Noise pollution

Today's lecture

- Noise – definition & history
- Properties of sound waves
- Sound power and intensity
- Sound levels
- Sound rating systems
- Noise control

Noise

- Definition
  - Unwanted sound
  - Any sound independent of loudness that can produce an undesired physiological or psychological effect in an individual, and that may interfere with the social ends such as communication, work, rest, recreation and sleep, of an individual or group.

Noise

- History
  - BC 800s, Old Greek City Sybaris: noise zoning for factories
  - BC 44, Rome (Julius Caesar): "no one shall drive a wagon along the streets of Rome or along those streets in the suburbs where there is continuous housing after sunrise or before the tenth hour of the night"
  - AD 1595, London: forbids any "sudden out-cry… in the still of night, as making any affray, or beating his wife, or servant, or reveling in house, to the disturbance of his neighbors"
  - After industrial revolution, noise pollution became quite significant

‘층간소음 윗집 이웃 살해’ 징역 15년 선고

서울북부지법 형사13부(이효두 부장판사)는 층간소음으로 다툼을 벌이다 윗집 이웃을 살해한 혐의(살인)로 기소된 조모(53)씨에게 징역 15년을 선고했다고 31일 밝혔다.

재판부는 “조씨는 아파트 층간 소음으로 인한 해묵은 앙금을 극단적인 방법으로 해소하려고 흉기로 피해자를 깊숙이 찔러 살해했다”며 “범행의 동기·수단과 생명 침해라는 결과가 너무나 무겁고 피해자의 유족들에게 용서를 받지 못하고 있다”고 양형 이유를 설명했다. 조씨는 지난 5월 서울 도봉구 창동의 한 아파트에서 층간소음 문제로 다투다 피해자 A(49)씨를 흉기로 찔러 숨지게 한 혐의로 기소됐다.

조씨는 2011년부터 A씨와 층간소음 문제로 갈등을 빚어 왔으며, A씨는 2년 전부터 같은 단지 다른 동으로 이사해 살고 있었다. 조씨는 아버지의 제사를 지내기 위해 살던 곳을 다시 찾은 A씨를 보고 흉기를 준비, “쿵쿵대는 소리가 들린다”고 항의하러 올라갔다가 범행을 저질렀다.

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"이렇게까지 해야하나"…층간소음 보복상품 등장 '맞불작전'

최종수정 2014.11.25 11:07 기사입력 2014.11.25 11:07

층간소음 보복상품 [사진=MBC 뉴스 캡쳐]

"이렇게까지 해야하나"…층간소음 보복상품 등장으로 '맞불작전'

[아시아경제 온라인이슈팀] 아파트 층간소음 문제가 날로 심각해지면서 일명 '층간소음 보복상품'까지 등장했다.

모양은 꼭 화재감지기다. 스피커가 한쪽으로 소리가 집중되도록 개조돼 이를 천장에 달아 놓으면 소음의 60~70%가 윗집으로 고스란히 전달되도록 만들어졌다.

층간소음에 항의하기 위해 초인종을 누르거나 문을 두드리는 건 안 되지만 천장을 두드리고 소리를 지르는 건 괜찮다는 법원 판결을 내세워 팔고 있는 이른바 '층간소음 보복상품'이다.

층간소음 보복상품은 온라인 오픈 마켓 등을 중심으로 '층간소음 종결자' '층간소음 우퍼스피커' '층간소음 우퍼' 라는 카테고리로 팔리고 있다.

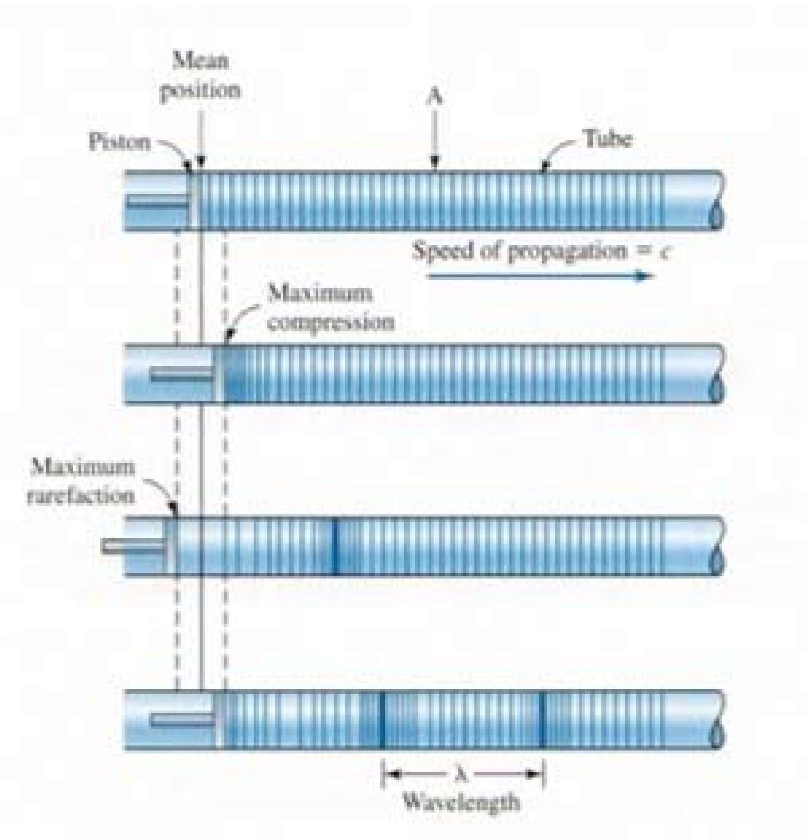
업체 측은 날이 추워지면서 집에 있는 시간이 늘어남에 따라 해당 상품의 주문량이 급격하게 늘고 있다고 전했다.
온라인이슈팀 issue@asiae.co.kr

Noise

- Why the noise pollution is slow in coming
  - Noise is a subjective experience
  - Noise has a short decay time and does not remain in the environment for extended periods
  - Effect of noise in human are subtle and insidious
  - Noise has been associated with many technological advances → people tended to accept the additional noise as part of the “price” of the progress

Properties of sound waves

- Sound waves result from the vibration of solid objects or the separation of fluids as they pass over, around, or through holes in solid objects
- The vibration or separation causes the surrounding air to undergo alternating compression and rarefaction
- The alternating pressure changes in the air are detected by the human ear



Properties of sound waves

$$P = \frac{1}{f}$$

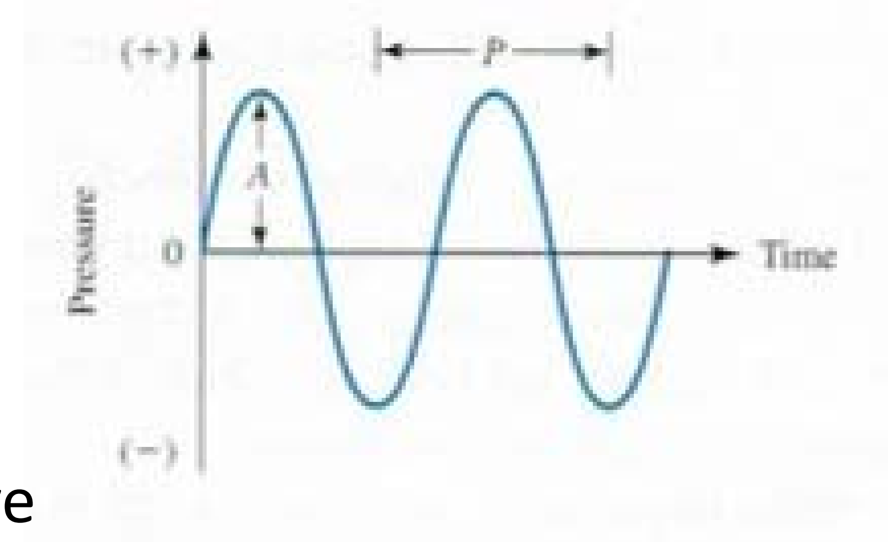
P = period [T]

f = frequency [T^{-1}]

$$\lambda = \frac{c}{f}$$

λ = wavelength [L]

c = speed of the sound [L/T]



- Magnitude of the sound wave
  - Amplitude, *A*: the height of the peak or the depth of the trough
  - root mean square sound pressure (p_{rms}): averaging the peak magnitude [Pa]

$$p_{rms} = \left(\overline{p^2}\right)^{1/2} = \left[\frac{1}{t_m}\int_0^{t_m} p^2(t)dt\right]^{1/2}$$

p(t) = magnitude at time *t* [Pa]

t_m = time period of measurement [T]

Sound power and intensity

- Sound power (W): the energy transmitted (=the work done) by the sound at a unit time
- Sound intensity (I): the time-weighted average sound power per unit area normal to the direction of wave motion

$$I = \frac{W}{A} = \frac{(p_{rms})^2}{\rho c}$$

I = sound intensity (in Watt./m^2)

W = sound power (in Watt.)

A = area normal to the direction of wave motion [L/T]

ρ = density of medium (in kg/m^3)

$c = 20.05\sqrt{T}$ in air at 1 atm (T = absolute temp.)

Levels and the decibels

- The sound has a large range of magnitude: a health individual can hear down to about 0.00002 Pa & a rocket noise can be up to more than 200 Pa at liftoff

  → better use a logarithmic unit!

- Level: a scale based on the logarithm of the ratios between the measured and the reference quantity

$$L' = log_{10}\frac{Q}{Q_o}$$

L' = level (in bels)

Q = measured quantity; Q_o = reference quantity

- Decibels (dB): a unit obtained by dividing a bel to 10 subunits

$$L = 10L' = 10log_{10}\frac{Q}{Q_o}$$

Decibel and sound levels

- Sound power level: *ref = 10^{-12} W*

$$L_w = 10log_{10}\frac{W}{10^{-12}}$$

- Sound intensity level: *ref = 10^{-12} W/m^2*

$$L_I = 10log_{10}\frac{I}{10^{-12}}$$

- Sound pressure level: *ref = 20 μPa*

$$L_p = 10log_{10}\frac{(p_{rms})^2}{{(p_{rms})_o}^2} = 20log_{10}\frac{(p_{rms})}{(p_{rms})_o}$$

Combining sound levels

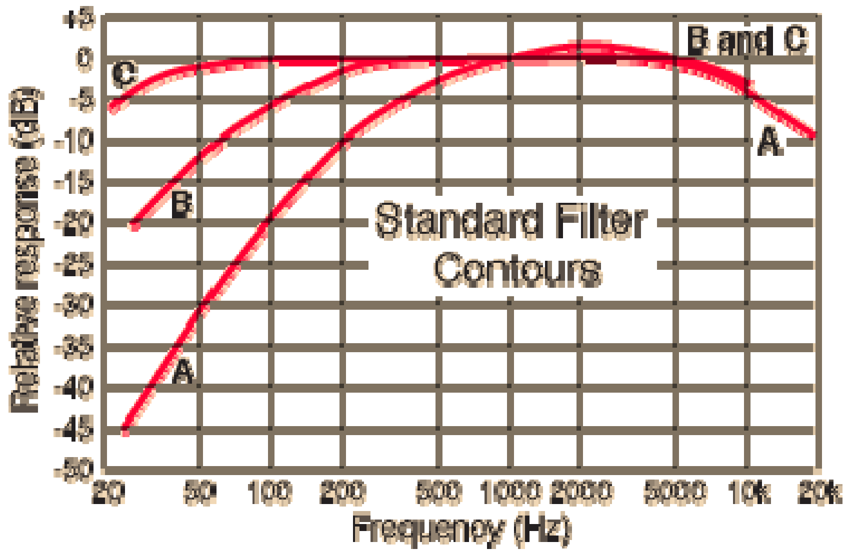
Q: If three sounds having power levels of 68 dB, 79 dB, and 75 dB, respectively, are combined, what sound power level will result?

Characterization of noise – weighting networks

- Our major interest is human reaction to sound, not the physical properties
- How loud it sounds to human is not related only to sound pressure level but, also to sound frequency
- Sound level meters employ “weighting networks” to address this issue
- Weighing network: electronic filtering circuits built into the meter to attenuate certain frequencies → the meter responds more to some frequencies than to others

Characterization of noise – weighting networks

- Three weighting characteristics: A, B, C
  - A: very low frequencies are severely filtered
  - B: very low frequencies are moderately filtered
  - C: very low frequencies are hardly filtered at all
- Sound level units: dB(A), dB(B), dB(C)



http://hyperphysics.phy-astr.gsu.edu

Frequency (Hz)	Curve A (dB)	Curve B (dB)	Curve C (dB)
10	−70.4	−38.2	−14.3
12.5	−63.4	−33.2	−11.2
16	−56.7	−28.5	−8.5
20	−50.5	−24.2	−6.2
25	−44.7	−20.4	−4.4
31.5	−39.4	−17.1	−3.0
40	−34.6	−14.2	−2.0
50	−30.2	−11.6	−1.3
63	−26.2	−9.3	−0.8
80	−22.5	−7.4	−0.5
100	−19.1	−5.6	−0.3
125	−16.1	−4.2	−0.2
160	−13.4	−3.0	−0.1
200	−10.9	−2.0	0
250	−8.6	−1.3	0
315	−6.6	−0.8	0
400	−4.8	−0.5	0
500	−3.2	−0.3	0
630	−1.9	−0.1	0
800	−0.8	0	0
1,000	0	0	0
1,250	0.6	0	0
1,600	1.0	0	−0.1
2,000	1.2	−0.1	−0.2
2,500	1.3	−0.2	−0.3
3,150	1.2	−0.4	−0.5
4,000	1.0	−0.7	−0.8
5,000	0.5	−1.2	−1.3
6,300	−0.1	−1.9	−2.0
8,000	−1.1	−2.9	−3.0
10,000	−2.5	−4.3	−4.4
12,500	−4.3	−6.1	−6.2
16,000	−6.6	−8.4	−8.5
20,000	−9.3	−11.1	−11.2

Courtesy: Dr. Sara Yasina Yusuf

Combining sound levels

Q: Determine the sound levels of dB(A), dB(B), and dB(C) for a sound pressure level of 60 dB having frequencies of 100, 1000, and 10000 Hz.

Sound rating systems

- To quantify the noise exposure at a certain period of time
- The L_N Concept: “how frequently a particular sound level is exceeded”
  - ex: L_{40} = 72 dB(A) → 72 dB(A) was exceeded for 40% of the measuring time
- The L_{eq} concept: “a constant noise level that, over a given time, expends the same amount of energy as the actual sound over the same period”

Sound rating systems

- The L_{eq} concept

$$L_{eq} = 10log_{10}\left[\sum_{i=1}^{n} 10^{L_i/10} \cdot t_i\right]$$

L_{eq} = the equivalent continuous equal energy level (in dB)

n = the total numbers of samples taken

L_i = the noise level of the i^{th} sample (in dB)

t_i = fraction of total sample time (unitless)

Sound rating systems

Q: A noise level of 90 dB(A) existed for 10 min followed by a reduced noise level of 70 dB(A) for 30 min. What is the equivalent continuous equal energy level for the 40-min period?

Evaluate your neighbors!

Korean regulation level for inter-story noise

Source		Standard values (in dB(A))	
		Daytime (06:00 – 22:00)	**Nighttime (22:00 – 06:00)**
Direct impact noise (직접충격소음)	L_{eq} for 1 min	43	38
	L_{max}*	57	52
Air-transmitted noise (공기전달소음)	L_{eq} for 5 min	45	40

* Regulation level is exceeded when the noise exceeds L_{max} for at least three times within an hour

Transmission of sound

- Inverse square law

$$I = \frac{W}{4\pi r^2}$$

I = sound intensity (in W/m^2)

W = sound power of source (in W)

r = radial distance from the source (in m)

For a point source of sound,

$$L_{p2} = L_{p1} - 10log_{10}\left(\frac{r_2}{r_1}\right)^2$$

L_{p1} & L_{p2} = sound pressure level (in dB) at distances r_1 & r_2 from the source

For a line source of sound (ex: highways),

$$L_{p2} = L_{p1} - 10log_{10}\left(\frac{r_2}{r_1}\right)$$

Noise control

- Source-path-receiver concept
  - Sound arises from a source;
  - Travels over a path;
  - Affects a receiver
- So, the solutions can be
  - Modifying the source to reduce its noise output;
  - Altering or controlling the transmission path and the environment to reduce the noise level reaching the receiver;
  - Providing the receiver with personal protective equipment

Noise control

- Control of noise source
  - Reduce impact forces
  - Reduce speeds and pressures
  - Reduce frictional resistance
  - Reduce radiating area
  - Reduce noise leakage
  - Isolate and dampen vibrating elements
  - Provide mufflers or other silencers

Noise control

- Noise control in the transmission path
  - Separation
  - Absorbing materials
  - Acoustical lining
  - Barriers and panels
  - Enclosure

- Protecting the receiver (when all else fails)
  - Alter work schedule
  - Use ear protection devices

Reading assignment

Textbook Ch. 15, 750-758; 770-772; 781-785.