

Overview of Noise Metrics and Acoustical Objectives

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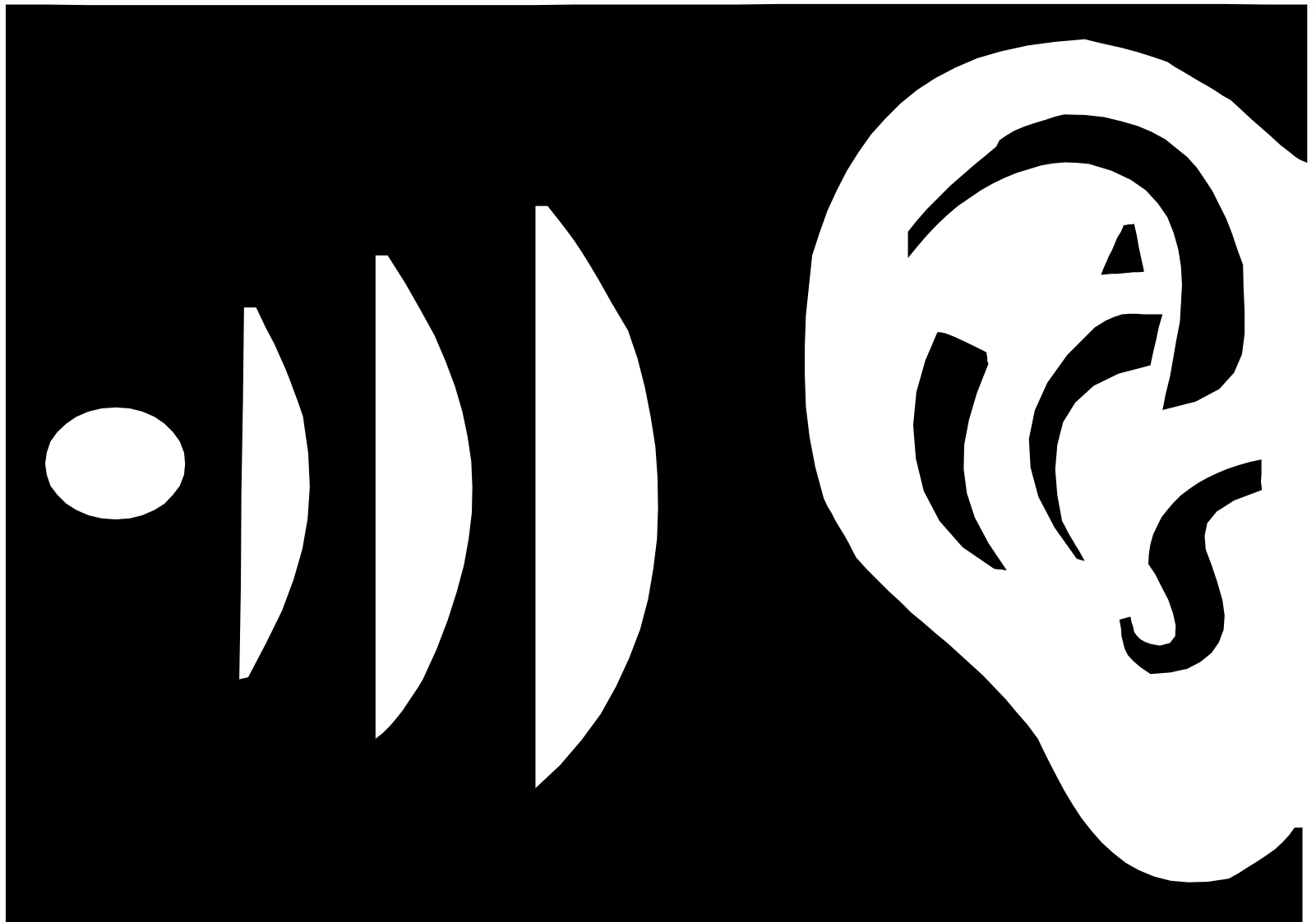
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Introduction to Acoustics

<http://www.hmmh.com/>

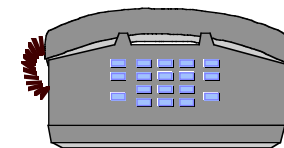
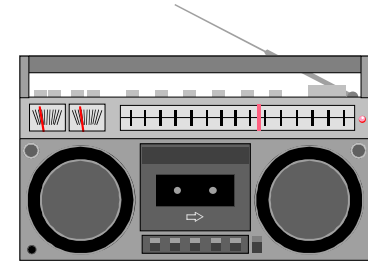


Sound and the Human Being

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Functions of Sound

- Provides enjoyable experiences
 - *listening to music*
 - *singing of birds*
- Enables communication
- It can alert or warn
 - *ringing of the telephone*
 - *wailing of a siren*
- Allow for diagnostics
 - *chattering valves of a car*
 - *a squeaking wheel*
 - *a heart murmur*



Definition of Noise

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Noise is unwanted sound



What is Sound?

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Sound

Any pressure variation (in air, water or other elastic medium) that the human ear can detect.

- Weather changes are much too slow for the human ear to detect
- Atmospheric pressure changes that occur at least 20 times a second can be heard and are thus called sound
 - *A barometer cannot respond quickly enough, therefore cannot be used to measure sound.*



What is Sound?

Frequency Characteristic

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- **Frequency in Hertz (Hz)**
 - *The number of pressure variations per second*
- **The frequency of a sound produces it's distinctive tone**
 - *Rumble of distant thunder is low frequency*
 - *A whistle is high frequency*
- **Normal range of hearing for a healthy young person is 20 Hz to 20,000 Hz (or 20 kHz)**
- **Range of the lowest to highest piano note is 27.5 Hz to 4186 Hz.**



The dB Level Characteristic

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Decibel

A main quantity used to describe sound is the size or amplitude of the pressure fluctuations.

- A healthy human ear can detect sound amplitudes from 20 millionths of a Pascal (20:Pa)
- The ear can tolerate sound pressures more than a million times higher
- The decibel (or dB) scale is used to accommodate this quite large range of pressures.



The dB

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The decibel scale

- It is a ratio
 - *Measured quantity to agreed reference level*
 - *Threshold of hearing (20 :Pa) is the reference used when measuring sound pressure levels (SPL)*
- Threshold of hearing is 0 dB (re 20 :Pa)
- 1 million times 20 :Pa is 120 dB
- Threshold of pain is 140 dB



The dB

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Sound Pressure Level (SPL)

$$L_P = 10 \text{ Log}_{10} \left[\frac{P_{rms}^2}{P_0^2} \right]$$

where

L_p = rms sound pressure level in dB

P_{rms} = rms sound pressure

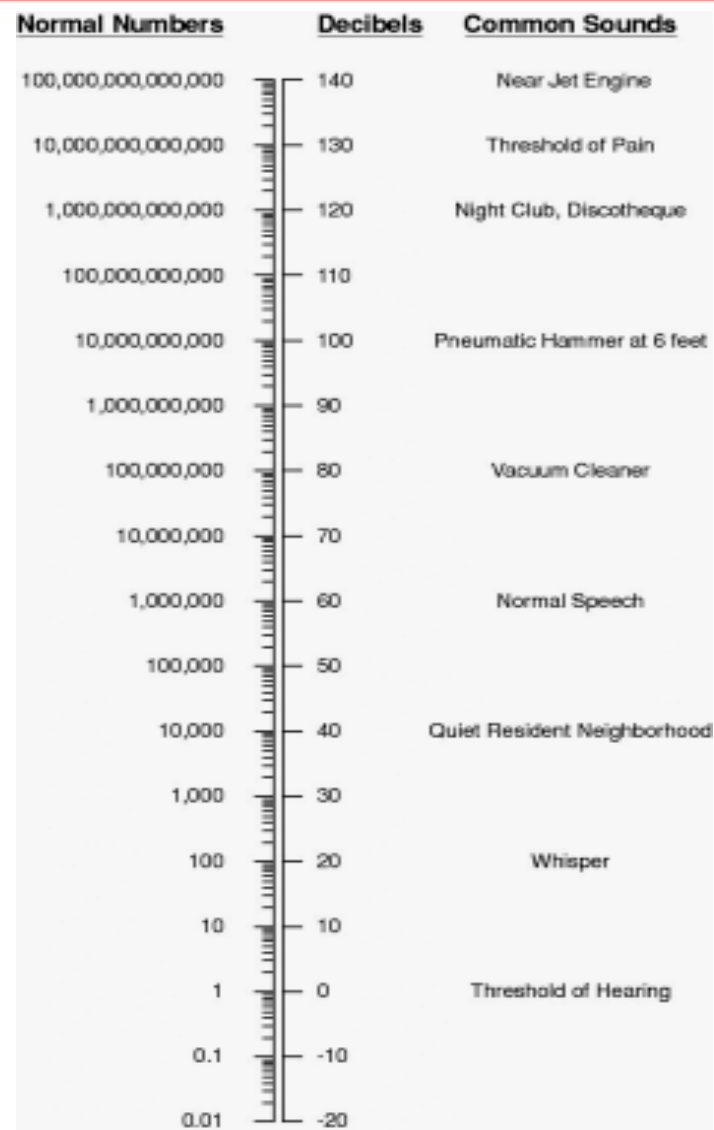
P_0 = reference pressure of 20×10^{-6} N/m² or 2.90×10^{-9} lb/in²

Log_{10} = base 10 logarithm



The dB

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What do we hear?

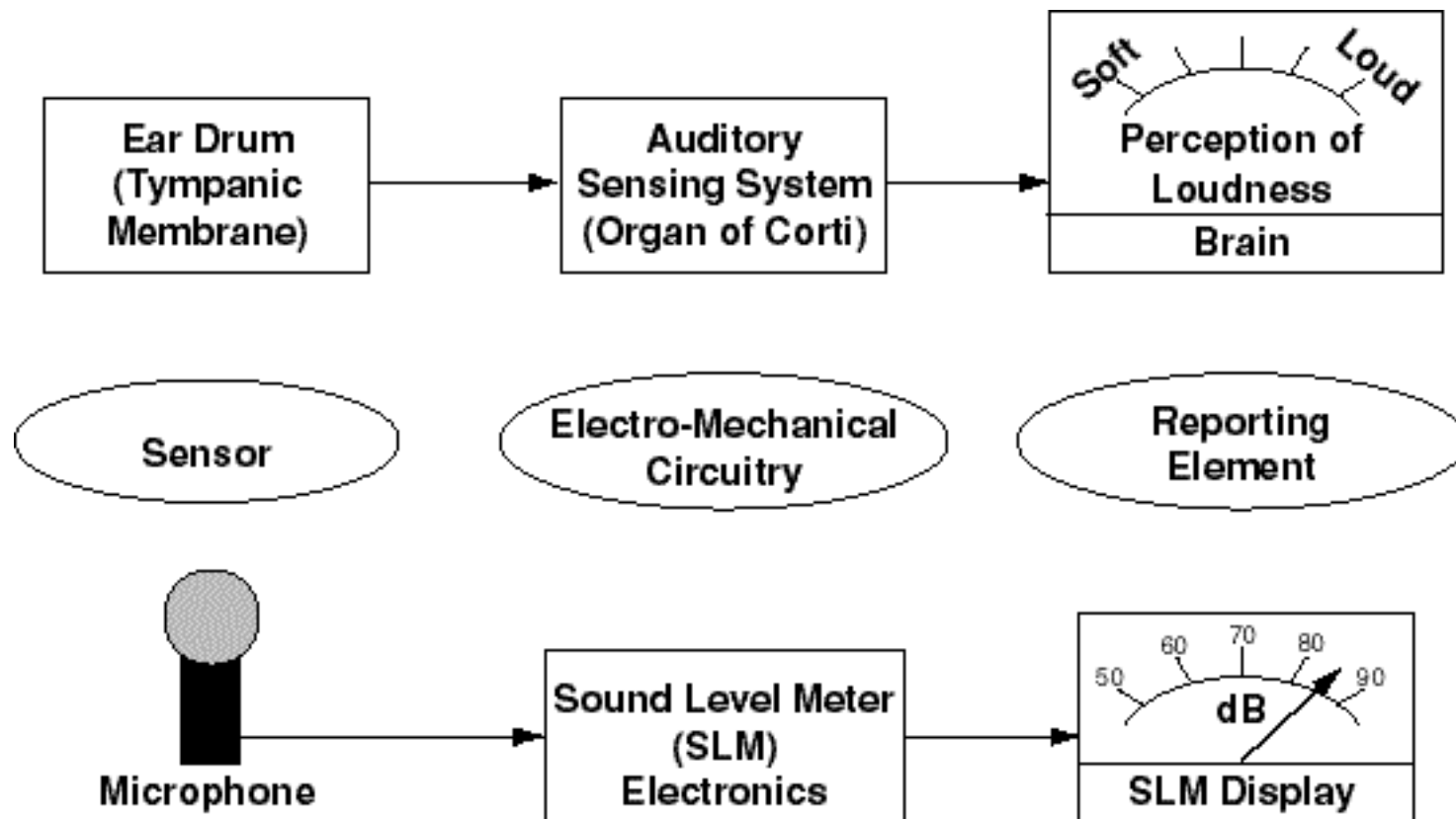
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- **Sound was already defined as any pressure variation which can be heard by the human ear.**
- **Frequency range**
 - *20 Hz to 20 kHz*
- **Sound Pressure Level (SPL)**
 - *Threshold of hearing (0 dB) and greater*
- **The smallest change in amplitude we can hear is about 3 dB (doubling of sound energy)**
- **A change of 6 to 10 dB is required before the sound subjectively appears to be twice as loud**



Human Ear - Sound Level Meter Relationship

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Introduction to Noise Metrics

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- Maximum Noise Level (Lmax)
- Sound Exposure Level (SEL)
- Equivalent-Continuous Sound Level (Leq)
- Day-Night Average Sound Level (DNL)
- Community Noise Equivalent Level (CNEL)



Sound Metric Equations - Lmax

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- **Maximum Sound Level**

$$L_{\max} = \max \left(L(t) \Big|_0^T \right)$$

- *In discrete form:*

$$L_{\max} = \max \left(L_i \Big|_{i=1}^n \right)$$

Sound Metric Equations - SEL

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- **Sound Exposure Level**

$$SEL = 10 * \log_{10} \left(\frac{1}{\text{sec.}} \int_0^T 10^{L(t)/10} dt \right)$$

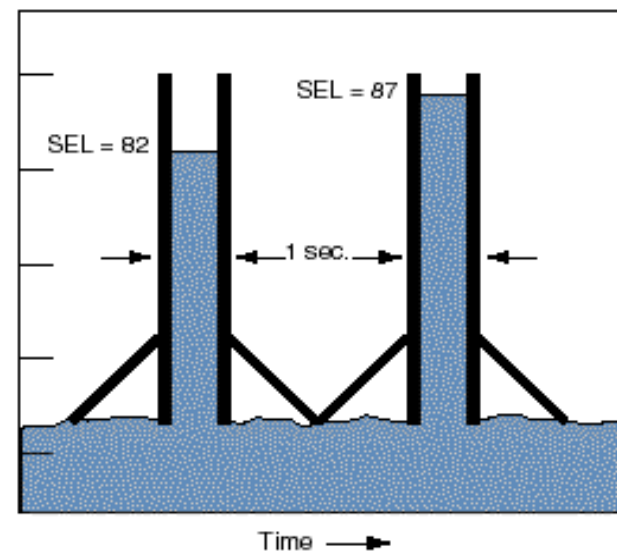
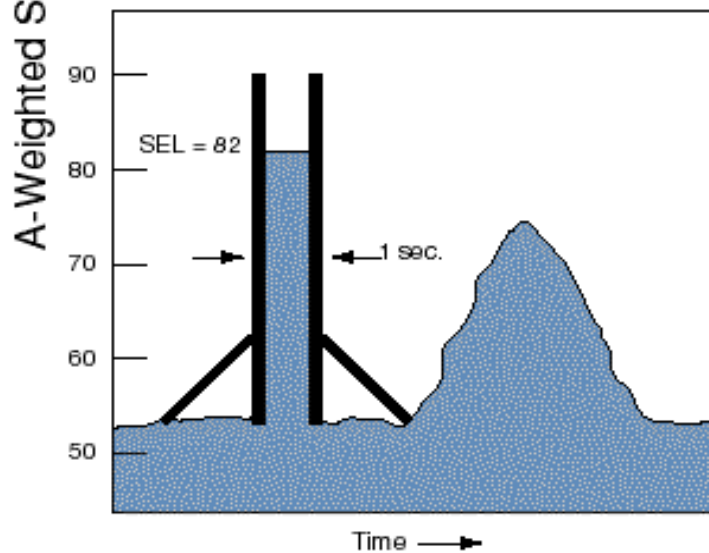
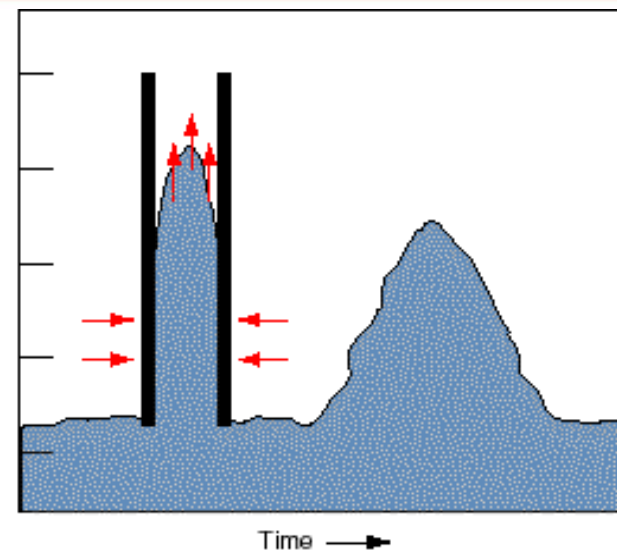
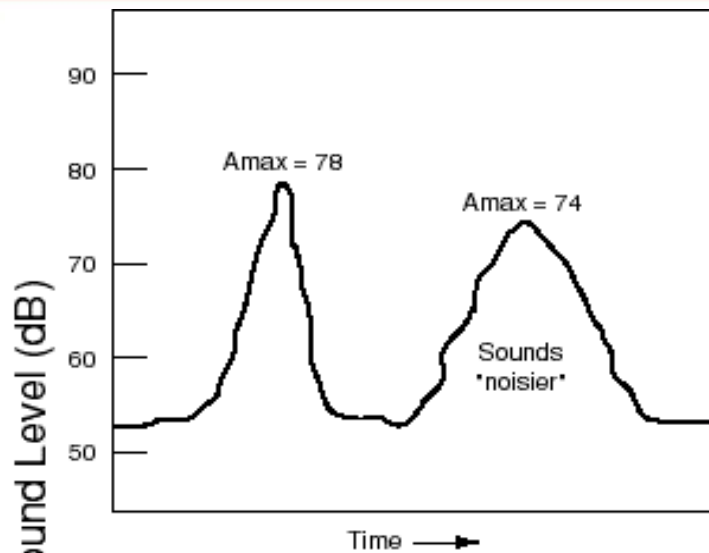
↖
Not dividing by time
Required to get units right
(no units in dB ratio)

- *In discrete form:*

$$SEL = 10 * \log_{10} \left(\sum_{i=1}^n 10^{L_i/10} \right)$$

Sound Exposure Level (SEL)

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Sound Metric Equations - Leq

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- **Equivalent-Continuous Sound Level**

$$L_{eq} = 10 * \log_{10} \left(\frac{1}{T} \int_0^T 10^{L(t)/10} dt \right)$$

Dividing by time!

- *In discrete form:*

$$L_{eq} = 10 * \log_{10} \left(\frac{1}{T} \sum_{i=1}^n 10^{L_i/10} \right)$$

Dividing by time!

Sound Metric Equations - Ldn

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- **Day-Night Average Sound Level (DNL)**

$$L_{dn} = 10 * \log_{10} \left(\frac{1}{86,400} \left[\int_{7am}^{10pm} 10^{L(t)/10} dt + \int_{10pm}^{7am} 10^{(L(t)+10)/10} dt \right] \right)$$

Day *Night*

- **In discrete form:**

Using SELs

$$L_{dn} = 10 * \log_{10} \left(\left[\sum_{i=1}^n 10^{SEL_i/10} + \sum_{i=n+1}^m 10^{(SEL_i+10)/10} \right] \right) - 49.4$$

Day *Night*

Sound Metric Equations – CNEL (California Only)

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- **Community Noise Equivalent Level**

$$CNEL = 10 * \log_{10} \left(\frac{1}{86,400} \left[\int_{7am}^{7pm} 10^{L(t)/10} dt + \int_{7pm}^{10pm} 10^{(L(t)+4.8)/10} dt + \int_{10pm}^{7am} 10^{(L(t)+10)/10} dt \right] \right)$$

Day *Evening* *Night*

- *In discrete form:*

Using SELs

$$CNEL = 10 * \log_{10} \left(\left[\sum_{i=1}^n 10^{SEL_i/10} + \sum_{i=n+1}^m 10^{(SEL_i+4.8)/10} + \sum_{i=m+1}^r 10^{(SEL_i+10)/10} \right] \right) - 49.4$$

Day *Evening* *Night*



Introduction to Sound Insulation Goals

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- **FAA Criteria**
 - 45 dB DNL (CNEL) inside residence
 - School-time Leq of 45 dB inside classroom
 - $Leq_{(7hr)}$, generally from 8 am to 3 pm
 - Minimum improvement of 5 dB noise reduction of structure



Determining Inside Levels

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- **Determine noise reduction of structure**
 - Noise reduction is simply the difference in level of an outdoor noise source measured outside the residence and measured inside the residence.
 - $NR = \text{Noise Level Outside} - \text{Noise Level Inside}$
- **Determine outside noise levels**
 - DNL (CNEL) for residences (INM Modeled Levels)
 - $Leq_{(7hr)}$ for educational facilities (Estimated or Measured)
- **Compute inside levels**
 - Inside Level = Outside Noise Level - NR



Thank you!

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