SOLUTIONS TO THE MODULE #14 STUDY GUIDE

1. a. Transverse wave – A wave with a direction of propagation that is perpendicular to its direction of oscillation

b. Longitudinal wave – A wave with a direction of propagation that is parallel to its direction of oscillation

c. Supersonic speed – Any speed that is faster than the speed of sound in the substance of interest

d. Sonic boom – The sound produced as a result of an object traveling at or above Mach 1

e. Pitch – An indication of how high or low a sound is, which is primarily determined by the frequency of the sound wave

2. The engineers need to adjust the electronics to emit sound waves with a shorter wavelength. Remember, wavelength and frequency are inversely proportional. If the engineers want higher pitch, they want higher frequency, which means they want a shorter wavelength.

3. To determine the speed of sound, we use Equation (14.2):

$$v = (331.5 + 0.6 \cdot 30)\ \frac{m}{sec}$$

$$v = (331.5 + 18)\ \frac{m}{sec}$$

$$\underline{v = 349.5\ \frac{m}{sec}}$$

4. To determine a wave's frequency, we use Equation (14.1):

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

$$f = \frac{349.5\ \frac{\cancel{m}}{sec}}{0.5\ \cancel{m}} = 699\ \frac{1}{sec}$$

The frequency is 699 Hz.

5. Infrasonic waves have frequencies less than 20 Hz (the lowest frequencies that human ears can hear). Ultrasonic waves have frequencies of more than 20,000 Hz (the highest frequencies that human ears can hear). Sonic waves have frequencies between 20 and 20,000 Hz. To determine whether a

wave is sonic, infrasonic, or ultrasonic, then, we must determine its frequency. That's what we can do with Equation (14.1):

$$f = \frac{v}{\lambda} = \frac{345\ \frac{\cancel{m}}{sec}}{500\ \cancel{m}} = 0.69\ \frac{1}{sec}$$

Since the frequency is less than 20 Hz, this is an infrasonic wave.

6. The physicist will not be able to hear the alarm because, without air, the sound waves from the alarm have nothing through which to travel. Thus, they cannot make waves. As a result, there is no sound.

7. Sound waves are longitudinal waves.

8. To determine the distance, we will use the time difference between the lightning flash and the sound. We will assume that the light from the lightning reaches our eyes essentially at the same instant as the lightning was formed. Thus, the time it takes for the sound to travel to you will determine the distance. First, then, we need to know the speed of sound:

$$v = (331.5 + 0.6 \cdot 13)\ \frac{m}{sec}$$

$$v = (331.5 + 7.8)\ \frac{m}{sec}$$

$$v = 339.3\ \frac{m}{sec}$$

Now we can use Equation (14.3):

$$\text{distance traveled} = (\text{speed}) \times (\text{time traveled})$$

$$\text{distance traveled} = (339.3 \frac{m}{\cancel{sec}}) \times (2.3\ \cancel{sec}) = \underline{780.39\ m}$$

9. Sound travels faster in solids than it does in gases or liquids. Thus, the sound travels faster in the wall.

10. Remember, when a wave strikes an obstacle, part of the wave is reflected and part of it is transmitted through the obstacle. Thus, only a portion of the wave actually starts traveling through the wall. This means the amplitude of the wave will be smaller, because only part of the wave is present in the wall.

11. To determine the speed of the jet, we first have to determine the speed of sound. After all, Mach 2.5 means 2.5 times the speed of sound. Thus, we need to know the speed of sound in order to determine the speed of the jet.

$$v = (331.5 + 0.6 \cdot T)\frac{m}{sec}$$

$$v = (331.5+0.6 \cdot 1)\frac{m}{sec}$$

$$v = (331.5+0.6)\ \frac{m}{sec} = 332.1\ \frac{m}{sec}$$

Since sound travels at 332.1 m/sec, Mach 2.5 is 2.5 x (332.1 m/sec), or 830.25 m/sec.

12. This is much like the previous problem. To determine the Mach number, we need to first determine how quickly sound travels in that air:

$$v = (331.5 + 0.6 \cdot T)\frac{m}{sec}$$

$$v = (331.5 + 0.6 \cdot 0)\frac{m}{sec} = 331.5\frac{m}{sec}$$

To determine the Mach number, then, we can just divide the speed of the jet by the speed of sound. This will tell us how many times faster than sound the jet is traveling:

$$464.1 \div 331.5 = 1.4$$

This means that the jet is traveling at Mach 1.4.

13. When a jet travels at Mach 1 or higher, it creates a shock wave of air that causes a very loud boom. This boom can damage people's ears and buildings. Thus, sonic booms must be avoided when people or buildings are nearby.

14. Since the string becomes shorter, the wavelength will be smaller. This will result in a higher frequency. Thus, the pitch will increase.

15. The wavelength, frequency, and speed will all be the same. After all, the pitch is determined by the frequency, which, in turn, determines the wavelength. The speed depends only on the temperature. The amplitudes of the waves will be different, however, because amplitude determines loudness.

16. As the car travels away from you, the sound waves that are produced by the horn get farther and farther apart. This makes the wavelength seem longer to your ears, which will result in a lower frequency. Thus, the horn's pitch is lower when it is moving away from you.

17. As you travel towards the police car, you will encounter the compressions of the sound waves faster than when you stand still. As a result, the wavelength will seem shorter to you, which will produce higher frequencies. This means that the pitch will get higher.

18. The bel scale states that every bel unit corresponds to a factor of ten increase in the intensity of the sound waves. Thus, we need to determine how many bel units the sound of the traffic is, as compared to the sound of your voice:

$$\frac{80\ \text{decibels}}{1} \times \frac{0.1\ \text{bel}}{1\ \text{decibel}} = 8\ \text{bels}$$

$$\frac{100\ \text{decibels}}{1} \times \frac{0.1\ \text{bel}}{1\ \text{decibel}} = 10\ \text{bels}$$

Since the traffic is 2 bels louder than your voice, the increase in sound wave intensity is 2 factors of ten higher. Thus, the traffic has sound waves with intensities that are 10 x 10 = 100 times larger than the intensities of sound waves from your voice.

19. The bel scale states that every bel unit corresponds to a factor of ten increase in the intensity of the sound waves. Thus, we need to determine how many bel units were fed into the amplifier:

$$\frac{30\ \text{decibels}}{1} \times \frac{0.1\ \text{bel}}{1\ \text{decibel}} = 3\ \text{bels}$$

If the amplifier magnifies the intensities of the waves by a factor of 1,000, that's the same as 10 x 10 x 10. Thus, the sound coming out of the amplifier will be 3 bels larger, as each factor of ten represents one increase in the bel level. Thus, the sound coming out will be 6 bels, which is the same as 60 decibels.