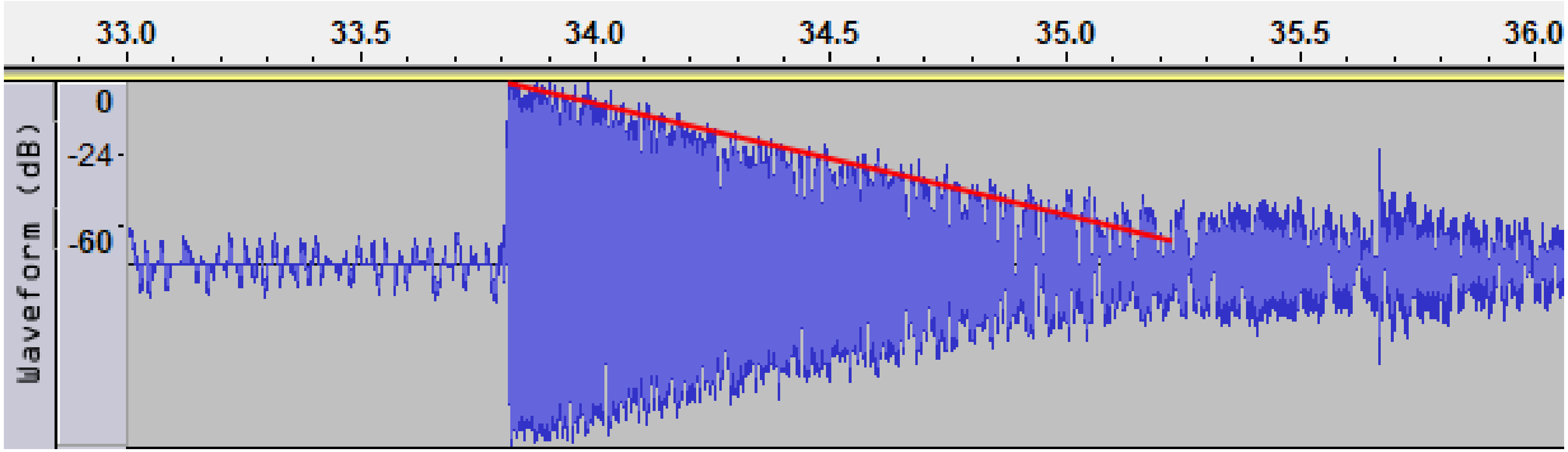
- <u>Bad acoustic design</u>: rounded walls, amplified room modes
- <u>Good acoustic design</u>: well-distributed sound, clarity, envelopment, source width, acoustical intimacy



Rossing 2002

Review

- Reverberation Time (T_r): how long it takes for a sound to decay 60 dB
  - Duane G1B30: $T_r \approx 1.4\ \text{seconds}$



Sabine's Formula

- Sabine's formula

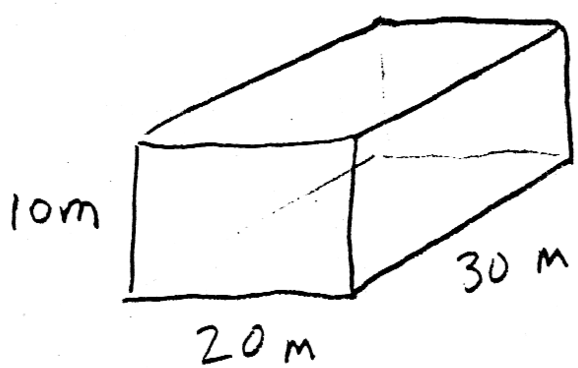
$$T_r = (0.16\ \mathrm{sec/m})\frac{V}{S_e}$$

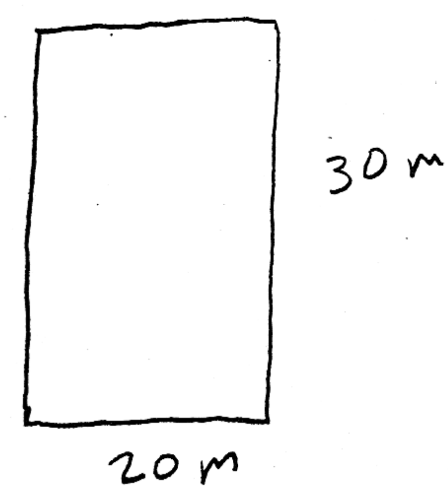
- S_e: effective surface area (equivalent area of fully-absorbing surface)

$$S_e = (a_1 \cdot S_1) + (a_2 \cdot S_2) + (a_3 \cdot S_3) + \cdots$$

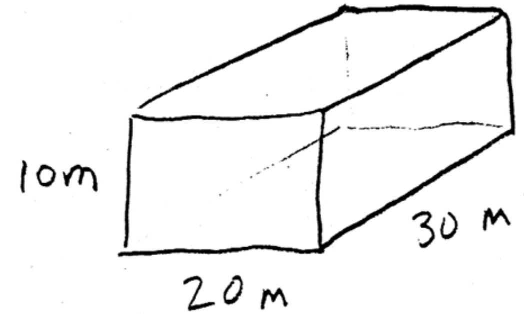
- V: total volume of the room
- S_1 – surface area for one component
- a_1 = absorption coefficient for one component
  (power absorbed / power incident)

Example: Calculate the reverberation time of a 20 m x 30 m concert hall with a ceiling height of 10 m. Assume the absorption coefficients for the walls, floor and ceiling are 0.1, 0.2, and 0.3, respectively.





Solution:



$$T_r = (0.16\ \text{sec/m})\frac{V}{S_e}$$

V = (20 m) · (30 m) · (10 m) = 6000 m^3

$$S_e = 2 \cdot (0.1 \cdot 20\ \text{m} \cdot 10\ \text{m}) \quad \text{(front \& back walls)}$$

$$+ 2 \cdot (0.1 \cdot 30\ \text{m} \cdot 10\ \text{m}) \quad \text{(side walls)}$$

$$+ (0.2 \cdot 20\ \text{m} \cdot 30\ \text{m}) \quad \text{(floor)}$$

$$+ (0.3 \cdot 20\ \text{m} \cdot 30\ \text{m}) \quad \text{(ceiling)}$$

$$= 40\ \text{m}^2 + 60\ \text{m}^2 + 120\ \text{m}^2 + 180\ \text{m}^2$$

$$= 400\ \text{m}^2$$

$$T_r = (0.16\ \text{sec/m})\frac{(6000\ \text{m}^3)}{(400\ \text{m}^2)} = 2.4\ \text{sec}$$

BA

Clicker Question 19.1

Suppose you are sitting in a center stage seat, listening to a solo soprano opera singer. The theater is perfectly symmetrical in design (looks the same on both sides of you). What acoustical quality would be compromised (negatively impacted) in such a situation?

A) source width

B) acoustical intimacy

C) reverberation

BA

Clicker Question 19.1

Suppose you are sitting in a center stage seat, listening to a solo soprano opera singer. The theater is perfectly symmetrical in design (looks the same on both sides of you). What acoustical quality would be compromised (negatively impacted) in such a situation?

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B) acoustical intimacy

C) reverberation

BA

Clicker Question 19.2

The absorption coefficient for a set of empty wooden pews in a cathedral is about 10 times smaller than the absorption coefficient for the same set of pews when they are fully occupied with people on a Sunday. Which will lead to a longer reverberation time?

A) Empty wooden pews

B) Fully occupied wooden pews

BA

Clicker Question 19.2

The absorption coefficient for a set of empty wooden pews in a cathedral is about 10 times smaller than the absorption coefficient for the same set of pews when they are fully occupied with people on a Sunday. Which will lead to a longer reverberation time?

A) **Empty wooden pews**

B) Fully occupied wooden pews

$$T_r = (0.16\ \mathrm{sec/m})\frac{V}{S_e}$$

$$S_e = (a_1 \cdot S_1) + (a_2 \cdot S_2) + (a_3 \cdot S_3) + \cdots$$

Types of Instruments

(Hornbostel–Sachs classification)

- Chordophones: vibrating strings

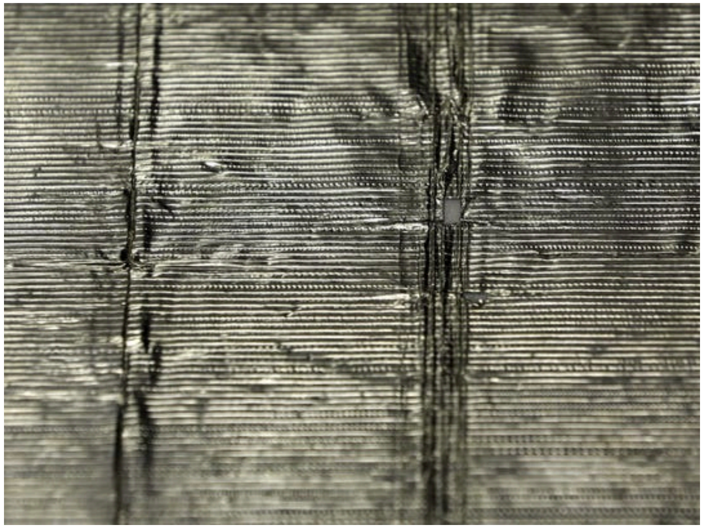
- Aerophones: vibrating columns of air

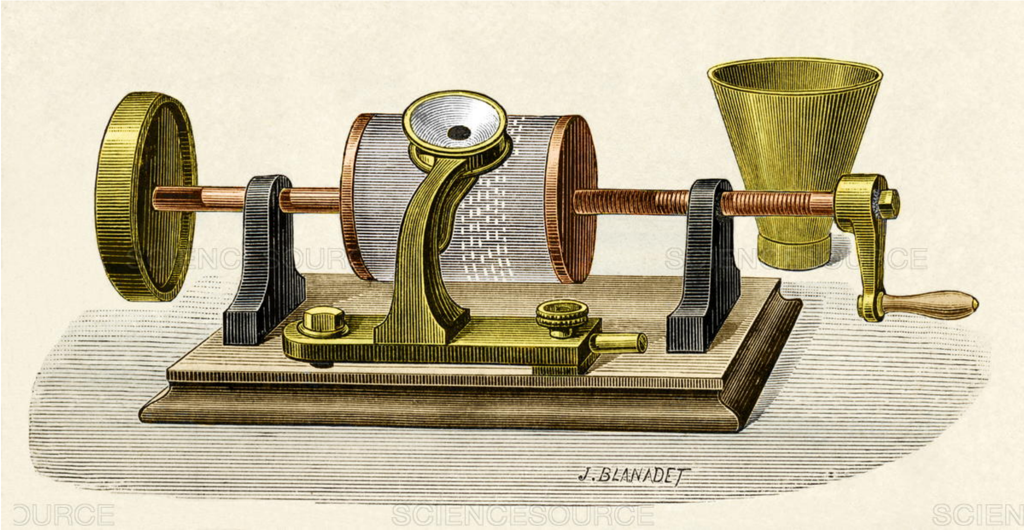
- Idiophones: vibrating the whole instrument

- Membranophones: vibrating membrane/skin
- Electrophones: vibrating loudspeaker

Electrophones

- Earliest electrophone: Edison's phonograph (1878)
  - Cut grooves into tin foil on cylinder
  - Later versions use wax cylinder





https://www.youtube.com/watch?v=wRTgl0qx6wE


the Henry Ford

Electrophones

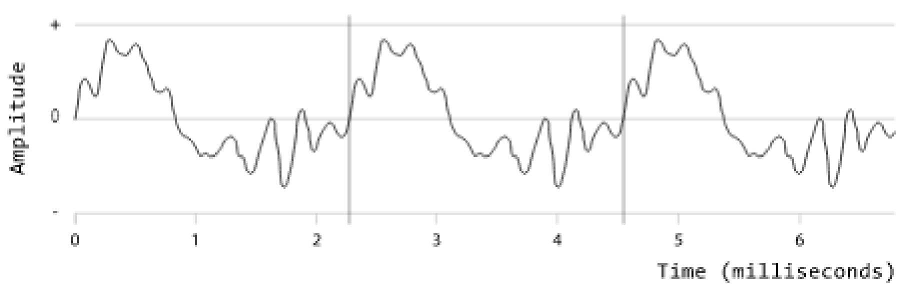
- <u>Transducer</u>: any device that converts a signal from one energy form to another

  - Forms of energy:
    - Electric (voltage oscillations)
    - Acoustic (air molecule vibrations)
    - Mechanical (solid object vibrations)

speaker

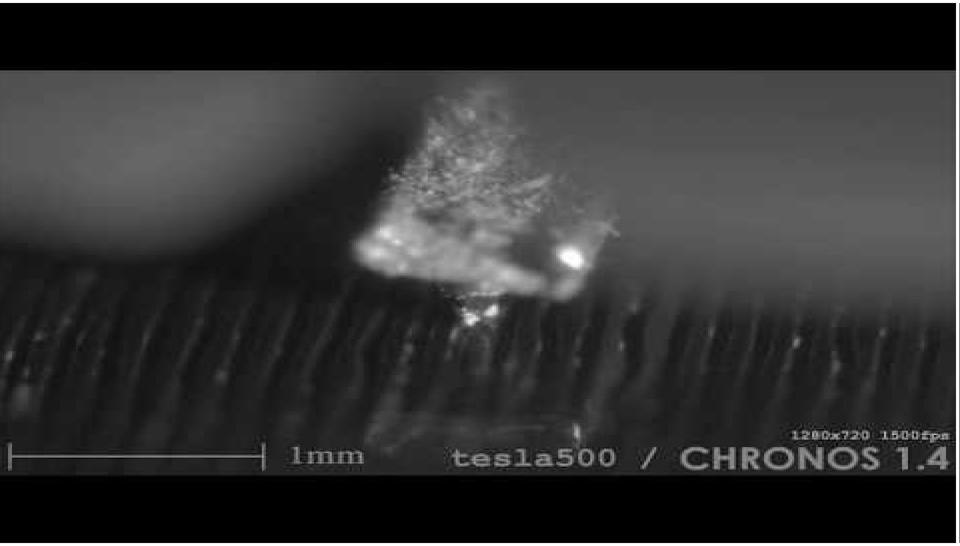
microphone

phonograph



Sound Recording

- Phonograph record
  (gramophone)
  (1910s)



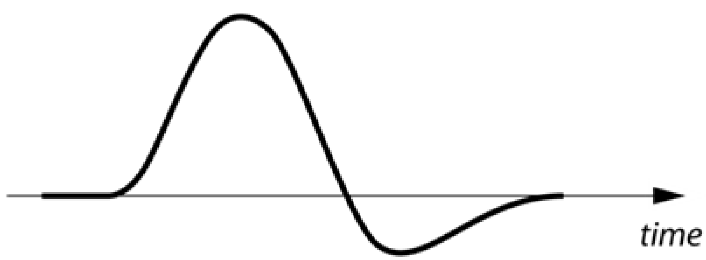
Sound Recording

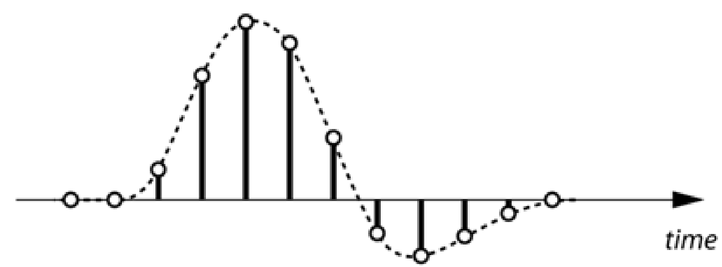
- Phonograph record described by:
  - Diameter (e.g. 12-inch)
  - Rotational speed (e.g. 78 rpm)
  - Time capacity (e.g. LP, SP, EP)

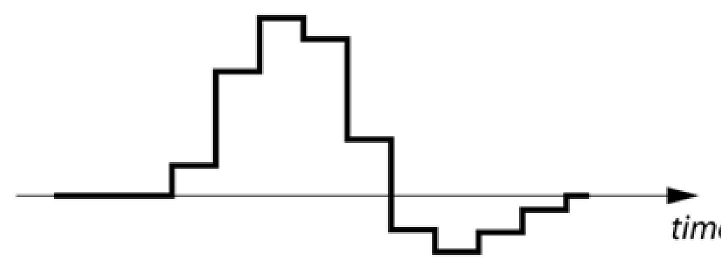
Electric Recording

- Analog: continuous signal that mimics the shape of acoustic sound pressure waves

- Digital: stream of discrete numbers that represent instantaneous amplitudes of analog signal, measured at equally-spaced points in time



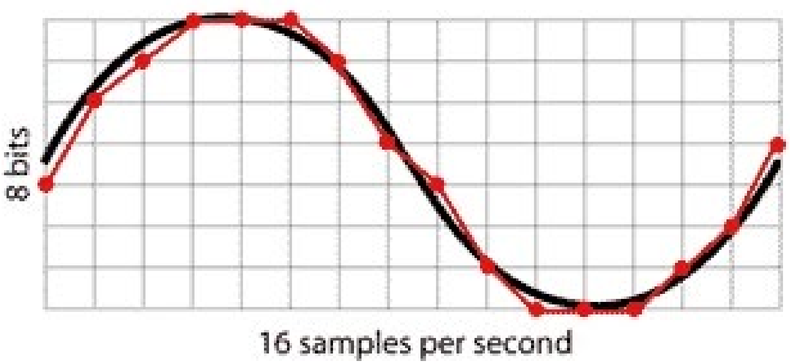


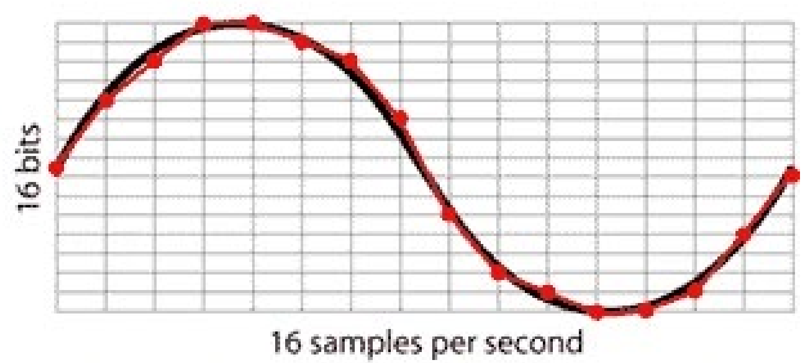


<u>Electric Recording</u>

- <u>Sampling rate</u>: how often analog signal is measured [samples per second, Hz]
  - e.g. 44,100 Hz

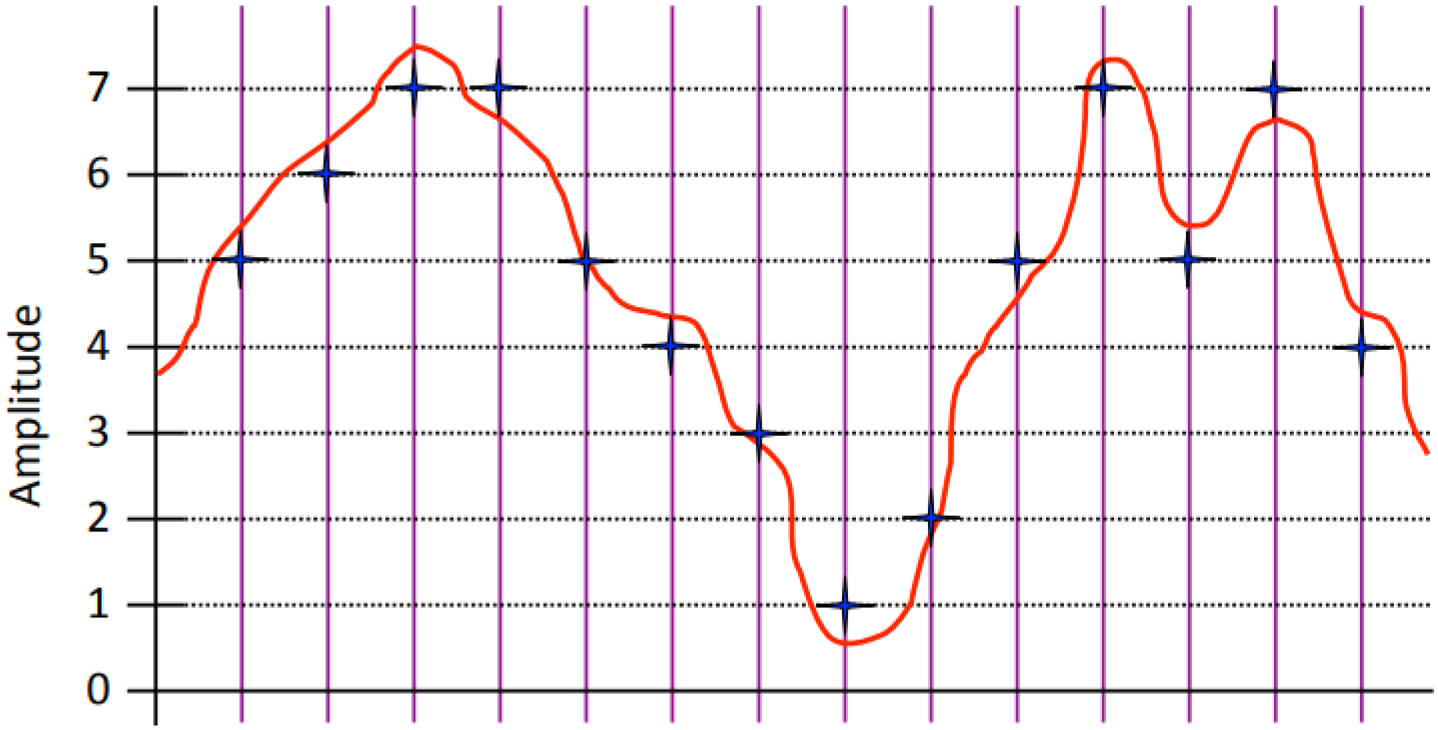
- <u>Sampling resolution</u> ("bit depth"): precision of numbers used for measurement: the more bits, the higher the resolution
  - e.g. 16 bit





3-bit Quantization

A 3-bit binary (base 2) number has $2^3 = 8$ values.

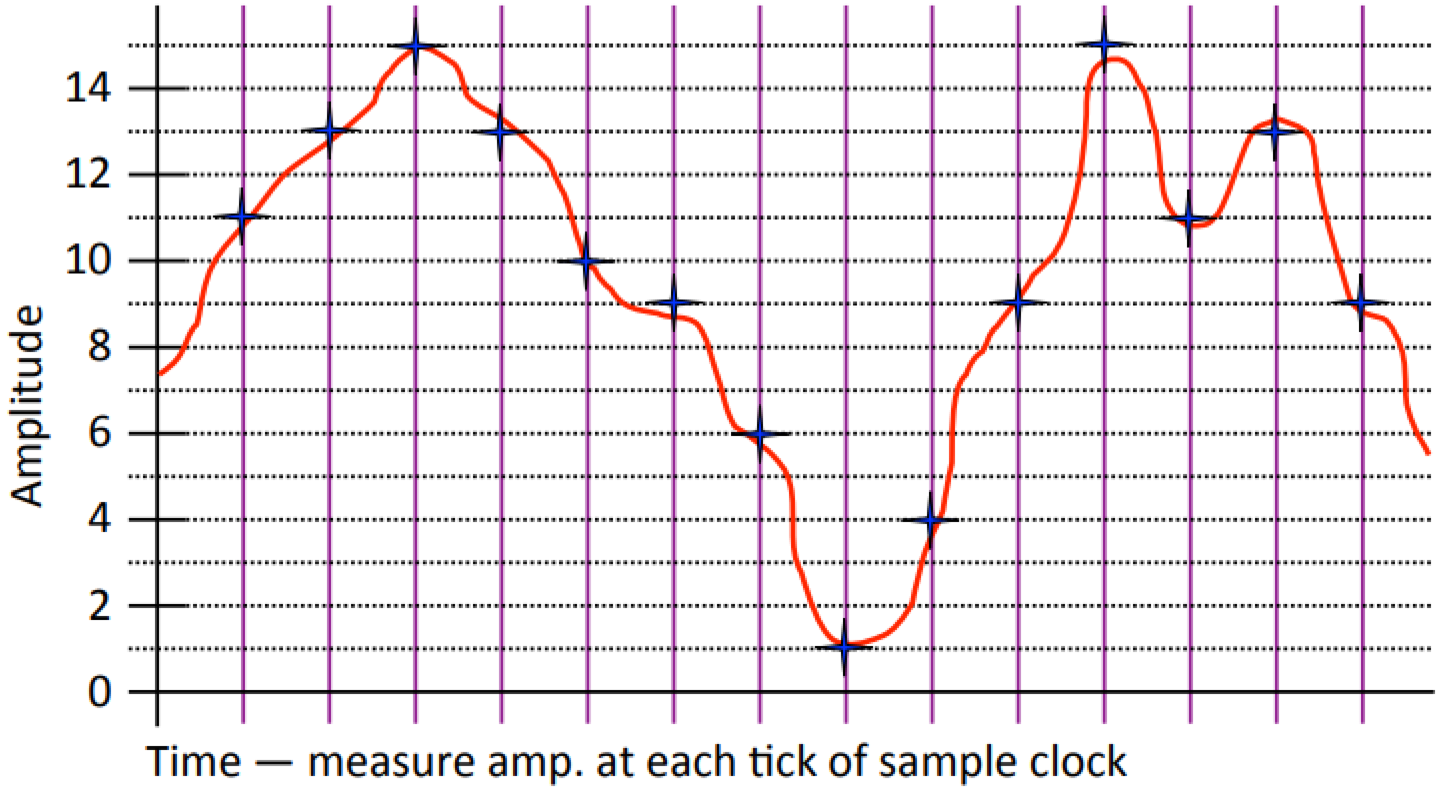


Time — measure amp. at each tick of sample clock

A rough approximation

4-bit Quantization

A 4-bit binary number has $2^4 = 16$ values.

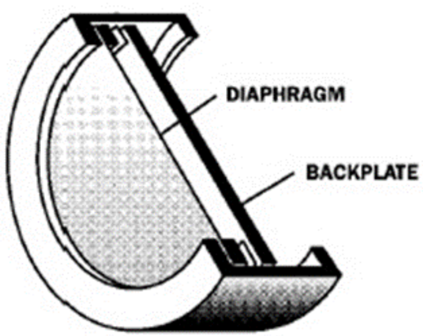


A better approximation

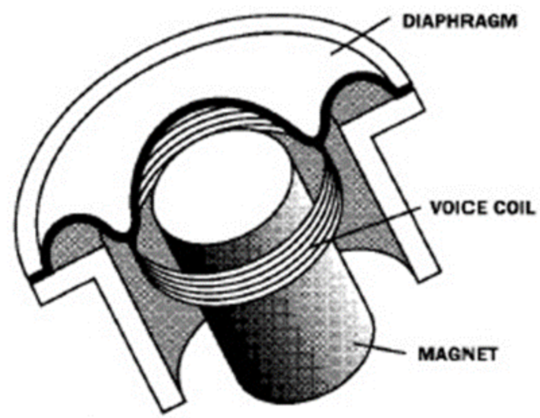
https://www.youtube.com/watch?v=53tdYmJuUmM

Condenser Microphone

Dynamic Microphone

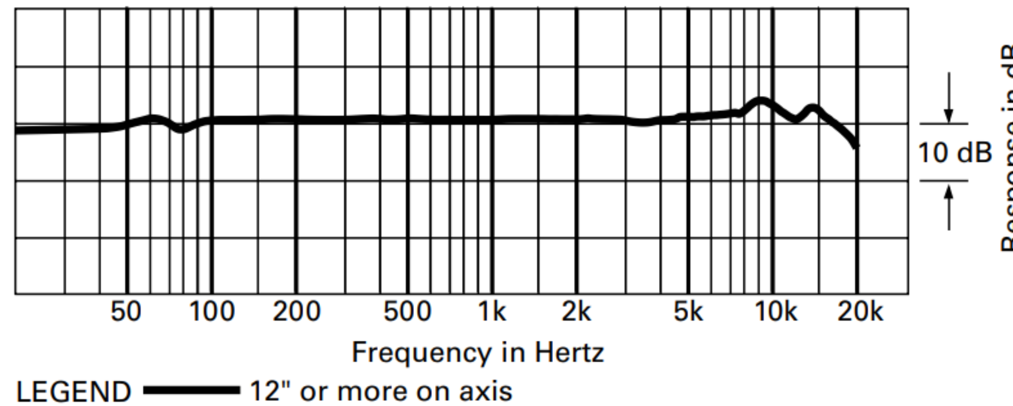


Condenser Microphone

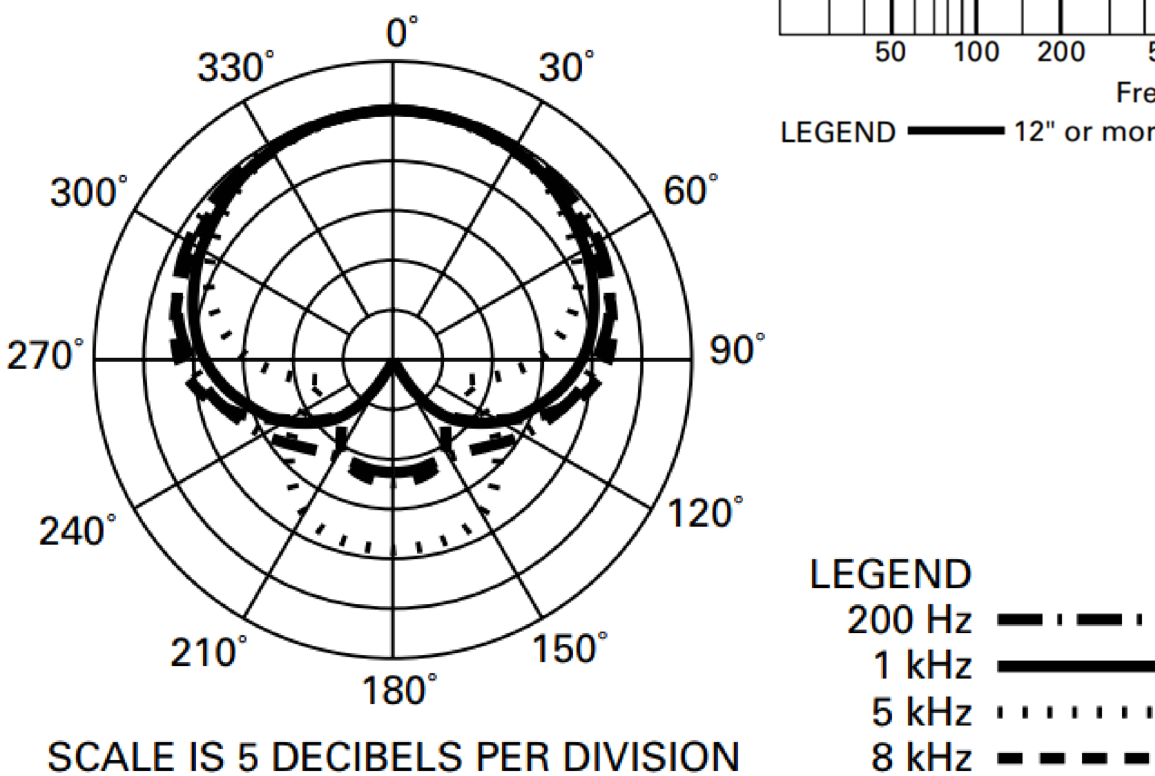


Dynamic Microphone

Frequency Response

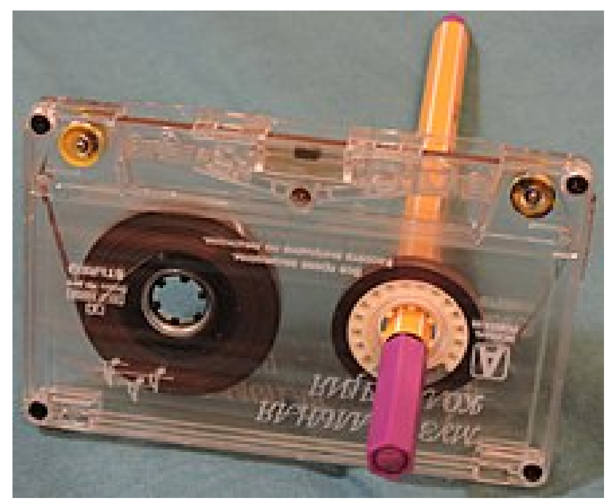


Polar Pattern



Sound Recording

- <u>Tape Recorder</u>: transfers sound information to magnetic strips
  - Eight-tracks
  - Cassettes



https://www.youtube.com/watch?v=NkGf1GHAxhE

BA

Clicker Question 19.3

If the sampling rate of a cassette tape recorder is 32 kHz, how much time is there between consecutive samples?

A) 0.03 ms

B) 0.3 ms

C) 3 ms

D) 0.03 s

E) 30 ks

BA

Clicker Question 19.3

If the sampling rate of a cassette tape recorder is 32 kHz, how much time is there between consecutive samples?

A) 0.03 ms

B) 0.3 ms

C) 3 ms

D) 0.03 s

E) 30 ks

BA

Clicker Question 19.4

If the sampling rate of a cassette tape recorder is 32 kHz, How many samples are present on a cassette where both sides record 30 minutes of audio?

A) 58 million

B) 91 million

C) 115 million

D) 906 million

BA

Clicker Question 19.4

If the sampling rate of a cassette tape recorder is 32 kHz, How many samples are present on a cassette where both sides record 30 minutes of audio?

A) 58 million

B) 91 million

C) 115 million

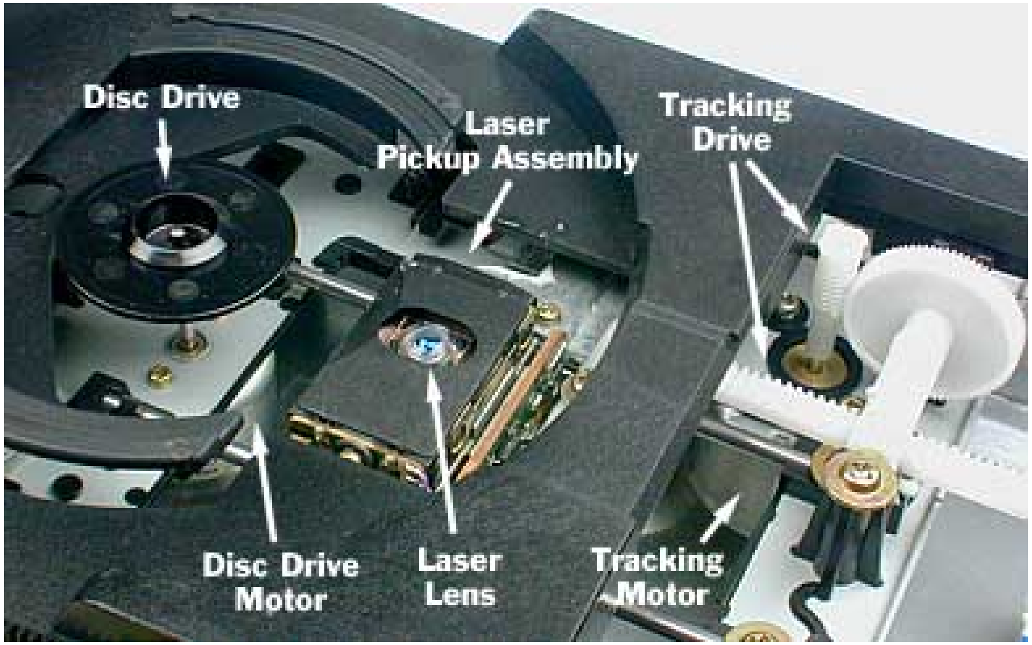
D) 906 million

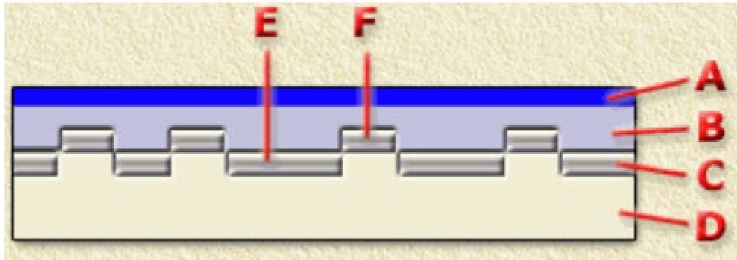
$$\left(32000\,\frac{\text{samples}}{\text{sec}}\right)(2\times 30\ \text{min})\left(\frac{60\ \text{sec}}{1\ \text{min}}\right)$$

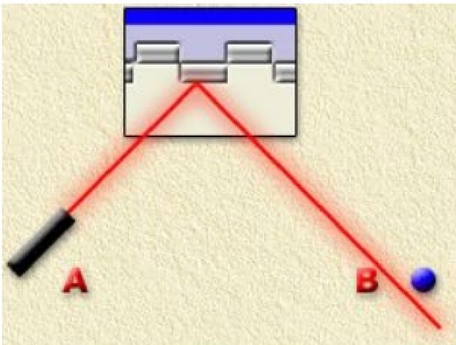
$=115{,}200{,}000$ samples

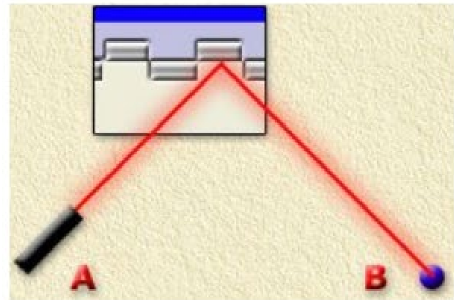
Sound Recording

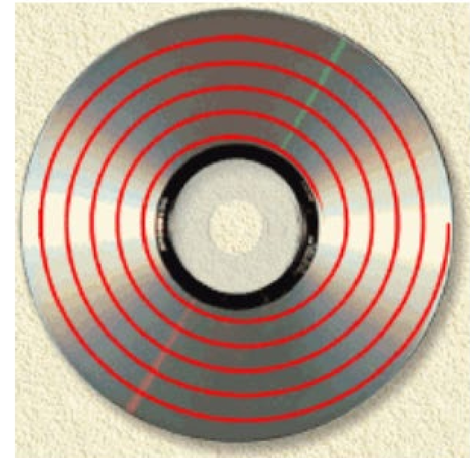
- Compact Disc (CD): digital optical disc data storage (data (pits) read by a laser)
  - 1 hour, 20 minutes
  - 4.7-in. diameter

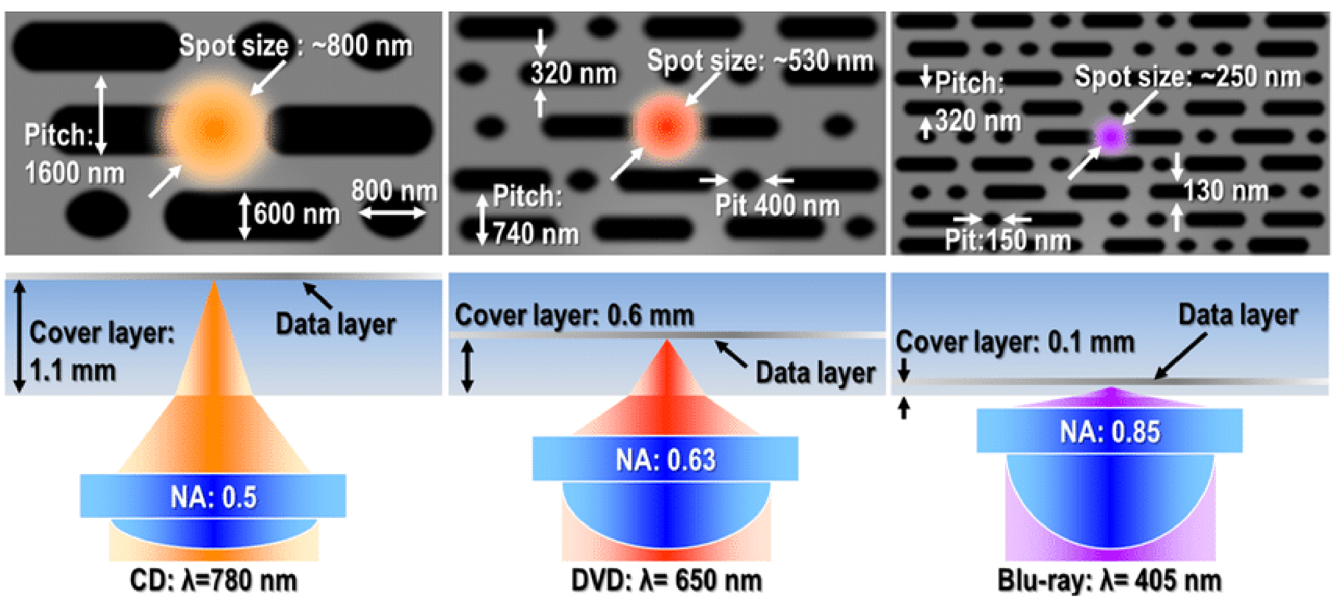



E
F
A
B
C
D


A
B


A
B




Spot size : ~800 nm
Pitch:
1600 nm
600 nm
800 nm
320 nm
Spot size: ~530 nm
Pitch:
740 nm
Pit 400 nm
Pitch:
320 nm
Spot size: ~250 nm
130 nm
Pit:150 nm
Cover layer:
1.1 mm
Data layer
Cover layer: 0.6 mm
Data layer
Data layer
Cover layer: 0.1 mm
NA: 0.5
NA: 0.63
NA: 0.85
CD: λ=780 nm
DVD: λ= 650 nm
Blu-ray: λ= 405 nm