→ http://www101.pair.com/gzik/401fall08/

Wind Power 101

http://www.inhabitat.com/wp-content/uploads/swift3.jpg

SITE SCALE WIND POWER POTENTIAL

Site-scale (building integrated) wind machines are becoming available; see, for building-scale examples:

- http://greenvolts.blogspot.com/2007/01/building-integrated-wind-turbines.html
- http://www.clubofpioneers.com/blog/bmw-group-designworks-wind-power-on-the-edge--the-avx400-aerovironment-avx400-bmw-group-designworksusa-wind-energy/27/stories/654/
- http://www.archinect.com/forum/threads.php?id=79351_0_42_0_C
- http://www.boston.com/news/local/articles/2008/03/05/wind_turbines_propel_logans_energy_efforts/
- http://newenergynews.blogspot.com/2008/08/boston-flies-architectural-wind.html
- http://www.avinc.com/ce_product_details.asp?Prodid=52

WIND POWER ESTIMATES

P = 0.5 x rho x **A** x Cp x $\mathbf{V^3}$ x Ng x Nb

- *where:*
  P = power in watts
  rho = air density (about 1.225 kg/m3 at sea level)
  A = rotor swept area, exposed to the wind (m2)
  Cp = coefficient of performance (0.59 {Betz limit} is the maximum theoretically possible, use 0.35 for a good design)
  V = wind speed in meters/sec (20 mph = 9 m/s)
  Ng = generator efficiency (50% for car alternator, 80% or possibly more for a permanent magnet generator or grid-connected induction generator)
  Nb = gearbox/bearings efficiency (depends, could be as high as 95% if good)

WIND POWER ESTIMATES

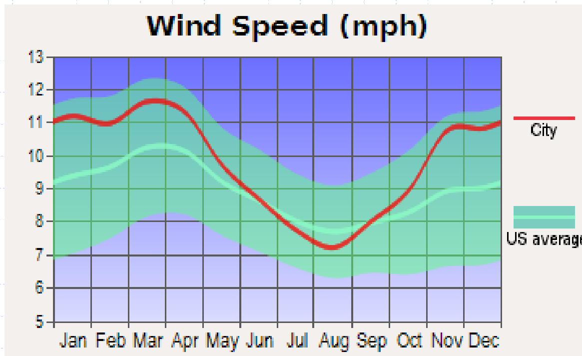
Examples:

- 3 ft (0.91 m) diameter blade span, 6 mph (2.68 m/s) wind speed
- P = (0.5) (1.225) ((0.91/2)2 x 3.14) (0.30) (2.68)3 (0.75) (0.9)
- P = 1.6 W [(1.6) (24) = 15 Wh per day] [450 Wh per month]

- 6 ft (1.8 m) diameter blade span, 10 mph (4.47 m/s) wind speed
- P = (0.5) (1.225) ((1.8/2)2 x 3.14) (0.30) (4.47)3 (0.8) (0.9)
- P = 30 W [(30) (24) = 720 Wh per day] [21 kWh per month]

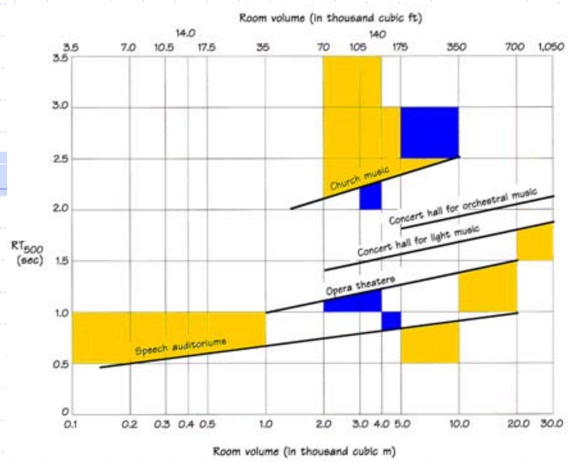
- For reference, my single-family residence uses about 200 kWh per month (rare air-conditioning use, with gas heating and hot water, electric stove)

MUNCIE WIND SPEEDS



http://www.city-data.com/city/Muncie-Indiana.html

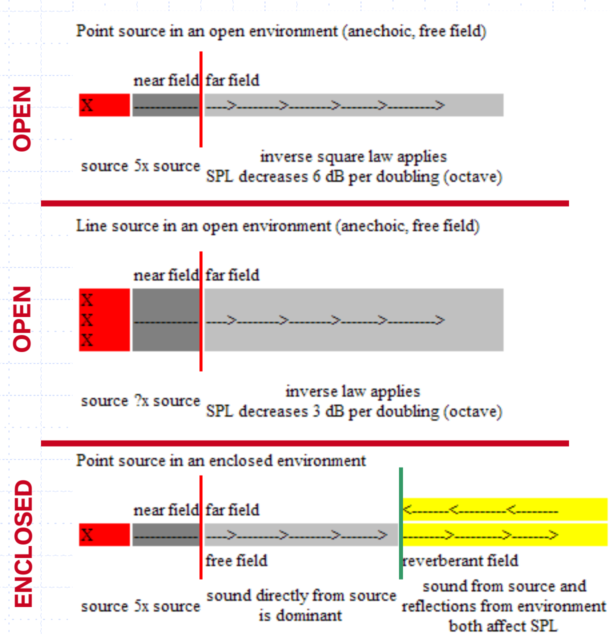
Acoustics 101



Architectural Acoustics Elements

- **Source**
  - The origin of wanted or unwanted sounds; architecture can exert some influence
- **Path**
  - How the source energy gets to the receiver; this is where architectural design can exert the most influence
- **Receiver**
  - Where sounds end up; the basis of design intent; little architectural influence possible

Acoustical Fields



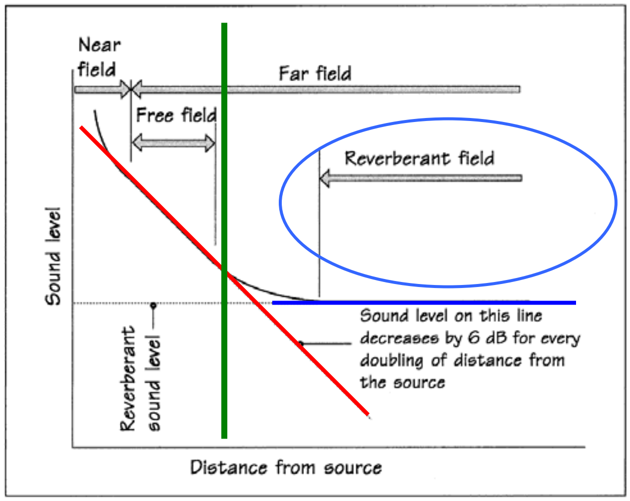
Near field

Far field

-- free

--reverberant

Acoustical Fields



OPEN
versus
ENCLOSED

Architectural Acoustics:
Mehta, Johnson, Rocafort

Sound Magnitude

Awkward numbers →

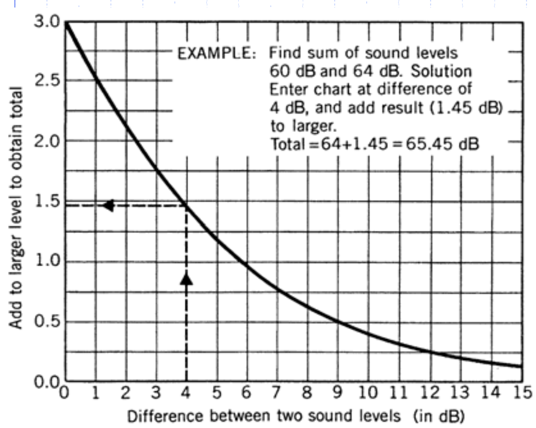
Very awkward numbers →

Calm, easy to use numbers →

Sound pressure (Pa)	Sound intensity (W/m^2)	Sound intensity level or sound pressure level (dB)	Noise in the environment
63.2	10	130	Threshold of pain
20	1	120	Near a jet aircraft at take-off
6.32	0.1	110	Riveting machine
2.0	0.01	100	Pneumatic hammer
0.632	0.001	90	
0.2	0.0001	80	Diesel truck at (15 m) 50 ft Shouting at 1 m (3 ft)
0.0632	0.00,001	70	Busy office
0.02	0.000,001	60	Conversational speech at 1 m (3 ft)
0.00632	0.0,000,001	50	Quiet urban area during daytime
0.002	0.00,000,001	40	Quiet urban area at night
0.000632	0.000,000,001	30	Quiet suburban area at night
0.0002	0.0,000,000,001	20	Quiet countryside
0.000632	0.00,000,000,001	10	Human breathing
0.00002	0.000,000,000,001	0	Threshold of audibility

Architectural Acoustics:
Mehta, Johnson, Rocafort

Adding decibels (dB)



Difference between two levels to be added (dB)	Decibels to be added to higher level
0 or 1	3
2 to 4	2
5 to 9	1
10 or more	0

Sound Power / Level (PWL)

Sound **power** … property of a source – independent of the environment; watts

Sound **power level** (a ratio)

PWL = 10 $\log_{10}$ (W / W_{ref})

PWL = sound power *level* (decibels)

Sound Pressure / Level (SPL)

Sound **pressure** … condition at a point in an environment – influenced by source and space; Pascals

Sound **pressure level** (a ratio)

SPL = $20 \log_{10} (P / P_{ref})$

SPL = sound pressure *level* (decibels)

Source/Path/Receiver

(S) -----	-------------------------------------	----- (P)
sound source	sound path	receiver
sound power level (dB) <PWL>		sound intensity level (dB) <SIL>
	design happens	*or* sound pressure level (dB) <SPL>
		or loudness (subjective)

Sound Loudness

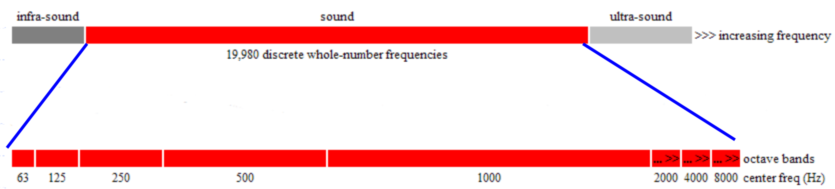
Sound **loudness** … perceived sound pressure condition at a point in an environment – influenced by source and space and receiver; qualitative (words)

Loudness: quiet, very quiet, indescribably quiet … we are not very expressive

Noise

Any unwanted sound

Frequency – Octave Bands

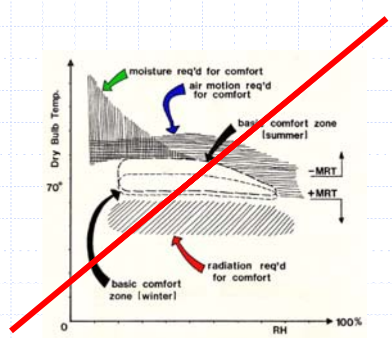


Acoustical Design Criteria

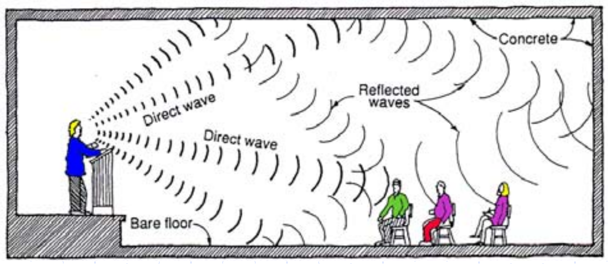
There is NO unified theory of acoustical success, comfort, acceptability, …

It's each intent for itself

Typically organized into **Room Acoustics** and **Noise Control** concerns



Room Acoustics



Room Acoustics

Design for the support and enhancement of wanted sounds ***within*** a given space.

Typical Room Acoustics Intents

- Adequate loudness
- Appropriate reverberation
- Appropriate articulation
- Avoidance of anomalies
  - Echo
  - Creep
  - Flutter
  - Distortion

Adequate Loudness

- Reflects the relationship between sound power and resulting sound pressure
- SPL = PWL + effects of the space
- $SPL = PWL + 10 \log [(Q/4\pi r^2) + (4/R)] + 0.2$

distribution (Q) distance (r) room (R)

Reverberation Time

- The time (in seconds) it takes for the sound pressure level in a space to decrease (decay) by 60 dB when the source of sound is turned off
- A numerical indication of the liveness/deadness of a space

Reverberation Time

RT = 0.16 V / A + xV

where,

RT = reverberation time (seconds)

V = volume of the space (m^3)

A = total surface absorption (Sabins)

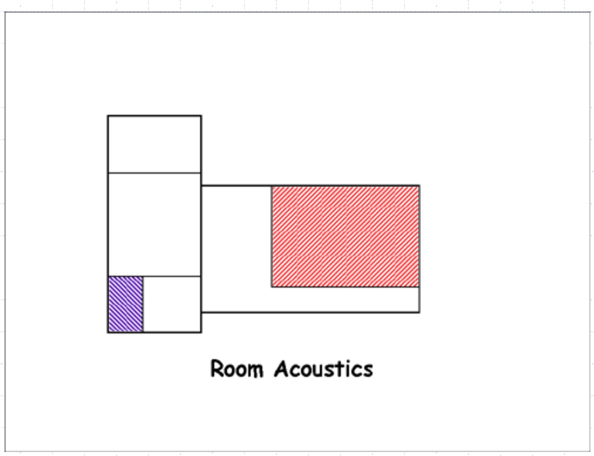
x = absorption coefficient of air

Note: RT is frequency dependent

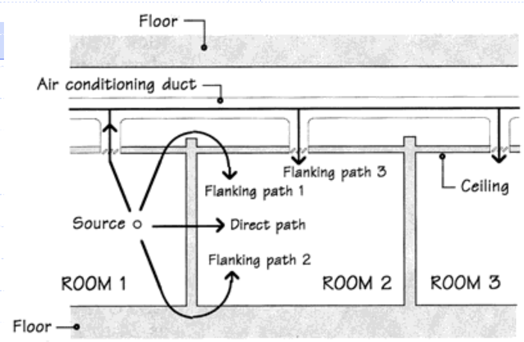
Sound Absorption Coefficients

General Building Materials and Furnishings[b]	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	NRC[c]
	Absorption Coefficients (α)						
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07	0.005
Brick, unglazed, painted	0.01	0.01	0.02	0.02	0.02	0.03	0.00
Carpet, heavy, on concrete	0.02	0.06	0.14	0.37	0.60	0.65	0.29
Carpet, heavy, on 40-oz hairfelt or foam rubber	0.08	0.24	0.57	0.69	0.71	0.73	0.55
Concrete block, coarse	0.36	0.44	0.31	0.29	0.39	0.25	0.35
Concrete block, painted	0.10	0.05	0.06	0.07	0.09	0.08	0.05
Fabrics							
Light velour, 10 oz/yd², hung straight, in contact with wall	0.03	0.04	0.11	0.17	0.24	0.35	0.15
Medium velour, 14 oz/yd², draped to half area	0.07	0.31	0.49	0.75	0.70	0.60	0.55
Heavy velour, 18 oz/yd², draped to half area	0.14	0.35	0.55	0.72	0.70	0.65	0.60
Floors							
Concrete or terrazzo	0.01	0.01	0.015	0.02	0.02	0.02	0.00
Linoleum, asphalt, rubber, or cork tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02	0.05
Wood	0.15	0.11	0.10	0.07	0.06	0.07	0.10
Glass							
Large panes of heavy plate glass	0.18	0.06	0.04	0.03	0.02	0.02	0.05
Ordinary window glass	0.35	0.25	0.18	0.12	0.07	0.04	0.15
Gypsum board, ½ in. nailed to 2 × 4's 16 in. o.c.	0.10	0.08	0.05	0.03	0.03	0.03	0.05
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02	0.00
Openings							
Stage, depending on furnishings				0.25–0.75			
Deep balcony, upholstered seats				0.50–1.00			
Grilles, ventilating				0.15–0.50			

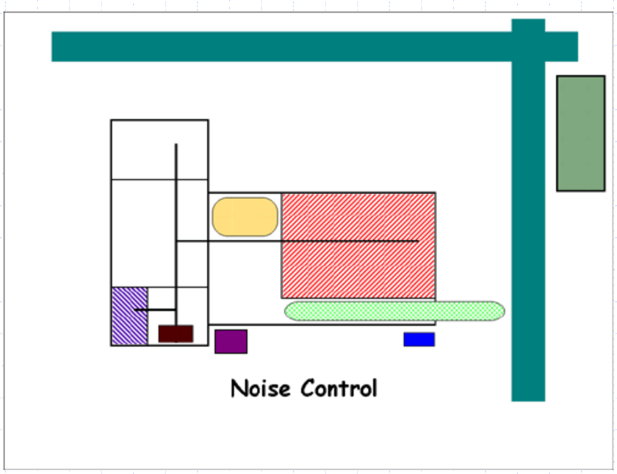
Room Acoustics Context



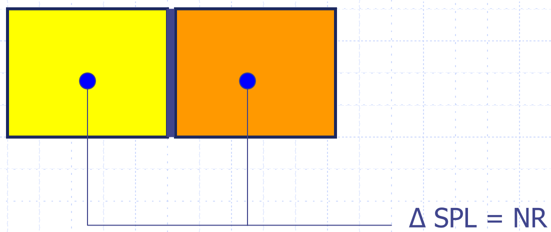
Noise Control



Noise Control Context

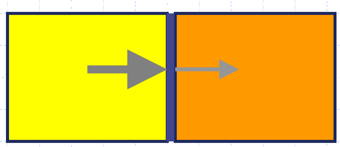


Noise Reduction (NR)



NR a function of barrier and space characteristics

Transmission Loss (TL)



TL a function only of barrier characteristics

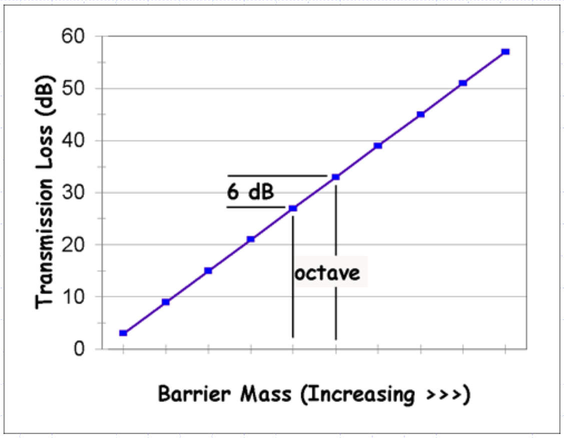
TL and NR (estimates)

- NR = TL – 1 for live receiving space
- NR = TL + 4 for average receiving space
- NR = TL + 7 for dead receiving space

Transmission Loss (TL)

Mass Law:

TL increases with increasing mass

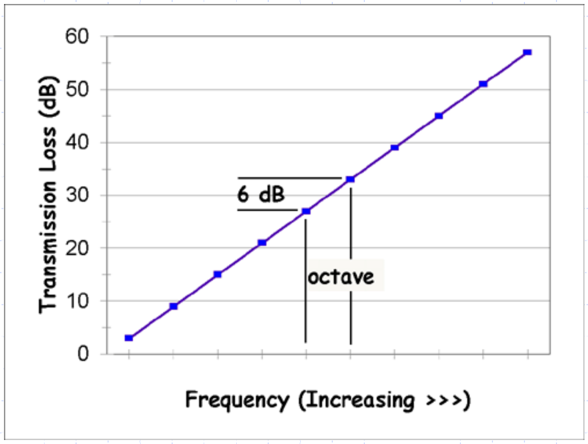


blocking high sound pressures is a massive undertaking

Transmission Loss (TL)

Frequency Law:

TL increases with increasing frequency



blocking high frequencies is easier than blocking low frequencies

Flanking

noise is sly, tricky, and cunning