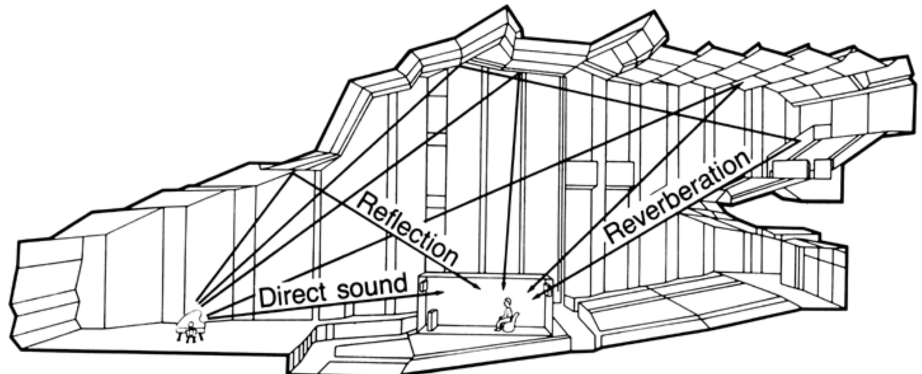
Physics 1240: Sound and Music

Today (8/2/19): Auditorium and Room Acoustics

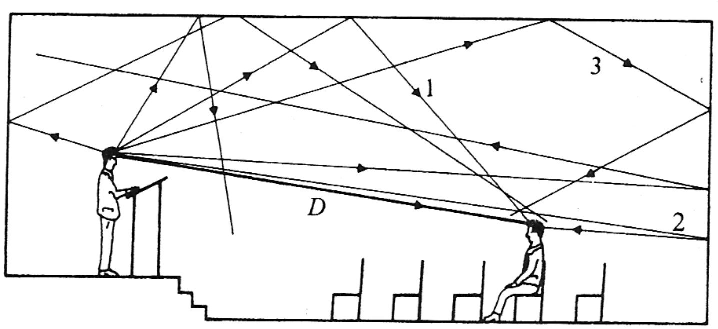
Next time: Electronic Sound: Recording

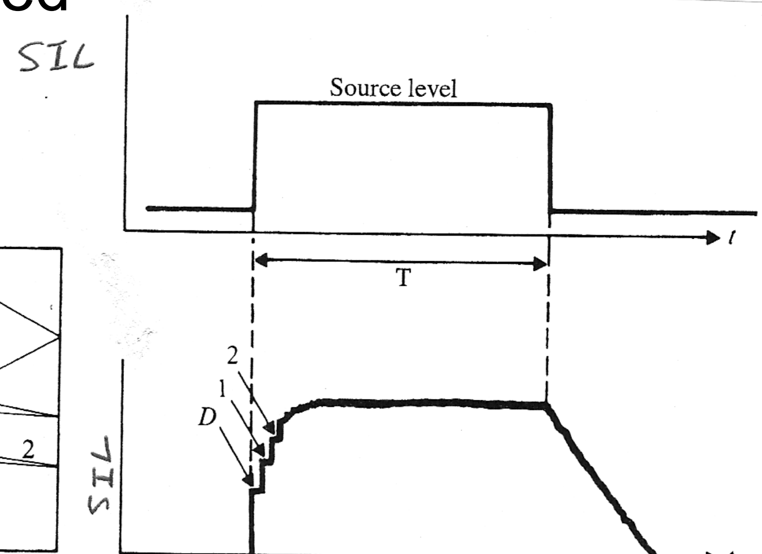
Acoustics

- Acoustical properties of rooms and concert halls depend on amounts of
    - Reflection (echo)
    - Absorption
    - Diffraction



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





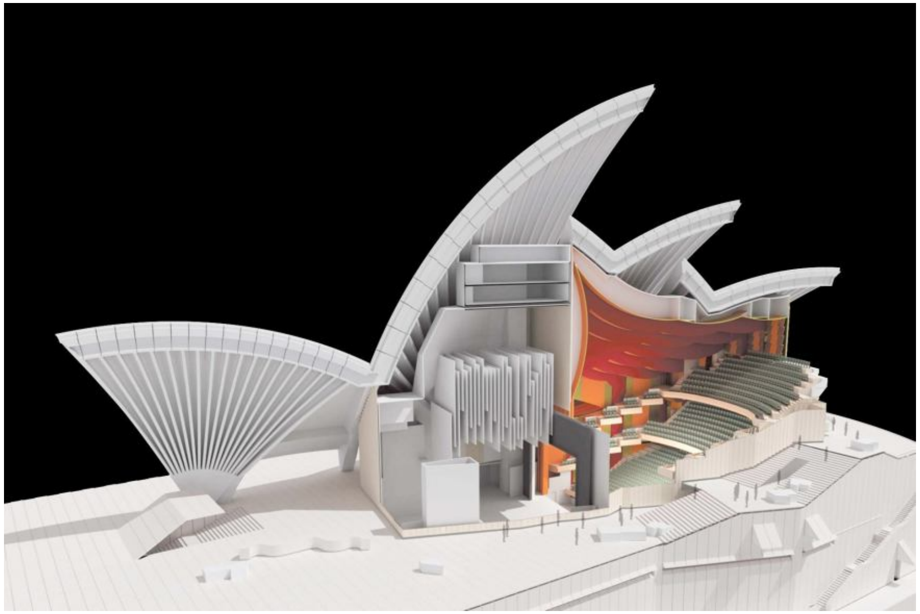
Rossing 2002

Concert Hall Design

- Good concert halls avoid…
  - Rounded walls
  - Strictly parallel plain walls (room modes)

Concert Hall Design

- Sydney Opera House



Concert Hall Design

- Qualities of good concert hall acoustics: (common sense things)

  - Loud enough **volume**
  - **Well-distributed** sound
  - **Clarity**
  - **Low background noise**
  - **Envelopment**/spaciousness
  - **Performer satisfaction**
  - **Reverberation** (not “acoustically dead”)

Concert Hall Design

- Two more critical design qualities for good acoustics:
  - **Source Width** – listeners like differences in the sound going to the left and right ear
  - **Acoustical Intimacy** – smaller rooms tend to sound better

Concert Hall Design

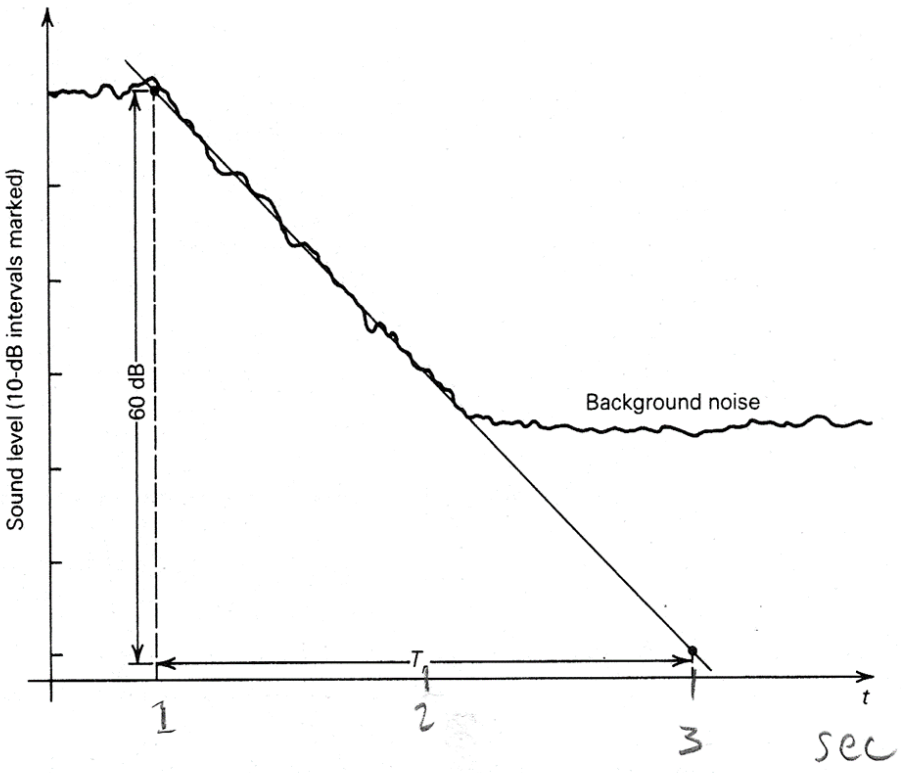
- Shoebox design: long, tall, narrow
  - Ideal source width & acoustical intimacy – narrow with strong early reflections

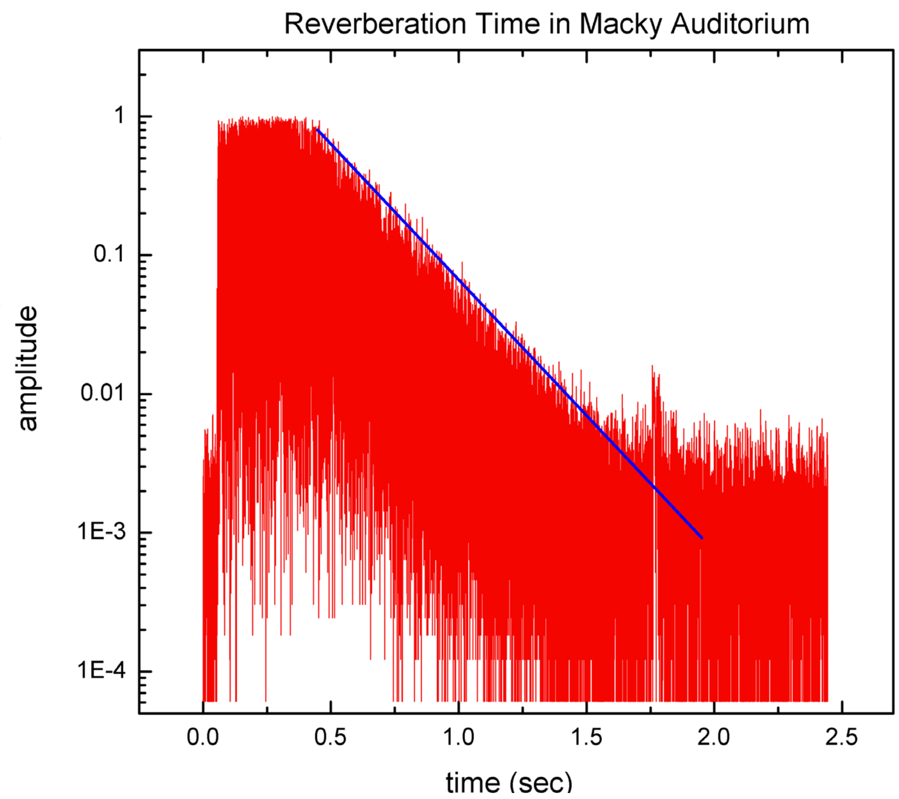
Vienna Musikverein

- Best place to sit in movie theater?
  - Visually: middle & center
  - Acoustically: 2/3rds of the way back (where acousticians test primary mics for playback levels, timings, etc.), and 1 or 2 seats off-center (enhance stereo effect)

Reverberation Time

- Reverberation Time (T_r): how long it takes for a sound to decay 60 dB





Reverberation Time

- Reverberation Time (T_r): how long it takes for a sound to decay 60 dB
- Typical reverberation times:

Practice room:
V = 27 m^3 , T_r = 0.6 sec (3m x 3m x 3m)

Rehearsal room:
V = 600 m^3 , T_r = 1.4 sec (6m x 10m x 10 m)

Large concert hall:
V = 20,000 m^3 , T_r = 2.2 sec (20m x 32m x 32m)

BA

Clicker Question 18.1

If your living room seems acoustically dead, what should you do to increase the reverberation?

A) Remove carpet and install a hardwood floor
B) Texture the walls and ceiling (make them rough)
C) Install heavy curtains over the windows
D) Add a large, soft sofa

BA

<u>Clicker Question 18.1</u>

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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)

Absorption coefficients - the a's in Sabine's formula

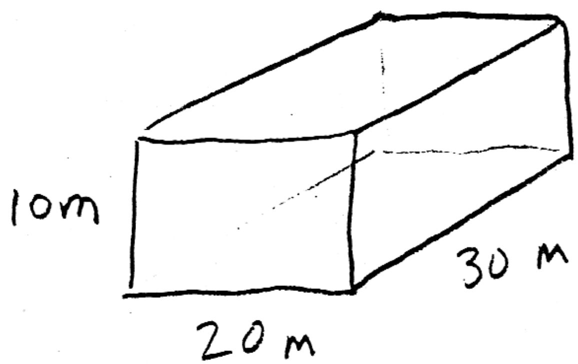
$a = 0$ for perfect reflection, $a = 1$ for perfect absorption

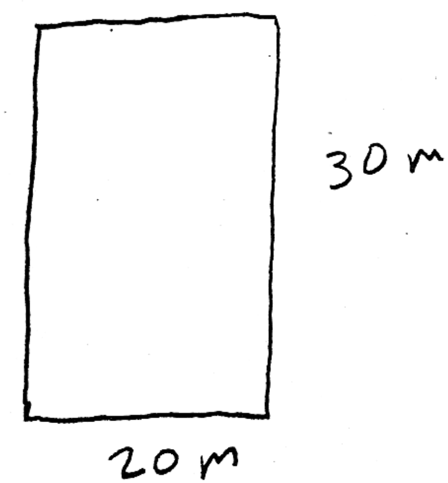
TABLE 15.1 Approximate typical absorption coefficients of various surfaces. Individual examples may vary considerably from these values.

Surface Treatment	Absorptivity at Frequency 125	250	500	1000	2000	4000
Acoustic tile, rigidly mounted	.2	.4	.7	.8	.6	.4
Acoustic tile, suspended in frames	.5	.7	.6	.7	.7	.5
Acoustical plaster	.1	.2	.5	.6	.7	.7
Ordinary plaster, on lath	.2	.15	.1	.05	.04	.05
Gypsum wallboard, $\frac{1}{2}''$ on studs	.3	.1	.05	.04	.07	.1
Plywood sheet, $\frac{1}{4}''$ on studs	.6	.3	.1	.1	.1	.1
Concrete block, unpainted	.4	.4	.3	.3	.4	.3
Concrete block, painted	.1	.05	.06	.07	.1	.1
Concrete, poured	.01	.01	.02	.02	.02	.03
Brick	.03	.03	.03	.04	.05	.07
Vinyl tile, on concrete	.02	.03	.03	.03	.03	.02
Heavy carpet, on concrete	.02	.06	.15	.4	.6	.6
Heavy carpet, on felt backing	.1	.3	.4	.5	.6	.7
Platform floor, wooden	.4	.3	.2	.2	.15	.1
Ordinary window glass	.3	.2	.2	.1	.07	.04
Heavy plate glass	.2	.06	.04	.03	.02	.02
Draperies, medium velour	.07	.3	.5	.7	.7	.6
Upholstered seating, unoccupied	.2	.4	.6	.7	.6	.6
Upholstered seating, occupied	.4	.6	.8	.9	.9	.9
Wood/metal seating, unoccupied	.02	.03	.03	.06	.06	.05
Wooden pews, occupied	.4	.4	.7	.7	.8	.7

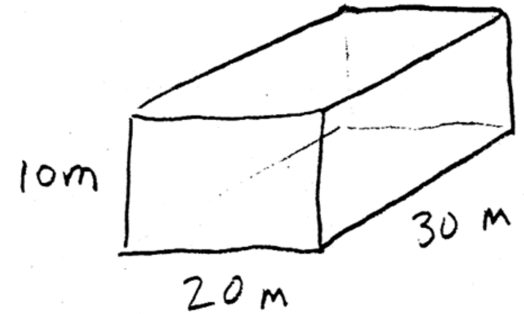
SOURCES: Backus (p. 172) and L. Doelle, *Environmental Acoustics* (McGraw-Hill, 1972), p. 227.

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

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

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

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

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

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

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

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