Summary of Chapter 17

1. **Objective:**
   1. Calculate the speed of sound in various media.
   2. Write the expression for the displacement wave S(x, t) and the pressure wave $\Delta p(x,t)$ in sound waves.
   3. Calculate the power transmitted in harmonic sound waves.
   4. Calculate the intensity of harmonic sound waves.
   5. Calculate the intensity in case of spherical sound wave and write the expression for the displacement wave.

I. Summary of major points:

1. ***Sound waves are longitudinal*.**

The velocity of sound in different media is given by;

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

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

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

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

$$S(x,t) = S_m \cos(kx - wt)$$

where s(x,t) is the diplacement of the particles in the medium

The pressure wave is given by;

$$\Delta p(x,t) = \Delta P_m \sin(kx - \omega t)$$

Where

$$\Delta P_m = \rho v \omega S_m$$

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

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

The intensity of a sound wave I is defined as $I = \frac{Power}{Area}$

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

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 Io = 10^{-12} W.m^2 is the reference intensity

The units for β is dB or decibel. Now β varies between 0 and 120 dB.

3. For ***spherical 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).

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

A spherical wave is represented by;

$$\phi(r,t) = (\frac{S_o}{r})\sin(kr - \omega t)$$

Where ϕ (r,t) is the dispalacement wave and S_o/r is the dispalacement amplitude. It is clear that the displacement amplitude varies with the ditance r.

At large distance from the source $(r >> \lambda)$ a spherical wave can be approximated by a ***plane wave***,

$$\phi(x,t) = (\frac{s_a}{r})\sin(kx - \omega t)$$

The Doppler Effect:

Observer	Source	Equation
0	S	$f' = f\left(\frac{v + v_0}{v}\right)$ Observer moving toward stationary source
0	S	$f' = f\left(\frac{v - v_0}{v}\right)$ Observer moving away from stationary source
0	S	$f' = f\left(\frac{v}{v + v_S}\right)$ Source moving away from a stationary
0	S	$f' = f\left(\frac{v}{v - v_S}\right)$ Source moving toward a stationary observer