The Big Ideas—Chapter 17

(Serway and Beichner, Physics for Scientists and Engineers, 5th Edition)

Sections 1 **Sound is a longitudinal mechanical wave and, therefore, involves compressions and rarefactions of the medium. Sound waves travel at a speed that is proportional to the square root of the ratio of the compressibility (the Bulk Modulus) to the mass density of the medium.** Sound waves exist in all media—gaseous, liquid, and solid. In *gases*—like air!—the bulk modulus is proportional to the ambient pressure which does not change much with temperature while the density is inversely proportional to the *absolute* temperature. Therefore, the speed of sound is inversely proportional to the absolute temperature and may be written in terms of its speed at a reference temperature such as 0°C.	$v_s = \sqrt{\frac{B}{\rho}}$ $v_s \quad \sqrt{T}$ $v_s = v_s(0°\text{C})\sqrt{1 + \frac{T_C}{273}}$
Section 2 **Sound waves can be described in terms of either the longitudinal displacement variations *or* the pressure variations.** It is important to remember that a graph of the displacement variations versus distance along the propagation direction represents the distance that individual air molecules are displaced *in the direction of wave propagation* from their normal positions. In a sinusoidal sound wave the pressure variations are 1/4 cycle out of phase with the displacement. For sinusoidal waves in a *given* medium, the pressure amplitude is directly proportional to the product of the frequency and displacement amplitude.	$\Delta P_{\max} = \rho v \omega s_{\max}$
Section 3 **Sound waves may be described in terms of their *intensity* which is the power they carry per unit area perpendicular to the direction of propagation.** The intensity is directly proportional to the square of the pressure amplitude which may also be expressed in terms of the frequency and displacement amplitude. (See section 2)	$I = \frac{\Delta P_{\max}^2}{2\rho v}$ $= \frac{1}{2}\rho v(\omega s_{\max})^2$

Section 3 (cont'd) **The "sound level" of a sound wave is a logarithmic measure designed to deal with the enormous audible range of sound intensities.** Sound level is measured in "decibels" (dB) and it is convenient to remember that a *factor* of two *change* in intensity corresponds to a *sound level* change of 3 dB, a factor of four change in intensity corresponds to 6 dB (twice that of 2!), and a factor of ten change in intensity corresponds to 10 dB.	$\beta = 10\log_{10}\left(\frac{I}{I_o}\right)$ $I_o \equiv 10^{-12}\ \mathrm{W/m^2}$ $10\log_{10}(2) = 3$
Section 4 **An isotropically expanding spherical sound wave has an intensity that is inversely proportional to the square of the distance from the source.** Therefore, doubling the distance from a source will reduce the intensity by a factor of 4 and the sound level by 6 dB. (See section 3) Also, therefore, the amplitude of a spherical wave must be inversely proportional to the first power of the distance. (See section 3)	$I = \frac{P_{\text{source}}}{4\pi r^2}$
Section 5 **When either the transmitter or the receiver moves, the observed frequency is shifted up or down from the transmitted frequency.** Just remember a) that all speeds must be measured with respect to the air itself (which is *usually* assumed to be motionless in the reference frame of the problem statement.) b) that observer ("receiver") motion affects the numerator of the Doppler shift formula and source ("transmitter") motion affects the denominator, c) that you pick the algebraic signs to reflect the fact that relative motion *toward* each other *raises* the received frequency and vice-versa. **When an object moves relative to the medium with a speed that exceeds that of sound, it creates a conical shock wave.** The apex angle of the conical shock wave is determined by the *mach number*—the ratio of the source speed to the sound speed.	$f_{\text{rec}} = f_{\text{trans}}\left(\frac{1 \pm \frac{v_{\text{rec}}}{v_s}}{1 \pm \frac{v_{\text{trans}}}{v_s}}\right)$ $\sin\theta = \frac{v_{\text{source}}}{v_s}$