# Sound

# 10

## 10.0 CHAPTER PREVIEW

In this chapter, we will:

- Learn about sound sources and reinforce that sound travels by waves.
- Review the hearing mechanism of humans and how sound waves stimulate the hearing response.
- Study various properties of sound, including loudness, intensity, resonance and amplitude.
- Investigate the speed of sound and what influences it.

## 10.1 INTRODUCTION

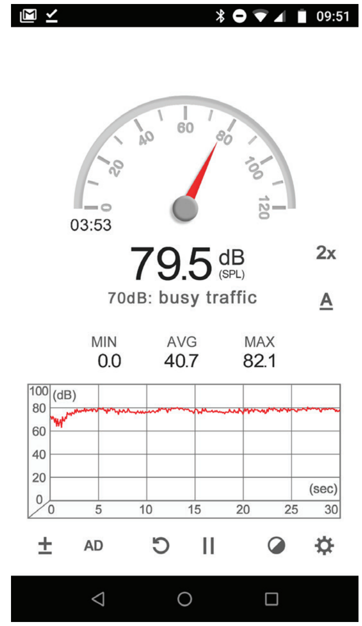
Sound is a phenomenon created when vibrations of certain frequencies travel through a medium, stimulate the ear, and then are perceived by the brain. But, coming up with a good definition of sound is somewhat of a fun challenge, as highlighted by the philosophical question, “If a tree fell in the forest and there was no one there to hear it, would it make any sound?” At first, you might think it is kind of a dumb question, but then when you think about it more, it really does highlight the challenge of defining sound. It actually is a fine question, with not such a great answer, because the answer is, “It depends.” It depends on how “sound” is defined, and I’ll show you why with just one definition.

Dictionary.com (accessed 4/30/2019):

1. *the sensation produced by stimulation of the organs of hearing by vibrations transmitted through the air or other medium.*

2. *mechanical vibrations transmitted through an elastic medium, traveling in air at the speed of approximately 1087 feet (331 meters) per second at sea level.*

There’s a big difference between those two definitions. The first definition requires an intact sound-sensing device (an “ear”)—“…by stimulation of the organs of hearing.” So, by this first definition, if there is no one around, then there would be no organ of hearing; hence, no sound when the tree falls in the forest. But the second definition simply defines “sound” as mechanical vibrations transmitted through an elastic




Before we move onto the next section, I want to clearly explain the difference between intensity—the objective measurement of sound wave energy (amplitude)—and loudness—the perceived volume of a given sound intensity, which we'll do in the following example: you are listening to some music and your dad says to turn it down because it is too loud. You say that it doesn't seem too loud to you. He shows you the sound level reading from his phone app and it shows 79.5dB

"Look," he says. "You have this music at almost 80dB. That's louder than a busy intersection!" Is he right? Is it "loud?" You can't argue with his report of the sound level, because it is measurable, it is objective—79.5dB. But that measurement he just gave you is the intensity of the sound, not its loudness. While you can't argue that the sound intensity is anything other than 79.5dB, you could very respectfully contend that 79.5dB isn't "loud" because sound loudness is in the ear of the beholder. The sound level is under 80dB, so we know that the wave that carries the sound isn't intense enough to do any permanent damage to your internal hearing mechanism; therefore, whether it is "too loud" is a matter of opinion, which means it is subjective. Your experience of a sound level intensity of 79.5dB tells you that it isn't too loud, but your dad's experience tells him that it is. Sound level—"intensity"—is measurable, while loudness is in the ear of the beholder. And, of course, honoring your father, you turn it down.

## 10.5 SPEED OF SOUND

When we discussed wave speed in the last chapter, we learned that waves—sound included—travel fastest through solids, slowest through gases, medium fast through liquids, and that the wave speed depends (mainly) upon the elasticity of the medium. This chapter, we'll advance this discussion a little bit further as it pertains to the speed of sound through air because there are other conditions that affect the way sound travels through air.

As we know, there are almost an infinite number of sound sources—musical instruments, radio speakers, traffic, thunder, explosions, voices, etc. No matter the sound source, though, sound waves are always created by vibrations and always travel at the same speed through air. This means that sound waves caused by an electric drill travel at the same speed as the sound waves emitted by a speed boat, or a waterfall, or a person singing or fireworks exploding. Sound waves are sound waves. Notice, also, that a larger amplitude wave does not make a faster wave. The sound waves of a jackhammer (which has very large amplitude waves) travel just as fast as the sound waves of a whisper (which has very small amplitude waves).

However, there are certain variables that affect how fast sound waves travel through the air. One of the variables that changes how fast sound waves move through air is temperature—the hotter the air, the faster it conducts the sound waves. And, the rate at which the speed of sound increases based on temperature is rather fixed. For every 1°C increase in temperature, the speed of sound increases by 0.6m/s, so if dry air at 0°C conducts sound waves at 331m/s, how fast will sound be conducted in dry air that is 30°C? Well, 30°C is 30 degrees above 0°C, so that means the speed of sound will be 30 x 0.6m/s = 18m/s faster than at 0°C. So, adding 18m/s to the speed of sound at 0°C, 331m/s, we get 349m/s for the speed of sound when the temperature is 30°C.

Why does sound travel faster when it is warmer? If we go back to what is happening when the wave gets conducted through the air, the actual air molecules. Not only do the air molecules—oxygen, nitrogen, argon, etc.—vibrate back and forth from the wave's energy as it passes through them, but, according to kinetic theory, they also have their own motion. Their kinetic motion makes them move around and bump into each other. When it gets hotter, that motion increases. The faster the individual particles move, the more they bump into each other and the faster they can get back into position to transmit the sound wave.

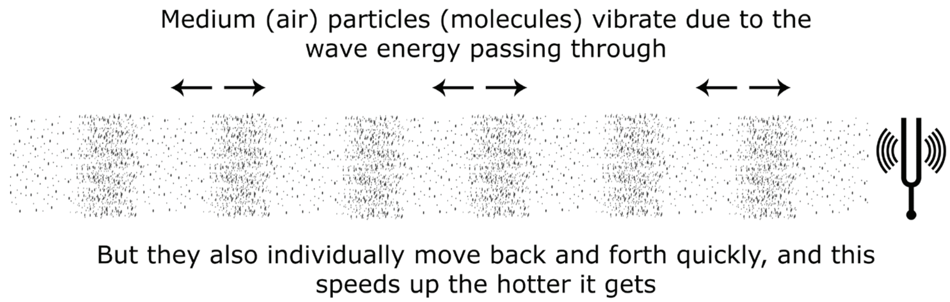



**Figure 10.5.1**

**Estimating Distance**

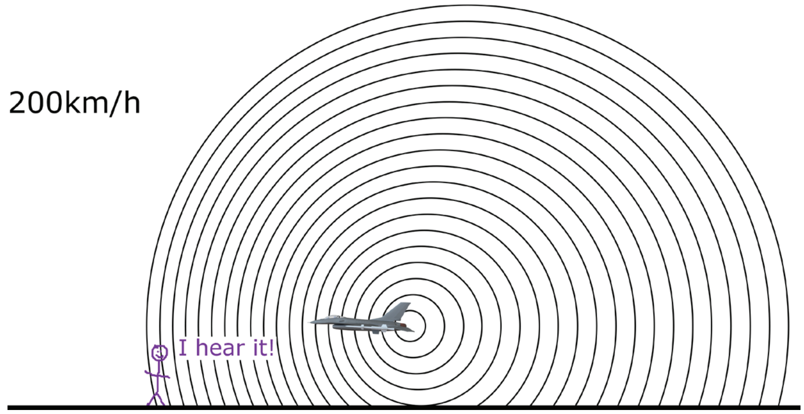
The predictable speed of sound allows you to do some fun estimating regarding how far away a sound source is. You have probably observed that when lightning flashes, hearing the boom of thunder is delayed, or when watching fireworks, the report of the explosion follows several seconds after you see the flash. This separation of sight from sound is because light travels faster—about 1,000,000 times faster—than sound. When lightning flashes or the firework explodes, you see it before you hear it, and the delay between sight and sound increases the farther away you are from the sound source. You can estimate how far away the lightning was when it struck, or how far away the firework was when it exploded, by counting the seconds between the flash and the boom. If we take an average speed of sound to be 340m/s, then sound travels 340 meters each second. In 3 seconds, then, sound will travel about 1,000m, or 1km. So, if the firework explodes and you count 3 seconds before you hear the sound, then the explosion was about 1km away (if you count to 5, then it was about a mile away). If you count 9 seconds before you hear the thunder clap, then the lightning strike was about 3km away.

Courtesy Chuck Derus MD

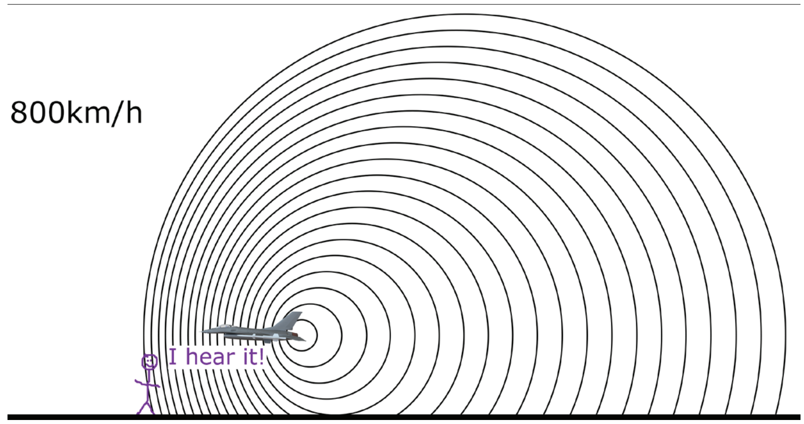
### 10.6 SOUND BARRIER

For this discussion, we are going to use the speed of sound of 343m/s, or 1234.8km/hr (767 mph). The **sound barrier** is the intersection between the speed of an object and the speed of sound. Normally, moving objects we are familiar with—cars, boats, airplanes, animals, any thrown object, etc.—don't move faster than the speed of sound, which means they don't move faster than the sound they make when they are moving. But when an object breaks the sound barrier—moves faster than the speed of sound—it is moving faster than 343m/s, which means that it moves faster than the sound it makes. Let's see how that works (because really cool stuff happens).

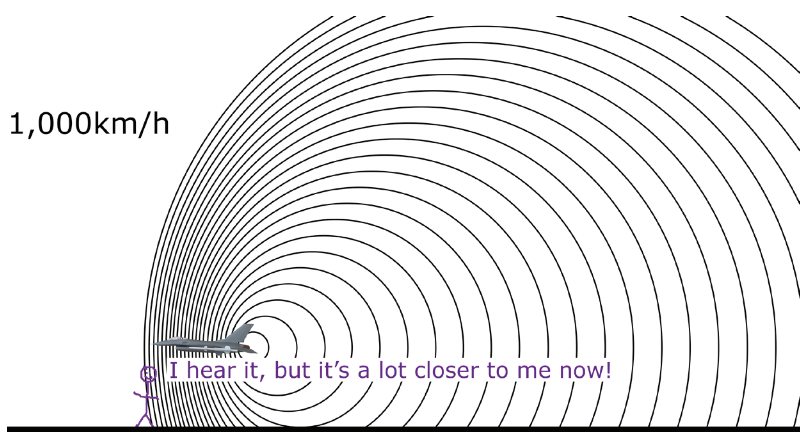
When a jet plane—let's just use a military jet since this is the object that most commonly moves faster than the speed of sound—moves through the air, its engines make sound, a lot of sound. As we learned, a sound source releases sound waves in all directions, so when the jet is flying quite a bit slower than the speed of sound, the sound from its engines propagate in all directions. If you were standing in front of the jet as it flew slower than the speed of sound toward you, its engines would be audible before the jet passed you because its sound waves are traveling faster than the plane, so the sound waves get to you before the jet does.



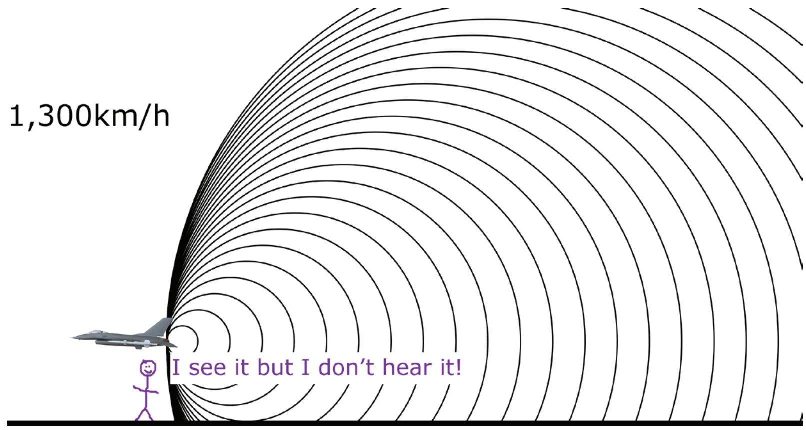

As the plane starts to fly faster, its speed gets closer to the speed of the sound waves its engines release. The faster the jet's speed, the closer it gets to the speed of the sound waves its engines make and the more it "catches up" on the sound in front of it. The faster the plane moves, the less far out in front of it the sound waves can get. When the plane flies 200km/h, its sound waves travel in front of it about 6 times as fast as the plane flies, but when the plane flies 800km/h, now the sound waves are only traveling 1.5 times as fast in front of it…




And so the plane must be closer to stickman before he can hear it as compared to when the plane was going slower. When the plane flies 1000km/h, now the sound waves and the plane are traveling at almost the same speed and the plane must get a lot closer to stickman before he can hear it. The plane almost outruns the sound its engines make, but not quite yet.



Notice that the faster the plane goes, the more the sound waves get squished up—compressed—in front. Once the jet breaks the sound barrier, it exceeds the speed of the sound its engines make. If you are standing in front of it now, you won't be able to hear it.




The sound waves get all compressed right at the source because the jet is flying so fast that the sound waves it makes are released after the sound source—the jet engine—passes the point where the sound is released! This creates a **sonic boom** (a very loud, well, boom, that occurs when sound waves get compressed by something that breaks the sound barrier) and also lets you get really cool pictures.

Note that you can't hear the jet until it passes you because it is flying faster than the sound it makes. However, you will hear it when it passes you and the sonic boom hits your eardrums! Sonic booms can shatter glass in windows that are kilometers away from the jet.