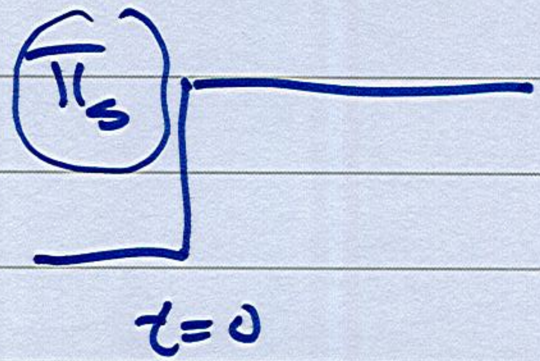
Room Acoustics

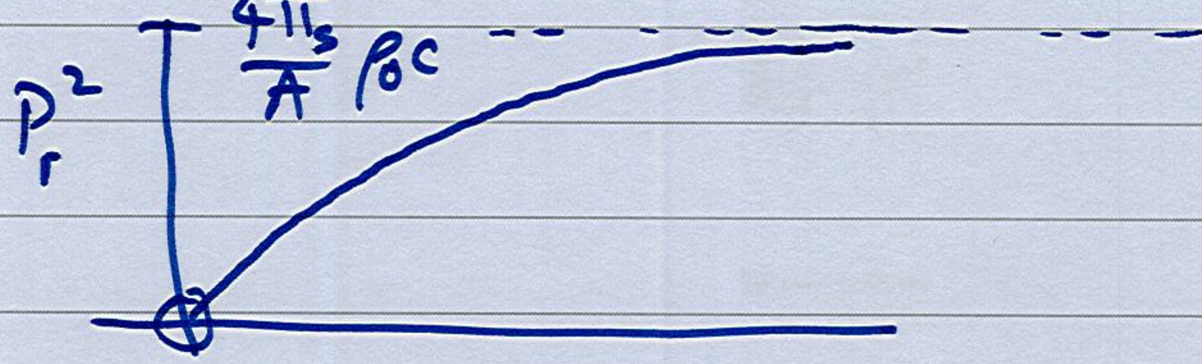
$$\overline{\Pi} = V\cancelto{0}{\frac{d\mathcal{E}}{dt}} + \frac{Ac}{4}\mathcal{E}$$

$$\mathcal{E} = \frac{1}{2}\frac{p^2}{\rho_0 c} \sim p_r^2$$

$$\mathcal{E} = \frac{4\overline{\Pi}}{Ac} \quad \text{steady state}$$

$$\boxed{p_r^2 = \frac{4\overline{\Pi}}{A}\rho_0 c}$$





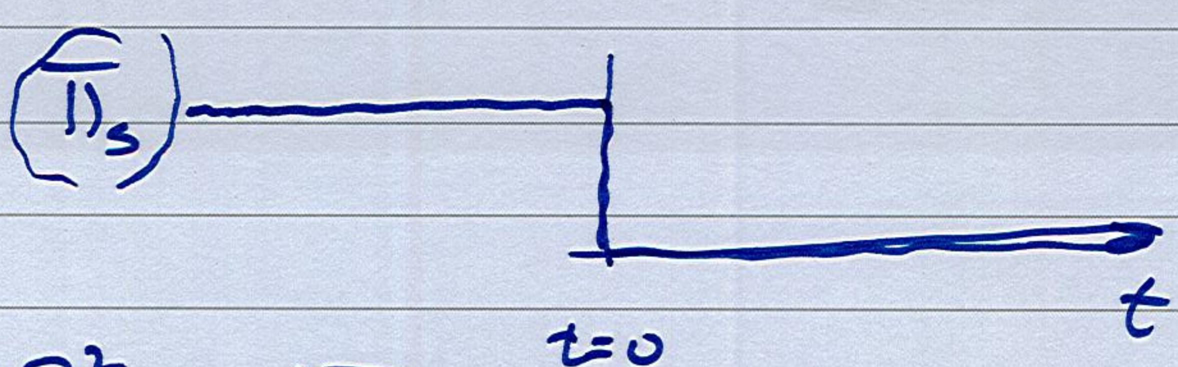
$$P_r^2 = \frac{4\Pi_s \rho_0 c}{A}\left(1 - e^{-t/\tau_e}\right)$$

$$\tau_e = \frac{4V}{Ac}$$

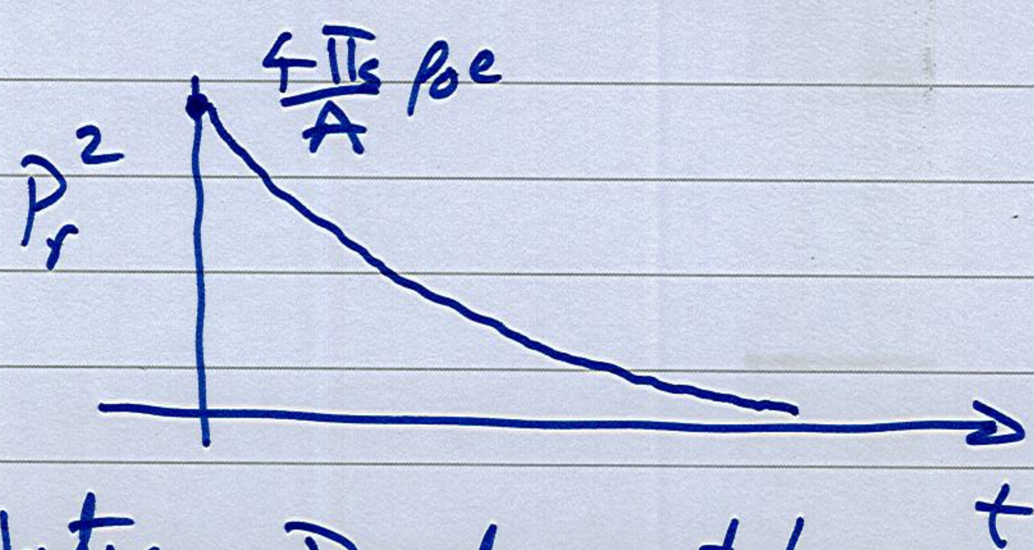
$$\tau_e = \frac{4V}{Ac}$$ time constant governing the rate of growth & decay.

large $V \rightarrow$ large τ_e

small $A \rightarrow$ "



$$p_r^2 = \frac{4\Pi_s \rho_0 c}{A} e^{-t/\tau_e}$$



Notes: - Development has assumed sound field is diffuse at all times

- cannot use this theory until the sound has experienced a certain number of reflections

  - 50ms

  · 1s in a large.

A cannot be too large.

- cannot be used to predict spatial variations

6.4 Reverberation Time

Recall $\quad P_r^2(t) = \underline{P_r^2(0)}\, e^{-t/\tau_e}$ $\qquad \tau_e = \dfrac{4V}{Ac}$

start at steady state

source turned off at $t=0$

$$\underbrace{10\log_{10}\frac{P_r^2(t)}{P_{ref}^2}}_{\text{SPL at } t=t} = \underbrace{10\log_{10}\frac{P_r^2(0)}{P_{ref}^2}}_{\text{SPL at } t=0} + 10\log_{10} e^{-t/\tau_e}$$

$$\underline{\Delta\, SPL} = -10\log_{10} e^{-t/\tau_e} = 4.34\,(t/\tau_e)$$

$$t = \underline{\delta SPL} \; \frac{\tau_e}{4.34}$$

Reverberation time - time taken to drop by 60 dB after source is turned off

$$T = \frac{60}{4.34} \frac{4V}{Ac} = 55.3 \frac{V}{Ac}$$

$20°c \sim c = 343$ m/s

$$\boxed{T = 0.161 \frac{V}{A}}$$

V ~ volume [m^3]

A ~ area [m^2]

$T = 0.049 \dfrac{V}{A}$ $V \sim ft^3$, $A \sim ft^2$ $T = 0.161 \dfrac{V}{A}$

$\equiv$

Rev time – directly proportional to the volume

– inversely proportional to A

$\equiv$

A = absorption area

$\bar{a}$ = average sabine absorptivity (random incidence abs. coeff.)

$A = \bar{a}S$

S = interior surface area of room

Usually assumed

$$A = \sum_i A_i = \sum_i S_i a_i$$

$$= \bar{a} S$$

S_i = surface area of the ith surface

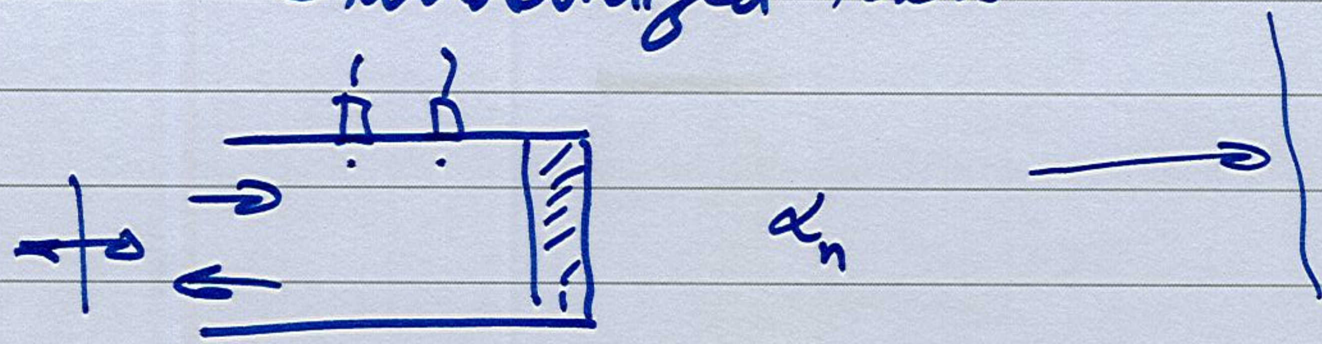
a_i = corresponding abs. coeff.

$$\bar{a} = \frac{\sum_i S_i a_i}{S} \qquad 0 < \bar{a} < 1$$

a_i's are usually a function of freq.

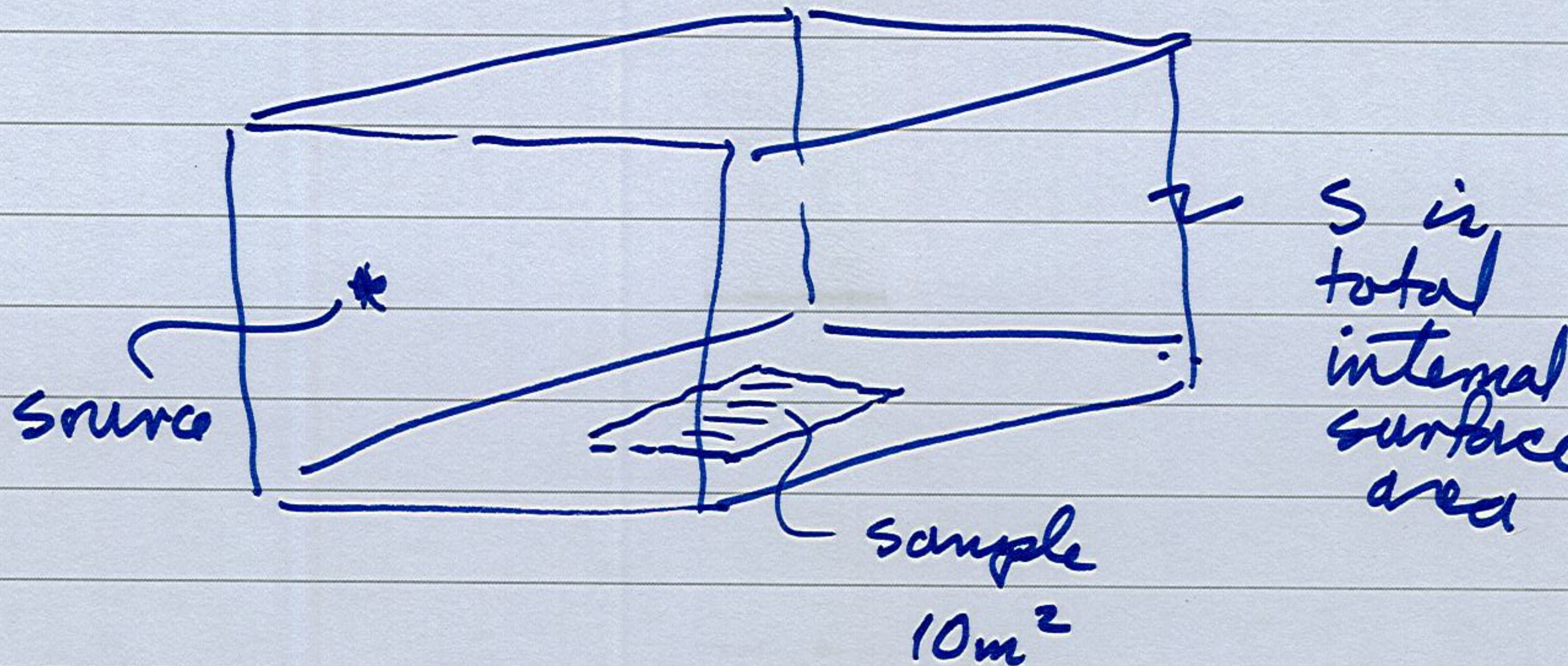
Rev time is a function of frequency.

a_i's are determined from standardized tests



Tests in a Reverberation room C423 ASTM standard.

Rev Room - hard walled space.



(i) Measure The rev time of The empty chamber (to measure average abs of bare walls)

$$T_0 = \frac{0.161\,V}{S\bar{a}_0}$$

$\approx$

$\bar{a}_0$ ~ average abs. coeff. of the walls.

- measure the rev time with sample in place

  sample area = S_e

Total absorption in this case

$$\underbrace{S_e \bar{a}_e}_{\text{abs. of the sample.}} + (S - S_e)\bar{a}_0$$

$$T_e = \frac{0.161\, V}{(S - S_e)\bar{a}_0 + S_e \bar{a}_e}$$

$$a_e = \frac{0.161\,V}{S_e T_e} - \frac{(S - S_e)}{S_e}\,\bar{a}_0$$

$$\bar{a}_0 = \frac{0.161\,V}{S T_0}$$

$$a_e = \bar{a}_0 + 0.161\frac{V}{S_e}\left(\frac{1}{T_e} - \frac{1}{T_0}\right)$$

T_e: sample in place

T_0: empty room

a_e = Sabine absorption coefficient (random incidence absorption coefficient)

a_e = tabulated as a function of frequency for many materials

use a_e's to predict the rev time of a space & steady state levels

- development for the rev time formula have ignored <u>air absorption</u>.