FUNDAMENTALS OF ACOUSTICS

Acoustical Facts

- The length of low and high frequency sound waves vary by 400 to 1
- Various audible frequencies behave differently when interacting with various materials, structure and shapes and finishes
- Room geometry and shape affect the acoustical performance of built space.
- Reverberation and echo differ from each other.
- Speech intelligibility matters a lot what architect does to help.
- Three simple tests are to be used to assess the acoustical merits of a room.
- Modern acoustical materials.

Architecture Acoustics AA

- What is AA: applications of Acoustical principles within the built space, it encompasses noise control, speech privacy, active and passive sound enforcement…
- **Objectives:**
- 1-to understand the fundamental of AA
- 2-introduce wave lengths of audible range of sounds, and their interaction within the physical structure they touch.
- 3-To visualize the physical shapes and dimensions of their work, and influence on sound behavior within. A- Arch. Require 3D and Sound require 4D. Which has to coexist within the 3D. B- The speed of sound is so slow such that the size of the built space and shape can always dictate the quality and clarity of the sound within.
- 4-The importance of interior geometry: the sound is not easily be controlled when it propagates, thus building geometry is important.

What is sound: it is stimulation for the medium molecules push pull nature it is transformative experience

- Compression and rarefaction of molecules.
- **Sound Propagation:** molecules barely move, it will transfer energy to the next molecule ex: dominoes reaction when released. sinusoidal wave is a wave length. Speed around 1.127 f/s, discrete vibration 500 Hz tone is around 2.25 foot length.
- **Sound wave Modeling:** difficult to calculate the f and Y with the arch. Shape, geometry and finishing materials for the walls. Thus computer model is being used to simulate and solve the complex acoustic questions.

Amplitude, Frequency, Wavelength And Velocity

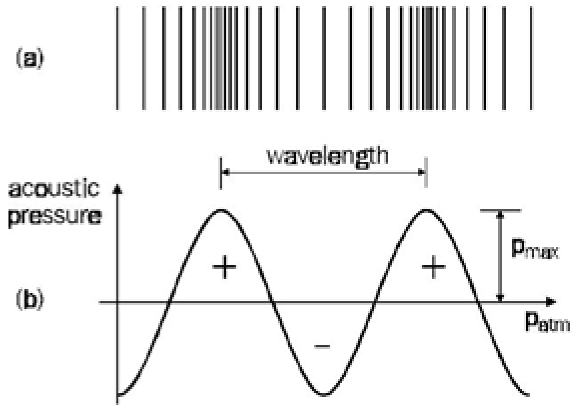
- the amplitude of pressure changes, which can be described by the maximum pressure amplitude, pm, or the root-mean-square (RMS) amplitude, prms, and is expressed in Pascal (Pa). Root-mean-square means that the instantaneous sound pressures (which can be positive
- the wavelength ( ), which is the distance travelled by the pressure wave during one cycle; the frequency (f), which is the number of pressure variation cycles in the medium per unit
- time, or simply, the number of cycles per second, and is expressed in Hertz (Hz). Noise is usually composed of many frequencies combined together. The relation between
- wavelength and frequency can be seen in Figure 1.2.
- the period (T), which is the time taken for one cycle of a wave to pass a fixed point. It is
- related to frequency by: $T = 1/f$

PURE TONE & Complex Sound

- All of the properties just discussed (except the speed of sound) apply only to a pure tone (single frequency) sound which is described by the oscillations in pressure shown in Figure 1.1. However, sounds usually encountered are not pure tones. In general, **sounds are complex** mixtures of pressure variations that vary with respect to phase, frequency, and amplitude. For such complex sounds, there is no simple mathematical relation between the different characteristics. However, any signal may be considered as a combination of a certain number (possibly infinite) of sinusoidal waves, each of which may be described as outlined above. These sinusoidal components constitute the frequency spectrum of the signal.

- To illustrate longitudinal wave generation, as well as to provide a model for the discussion of sound spectra, the example of a vibrating piston at the end of a very long tube filled with air will be used, as illustrated in Figure 1.3

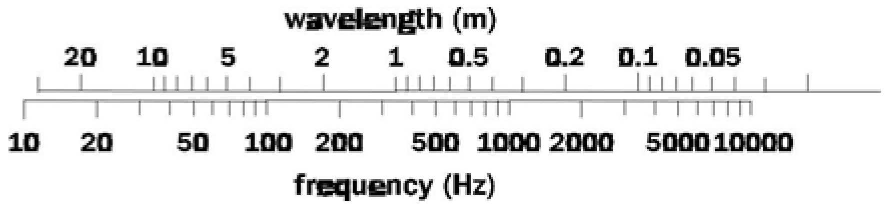
PURE TONE



PURE TONE

- Figure 1.1. Representation of a sound wave.
- (a) compressions and rarefactions caused in air by the sound wave.
- (b) graphic representation of pressure variations above and below atmospheric pressure

WAVE LENGHTH & FREQUENCY



Speed of sound

- The speed of sound propagation, c, the frequency, f, and the wavelength, , are related by the following equation:

- c = fY

$$C = fY$$

- the speed of propagation, c, of sound in air is 343 m/s, at 20 C and 1 atmosphere pressure. 1.127 feet per second, fluctuate due to temp. and humidity, all complex wave of say music all moves at the same speed in air. Wave is the linear distance required to complete one sinusoidal wave cycle is called wave length. At other temperatures (not too different from 20 C), it may be calculated using:

c = 332 + 0.6Tc

The wave length of a 500 Hz is 2.25 feet

Sound speed and physical properties of Medium

where T_c is the temperature in C . Alternatively the following expression may be used for any temperature and any gas. Alternatively, making use of the equation of state for gases, the speed of sound may be written as:

$$c \quad \sqrt{RT_k / M} \qquad (\mathrm{m\ s}^{\ 1}) \qquad (1)$$

where T_k is the temperature in K, R is the universal gas constant which has the value 8.314 J per mole K, and M is the molecular weight, which for air is 0.029 kg/mole. For air, the ratio of specific heats, , is 1.402.

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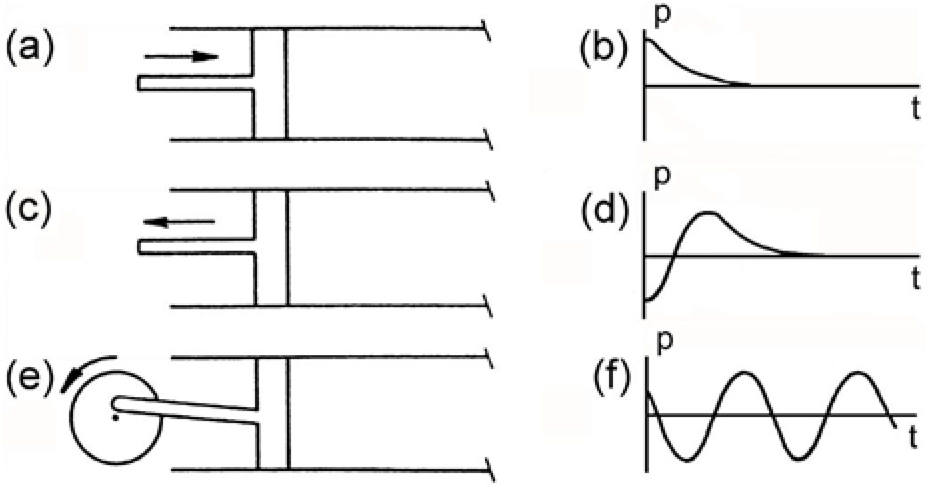
PURE TONE GENERATION



SOUND WAV MODELING

- SOUND WAVES MOVE LONGITUDENAL BUT DIFFICULT TO VISUALIZE AA CORELATES THE FERQ.AND WAVELENGTHS OF AUDIBLESOUND WITH THE AUDIBLE SOUND WITH COMPLEXICITY OF ARCH GEOMETRY. AND THE INFLUNCE OF MULTIPLE FINSH MATERIALS.
- COMPUTER MODELING IS USED TO SIMULATE THE COMPLEX SOUND IN BUILT ARCH.
- RAY TRACING THEORY:

Sound delivery methods to live audience :

- 1-acoustically –with no electronic reinforcement., electronic is reserved for very sophisticated rooms and end users, like symphony operas…..
- 2-point source or line array, sound reinforcement system.: seats more than 50 people.
- 3-overhead, distributed loudspeakers systems: used with limited frequency response or power requirements are needed. Effective when low flat ceiling are needed.

Low and high frequency waves

- The distinction is based on the physical size of the the various wavlenths. Classic rep of audible sound is within 20Hz to 20Khz. Sound renforcement systems are within 40Hz to 16Khz. Wave lenth related to AA is of interest.
- 1- 40 to 320Hz and 8KHz to 16KHz.,

40 Hz 80Hz	160Hz	320Hz	8KH	16KHz
28 14feet	7 feet	3.5feet	1/2inhes	7/8inches

- Ratio of 400 to 1, 9 octave musical terms. On the other hand when compare to light it is 2:1 between red and violet. One octave compared to 9 in musical wavelengths.
- That is why it so difficult to manage sound than light. LF sound is in the range less than375Hz, mid and high-frequency rays above 375Hz. 343 Hz lead to 1 meter, 375 lead to 36inches easily recognize. 36 and 375 to complete one cycle it takes 3 (mS)to travel.

Ray Trace Modeling

- Ray trace modeling is the most accurate when evaluating the HF-ray group of frequencies.

Acoustic Shadow

- Occurs when objects block the direct sound path between a sound source and one and more listeners.
- 36 inches is a small dimension for any architectural element.
- Blockage: **1- full blockage** if blocking structure is > 2 times the wave length. All sound is blocked.
- **Partial blockage:** significant dimension of the blocking structure between 0.25—2 times the wavelength. Diffraction zone where destructed sound is received.
- **3-No blockage**: significant. dimension is < ¼ wavelength, thus no blockage to sound to occur.
- **The Grand takeaway**: no object blocks the line between listener and the source or loudspeaker thus it provides direct coverage to those seats or positions.

THE THREE ACOUSTICAL TOOLS

- 1-absorption
- 2-reflection
- 3-diffusion