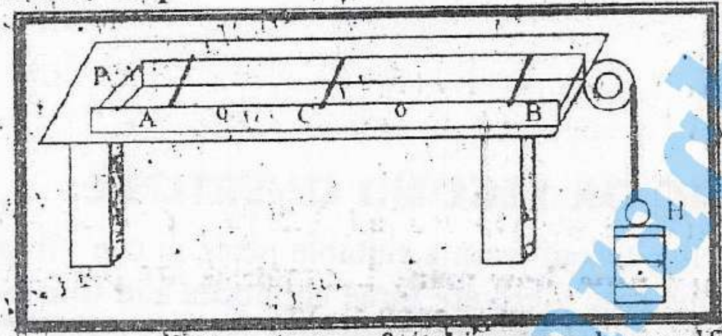
SONOMETER:

A sonometer consists of a sounding box with two fixed bridges A & B and one movable bridge C. A vibrating string is stretched over the bridges. End of the string is tied to a peg P at one end of the sounding box and the other end passes over a pulley and carries a hanger on which weights can be slipped. Increasing or decreasing the number of weights on the hanger can alter the stretched force or the tension "T" in the string. The string can be made to vibrate in many loops. The lowest or fundamental frequency will be obtained if the string over the two bridges AC or BC vibrates in one loop.



The laws of transverse vibrations of strings can be verified by sonometer for which we have to confine ourselves to the fundamental mode of vibration. If V be the frequency of vibration of fundamental mode, then it is given by.

$$\nu = \frac{V}{\lambda} \rightarrow (1)$$

Where $\lambda =$ wavelength $= 2L$

And $V =$ velocity of the wave $= \sqrt{\frac{T}{\mu}}$

Where $T =$ tension on the string &

$\mu =$ mass per unit length or linear density of the string

By putting the values of "V" and "λ" in e.g. (1), we get $\nu = \frac{V}{\lambda}$

$$\nu = \frac{\sqrt{T/\mu}}{\lambda L}$$

$$\boxed{\nu = \frac{1}{2L}\sqrt{\frac{T}{\mu}}} \longrightarrow (2)$$

From e.q. (2) we can write the following relations which are the laws of transverse vibrations of string.

LAWS OF TRANSVERSE VIBRATIONS OF STRING:

1. $\nu \propto \frac{1}{L}$ i.e frequency produced in the string is inversely proportional to its length for a given tension and linear density
2. $\nu \propto \sqrt{T}$ i.e for a given length and material, the frequency is directly proportional to the square root of the tension i.e. stretching force.
3. $\nu \propto \frac{1}{\sqrt{\mu}}$ i.e for a given length and tension, the frequency is inversely proportional to the square root of the linear density of the string.

SOUND

LONGITUDINAL WAVES:

Longitudinal waves are those in which particles of the medium vibrate along the direction of propagation of waves.

These waves consist of compressions and rarefactions. The waves in a helical spring and sound waves are the examples of longitudinal waves. Sound waves can travel through any material medium i.e gases, liquids and solids with a speed which depends upon the properties of the medium. Sound waves can be divided into three categories.

1. Audible sound waves,
2. Infrasonic waves and
3. Ultrasonic waves.

AUDIBLE WAVES:

The sound waves whose frequency lies between 20 Hertz and 20,000 Hertz are called audible waves. Musical instruments, human vocal chords, feathers of birds& insects etc, can produce audible waves.

INFRASONIC WAVES:

The sound waves whose frequency is less then 20 Hertz are called "infrasonic waves". Earthquake waves are the examples of infrasonic waves.

ULTRASONIC WAVES:

The sound waves whose frequency is greater than 20,000 Hertz are called "ultrasonic waves" these waves can be produced by inducing vibrations in a quartz crystal with an applied alternating electric field.

SPEED OF SOUND WAVES

NEWTON'S FORMULA FOR THE SPEED OF SOUND WAVES:

Sound waves are compressional waves, which propagate through a compressive medium such as air. The speed of such compressional waves depends upon the compressibility and the inertia of the medium. The compressible medium which has bulk modulus "B" & density (inertial property) "ρ" then the speed of sound "V" in the medium is given by.

$$V = \sqrt{\frac{B}{\rho}} \longrightarrow (1)$$

This formula is known as "Newton's formula" for the speed of sound waves.

The Bulk modulus is given by. $B = \dfrac{\text{stress}}{\text{volumetric strain}}$

As stress = F/A = ΔP = change in pressure, &

$$\text{volumetric strain} = \frac{\text{change in volume}}{\text{original volume}} = \frac{\Delta V}{V}$$

$$B = -\frac{\Delta P}{\frac{\Delta V}{V}}$$

The ratio $(\Delta P/\Delta V)$ is always negative because volume decreases as pressure increases and vice versa. This shows that "B" is always positive.

Sound waves are mechanical waves and the speed of all mechanical waves can be expressed in a general form as.

$$V = \sqrt{\frac{\text{Elastic property}}{\text{inertial property}}}$$

Newton assumed that the compressions and rarefactions take place at constant temperature. This process is called "ISOTHERMAL PROCESS" for constant temperature Newton used Boyle's law and found that

$B = P$ From eq. (1) $v = \sqrt{\frac{P}{\rho}}$

Erorr: speed of sound in air at O°C as calculated by Newton's formula is 281m/s.

But experimental value is 332 m/s.

There is an error of 16%.

LAPLACE'S CORRECTION:

Laplace corrected Newton's formula for the speed of sound. He said that during compression, temperature increases & during a rarefaction, temperature decreases. Thus the temperature of the medium does not remain constant. The compression and rarefactions occur "adiabatically. Under this condition

$$B = \gamma P$$

Where $\gamma = \frac{Cp}{Cv} = \frac{\text{Molar specific heat at constant pressure}}{\text{Molar specific heat at constant volume}} = 1.42$ **(For air)**

Thus eq. (1) becomes. $V = \sqrt{\frac{\gamma P}{\rho}} \longrightarrow (2)$

This is called Laplace correction.

SPEED OF SOUND AND TEMPERATURE:

By general gas equation

$$PV = nRT$$

$$P = \frac{nRT}{V}$$

Thus eq (2) becomes $V = \sqrt{\frac{\gamma nRT}{\rho V}}$

As ρ = density $= \frac{M}{V}$

Then $= \sqrt{\frac{\gamma nRT}{m}}$

Where R = Universal gas constant = 8.314 J/mole x K

T = absolute temperature of the gas

M = Molecular mass of gas (for air M=28.8 gm/mol)

n = number of moles

If $n = 1$ mole then

$$\boxed{V = \sqrt{\frac{\gamma RT}{M}}}$$

This shows that the speed of sound depends upon temperature. At $0°C$, the speed of sound in air is 332m/s. At any other temperature T_K, the speed of sound in air can be obtained by multiplying this result (i.e 332 m/s) by $\sqrt{\frac{T_K}{273}}$ thus

$$V = 332\sqrt{\frac{T_K}{273}}$$

MUSICAL SOUND AND NOISE:

The sound that produces pleasant effect on ear is known as musical sound and that which produces a jarring effect is know as noise. For example, the clamming of a door or the rumbling of a truck is considered as a noise whereas the sound produced by a piano or guitar is regarded as musical sound. If a graph is plotted between frequency and amplitude it will be irregular, non-symmetric, random fluctuations for noise as shown in fig (1) for musical sound it will be regular symmetric fluctuation periodic pattern as shown in fig (2).

Fig (1)

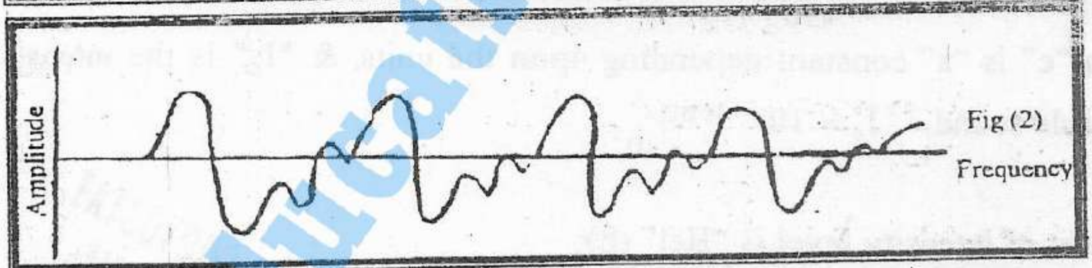


Fig (2)

CHARACTERISTICS OF MUSICAL SOUND:

Following are the characteristics of musical sound.

Intensity and loudness

Pitch or frequency

Quality or timber.

INTENSITY:

The energy of the sound waves passing every second through a unit area perpendicular to the direction of propagation of sound is called "intensity of sound." Its unit is watt/m^2.

Intensity of the sound is purely a physical quantity and can be measured accurately. It does not depend upon the auditory sensation of the ear.

LOUDNESS:

The magnitude of auditory sensation produced by the sound is called "loudness." It depends upon the intensity of the sound as well as the auditory sensation of the ear.

WEBER FECHNER LAW:

Loudness and intensity of sound are related with each other by a law called "Weber Fechner Law" according to law "the loudness is proportional to the logarithm of intensity" If "L" be the loudness and "I" be the intensity then by this law.

$$L \propto \log I$$

$$L = c \log I \longrightarrow (1)$$

Similarly if "L_0" be the loudness of faintest audible sound & "I_0" be its intensity then like equation (1) we can write

$$L_0 = c \log I_0 \longrightarrow (2)$$

INTENSITY LEVEL:

Intensity level is defined as difference in loudness of two sound.

Subtracting equation (2) from equation (1)

$$L - L_0 = c \log I - c \log I_0$$

$$L - L_0 = c \left[\log I - \log I_0\right]$$

$$L - L_0 = c \log \left(\frac{I}{I_0}\right)$$

$(L - L_0)$ is the difference of two loudness & is called as "INTENSITY LEVEL(β)"

$$\therefore \text{ Intensity level} = \beta = c \log \left(\frac{I}{I_0}\right) \longrightarrow (3)$$

When "c" is "a" constant depending upon the units, & "I_0" is the intensity of faintest audible sound. $I_0 = 10^{-12}\ \text{watt}/\text{m}^2$

Unit:

The unit of intensity level is "Bel" (β):

Intensity level of sound is 1 Bel if $I = 10\,I_0$

$$\therefore\ 1 = c \log \frac{10 I_0}{I_0}$$

$$1 = c \log 10$$

$$1 = c \times 1$$

$$\therefore\ c = 1 \text{ bel}$$

Bel is a large unit. The smaller unit is "decibel" (dB). $1\ \text{dB} = \frac{1}{10}$ Bel

When intensity level is measured in decibel C = 10 dB

Thus intensity level in decibel is given by (3) = $\beta = 10 \log \left[I/I_0\right]$

This is called dB scale for intensity level of sound.

If $I = 10{,}000\, I_0 = 10^4 I_0$ then

$$\beta = 10 \log \frac{10^4 I_0}{I_0}$$

$$\beta = 10 \times 4 = 40 \text{ dB}$$

POWER LAW:

A power law between loudness and intensity level of the sound is $L = K\left(\frac{I}{I_0}\right)^{0.3} \rightarrow (3)$

Where "K" is an arbitrary constant which can be evaluated by defining the unit of loudness which is "sone".

1 sone = 40 dB at 1000 Hz for this $I = 10^4 I_0$

This e.g. (3) becomes.

$$1 \text{ sone} = K\left(\frac{10^4 \ I_0}{I_0}\right)^{0.3} = K(10^4)^{0.3} = K10^{1.2}$$

$$K = \frac{1}{10^{1.2}} = \frac{1}{16}$$

Now equation (3) becomes. $\boxed{L = \frac{1}{16}\left(\frac{I}{I_0}\right)^{0.3}}$

This is called sone scale for loudness of sound.

PITCH:

It is defined as the sensation that sound produces in the ear of a listener. It is related to the frequency of sound. The greater the frequency greater the pitch & lower the frequency lower the pitch. The sound produced by various physical instruments usually depends upon the natural resonant frequency of the source. If the frequency is greater, sound will be shrill. If frequency is less, sound wave will be grave. The sound of a sparrow is shrill because its frequency or pitch is high while that of a Lamb is grave because its frequency or pitch is low.

QUALITY:

The characteristic of sound by which two sounds of same pitch & intensity can be distinguished is called "quality or timbre".

Quality of sound depends upon the resultant waveforms. The resultant waveform of any sound is reobtained by combining the amplitudes of fundamental & the harmonics of the given sound. Figure (1) shows fundamental, second harmonics & their resultant wave form. Figure (2) shows fundamentals third harmonic & their resultant wave form.

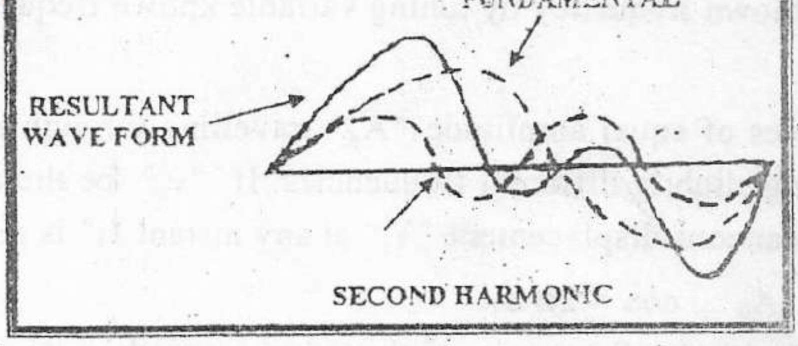
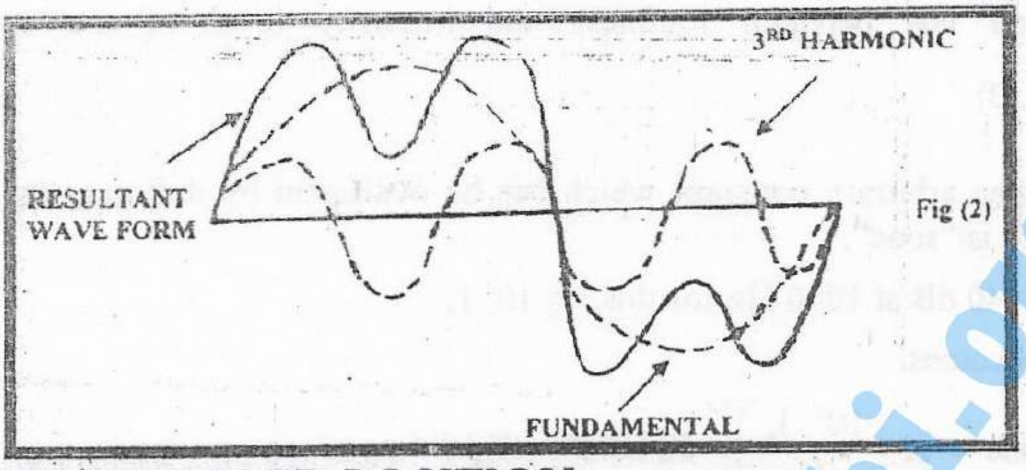


Fig (1)



PRINCIPLE OF SUPER POSITION:

According to the principle of super position when two or more waves travel, in the same medium the net displacement of the medium caused by the resultant wave at any point is equal to the algebraic sum of the displacement of all waves. i.e.

$$Y = Y_1 + Y_2 + Y_3 + \text{--------} Y_n.$$

BEATS:

When two sound waves of same amplitude & slightly different frequencies reach the ear, we do not hear two different sounds but a single sound which rises & falls in intensity periodically. This phenomenon is known as "BEATS".

Let us suppose that sound waves are produced in a big hall these sound waves spread out, scatter and strike the surfaces of the walls, the floor & the ceiling of the hall. Some of the sound energy is absorbed by these surfaces & some is reflected and travel back and when two sound waves are in phase, constructive interference takes place & loud sound is heard. When compression of one falls on rarefaction of the other, destructive interference takes place therefore no sound is heard.

One rise & one fall and then again rise of sound is known as one beat. The number of beats produced per second is called "beat frequency". It is equal to the difference in frequency of the two waves. It is denoted by "υ_b" if the frequency of the two sound waves are ν_1 & ν_2 then $\upsilon_b = \upsilon_1 - \upsilon_2$ the maximum beat frequency that the human ear can detect is about 7. When the beat frequency is greater then 7.we can not hear them clearly.

USES:

The phenomenon of beats is used:-

1. To adjust the frequency of various musical instruments
2. To find unknown frequency by tuning variable known frequency.

DERIVATION:

Consider two waves of equal amplitude "A_0" travelling through a medium in the same direction having slightly different frequencies. If "ν_1" be the frequency of one wave then its instantaneous displacement "Y_1" at any instant "t" is given by.

$$\therefore \quad Y_1 = A_0 \cos 2\pi \upsilon_1 t$$

Similarly if "ν_2" be the frequency of the other wave then its displacement "Y_2" at the instant "t" is given by. $Y_2 = A_0 \cos 2\pi\upsilon_2 t$

If "Y" be the resultant displacement caused by the two waves then.

$$Y = Y_1 + Y_2$$

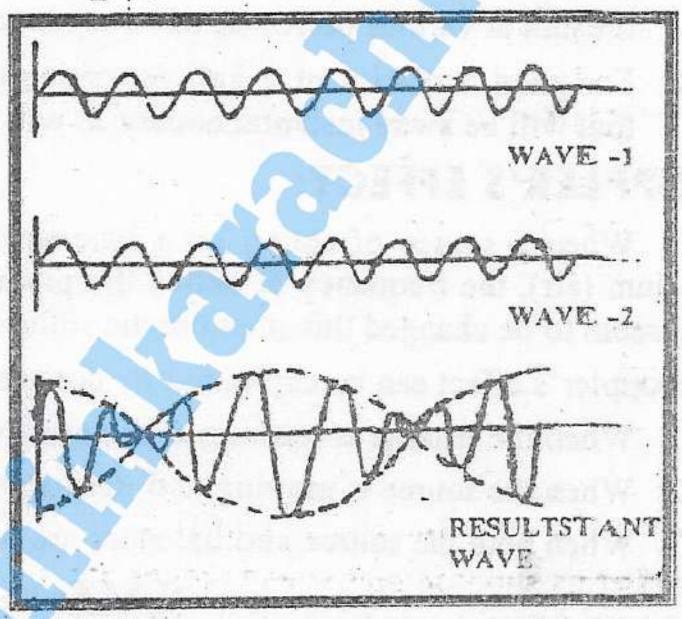
$$Y = A_0 \cos 2\pi \nu_1 t + A_0 \cos 2\pi \nu_2 t$$

$$Y = A_0 (\cos 2\pi \nu_1 t + \cos 2\pi \nu_2 t)$$

$$[\cos\alpha + \cos\beta = 2 \cos \frac{\alpha - \beta}{2} \cos \frac{\alpha + \beta}{2}]$$

$$Y = A_0[2\cos(\frac{2\pi\nu_1 t - 2\pi\nu_2 t}{2})\cos(\frac{2\pi\nu_1 t + 2\pi\nu_2 t}{2})]$$

$$Y = 2A_0 \cos 2\pi (\frac{\nu_1 - \nu_2}{2})t \cos 2\pi (\frac{\nu_1 + \nu_2}{2})t$$



In the above equation $\left(\frac{\nu_1 + \nu_2}{2}\right)$

is the " effective frequency" &

$\left[2A_0 \cos 2\pi \left(\frac{\nu_1 - \nu_2}{2}\right)t\right]$ is the

"amplitude" "A" i.e

$$A = 2A_0 \cos 2\pi \left(\frac{\nu_1 - \nu_2}{2}\right)t$$

The amplitude varies with frequency. $\frac{\nu_1 - \nu_2}{2}$ The amplitude will be maximum when $\cos 2\pi \left(\frac{\nu_1 - \nu_2}{2}\right)t$ have its maximum value

i.e $\cos 2\pi \left(\frac{\nu_1 - \nu_2}{2}\right)t = \pm 1$

It means that variation of frequency $\frac{\upsilon_1 - \upsilon_2}{2}$ occurs twice in on second, so beat frequency is given by.

$$\upsilon_b = 2\left(\frac{\upsilon_1 - \upsilon_2}{2}\right)$$

$$\upsilon_b = \upsilon_1 - \upsilon_2$$

This shows that the number of beats per second will be equal to the difference of frequencies of two second waves.

ACOUSTICS:

The study of production and properties of sound is called "acoustics". The term "acoustics" is also used to describe the way in which sound is reproduced in practical situations, the reproduced sound may be indistinct & confusing and may also be clear & distinct and may.

Recombine to form undesirable echoes. These echoes interfere with the original sound waves coming directly from source. This result in indistinct and unintelligible sound and hence give rise to bad Acoustics.

CONDITIONS FOR GOOD ACOUSTICS:

1. The deciphering of each syllable should be-small so that the succeeding syllable can be heard clearly.
2. The loudness of each syllable should be sufficiently large.
3. Echoes should be just sufficient to maintain the continuity of sound.
4. The hall should have some open windows. Sound absorbing soft porous materials like cloth, cork, asbestos etc. Or heavy curtains should be placed in the hall at various places so as to avoid much reflection.
5. For good acoustics of a hall reverberation should not be too small otherwise that will be away instantaneously & will give dead effect to the hall.

DOPPLER'S EFFECT:

When a source of sound or a listener, or both are in motion relative to the medium (air), the frequency & hence the pitch of the sound, as heard by the listener will seem to be changed this phenomena referred to as DOPPLER'S EFFECT.

Doppler's effect can be explained by considering three possibilities.

1. When the listener is moving & the source is at rest
2. When the source is moving and the listener is at rest
3. When both the source and listeners are moving

CASE-1 (A)

WHEN THE LISTENER IS MOVING TOWARDS A STATIONARY SOURCE

Consider a source emitting sound waves of frequency "υ". If "V" be the speed of sound waves then the wavelength "λ" of the waves is given by.

$$\lambda = \frac{V}{v} \rightarrow (1)$$

If listener is at rest then the waves will approach him with speed "V" but if listener is moving towards the source with speed "V_0" the sound waves approach him with a speed of $V + V_0$ thus he receives more waves per unit time as compared to that when he was at rest i.e. frequency increases. Thus if υ^1 be the changed frequency then it is given by.

$$\upsilon'\lambda = V + V_o$$

$$\upsilon' = \frac{V + V_o}{\lambda}$$

Putting the value of "λ" from e.q. (1) $\upsilon' = \dfrac{V + V_0}{\dfrac{V}{\upsilon}}$

$$\boxed{v' = \left(\frac{V + V_0}{V}\right) v} \longrightarrow (2)$$

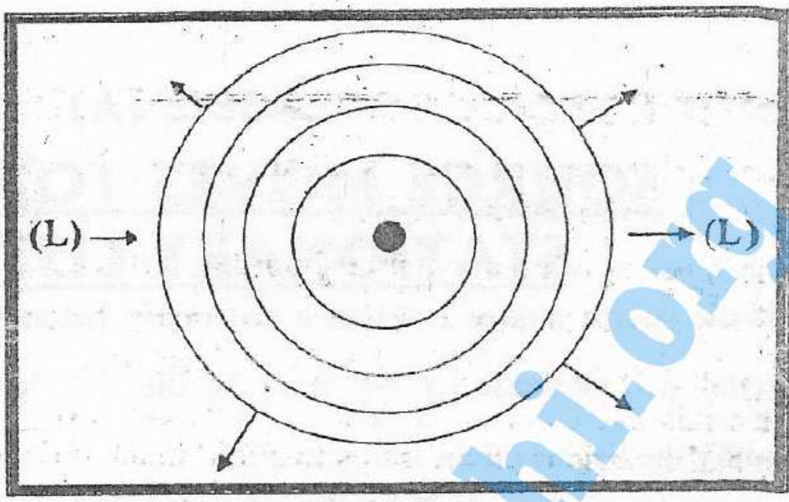
$$\nu' = \left(1+\frac{V_0}{V}\right)\nu$$

$$\nu' = \nu+\left(\frac{V_0}{V}\right)\nu$$

$$\nu' - \nu = \frac{V_0}{V}\nu$$

$$\nu' - \nu = \Delta\nu$$

$$\boxed{\Delta\nu = \frac{V_0}{V}\nu}$$



This gives change in frequency of sound heard by the listener.

CASE-1(B)

WHEN THE LISTENER MOVES AWAY FROM THE Stationary SOURCE

Consider a source emitting sound waves of frequency "υ". If "V" be the speed of sound waves then the wavelength "λ" of the waves is given by.

$$\lambda = \frac{V}{\nu} \rightarrow (1)$$

If listener is at rest then the waves will approach him with speed "V" but if listener is moving away from the source with speed "V_0" the sound waves approach him with a speed of $V-V_0$ thus he receives less waves per unit time as compared to that when he was at rest i.e. frequency decreases. Thus if υ' be the changed frequency then it is given by.

$$\upsilon'\lambda = V - V_0$$

$$\nu' = \frac{V-V_0}{\lambda}$$

Putting the value of "λ" from equation (1)

$$\nu' = \frac{V-V_0}{\frac{V}{\nu}}$$

$$\boxed{\nu' = \left(\frac{V-V_0}{V}\right)\nu} \longrightarrow (3)$$

$$\nu' = (1-\frac{V_0}{V})\nu$$

$$\nu' = \nu - \frac{V_0}{V}\nu$$

$$\nu' - \nu = -\frac{V_0}{V}\nu$$

$$\nu' - \nu = \Delta\nu$$

$$\boxed{\Delta\upsilon = -\frac{V_0}{V}\upsilon}$$

This gives change in frequency of sound heard by the listener. And shown that $\upsilon' < \upsilon$

CASE-2 (A)

SOURCE MOVES TOWARDS A STATIONARY LISTENER

If the source moves towards a stationary listener then wavelength received by the listener will decrease by $\frac{V_s}{V}$ if λ' be the wavelength (decreased) of the waves received by the listener then it is given by.

$$\lambda' = \lambda - \lambda_s$$

Where λ_s = increase in wave lenght due to motion of source.

$$\lambda' = \frac{V}{\nu} - \frac{V_s}{\nu} = \frac{V - V_s}{\nu} \rightarrow (4)$$

As the wavelength decreases, frequency increases. If "υ'" be the apparent frequency then it is given by $\upsilon' = \frac{v}{\lambda'}$ putting the value of λ' from eq (4)

$$\upsilon' = \frac{V}{\frac{V - V_s}{V}}$$

$$\boxed{\upsilon' = \left(\frac{V}{V - V_s}\right) \nu} \longrightarrow (5)$$

CASE-2 (B):

SOURCE MOVES AWAY FROM THE LISTENER

If the source moves away from the listener with velocity V_s, then the wavelength of the waves received by the listener will increase by. $\frac{V_s}{V}$ if λ be the

$\lambda' = \lambda - \lambda_s$ where λ_s = Decrease in wave length by the due to motion of source.

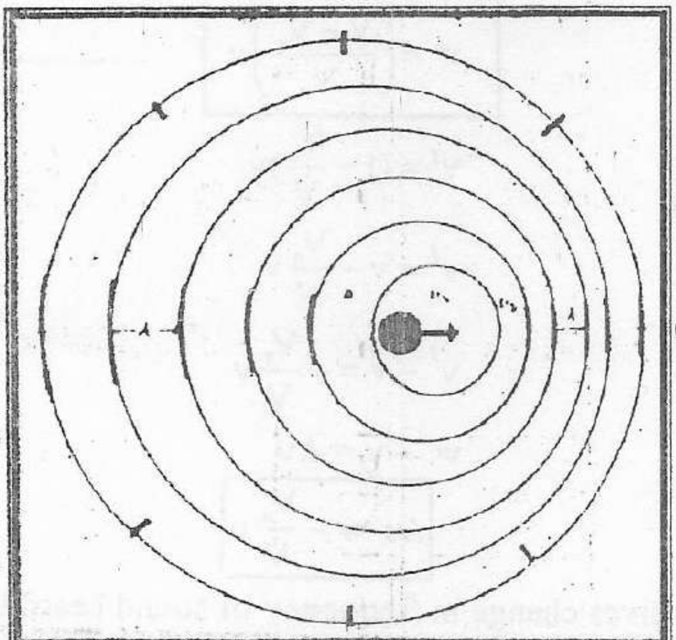
increased wavelength then it is given by. $\lambda' = \frac{V}{\nu} + \frac{V_s}{\nu} = \frac{V + V_s}{\nu} \rightarrow (6)$

As the wavelength increases, frequency decreases. If "υ'" be the apparent frequency then it is given by. $\upsilon' = \frac{V}{\lambda'}$

Putting thes value of λ' from eq. (6)

$$\upsilon' = \frac{V}{\frac{V + V_s}{\nu}}$$

(L)



(L)

For case 2 (b)

For Case 2 (a)

$$\therefore \boxed{\upsilon' = \left(\frac{V}{V + V_s}\right) \nu} \longrightarrow (7)$$

CASE-3(A):

SOURCE & LISTENER ARE MOVING TOWARDS EACH OTHER

If the listener is moving with velocity v_0 towards the source of sound then frequency changes from υ to υ' and is given by. $\upsilon' = \left(\frac{V+V_0}{V}\right)\upsilon \rightarrow (8)$

If the source of sound is also moving with velocity Vs towards two listeners then frequency further changes υ' to υ'' and is given by.

$$\upsilon'' = \left(\frac{V}{V - Vs}\right)\upsilon' \rightarrow (9)$$

Putting the value of υ' from e.q. (8) in e.g. (9)

$$\upsilon'' = \left(\frac{V}{V - V_s}\right)\left(\frac{V+V_0}{V}\right)\upsilon$$

$$\therefore \boxed{\upsilon'' = \left(\frac{V+V_0}{V - Vs}\right)\upsilon}$$

CASE-3(B):

SOURCE & LISTENER ARE MOVING AWAY FROM EACH OTHER

If the listener is moving with velocity V_0 away from the source of sound then frequency changes from υ to υ' & is given by.

$$\upsilon' = \left(\frac{V - V_0}{V}\right)\upsilon \rightarrow (10)$$

If the source of sound is also moving with velocity V_s away from the listener then frequency further changes.

From υ' to υ'' & is given by. $\upsilon'' = \left(\frac{V}{V+V_s}\right)\upsilon' \rightarrow (11)$

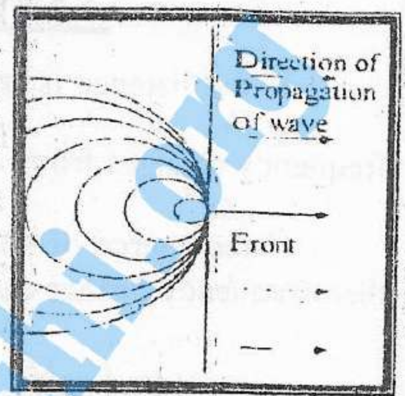
Putting the value of υ' from eq (10) in e.g (11)

$$\therefore \boxed{\upsilon'' = \left(\frac{V - V_0}{V+V_s}\right)\upsilon}$$

SPECIAL CUSSES:-

WHEN VELOCITY OF SOURCE IS EQUAL TO THE VELOCITY OF SOUND:

When velocity of source is equal to the velocity of sound i.e $V_S = V$ then the source & sound waves move intact with each other and high pressure is formed. As the process continues the pile region extends further and further from the source in the direction perpendicular to its motion due to which a thick wave front or sheet is formed as shown in the figure. This sheet exerts tremendous pressure on the source.



WHEN VELOCITY OF SOURCE IS GREATER THAN THE VELOCITY OF SOUND:

When velocity of sound exceeds the wave speed i.e $V_s > V$ the source runs ahead of outgoing waves and in such a case the waves pile up and produce the shape of a cone with the moving object at its apex, as shown in figure.

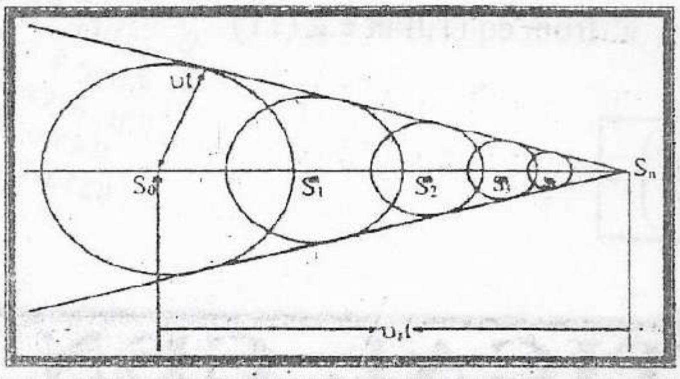
To explain this situation consider the source at S_o when $t = 0$. after time "t" the wave front will cover the distance "vt" while the source will cover a distance "$V_s t$" at this instant the source is at "S_n" & the waves just beginning to be generated at this point have wave of zero radius.

If the source were at "S_1" the mid point of "S_o" & "S_n" then after time $\frac{T}{2}$ it will cover distance $\frac{V_s t}{2}$ while the wave point will cover distance $\frac{Vt}{2}$ if the source were at S_2 the mid point of S_1 & S_n then after time t/4 it will cover distance $\frac{V_s t}{4}$ while the wave front will cover distance $\frac{Vt}{4}$ if the lines are drawn to join S_n & the wave fronts centered on S_0, S_1 & S_2, a cone shaped wave front is formed as shown in the figure. If θ be the angle between the direction of motion of source and the cone shaped wave front then.

$$\text{Sin } \theta = \frac{Vt}{V_s t} = \frac{V}{V_s}$$

In aerodynamics the ratio $\frac{V_s}{V}$ is referred to as the "Mach number".

Along the cone-shaped wave front, that is produced by supersonic object, the air is highly compressed. This moving sheet of high pressure air is called SHOCK WAVE. This shock wave will result in loud explosion of sonic boom which can damage buildings if the source is near to it.



APPLICATION OF THE DOPPLER EFFECT:

(i) Tracking a Satellite:

The Doppler effect provides a method for tracking a satellite Suppose the satellite is emitting a radio signal (i.e an electromagnetic wave) of constant frequency fs. The frequency f_L of the signal received on the earth decreases as the satellite is passing. The received signal is combined with a constant signal generated in the receiver to produce beat. The beat frequency produces an audible note whose pitch changes as the satellite passes overhead.

(ii) Radar gun:

The Doppler effect is used in measuring the speed of automobile by traffic police. A "radar gun" is fixed on police car. An electromagnetic signal is emitted by the radar gun in the direction of the automobile whose speed is to be checked. The wave is reflected from the moving automobile and received back. The reflected wave is then mixed with the locally generated original signal and beats are produced. The frequency shift is measured using beats and hence the speed of the automobile is determined.

(iii) Radars:

Radars (Radio detection and ranging) are commonly used for civil and military purposes at civilian airports and military air-bases respectively, to detect the presence of any aircraft (for or friend) in the airspace by evaluating the range. The Doppler Radar is based on the principle of the Doppler Effect, and is extensively used in the detection of aircraft speed and direction.

(iv) VOR:

VOR (very high frequency Omni Range) is a guiding system usually installed at the airports to guide the incoming aircrafts toward to location of the airport. Nowadays big and modern airports for example Quaid-e-Azam International Airport, Islamabad Airport, are equipped with Doppler VOR whose principle is once again based on the Doppler effect and provides air effective and better guiding system to the aircraft. The electromagnetic signal used here has frequency in the VHF range (30MHz – 300MHz).

(v) Homosonde:

X – rays have been a major diagnostic tool of medicine, but recent years have seen the emergence of an alternate tool which is inherently safer then X – rays: ultrasound. Unlike X – rays, ultrasound radiations have not been reported to damaged living cells so far. Measurements of internal reflections of ultra sound have facilitated the diagnosis of breast cancer and taking the heartbeats of fetuses and newborns.

An ultrasonic instrument called Homosonde uses the Doppler effect of ultrasonic waves reflected from moving masses in the patient. The device is very sensitive for detecting blood flow and measures faint heartbeats in a very noisy environment where the use of stethoscope may not be reliable.

(vi) Sonar:

In similar manner, we can detect the motion of an objects under-water (for example a submarine) by employing sonar (ultrasonic waves) based on effective use of Doppler effect.

(vii) Red Shift:

The Doppler effect for light is important in astronomy. Spectral analysis of light emitted by the elements in distant stars shows shift in the wavelength compared to light from the same element on earth. These shifts can be interpreted as Doppler shifts due to the motion of the stars. The shift is nearly always toward the longer wavelength, or red end of the spectrum, and is therefore called the red shift. Such observations have provided practically all the evidence for "expanding universe" cosmological theories, which represents the universe as having evolved from a great explosion several billion years ago in a relatively small region of space.