Summary of Chapter 17

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1. ***Sound waves are longitudinal***; that is the particles of the medium move parallel to the direction of motion of the wave.

The velocity of sound in different media is given by;

$v_{solid} = \sqrt{\frac{Y}{r}}$ where Y is the Young modulus (N/m^2)

$v_{Fluid} = \sqrt{\frac{B}{r}}$ where B is the Bulk modulus (N/m^2)

v_{air} = 343 m/s at a temperature of about 20 ^{o}C and v_{vacuum} = 0

2. A harmonic sound wave can be described by a *displacement wave* or a *pressure wave*.

The displacement wave for a harmonic sound wave is given by;

$$S(x,t) = S_m \cos(k\,x - w\,t)$$

where s(x,t) is the diplacement of the particles in the medium, k is the wave number, w is the angular frequency, and S_m is the displacement amplitude.

The pressure wave is given by;

$$\Delta P(x,t) = \Delta P_m \sin(k\,x - w\,t)$$

Where

$$\Delta P_m = r\,\mathrm{v} w S_m$$

DP_m is the pressure amplitude and r is the density of the medium and v is te speed of sound in the medium.

3. *Interference of sound waves*

The relationship between the difference in path and the phase difference between the two sound waves at the location of a listener is

$$\Delta L = \frac{l}{2p} f$$

DL is the path length difference between the two sound waves.

2 Cases:

a) **Constructive interference** (maximum sound) *DL = 0, l, 2 l, 3 l …*

$$\Rightarrow \Delta L = n\,l \qquad \text{for } n = 0, 1, 2, 3, 4,\ldots$$

b) **Destructive interference** (minimum sound) $\Delta r = 0, \lambda/2, \lambda, 3\lambda/2$ ….

$$\Rightarrow \qquad \Delta L = n\frac{l}{2} \qquad \text{for } n = 1, 3, 5, 7,\ldots$$

4. ***The power*** transmitted in a harmonic sound wave is given by;

$$P = \frac{1}{2}\rho A v(\omega S_m)$$

The intensity of a sound wave I is defined as $I = \frac{\text{Power}}{\text{Area}}$ (W/m^2)

$$\Rightarrow \qquad I = \frac{1}{2}\rho v(\omega S_m)^2$$

Since the intensity of sound varies between 10^{-12} W/m^2 to 1 W/m^2 we define a new quantity called ***sound intensity level*** β as

$$\beta = 10\log\frac{I}{I_o}$$

where $I_o = 10^{-12}$ $W.m^2$ is the reference intensity.

The units for β is dB (Decibel). Now β varies between 0 and 120 dB.

For ***spherical sound waves***, the intensity is given by;

$$I = \frac{P_{av}}{4\pi r^2}$$

(r: distance between the source and the point where we want to measure the intensity).

$$I_1 = \frac{P_{av}}{4\pi r^2} \quad \text{and} \quad I_2 = \frac{P_{av}}{4\pi r^2 r_2^2} \qquad \Rightarrow \qquad \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

5. Standing Waves in air columns (pipes)

Sound sources can be used to produce longitudinal standing waves in air columns.

2 Cases:

a) ***pipe open at both ends***: The resonances occur for

$L = n\lambda/2$ for n = 1, 2, 3, 4, …..

since $v = \lambda f$ $\Rightarrow$ **$f = (n\,v)/2L$** for n = 1, 2, 3, 4, …..

where v is the speed of sound waves

b) ***pipe closed at one end***: the resonances occur when

$L = n\lambda/4$ for n = 1, 3, 5, 7, ……

$\Rightarrow$ **$f = n\,v/4L$** for n = 1, 3, 5, 7, ……

6. The Doppler Effect

The Doppler effect is the change in frequency *f'* heard by a detector whenever there is relative motion between a source and a detector. There are 8 cases described as follows:

Detector	Source	Equation	
D →	S	$f' = f\left(\frac{v + v_D}{v}\right)$	Detector moving toward stationary source
← D	S	$f' = f\left(\frac{v - v_D}{v}\right)$	Detector moving away from stationary source
D	← S	$f' = f\left(\frac{v}{v - v_S}\right)$	Source moving away from a stationary detector
D	S →	$f' = f\left(\frac{v}{v + v_S}\right)$	Source moving toward a stationary detector
D →	S →	$f' = f\left(\frac{v + v_D}{v + v_S}\right)$	Detector approaching and source is moving away
← D	← S	$f' = f\left(\frac{v - v_D}{v - v_S}\right)$	Source approaching and detector moving away
D →	← S	$f' = f\left(\frac{v + v_D}{v - v_S}\right)$	Source and detector are both approaching
← D	S →	$f' = f\left(\frac{v - v_D}{v + v_S}\right)$	Source and detector are both moving away

InGeneral $f' = f\left(\frac{v \pm v_D}{v \mp v_S}\right)$