Acoustics

10.3

In ancient times, people would gather to watch plays and listen to music in theatres like the one in **Figure 1**. It was as important then as it is today for people to be able to hear clearly and for the music to be of high quality. Some people say their voice has a higher quality in the shower than anywhere else. Others notice that the sound quality of one theatre or large room is better than that of another. **Building acoustics** is the total effect of sound produced in an enclosed or restricted space.

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Acoustics of a Room

When sound is produced in one part of a room, it spreads out toward the walls, where it can reflect or be absorbed. One of the main factors contributing to the acoustics of a room is the number and intensity of the reflections, or echoes. Without any echoes the music sounds flat, while too many echoes make the music sound muddy. When designing a room's acoustic qualities, the goal is to use echoes to improve the sound quality as much as possible and to ensure that everyone can hear clearly. The direct sound (sound that does not reflect from anything) should come from the stage to the audience. Several early reflections (reflections that take minimal time to reach the audience) should be directed at the audience, as shown in **Figure 2**. However, subsequent reflections should be minimized to improve sound quality.

Figure 1 The Roman theatre in the city of Amman in Jordan. The principles of acoustics have been applied to theatres since ancient times.

Reverberation Time

In some theatres, the music continues for a short time even after the musicians have stopped. This continuation of the music is due to echoes. **Reverberation time** is the time for the sound to drop by 60 dB from its maximum loudness or to drop to an inaudible level. In a well-designed concert hall the reverberation time is at most 1 s or 2 s. If reverberation times for a concert hall are too long, the sound quality is lessened. Reverberation time is the most important factor of sound quality in a concert hall.

You can change the reverberation time by changing the texture or materials in the wall, ceiling, and floor coverings and even changing the furniture. The presence or absence of an audience can also affect reverberation time. When designing a concert hall with reverberation time in mind, factors such as the length of the hall, the height of the ceiling, and the slope of the floor and ceiling must be considered. Materials such as brick and concrete reflect sound easily and increase the reverberation time due to subsequent echoes. Other materials found in acoustic tiles, the seats, and the audience will absorb more sound and reduce the reverberation time because subsequent reflections will be much quieter. Comparative absorption coefficients are given in **Table 1**. Substances with larger coefficients have greater sound-absorption qualities and, hence, shorter reverberation times. Notice from Table 1 that the absorption of sound by a material also depends on the frequency of the source.

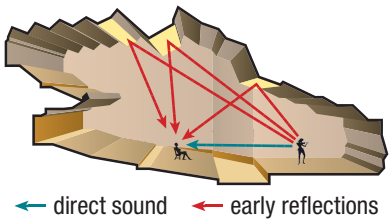

Figure 2 The design of this auditorium allows both direct sound and several early reflections to reach the audience.

reverberation time the time required for the loudness of the sound to drop by 60 dB or until the sound is inaudible

Table 1 Sound Absorption Coefficients for Various Materials*

Substance	Frequency (512 Hz)	Frequency (2048 Hz)
concrete	0.025	0.035
brick	0.03	0.049
wood (pine)	0.06	0.10
carpet	0.02	0.27
fibreglass	0.99	0.86
acoustic tile	0.97	0.68
theatre seats	1.6–3.0	—
seated audience	3.0–4.3	3.6–6.0

* To simplify the table, units have been omitted.

Investigation 10.3.1

Investigating Acoustic Surfaces (p. 477)

In this investigation, you will use what you have learned about acoustics to design a soundproof box to reduce the amount of loudness of a sound source.

CAREER LINK

Acoustical engineers help design halls and theatres to improve the sound heard by the audience. To learn more about becoming an acoustical engineer,

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Problems may result when a room is designed to be used for many different purposes. The acoustics for a speech are not the same as the acoustics for a concert. Typically, rooms designed for speaking should have much shorter reverberation times than those designed for music. Choral music (large groups of people singing together) requires reverberation times from 2 s to 5 s. In addition, large rooms require longer reverberation times than smaller rooms. Acoustical engineers have a challenging task when designing a large room to be used for many purposes.

Designing Spaces for Acoustics

When designing a room with acoustics in mind, designers try to avoid curved surfaces. When sound reflects off curved surfaces, it becomes either more concentrated or more dispersed (spread out). From a concave surface the reflected sound becomes concentrated at a single focal point, making the sound uncomfortably loud, while people nearby hear little or no sound (**Figure 3(a)**). If the surface is convex, the sound intensity drops off more quickly than usual, making it much more difficult to hear clearly (**Figure 3(b)**). Most surfaces should be flat to avoid these issues (**Figure 3(c)**).

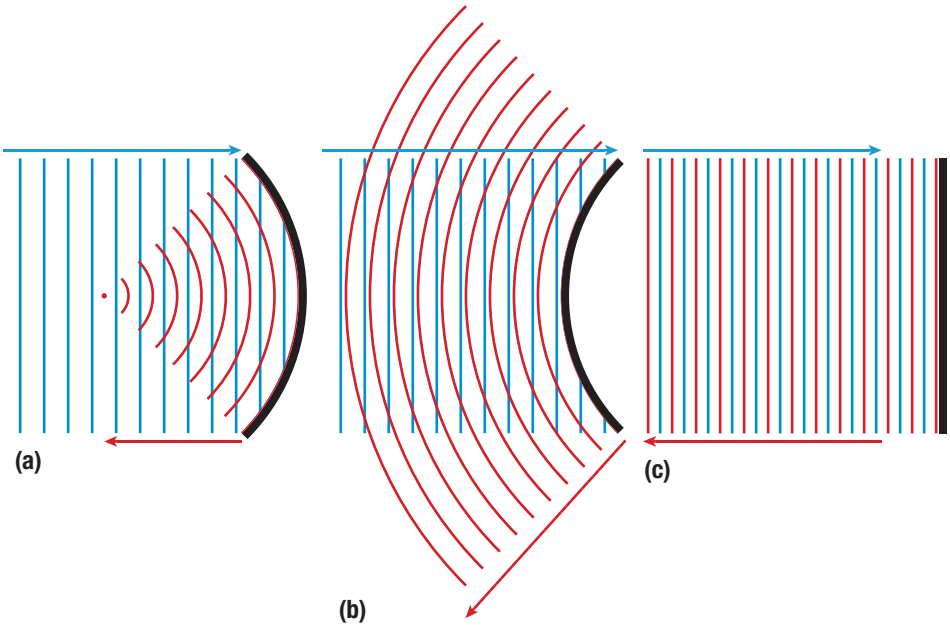

Figure 3 (a) A concave wall reflects sound to a single focal point. (b) A convex surface reflects sound so that the sound waves are dispersed. (c) Flat surfaces reflect sound evenly.

Figure 4 (a) The parabolic shape of an outdoor band shell works well outdoors. (b) The Chan Centre for the Performing Arts in Vancouver, British Columbia, uses many different acoustical principles to produce an intimate musical experience.

However, curved surfaces are used in the design of outdoor band shells, which are often in the shape of a parabola with the performers at the focal point (**Figure 4(a)**). In this design, a person speaking with a normal voice on stage can be heard by everyone in the outdoor theatre. Using curved surfaces indoors is not a good design. The curved surfaces would focus the reflected sound waves back toward focal points in the audience.

Another problem that can arise from a poor design is acoustical shadow. An acoustical shadow occurs when compressions and rarefactions combine in an area of the seating to produce destructive interference. The resulting reduction in loudness can make it difficult for an audience member to hear the performance.

Many present-day theatres, such as the one shown in **Figure 4(b)**, have numerous design features that produce acoustical effects unique to the building. There are many different terms to describe the acoustical properties of these rooms. For example, an intimate room is one where the first early reflection reaches the audience less than 20 ms after the direct sound. A live room is one with a longer reverberation time. In some rooms, much of the sound energy is absorbed and only a portion is reflected. In other rooms, more of the sound energy is reflected. A full room means the reflected sound intensity is very close to the direct sound intensity.

Devices such as speakers, microphones, and telephones must sometimes be tested in an environment that has a reverberation time as close to zero as possible. These anechoic (ann-e-KO-ick) rooms are designed by carefully choosing the materials in the room to make it acoustically dead. The term "anechoic" means without echo. As the name implies, the materials absorb most of the sound energy and reflect as little as possible.

10.3 Summary

- The properties of sound influence the design of structures.
- Building acoustics is the total effect of sound produced in an enclosed or restricted space.
- Reverberation time is the time for the sound to drop by 60 dB from its maximum intensity or to drop to an inaudible level.
- The materials, textures, shape, and size of a room are some of the factors that affect a room's acoustics.

UNIT TASK BOOKMARK

As you carry out the Unit Task on page 486, apply what you have learned about how acoustics can influence the design of your researched structure or your device.

10.3 Questions

1. A concert has a loudness of 82 dB. What will the sound level drop to after the reverberation time? T/I
2. The graph in **Figure 5** is used to determine the reverberation time for a theatre. T/I

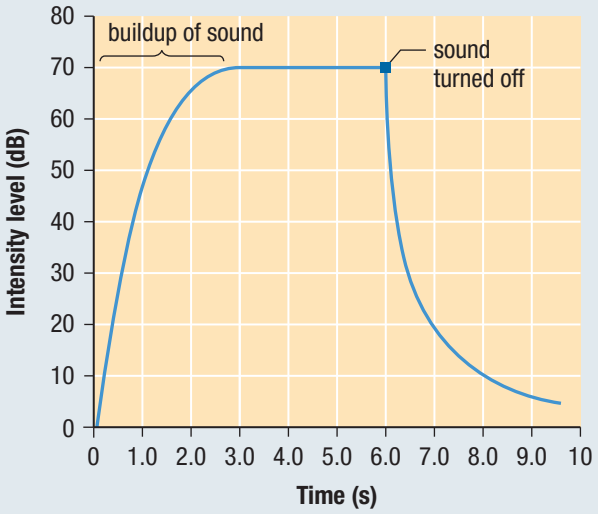

Figure 5

   (a) What is the reverberation time for the theatre?
   (b) What could be done to decrease the reverberation time?
   (c) What could be done to increase the reverberation time?

3. Auditorium A has wooden-backed seats, and auditorium B has cloth-covered, padded theatre seats. How will the acoustical properties of the two theatres compare when they are (a) empty and (b) full? Explain your reasoning. K/U C
4. When a theatre is adjusted to accommodate choral music instead of a speaker, the theatre staff often remove large curtains from the wall and adjust the ceiling features. Explain why they make these adjustments. K/U
5. Why is it preferable to have short reverberation times for auditoriums where speeches are performed and longer reverberation times for auditoriums where music is performed? K/U
6. What features need to be incorporated into the acoustic design of an outdoor concert venue in order for it to provide optimal sound quality for the audience but limited noise in the surrounding area? K/U
7. In a large room with one wall covered by windows, a speaker's words seem to lack clarity. Will closing the curtains help? Explain your answer. K/U T/I
8. Examine an enclosed space like a stage or an auditorium in your school or community for acoustical design features. Find out the primary purpose of the room (lectures, music, and so on), and then list some of the acoustical design features in the room. A
9. Why are few if any acoustical design features required in an average classroom in your school? A