Sound

Characteristics of sound:

i) Sound is a form of energy

ii) Sound is produced by a vibrating body.

iii) Sound requires a material medium for its propagation. Sound can be transmitted through solids, liquids and gases.

iv) When sound is conveyed through a medium from one point to another point, there is no bodily motion of the medium.

v) Sound requires a definite time to travel from one point to another in a medium. Its velocity is always smaller than the velocity of light.

vi) Velocity of sound is different in different media. It has the maximum value in solids. Which have higher bulk modulus, and least in gases.

vii) Sound may be reflected, refracted or scattered. It exhibits diffraction and interference. In the transverse mode, it exhibits polarisation also.

Classification of sound:

Classified on the basis of frequency, as

1. Infra sound
2. Audible sound
3. Ultrasound

Infrasound and Ultrasound are not audible.

Infrasound – below 20 Hz

Ultrasound – above 20KHz

• Musical sounds are produced when a series of similar impulses follow each other regularly at equal intervals of time.

• Noise produce a jarring and unpleasant effect on the ear. Noises are the sounds of complex nature having irregular periods and amplitudes.

Characteristics of a musical sound are:

1. Pitch ⟶frequency of sound
2. Loudness ⟶ intensity of sound
3. Timbre ⟶ quality of sound

Pitch:

The pitch of a musical sound is determined by its frequency but it is also a function of its intensity and waveform. Greater is the frequency of a muscial note, higher is the pitch and viceversa. The frequency and pitch are two different things. The frequency is a physical quantity and can be measured accurately, while the pitch of a note is a physiological quantity which is merely the mental sensation experienced by the observer.

The change in pitch with loudness is most pronounced at a frequency of about 100 Hz. In the 100 Hz range with increasing loudness, the pitch decreases, even though the frequency remains constant. For frequencies between 1000 Hz and 5000 Hz which is the range for which the ear is most sensitive, the pitch of a tone is relatively independent of its loudness. Generally in the range 20 Hz to 10,000 Hz the pitch varies in a parabolic manner with frequency.

Loudness:

Loudness measures the amount of sensation produced in the ear and hence depends upon the listener. Loudness is not a purely physical quantity but is subjective in nature. Loudness signifies how far and to what extent, sound is audible. Loudness 'L' is directly related to intensity 'I' and is proportional to log I.

i.e. L = K log I [Weber - Fechner Law]

Here K is a constant depending on the sensitivity of the ear, quality of the sound and other factors.

Loudness is found to vary with frequency also, Intensity of sound is a physical quantity and does not depend upon the listener.

Intensity of sound is measured by the quantity of wave energy flowing: across unit area held normally to the direction of propagation of the sound waves per second and its unit is watt/m^2.

Factors affecting intensity of loudness of sound:

$I = 2\pi^2 v^2 a^2 v\rho$

where v = frequency

a = implitude

v = velocity of sound

ρ = density of the medium

Measurement of Intensity of sound and Bel:

Intensity is measured in watt/m2. The lowest intensity of sound (at 1000 Hz) to which a normal human ear can respond is 10-12 watt/m2. This is chosen as "zero" or "standard" of intensity. Intensity of a sound is measured with reference to this standard intensity.

The ratio of intensity of a sound to the standard intensity is known as Intensity level or Relative Intensity of sound. The unit chosen for intensity level is called Bel. Bel is the intensity level of a sound whose intensity is ten times the standard intensity. Bel is large unit and hence decibel (dB) is used in practice.

1 dB = $\frac{1}{10}$ bel. Thus

Intensity level = Log (I/I_o) bel

= 10 log(I/I_o) dB

where I = Intensity of sound &

I_o = Standard intensity = 10^{-12} watt $1m^2$

1 dB corresponds to log (I/I_o) = 0.1

i.e. I/I_o =1.26

Hence 26% change in intensity corresponds to 1 dB of difference in intensity levels. This is the smallest change in intensity level that a normal ear can detect. The intensity level is measured in decibel scale (or) logarithmic scale because the response of human ear to sound is found to be logarithmic.

Sound signal	dB
Passing motor car	30
Busy traffic	70-80
Running train	100
Thunder	100-110

P2 Since the intensity I = $\frac{p^2}{\rho_0 C}$

the sound pressure level (spl) is expressed in decibels as

SPL = 20 log (P_e / P_o)

where p_e = effective pressure of sound &

p_o = reference effective pressure

= 0.00002 new tow/m^2

The sound level meters are used to measure the intensity level of sounds and loudness. It consists of a high sensitive microphone of good stability, a linear amplifier with uniform frequency response, a set of frequency weighing networks and an indicating meter. The frequency weighting network is to make the readings of the sound level meter correspond as closely as possible to observed loudness levels. At high intensity levels, no frequency weighing network is used. Initially the microphone converts sound energy into electrical energy in the form of voltage. Then this voltage is amplified and then passed through a suitable frequency weighting network and is then used to operate a calibrated indicating meter to read sound levels in decibels above the standard reference intensity of 10^{-12} watt/m^2.

Measurement of loudness and phon:

Loudness level of sound is measured with reference to a standard source producing a tone of frequeny 1000 Hz. The loudness level or equivalent loudness of a sound is said to be one phon, it the intensity level of standard to be with equal loudness is 4 decibel above th6 standard intensity.

The unit of loudness is a sone which is defined as being the loudness of a 1000 Hz tone of to dB intensity level. It is also equal to the loudness of any sound haying a loudness level of 40 phons: In the range from 40 phonal to 100 phons empirically we can write

$\log L = 0.033 (LL = 40)$

where

L = the loudness in sones and

LL = the loudness level in phons

For a frequency of 1000 Hz, the loudness level LL in phons is by definition numerically equal to the intensity level in decibels.

$\therefore LL = 10 \log (I/I_o)$

Since $I_o = 10^{-2}$ watt / m^2

$LL = 10 \log I + 120$

$\log L = 0.033 (10 \log I+120-40)$

$= 0.33 \log I+2.64$

which reduces to

$L = 445\ I^{0.33}$

i.e. $L \propto I^{1/3}$ for a 1000 Hz tone.

Timbre:

The timbre of a muscial sound is used to distinguish between two tones having the same intensity level and fundamental frequency but different waveforms. Thus it expresses our ability to recognize the sound of a violin as different from that of a trumpet, even when the two instruments are sounding the same note with equal loudness. Like loudness and pitch, timbre is a complex [one. Although it is primarily dependent on the waveform of the tone being heard, it is also a function of its [intensity and frequency. Normally the timbre or quality of sound depends on the number of overtones present with the fundamental, their relative intensity and pitch.

Amplitude:

The maximum distance travelled by a vibrating particle from its mean position is called the amplitude of vibrating body.

Period:

The time taken by the vibrating particle to complete one vibration is called the period of the vibrating body.

Frequency:

The frequency of the vibrating particle is equal to the number of vibrations made by the particle in one second. It is also equal to the reciprocal of its period.

Phase:

The phase of the vibrating particle at any instant is state or condition as regards its position and direction of motion with the respect to mean position.

Wavelength:

The wavelength of a wave is defined as the distance b/W two successive points which are in the same phase of vibration. It will be therefore the distance between two successive crests or troughs in a transverse wave. In a longitudinal wave it is the distance between two successive condensations or rarefactions.

Equation of Simple Harmonic Motion:

$\frac{d^2y}{dt^2} + w^2y = 0$

This is called the differential equation of free harmonic vibrations. If we solve this equation we will get y=a sin wt. Here 'a' is a constant called the amplitude. It is equal to the maximum displacement possible and happens when wt=90° = $\pi/2$

In a simple harmonic motion, the velocity of the vibrating particle is leading the displacement by an angle $\pi/2$ and is lagging behind the acceleration of the particle by an angle $\pi/2$.

Transverse wave motion:

Transverse wave motion is that wave motion in which the particles of the medium vibrate about their mean positions in a .direction at right angle to the direction of prepagation of the wave. Transverse waves are propagated in the form of crests (the points having maximum positive displacements) and troughs (the points having maximum negative displacements).

Ex: Propagation of light waves

Longitudinal wave motion:

Longitudinal wave motion is that wave motion in which the particles of the medium vibrate about their mean positions in the same direction in which the wave is propagated. The longitudinal waves are propagated in the form of condensations (the points having high pressures) and rarefactions the points having low pressures.

Example: Propagation of sound waves in air.

Sound (Elastic) wave propagation in isotropic solid medium:

a) Compressional or longitudinal waves (dilatational waves)

b) Extensional waves.

c) Shear or transverse waves.

d) Flexural waves.

e) Torsional waves

f) Surface waves (Rayleigh waves)

Free and Forced vibrations:

Free vibrations:

If the body vibrates with its natural frequency which depends upon the dimensions, moment of inertia and elastic constants of the vibrating system, then these vibrations are called free vibrations. But if a body is allowed to execute free vibrations for a length of time, the vibrations die down due to friction and viscous drag.

Example: Vibrations of a tuning fork when it is excited and left to itself vibrates with its natural frequency.

Forced vibrations:

Forced vibrations are the vibrations of a body when it oscillates with a frequency .different from its natural frequency with the help of a strong periodic force. Thus a body can be forced to vibrate with any frequency depending upon that of the applied force but these vibrations die out as soon as the applied force is removed.

Example: An excited tuning fork placed on a table makes the air column below execute forced oscillations and hence a loud sound is heard due to the greater amplitude of vibrations of the air column. If the fork is removed no sound will be heard.

Resonance:

Resonance is the phenomenon of setting a body into vibrations with its natural frequency by the applicatioin of a periodic force of the same frequency. Hence even when the periodic force is removed we can hear the sound. Resonance vibrations are also called "Sympathetic vibrations".

Example: Resonance of air Column using a vibrating tuning fork in resonance of air column apparatus.

Overtones and harmonics:

Overtones are the sounds accompanying the fundamental note and bear simple ratios to the fundamental frequency. Harmonics are the integral multiples of the fundamental frequency. The Nth harmonic means that its frequency is N times the fundamental frequency. So the fundamental frequency is called the first harmonic frequency which is the loudest of ail harmonics. The second harmonic frequency is called the first over tone and so on. The number of overtones present in a sound determines the quality of sound.

Velocity of transverse wave along a stretched string:

$$v = \sqrt{\frac{T}{m}}$$

where

T = Tension

m = mass per unit length of the string

Lowest frequency $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$

where l = length of the string.

Laws of vibrations of stretched strings:

The frequency 'n' of the fundamental note produced by a string depends upon the following factors.

The frequency is inversely proportional to length of the string

i.e. $n \propto \frac{1}{l}$

ii) The frequency is directly proportional to the square root of the stretching force or tension i.e. $n \propto \sqrt{T}$

iii) The frequency is inversely proportional to the square root of mass per unit length of the string.

i.e. $n \propto \frac{1}{\sqrt{m}}$

Sonometer and its applications:

Sonometer or monochord consists of a string of steel or brass attached to a peg p at one and and passing over two fixed knife edges A and B on a wooden sound box W. The other end of the string passes over a smooth pulley L and carries a mass M whose weight gives the desired tension to the string. C is a movable knife edge (or bridge) whose distance from the knife edge B can be altered when necessary, Usually a metre scale is fixed on the sonometer box to measure the length of the string between the knife edges.

• Sonometer is used to verify the three laws of vibrations.

• It is also used to determine the specific gravity of a stone, which is given as

$$\frac{M_1}{M_1 - M_2} = \frac{l_1^2}{l_1^2 - l_2^2}$$

where M_1 and M_2 are the masses of stone in air and water respectively.

l_1 and l_2 are the resonating lengths corresponding to M_1 and M_2 respectively.

Melde's string:

Melde's string apparatus consists of an electrically maintained tuning fork.

It is used to find the frequency of

a) Transverse mode of vibrations

b) Longitudinal mode of vibrations

c) Determination of the frequency of A.C. power supply.

Longitudinal waves in solids:

The velocity of a longitudinal wave in a solid is given by

$v = \sqrt{k/\rho}$

where K is the coefficient of volume elasticity (bulk modulus) of the medium and p density.

Even though the density of the solid is greater than liquid or gas, the velocity of sound in a solid is greater than the velocity of sound in liquid or gas due to its enormous value of the bulk modulus.

In the case of gaseous media,

$K = \gamma p$ and $v = \sqrt{\frac{\gamma p}{p}}$

where P is the pressure and

γ is the ratio of specific heat at constant pressure ; to the specific heat at constant volume.

Similarly the velocity of sound waves along, a string is given by

$V = \sqrt{E/\rho}$

where E is Young's modulus of elast5city of the material of the string.

Kundt's tube and its applications:

a) Determination of velocity of sound in the metallic rod.

b) Determination of velocity of sound in gases.

c) Determination of velocity of sound in liquids;

d) Determination of Young s modulus of rod.

e) To compare the ratio of specific heats in different gases.

f) To find the temperature coefficient of velocity in gas.

Vibrations of air columns:

Vibrations can be set up inside a cylindrical pipe by blowing air by the mouth. This is the basic principle of organ pipe which is a wind instrument. The waves are reflected at the ends of the pipe and so a system of stationary longitudinal waves are formed. At the closed end of the pipe nodes are formed because the layer of air in contact with the closed end is not free to vibrate. Since maximum vibrations are possible for the layer of the air at the open end, antinode is formed. Nodes are the points where the displacement is minimum and particles are at rest. Antinodes are the points midway between nodes, where the displacement is maximum. Distance between two successive nodes or antinodes is equal to half wavelength.

Transmission of sound:

When a progressive plane wave in a medium-I impinges on the boundary of a second medium-II, a reflected wave is generated in the first medium and a transmitted wave is in the second medium. The intensity of the transmitted wave depends on the intensity of the incident wave, characteristic impedances of the two media and angle of the incident wave.

Characteristic impedance (or) specific acoustic impedance 'z' of the medium is defined as the ratio of acoustic pressure 'p' in the medium to the associated particle velocity u.

Thus $z = \frac{P}{u} = \frac{\rho_o cu}{u} = \rho_o c$

where ρ_o = equilibrium density of the medium

c = the velocity of sound in that medium

For standing and diverging waves, it is a complex quantify, such that

Z = r + hX

where r is the specific acoustic resistance

X is the specific acoustic reactance of the medium

The specific acoustic resistance ™ is expressed as $r = \rho_o c \text{ kgm}^{-2} \text{ s}^{-1}$

It may be positive for waves travelling in positive direction or negative for eaves travelling in the negative direction.

The standard characteristic impedance of air (at 20°C),

$(\rho_o c)$ 20°c = 1.21×343=415 $\text{ksm}^{-2}\text{s}^{-1}$

Transmission Loss:

For normal incidence the transmission loss (TL) = 10 log (I_i/I_t).

Since $a_t = I_t/ I_i$

TL = 10 log (1/at)

= 20 log $(\pi/\rho_1 c_1)$+20 log σf

since $\rho_1 c_1$ = 415 $\text{kgm}^{-2}\text{s}^{-1}$ for air,

TL = 20 log (π/415)+20 log of

For concrete wall of unit thickness,

σ = 65.3 kg/m^2 and f = 500 Hz

TL = 20 log (π/415)+20 log (65.3×500)

= -42.42+90.28

= 47.85 dB

It is found that the transmission loss for a single wall increases about 5 dB for each doubling of frequency or doubling of surface density. The surface density is doubled when the thickness of the wall is doubled.

Acoustics of Buildings:

An auditorium of a hall is said to be acoustically good if the following conditions are satisfied.

i) The music (of) speech performed on the dias should be audible in the entire hall either direct or with the amplifier system as the case may be.

ii) The frequency combination, that is the quality of sound should be uniform through out the theatre.

iii) The syllables ought to be clear without overlapping.

iv) Whether the hall is full! with audience or not, the quality of music heard should be the same.

v) These must not be any pockets of maxima or minima due to interference or reflections.

vi) The sounds from the exterior must not disturb the proceedings inside.

vii) The loudness of the sound should be uniform through out the hall.

viii) No echo should be present.

ix) The hall should have proper reverberation time about 1.1 to 1.5 second.

x) Resonance effect (jarring effect of sound) should 1 be avoided.

Sabine showed that the time of reverberation

$T = \frac{0.153v}{\sum as}$

where v is the volume of the hall in cubic metre. $\sum$as is the sum of the products of absorption coefficients of different surfaces lining the interior of the hall and their respective surface areas.

Measurement of absorption coefficient:

Since an open window is a perfect absorber of sound, it is taken as a standard to define the absorption coefficient of a surface. Absorption coefficient of a surface is defined as the reciprocal of its area which absorbs the same sound energy as absorbed by an unit area of an open window. For example, 4 square metre of a certain carpet absorbs the same amount of sound energy as absorbed by 1 square metre of open window, the coefficient of absorption of that carpet is 1/4.

The absorption coefficient can be measured in terms of the reverberation time. First the reverberation time T_1 is measured when the absorbing material is not in the room. Next the absorbing material is put inside the room and the reverberation time T_2 is measured.

Now,

$$\frac{1}{T_1} = \frac{\sum \text{as}}{0.16\text{v}}$$

$$\frac{1}{T_2} = \frac{\sum(as+q_2s_2)}{0.16v}$$

$$a_2 = \frac{0.16v}{s_2}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

knowing the values of s_2 and v, a_2 can be calculated.

Noise pollution:

The noise has some harmful effects upon the human beings. It contributes to mental fatigue and irritation, lowers the efficiency of workers by lessoning their attention and-making the concentration on work difficult, impairs hearing, strains and wears down the nervous system to a considerable extent, lowers the restorative quality of sleep. It also retards the normal growth of infants and young children.

Everyone with normal hearing power is continually subjected to different types of sound. In rural areas, the natural sounds of wind and animals can present a noise problem and residents of urban areas are continually subjected and disturbed by different types of sounds such as noises from factories, a.ir craft noises, automobile noises and noises from trains. These will create V noises’ There are many other systems which add to noise problems. Air conditioners, Television sets, automatic washers and even playing children contribute much to the above problem. These will create 'inside noises’. The noises which are conveyed through the structure of the buildings will create structure borne noises.

Noise control measures:

1. by redesigning the source of sound for quieter operation.
2. By isolating the source with sound-reducing housings.
3. By installing sound absorbent materials near noise sources and in areas where silence is required.
4. The structure borne noises can be reduced by using double doors or double walls with the air space b/w them.

Ultrasonics:

The sound waves having frequencies above the audible range are known as ultrasonic waves. Normally they are called high frequency sound waves.

Ultrasonic waves are usually produced by the application of magnetostriction effect and piezoelectric effect. Galton's whistle is also a mechanical ultrasonic transducer.

a) Magnetostriction ultrasonic generator:

Frequency of vibration of rod is

$$f = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

where l = length of the rod

E = Young's modulus of the material of the rod material

ρ = density of the rod

b) Piezoelectric Ultrasonic generator:

The frequency of the thickness vibration is given by

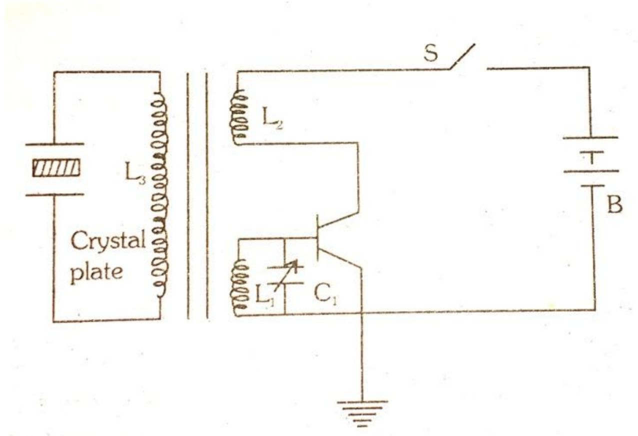
$$n = \frac{p}{2t}\sqrt{\frac{E}{\rho}}$$

c) Galton's whistle:

Galton's whistle is a source of producing low - frequency ultrasonic waves.

Detection of ultrasonic:

The piezo-electric, oscillator circuit can be used as a detector of ultrasonic waves.



Let us place one reflector with vernier screw arrangement opposite to one face of the crystal. If, the distance between the crystal and the reflector is an integral multiple of half wavelength, stationary waves are set up between the reflector and crystal face. If the wave reflected by the reflector arrives at the face of the crystal in the same phase, some oscillatory Current is flowing in the collector circuit. When the distance between the reflector and crystal face is changed, the milliammeter connected in the collector circuit shows maximum and minimum deflections. The distance moved between any two successive maxima or minima gives the half wavlength of the ultrasonic waves; the magnitude of the maximum deflection in the milliammeter gives the intensity of the ultrasonic waves. The frequency of ultrasonic, waves can be found using an frequency counter attached in the collector circuit of the oscillator.

a) Applications of ultrasonics

i) Industrial applications

ii) Ultrasonic welding

iii) Ultrasonic soldering

iv) Ultrasonic drilling and cutting

v) Ultrasonic cleaning and drying

vi) Metallurgical use

vii) Acoustic microscope

b) Medical applications

c) Ultrasonics as communication link

d) Chemical applications

e) Physical ultrasonics

f) Absorption and dispersion of ultrasonic waves

Doppler effect:

The apparent change in frequency .of vibration of a source of waves when there is a relative motion between the source arid the observer is called Doppler effect. Even though it applies to waves in general, it can be applied to sound waves too.

Microphones and Loudspeakers:

Microphones and loud-speakers are electro acoustic transducers. A microphase converts sound energy into electrical energy and a loud speaker converts electrical I energy into sound energy. A good microphone should have the following properties,

a) It has an uniform frequency characteristic over the audible range of frequency.

b) It has greater linearity of response.

c) It should be free from hiss or other background noise.

d) It should have adequate sensitivity and easy

maintenance and reliability of operation.

Types:

1. Pressure microphones

a) Carbon microphones

b) Condenser microphones

c) Crystal microphone's

2. Velocity microphones

a) ribbon microphones

Loudspeakers:

A loudspeaker converts the varying current back into original soundwaves. Thus it does the opposite of what a microphone does. Hence almost any principle which can be used as the basis of action of a loudspeaker.

Moving coil loudspeaker has large Output and higher fidelity. These are widely used in public address systems and sound motion pictures,

Problems:

1. A source of sound has a frequency of 512 Hz and an amplitude of 0.5 cm. What is the flow of energy across 1 m^z/sec if the velocity of sound in air is 340 m/s and the density of air is 1.29 kg/m^3?

   Solution:

   Flow of sound energy per unit area/sec, is = intensity of sound

   $\therefore$ I = $2\pi^2 f^2 \rho^2 a^2 c = 2\pi^2 \times (512)^2 \times (1.29)^2 \times (0.5\times10^{-2})^2\times340$

   = 7.32×10^4 $Jm^{-2}s^{-1}$

2. The sound from a drill gives a noise level of 90 dB at a point a few metre away from it. What is the noise level at this point when four such drills are working at the same distance away?

   Solution:

   Intensity level = 10 log $\left(\frac{I}{I_0}\right)$ 90 dB

   When four drills are working, the intensity will be 4I

   New Intensity level = 10log $\left(\frac{4I}{I_0}\right) dB$

   = 10log4 + 101og $\left(\frac{I}{I_0}\right)$

   = 10×0.6021+90

   = 96.021 Db

3. The intensity of sound in a busy street is 8×10^{-5} watt/m^2. Calculate the intensity level in dB.

   Solution:

   Intensity level == 10 log (I/I_o)

   = 10 log ($8\times10^{-5}/10^{-12}$)

   = 10 (log 8+log 10^7)

   = 10(0.9031+7)

= 79.031 dB

4. The power of sound from the loud speaker of a radio is increased from an initial value of 50 mW by adjusting the volume control. If the change in intensity level is 10 dB, what is the final value of power?

Solution:

Let P_0, P_1, P_2 are the standard power, initial power and final power respectively.

Initial intensity level = 10 log(p_1 / p_0)

Final intensity level = 10 log (p_2/p_0)

Change in intently level =10dB

= 10 [log(log(p_1/p_0) – log (p_1/p_0)]

= 10 log (p_1/p_2)

∴ log (p_2 / p_1) = 1

or p_2 = p_1

Hence p_2 = 10×50 mW = 500 mW

Final power of sound = 500 mW

5. A hall has a volume 2265 m^3. Its total absorption is equivalent to 92.9 m2 of open window. What will be the effect on reverberation time if an audience fills the hall and thereby increases the absorption by another 92.9 m^2?

Solution:

From Sabine's formula, reverberation time

$$T = \frac{0.16V}{A}$$

Initial reverberation time, $T_1 = \frac{0.16\times2265}{92.9} = 3.95$

When the audience fills the hall, the total absorption becomes 92.9×2m^2 of open window.

Final reverberation time, $T_2 = \frac{0.16\times2265}{2\times92.9} = 1.95$s

Thus the reverberation time is reduced to one-half of its initial value.

6. A price of wire 0.5m long is stretched by a load of 2.5 kg and has a mass of 1.44 grams. Find the frequency of the second harmonic.

Solution:

The second harmonic frequency is-given by

$$n = \frac{2}{2\times l}\sqrt{\frac{T}{m}}$$

$$= \frac{2}{2\times0.5}\sqrt{\frac{2.5\times9.8}{1.44\times10^{-3}/0.5}} = 184.22 \text{ Hz}$$

7. An air column closed at one end of length 0.17m has a frequency of 512 Hz in its first mode of vibration. If so calculate the wavelength and velocity of sound at the temperature.

Solution:

In the first mode of vibration of the closed tube, l = λ/4.

∴ λ = 4λ = 4 × 0.17 = 0.68 m

v = nλ = 512 × 0.68 = 348.16 m/s

8. An Ultrasonic generator consists of a quartz plate of thiclcness.0.7.him and density 2800 kg/m^3 with its free opposite faces vibrating longitudinally. Find the fundamental frequency of such an ultrasonic generator. Given that Young's modulus of quartz is 8.8× 10^{10} N/m^2.

Solution:

$$f = \frac{1}{2t}\sqrt{\frac{E}{\rho}} = \frac{1}{2\times0.7\times10^{-3}}\sqrt{\frac{8.8\times10^{10}}{2800}}$$

$$= 4\times10^6 Hz$$