14.1.1 INTRODUCTION

In the previous Chapter, we studied the motion of objects oscillating in isolation. What happens in a system, which is a collection of such objects ? A material medium provides such an example. Here, elastic forces bind the constituents to each other and, therefore, the motion of one affects that of the other. If you drop a little pebble in a pond of still water,the water surface gets disturbed. The disturbance does not remain confined to one place, but propagates outward along a circle. If you continue dropping pebbles in the pond, you see circles rapidly moving outward from the point where the water surface is disturbed. It gives a feeling as if the water is moving outward from the point of disturbance. If you put some cork pieces on the disturbed surface, it is seen that the cork pieces move up and down but do not move away from the centre of disturbance. This shows that the water mass does not flow outward with the circles, but rather a moving disturbance is created. Similarly, when we speak, the sound moves outward from us, without any flow of air from one part of the medium to another. The disturbances produced in air are much less obvious and only our ears or a microphone can detect them. These patterns, which move without the actual physical transfer or flow of matter as a whole, are called waves. In this Chapter, we will study such waves.

In a wave, information and energy, in the form of signals, propagate from one point to another but no material object makes the journey. All our communications depend on the transmission of signals through waves. When we make a telephone call to a friend at a distant place, a sound wave carries the message from our vocal cords to the telephone. There, an electrical signal is generated which propagates along the copper wire. If the distance is too large, the electrical signal generated may be transformed into a light signal or electromagnetic waves and transmitted through optical cables or the atmosphere, possibly by way of a communication satellite. At the receiving end, the electrical or light signal or the electromagnetic waves are transformed back into sound waves travelling from the telephone to the ear.

Not all waves require a medium for their propagation. We know that light waves can travel through vacuum. The light emitted by stars, which are hundreds of light years away, reaches us through inter-stellar space, which is practically a vacuum.

The waves we come across are mainly of three types: (a) mechanical waves, (b) electromagnetic waves and (c) matter waves. Mechanical waves are most familiar because we encounter them constantly; common examples include water waves, sound waves, seismic waves, etc. All these waves have certain central features : They are governed by Newton’s laws, and can exist only within a material medium, such as water, air, and rock. The common examples of electromagnetic waves are visible and ultraviolet light, radio waves, microwaves, x-rays etc. All electromagnetic waves travel through vacuum at the same speed c, given by

$$c = 299,792,458 \text{ m s}^{-1} \text{ (speed of light)}$$

Unlike the mechanical waves,the electro-magnetic waves do not require any medium for their propagation. You would learn more about these waves later.

Matter waves are associated with moving electrons, protons, neutrons and other fundamental particles, and even atoms and molecules. Because we commonly think of these as constituting matter, such waves are called matter waves. They arise in quantum mechanical description of nature that you will learn in your later studies. Though conceptually more abstract than mechanical or electromagnetic waves, they have already found applications in several devices basic to modern technology; matter waves associated with electrons are employed in electron microscopes.

In this chapter we will study mechanical waves, which require a material medium for their propagation.

The aesthetic influence of waves on art and literature is seen from very early times; yet the first scientific analysis of wave motion dates back to the seventeenth century. Some of the famous scientists associated with the physics of wave motion are Christiaan Huygens (1629-1695), Robert Hooke and Isaac Newton. The understanding of physics of waves followed the physics of oscillations of masses tied to springs and physics of the simple pendulum. Waves in elastic media are intimately connected with harmonic oscillations. (Stretched strings, coiled springs, air, etc., are examples of elastic media.) We shall illustrate this connection through simple examples.

A collection of springs connected to each other. The end A is pulled suddenly generating a disturbance, which then propagates to the other end.

Consider a collection of springs connected to one another as shown in Fig. If the spring at one end is pulled suddenly and released, the disturbance travels to the other end. What has happened ? The first spring is disturbed from its equilibrium length. Since the second spring is connected to the first, it is also stretched or compressed, and so on. The disturbance moves from one end to the other; but each spring only executes small oscillations about its equilibrium position. As a practical example of this situation, consider a stationary train at a railway station. Different bogies of the train are coupled to each other through a spring coupling. When an engine is attached at one end, it gives a push to the bogie next to it; this push is transmitted from one bogie to another without the entire train being bodily displaced.

Now let us consider the propagation of sound waves in air. As the wave passes through air, it compresses or expands a small region of air. This causes a change in the density of that region, say $\delta\rho$, this change induces a change in pressure, δp, in that region. Pressure is force per unit area, so there is a restoring force proportional to the disturbance, just like in a spring. In this case, the quantity similar to extension or compression of the spring is the change in density. If a region is compressed, the molecules in that region are packed together, and they tend to move out to the adjoining region, thereby increasing the density or creating compression in the adjoining region. Consequently, the air in the first region undergoes rarefaction. If a region is comparatively rarefied the surrounding air will rush in making the rarefaction move to the adjoining region. Thus, the compression or rarefaction moves from one region to another, making the propagation of a disturbance possible in air.

In solids, similar arguments can be made. In a crystalline solid, atoms or group of atoms are arranged in a periodic lattice. In these, each atom or group of atoms is in equilibrium, due to forces from the surrounding atoms. Displacing one atom, keeping the others fixed, leads to restoring forces, exactly as in a spring. So we can think of atoms in a lattice as end points, with springs between pairs of them.

In the subsequent sections of this chapter we are going to discuss various characteristic properties of waves.

Mechanical & Non – Mechanical Waves:

A wave that travels from a source into an infinite medium and never returns to the origin is called a progressive wave.

However a wave may or may not require a medium for its propagation. The waves which require a medium for their propagation are called mechanical wave. Water for their propagation are called mechanical waves. Water waves and sound waves are the examples of this type. Mechanical waves are also called elastic waves.

The waves which don't require a medium for their prorogation are called Non – mechanical or

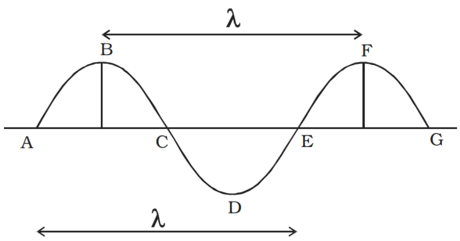
Electromagnetic waves. Light waves, heat radiations and radio waves are the examples of this type. In this chapter we restrict only to one dimensional mechanical waves.

14.1.2 Mechanical wave motion

The two types of mechanical wave motion are (i) transverse wave motion and (ii) longitudinal wave motion

(i) Transverse wave motion

Transverse wave motion is that wave motion in which particles of the medium execute SHM about their mean positions in a direction perpendicular to the direction of propagation of the wave. Such waves are called transverse waves. Examples of transverse waves are waves produced by plucked strings of veena, sitar or violin and electromagnetic waves. Transverse waves travel in the form of crests and troughs. The maximum displacement of the particle in the positive direction i.e. above its mean position is called crest and maximum displacement of the particle in the negative direction i.e below its mean position is called trough.



Transverse wave

Thus if ABCDEFG is a transverse wave, the points B and F are crests while D is trough (Fig.).

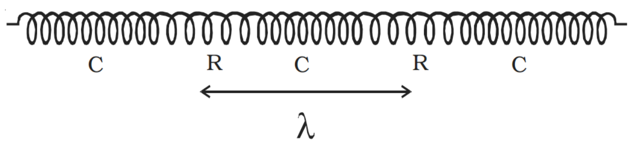
For the propagation of transverse waves, the medium must possess force of cohesion and volume elasticity. Since gases and liquids do not have rigidity (cohesion), transverse waves cannot be produced in gases and liquids. Transverse waves can be produced in solids and surfaces of liquids only.

(ii) Longitudinal wave motion

'Longitudinal wave motion is that wave motion in which each particle of the medium executes simple harmonic motion about its mean position along the direction of propagation of the wave.'

Sound waves in fluids (liquids and gases) are examples of longitudinal wave. When a longitudinal wave travels through a medium, it produces compressions and rarefactions.

In the case of a spiral spring, whose one end is tied to a hook of a wall and the other end is moved forward and backward, the coils of the spring vibrate about their original position along the length of the spring and longitudinal waves propagate through the spring (Fig.).



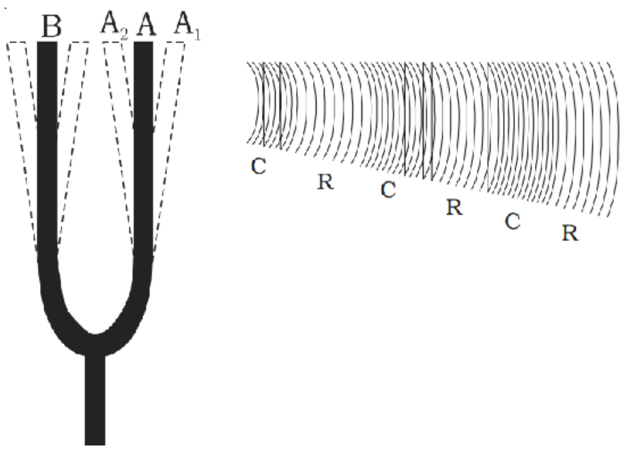
Compression and rarefaction in spring

The regions where the coils are closer are said to be in the state of compression, while the regions where the coils are farther are said to be in the state of rarefaction.

When we strike a tuning fork on a rubber pad, the prongs of the tuning fork begin to vibrate to and fro about their mean positions. When the prong A moves outwards to A_1, it compresses the layer of air in its neighborhood. As the compressed layer moves forward it compresses the next layer and a wave of compression passes through air. But when the prong moves inwards to A_2, the particles of the medium which moved to the right, now move backward to the left due to elasticity of air. This gives rise to rarefaction.

Thus a longitudinal wave is characterised by the formation of compressions and rarefactions following each other.

Longitudinal waves can be produced in all types of material medium, solids, liquids and gases. The density and pressure of the medium in the region of compression are more than that in the region of rarefaction



Longitudinal wave

14.1.3 Important Definitions:

a) Amplitude: The maximum displacement of a particle from its mean position in wave motion is called amplitude.

b) Phase: The phase of vibrating particle at any instant is the state of the particle in regard to its position and direction of motion in the path of its vibration. Two particles moving in the same state of vibration are said to be in the same phase.

c) Wave length (λ): The distance between two successive particles in wave motion which are in the same state of vibration or in the same phase.

It is also defined as the distance travelled by the wave by the time the particle of medium completes one oscillation.

d) Time Period(T): The time taken by a wave to travel a distance of one wavelength(λ) is called the period of the wave motion. (or) It is also equal to the period of oscillation of any particle on the wave.

e) Frequency(f): The frequency of wave motion is the number of vibrations made by a particle of the medium per second and is equal to the number of waves passing any given point per second.

Frequency $f = 1/T$.

The unit of frequency is vibrations per second (or) c.p.s or Hertz (Hz).

f) Wave Velocity (V): The distance through which the wave travels in unit time is called the wave velocity (V).

14.2.1 Progressive wave

A progressive wave is defined as the onward transmission of the vibratory motion of a body in an elastic medium from one particle to the successive particle.

Equation of a plane progressive wave

An equation can be formed to represent generally the displacement of a vibrating particle in a medium through which a wave passes. Thus each particle of a progressive wave executes simple harmonic motion of the same period and amplitude differing in phase from each other.

Let us assume that a progressive wave travels from the origin O along the positive direction of X axis, from left to right (Fig).The displacement of a particle at a given instant is

$$y = a \sin \omega t \qquad ... (1)$$

where a is the amplitude of the vibration of the particle and $\omega = 2\pi n$

The displacement of the particle P at a distance x from O at a given instant is given by,

$$y = a \sin (\omega t - \phi) \qquad ... (2)$$

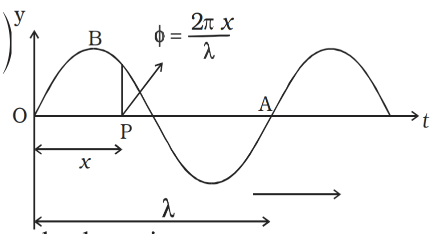
If the two particles are separated by a distance λ, they will differ by a phase of 2π.

Therefore, the phase φ of the particle P at a distance x is $\phi = \frac{2\pi}{\lambda}.x$ ...(3)

Since $\omega = 2\pi n = 2\pi \frac{v}{\lambda}$, the equation i given by

$$y = a \sin \left(\frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}\right)$$

$$y = a \sin \frac{2\pi}{\lambda}(vt - x)$$



Since $\omega = \frac{2\pi}{T}$, the eqn. (3) can also be written as

$$y = a \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \qquad ...(5)$$

If the wave travels in opposite direction, the equation becomes.

$$y = a \sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right) \qquad ...(6)$$

(i) Variation of phase with time

The phase changes continuously with time at a constant distance.

At a given distance x from O let ϕ_1 and ϕ_2 be the phase of a particle at time t_1 and t_2 respectively

$$\phi_1 = 2\pi\left(\frac{t_1}{T} - \frac{x}{\lambda}\right)$$

$$\phi_2 = 2\pi\left(\frac{t_2}{T} - \frac{x}{\lambda}\right)$$

$$\therefore\ \phi_1 - \phi_2 = 2\pi\left(\frac{t_1}{T} - \frac{t_2}{T}\right) = 2\pi(t_2 - t_1)$$

$$\Delta\phi = \frac{2\pi}{T}\Delta t$$

This is the phase change $\Delta\phi$ of a particle in time interval Δt. If$\Delta t = T$, $\Delta\phi = 2\pi$. This shows that after a time period T, the phase of a particle becomes the same.

(ii) Variation of phase with distance

At a given time t phase changes periodically with distance x. Let ϕ_1 and ϕ_2 be the phase of two particles at distance x_1 and x_2 respectively from the origin at a time t.

$$\phi_1 = 2\pi\left(\frac{t}{T} - \frac{x_1}{\lambda}\right)$$

$$\phi_2 = 2\pi\left(\frac{t}{T} - \frac{x_2}{\lambda}\right)$$

$$\therefore\ \phi_1 - \phi_2 = -2\pi(x_2 - x_1)$$

$$\Delta\phi = -\frac{2\pi}{T}\Delta x$$

The negative sign indicates that the forward points lag in phase when the wave travels from left to right.

When $\Delta x = \lambda$, $\Delta\phi = 2\pi$, the phase difference between two particles having a path difference λ is 2π.

14.2.2 Characteristics of progressive wave

1. Each particle of the medium executes vibration about its mean position. The disturbance progresses onward from one particle to another.
2. The particles of the medium vibrate with same amplitude about their mean positions.
3. Each successive particle of the medium performs a motion similar to that of its predecessor along the propagation of the wave, but later in time.
4. The phase of every particle changes from 0 to 2π.
5. No particle remains permanently at rest. Twice during each vibration, the particles are momentarily at rest at extreme positions, different particles attain the position at different time.
6. Transverse progressive waves are characterised by crests and troughs. Longitudinal waves are characterised by compressions and rarefactions.
7. There is a transfer of energy across the medium in the direction of propagation of progressive wave.
8. All the particles have the same maximum velocity when they pass through the mean position.
9. The displacement, velocity and acceleration of the particle separated by $m\lambda$ are the same, where m is an integer.

14.2.3 Different forms of progressive wave:

A plane progressive wave (either transverse or longitudinal, mechanical or non – mechanical) can be written in many forms such as:

i) $y = A \sin[\omega t - kx]$

ii) $y = A \cos[\omega t - kx]$

iii) $y = A \sin 2\pi\,[ft - (x/\lambda)]$

as $[\omega = 2\pi f$ and $k =- (2\pi/\lambda)]$

iv) $y = A \sin 2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right]$ [as $f = 1/T$]

v) $y = A \sin k[Vt - x]$ since $V = \frac{\omega}{k}$

vi) $y = A \sin \omega\,[t - (x/V)]$

14.2.4 Energy, Power and Intensity of a wave:

If a wave given by $y = A \sin(\omega t - kx)$is propagating through a medium, the particle velocity will be

$$v_p = \frac{dy}{dt} = A\omega \cos(\omega t - kx)$$

So if ρ is the density of the medium, kinetic energy of the wave per emit volume will be

$$= \frac{1}{2}\rho\left[\frac{dy}{dt}\right]^2 = \frac{1}{2}\rho\,\omega^2 A^2 \cos^2(\omega t - kx)$$

So if ρ is the density of the medium, kinetic energy of the wave per unit volume will be

$$= \frac{1}{2}\rho\left[\frac{dy}{dt}\right]^2 = \frac{1}{2}\rho\omega^2 A^2 \cos^2(\omega t - kx)$$

and its maximum value will be equal to energy unit volume i.e., energy density U.

$$U = \frac{1}{2}\rho A^2\omega^2$$

So the energy associated with a volume $\Delta V = S\Delta x$ will be (where 'S' is the area of cross section).

$$\Delta E = U\Delta V = \frac{1}{2}\rho A^2\omega^2 \; S\Delta x$$

So power (rate of transmission of energy) will be $P = \frac{\Delta E}{\Delta t} = \frac{1}{2}\rho V\omega^2 A^2 S$

[as $\frac{\Delta x}{\Delta t} = V$, (speed of wave)]

Now as Intensity is defined as power per unit area. So

$$I = \frac{\Delta E}{\Delta t} = \frac{P}{S} = \frac{1}{2}\rho V\omega^2 A^2$$

$$\Rightarrow I = 2\pi^2 f^2 A^2 \rho V$$

If f is constant then $I \propto A^2$

14.2.5 Relation between wave velocity and particle velocity:

A plane progressive wave propagating along positive x – axis is given by

$$y = A \sin(\omega t - kx)$$

So the velocity of a particle on it will be

$$v_p = \frac{dy}{dx} = A\omega \cos(\omega t - kx)$$

Furthermore, the slope of the wave will be

$$\frac{dy}{dx} = -Ak \cos(\omega t - kx)$$

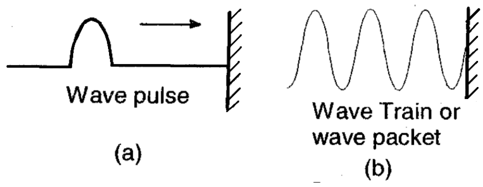
From 1 & 2 $\quad \frac{dy}{dx} = -Ak \frac{v_p}{A\omega} = -\frac{v_p}{V}$

$\therefore \quad v_p = -V \times$ (slope of the wave)

i.e., particle velocity at a given position and time is equal to negative of the product of wave velocity with slope of the wave at that point.

14.2.6 Wave pulse and wave train:

A wave pulse is a short wave produced in a medium when the disturbance is created for a short time. When pulse travels through the medium each particle in the medium begins at rest experiences a displacement as the pulse passes through it and then returns to the mean position. A wave pulse is generated in a string by rapidly displacing one end of the string up and down at once.



es of wave pulses. A wave train can be generated on a string by continuously moving the end of the string up and down.

Speed of a travelling wave:

To determine the speed of propagations of travelling wave, we can fix our attention on an particular point on the wave (characterized by some value of the phase) and see how that point moves in time. It is convenient to look at the motion of the crest of the wave. Fig. gives the shape of the wave at two instants of time which differ by a small time internal Δt, The entire wave pattern is seen to shift to the right (positive direction of x – axis) by a distance Δx. In particular the crest shown by a dot (●) moves a distance Δx in time Δt. The speed of the wave is then Δx/Δt. We can put the dot (●) on a point with any other phase. It will move with the same speed v (otherwise the wave pattern will not remain fixed). The motion of fixed phase point on the wave is given by

$$kx - \omega t = \text{constant}$$

Thus, as time t changes, the position x of the fixed phase point must changes so that the phase remains constant. Thus

$$kx - \omega t = k(x + \Delta x) - \omega(t + \Delta t) \quad \text{(or)}$$

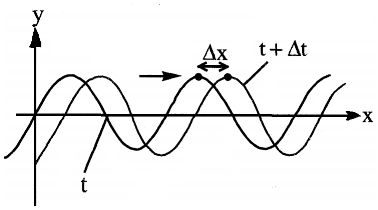
$$k\Delta x - \omega\Delta t = 0$$

Taking Δx , Δt vanishingly small, this gives

$$\frac{\Delta x}{\Delta t} = \frac{\omega}{k} = v \qquad ...(1)$$

Relating ω to T and k to λ, we get

$$v = \frac{2\pi\omega}{2\pi k} = \lambda f = \frac{\lambda}{T} \quad ....(2)$$



It is a general relation for all progressive waves, showing that in the time required for one full oscillation by any constituent of the medium, the wave pattern travels a distance equal to the wavelength of the wave. It should be noted that the speed of a mechanical wave is determined by the inertial (linear mass density for strings, mass density in general) and elastic properties (young's modulus for linear media/ shear modulus, bulk modulus) of the medium. The medium determines the speed; Eq.(2) then relates wavelength to frequency for the given speed. Of course, as remarked earlier, the medium can support both transverse and longitudinal waves, which will have different speeds in the same medium.

Speed of a transverse wave on stretched string:

The speed of mechanical wave is determined by the restoring force setup in the medium when it is disturbed and the inertial properties (mass density) the medium. The speed is expected to be directly related to the former and inversely to the latter. For waves on a string, the restoring force is provided by the tension T in the string. The inertial property will in this case be linear mass density μ, which is mass m of the string divided by its length L. Using Newton's Law of Motion, an exact formula for the wave speed on a string can be derived.

14.2.7 Expression for the wave speed on a string using dimensional analysis:

The dimension of μ is $[ML^{-1}]$ and that of T is like force, namely $[MLT^{-2}]$. We need to combine these dimensions to get the dimension of speed $v[LT^{-1}]$. Simple inspection shows that the quantity T/μ has the relevant dimension.

$$\frac{[MLT^{-2}]}{[ML^{-1}]} = [L^2T^{-2}]$$

Thus if T and μ are assumed to be the only relevant physical quantities.

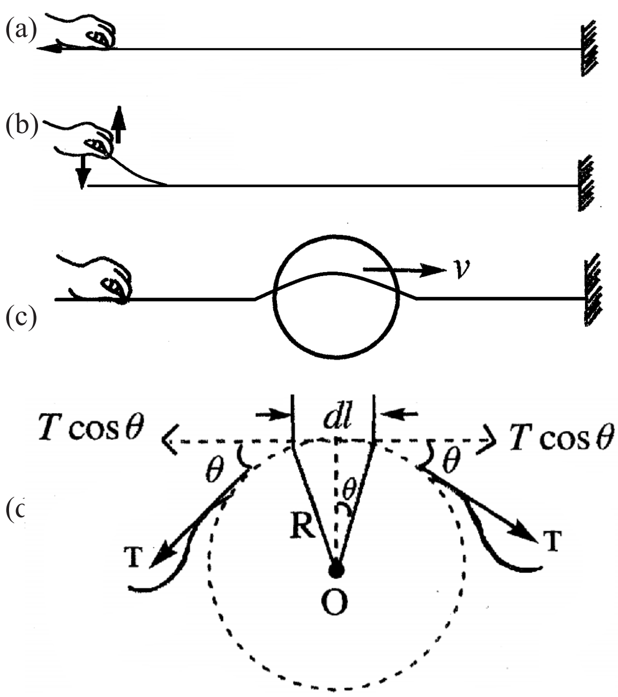
$$v = C\sqrt{\frac{T}{\mu}} \quad ...(1)$$

Where C is the undetermined constant of dimensional analysis. In the exact formula, it turns out, C = 1. The speed of transverse waves on a stretched string is given by

$$v = \sqrt{\frac{T}{\mu}} \quad ....(2)$$

Speed of Transverse wave in a string (II method):

On a stretched string if a transverse jerk is given, a pulse is created (fig. c), which travels toward right with a wave speed v. For convenience, we choose a reference frame in which the pulse remains stationary. That is, we run along with the pulse, keeping it constantly in view. In this frame, the string appears to move past us, from right to left with speed v. We start our analysis by looking at the pulse carefully as shown in enlarged view (fig. d).



Now consider a small element of length *dl* on this pulse shown. This element is forming an arc, say of radius R with centre at O and subtending an angle 2θ at O. We can see that two tensions T are acting on the edges of *dl* along tangential directions (fig. d). The horizontal components of these tensions cancels each other, but the vertical components add to form a radial restoring force in downward direction, which is given as

$$F_R = 2T \sin\theta$$

$$\simeq 2T\theta \qquad [\text{As } \sin\theta \simeq \theta]$$

$$= T\frac{dl}{R} \qquad [\because 2\theta = \frac{dl}{R}] \quad ....(1)$$

If μ be the mass per unit length of the string, the mass of this element is given as dm = μ*dl*. As the element of string is moving with velocity v in an arc of circle, it has centripetal acceleration towards the centre of circle given by

$$a = v^2/R \qquad ....(2)$$

Now from equations (1) and (2) we have

$$F_R = \frac{(dm)v^2}{R} \text{ or } T\frac{dl}{R} = \frac{(\mu dl)v^2}{R} \text{ or } v = \sqrt{\frac{T}{\mu}} \quad ...(3)$$

Note the important point that the speed v depends only on the properties of the medium T and μ (T is a property of the stretched string arising due to an external force). It does not depend on wave length or frequency of the wave itself.

14.2.8 Speed of Longitudinal Waves:

We know that in a longitudinal wave, the constituents of the medium oscillate forward and backward in the direction of propagation of the wave. Therefore, a longitudinal wave travels through a medium in the form of compressions and rarefactions. The property that determines the fractional change in volume (ΔV/V) when pressure is changed by (ΔP) is bulk modulus B of the medium, given by

$$B = \frac{\Delta P}{\Delta V/V} \qquad ...(1)$$

As compressions and rarefactions involve changes in density (ρ) of the medium, therefore, speed of a longitudinal wave would depend upon two factors : bulk modulus B and density ρ.

We can use method of dimensions to derive an expression for the speed v of the longitudinal waves.

Let $v \propto B^a\rho^b$ where a and b are the dimensions.

$$v = k\,B^a\rho^b \qquad ...(2)$$

where k is a dimensionless constant of proportionality.

Now,

$v = [M^0L^1T^{-1}]$, $B = [M^1L^{-1}T^{-2}]$, $\rho = [M^1L^{-3}T^0]$

Putting in (2), we get

$[M^0L^1T^{-1}] = [M^1L^{-1}T^{-2}]^a\,[M^1L^{-3}T^0]^b = M^{a+b}L^{-a-3b}T^{-2a}$

Applying the principle of homogeneity of dimensions, we get

$$a + b = 0 \qquad ...(3)$$

$$-a - 3b = 1$$

$$-2a = -1,\ a = 1/2$$

From (3), $b = -a = -1/2$

Putting in (2), we get $v = k\,B^{1/2}\rho^{1/2} = k\sqrt{\frac{B}{\rho}}$

By other methods, we can show that dimensionless constant, k = 1.

$$\therefore \quad v = \sqrt{\frac{B}{\rho}} \qquad ...(4)$$

This is the expression for speed of a longitudinal wave in a fluid.

Note.

When a solid bar is struck a blow at one end, the relevant modulus of elasticity is Young's modulus (Y). This is because the sideways expansion of the bar is negligible and only longitudinal strain needs to be considered. Thus, speed of longitudinal waves in a solid bar is given by

$$v = \sqrt{\frac{Y}{\rho}} \qquad ...(5)$$

14.2.9 Newton's formula for velocity of sound in gases

Sound is a form of energy, which is emitted by a vibrating source and transmitted through a material medium producing in us the sensation of hearing. The waves which carry sound energy are called sound waves.

As discussed already, formation of transverse waves is possible only when the medium possesses the elasticity of shape. Solids alone possess the elasticity of shape. Therefore, sound can travel through solids in the form of transverse waves. However, solids, liquids and gases, all possess volume elasticity. Therefore, longitudinal waves can be transmitted through all the three states of matter. Thus, through gases, sound is carried by the longitudinal waves.

From purely theoretical considerations, Newton gave an empirical relation to calculate the velocity of sound in a gas.

$$v = \sqrt{\frac{B}{\rho}} \qquad ...(6)$$

where B is bulk modulus of elasticity of the gas and p is density of the gas.

As sound travels through a gas in the form of compressions and rarefactions, Newton assumed that the changes in pressure and volume of a gas, when sound waves are propagated through it, are isothermal. The amount of heat produced during compression, is lost to the surroundings and similarly the amount of heat lost during rarefaction is gained from the surroundings, so as to keep the temperature constant. Using coefficient of isothermal elasticity, i.e., Bt of gas, in (6), Newton's formula becomes :

$$v = \sqrt{\frac{B_i}{\rho}} \qquad ...(7)$$

Calculation of B_i

Consider a certain mass of the gas.

Let P = initial pressure of the gas,

V = initial volume of the gas.

Under isothermal conditions, PV = constant

Differentiating both sides, we get

$$PdV + VdP = 0$$

$$PdV = -VdP$$

$$P = -\frac{VdP}{dV} = -\frac{dP}{dV/V} = B_i \text{ (By definition)}$$

Substituting this value in (7), we obtain

$$v = \sqrt{\frac{P}{\rho}} \qquad ...(4)$$

Error in Newton's formula

Let us use Newton's formula to calculate the velocity of sound in air at NTP.

As,

$P = h \rho g$ and h = 0.76 m of Hg column ; ρ = 13 6 x 10^3 kg m^{-3}; g = 9.8 ms^{-2}.

$$P = 0.76 \times 13.6 \times 10^3 \times 9.8 \ Nm^2$$

Density of air, ρ = 1.293 kg/m^3

From (8), $v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{0.76 \times 13.6 \times 10^3 \times 9.8}{1.293}}$

$= 280 \ ms^{-1}$ (9)

The experimental value of the velocity of sound in air at NTP is 332 ms^{-1}. Difference between the experimental value of velocity of sound in air and the value calculated from Newton's formula

$$= 332 - 280 = 52 \ ms^{-1}$$

Percentage Error = $\frac{52}{332}$ x 100 = 15.7% ≈ 16%

Thus the value calculated on the basis of Newton 's formula was less than the experimental value of velocity of sound in air by about 16%. Such a large error could not be taken as an experimental error

Newton put forward a number of arguments to explain the above discrepancy, but none of them was satisfactory.

Laplace's correction

Laplace, a French mathematician succeeded in explaining the exact cause of discrepancy between the theoretical and the experimental values of the velocity of sound in air.

He pointed out that Newton's assumption was wrong. According to Laplace, the changes in pressure and volume of a gas, when sound waves are propagated through it, are not isothermal, but adiabatic. This is because :

It means that neither the heat is transferred to the surroundings during compression and nor the heat is taken from the surroundings during rarefaction.

(ii) A gas is a bad conductor of heat. It does not allow the free exchange of heat between compressed layer, rarefied layer and surroundings.

Thus no exchange of heat is possible, when a sound wave passes through a gas. Heat produced during compression raises the temperature of the gas and the heat lost during rarefaction reduces the temperature of the gas. Hence the changes in pressure and volume of gas when sound waves are propagated through it are accompanied by change of temperature of gas. Hence changes are adiabatic and not isothermal.

Using the coefficient of adiabatic elasticity, i.e. B_a of gas, in (7) instead of B_i, we have

$$v = \sqrt{\frac{B_a}{\rho}} \qquad ...(10)$$

Calculation of ' B_a'

Consider a certain mass of the gas. Let P be the initial pressure and V be the initial volume of the gas. Under adiabatic conditions,

$$PV^{\gamma} = \text{constant} \qquad ...(11)$$

where, $\gamma = C_p/C_v$ = ratio of two principal specific heats of the gas

Differentiating both sides of (11), we get

$$P(\gamma V^{\gamma-1}dV) + V^{\gamma}(dP) = 0$$

or $\gamma PV^{\gamma-1}dV = -V^{\gamma}(dP)$

or

$$\gamma P = \frac{V^{\gamma}}{V^{\gamma-1}}\left(\frac{dP}{dV}\right) = -\frac{dP}{dV/V} = B_a \qquad \text{(by definition)}$$

$$\therefore \quad B_a = \gamma P \qquad ...(12)$$

Corrected formula. Substituting this value of B_a in (10), we get the corrected formula for velocity of sound in a gas as

$$v = \sqrt{\frac{\gamma P}{\rho}} \qquad ...(13)$$

The value of γ depends on nature of the gas.

For air, $\gamma = 1.41$ and from (9),

$$\sqrt{P/\rho} = 280 \text{ m/s}.$$

$\therefore$ From (13),

$$v = \sqrt{\gamma}\sqrt{\frac{P}{\rho}} = \sqrt{1.41} \times 280 = 332.5 \text{ ms}^{-1}$$

This value agrees fairly well with the experimental value of the velocity of sound in air at NTP. Hence the validity of Laplace's correction is established and (13) is the correct relation for the velocity of sound in any gaseous medium.

Table gives the **speed of sound in some media.**

Medium	Speed of sound (ms^{-1})
Gases:	
1. Air(0^0C)	331
2. Air(20^0C)	343
3. Helium	965
4. Hydrogen	1284
Liquids	
1. Water(0^0C)	1402
2. Water(20^0C)	1482
3. Sea water	1522
Solids	
1. Copper	3560
2. Steel	5941
3. Granite	6000
4. Aluminium	6420

Note:

Table shows that speed of sound in solids > speed of sound in liquids > speed of sound in gases – although the densities of solids and liquids are much higher than those of the gases. This is because liquids and solids are less compressible than gases, i.e., liquids and solids have much greater bulk modulus than that of gases.

Further, for sound waves $v_w > v_a$. Therefore, in travelling from air to water, a beam of sound bends away from normal, whereas a beam of light bends towards the normal. Thus for sound waves, water is a rarer medium compared to air.

FACTORS AFFECTING VELOCITY OF SOUND

The velocity of sound in any gaseous medium is affected by a large number of factors like density, pressure, temperature, humidity and wind velocity etc. Let us discuss each :

(a) Effect of density.

The velocity of sound in a gaseous medium is given by $v = \sqrt{\frac{\gamma P}{\rho}}$

Clearly, the velocity of sound in a gas is inversely proportional to the square root of density of the gas.

For example, density of oxygen is 16 times the density of hydrogen.

Therefore, the velocity of sound in hydrogen is four times the velocity of sound in oxygen.

(b) Effect of Pressure.

The formula for velocity of sound in a gas is $v = \sqrt{\frac{\gamma P}{\rho}}$

Put

$$\rho = \sqrt{\frac{M}{V}} \qquad \therefore \qquad v = \sqrt{\frac{\gamma PV}{M}}$$

When T is constant, PV = constant.

$\therefore$ v = Constant ($\therefore$ γ and M are constant)

Hence, velocity o f sound is independent of the change in pressure of the gas, provided temperature remains constant

This happens because effect of change in pressure in completely annulled by the corresponding change in density of the gas at constant temperature.

(c) Effect of Temperature.

The formula for velocity of sound in a gas is

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

According to standard gas equation, PV = RT or P = RT/V

$$\therefore \quad v = \sqrt{\frac{\gamma RT}{\rho \times V}} = \sqrt{\frac{\gamma RT}{M}} \qquad ...(14)$$

where, $\rho \times V = M$, the molecular weight of the gas.

Clearly, $v \propto \sqrt{T}$ (or)

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}} \qquad ...(15)$$

Hence, velocity of sound in a gas is directly proportioned to the square root of its absolute temperature. Clearly, sound would travel faster on a hot summer day than on a cold winter day.

Note:

When a person talks before and after taking a deep breath of helium, the pitch of his sound increases. This increase in pitch (or frequency) of sound is due to increase in speed of sound in Helium (= 965 m/s) compared to the speed of sound in air (= 331 m/s).

Temperature coefficient of velocity of sound in air (α)

The temperature coefficient of velocity of sound in air is defined as the change in the velocity of sound in air, when temperature changes by 1°C.

If v_t = velocity of sound in air at t°C ,

v_0 = velocity of sound in air at 0°C, then, by definition,

$$\alpha = \frac{v_t - v_0}{t}$$

The unit of a is m s^{-1} °C^{-1}.

From (15),

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273+t}{273+0}} = \left(1+\frac{t}{273}\right)^{1/2}$$

Expanding Binomially, when t is small, we get

$$\frac{v_t}{v_0} = \left(1+\frac{1}{2}\times\frac{t}{273}\right) \quad \therefore \quad \frac{v_t}{v_0} = \left(1+\frac{t}{546}\right)$$

$$\text{or} \quad \frac{v_t}{v_0} - 1 = \frac{t}{546} \quad \text{or} \quad \frac{v_t - v_0}{v_0} = \frac{t}{546}$$

$$\text{or} \quad \frac{v_t - v_0}{t} = \frac{v_0}{546} \quad \therefore \alpha = \frac{v_0}{546} = \frac{332}{546}$$

$= 0.608$ ms^{-1} °C^{-1} ($\because v_0 = 332$ ms^{-1})

Hence, velocity of sound in air increases approximately by 0.61 ms^{-1} for every 1°C rise in temperature.

(d) Effect of Humidity.

The presence of water vapours in air changes its density. That is why the velocity of sound changes with humidity of air.

Suppose, ρ_m = density of moist air,

ρ_d = density of dry air,

v_m = velocity of sound in moist air,

v_d = velocity of sound in dry air.

Assuming that effect of humidity on γ is negligible we get from (13),

$$v_m = \sqrt{\frac{\gamma P}{\rho_m}} \quad \text{and } v_d = \sqrt{\frac{\gamma P}{\rho_d}}$$

Dividing, we get

$$\frac{v_m}{v_d} = \sqrt{\frac{\rho_m}{\rho_d}} \qquad ...(17)$$

The presence of water vapours reduces the density of air.

i.e., $\rho_m < \rho_d$

therefore, from (17),$v_m < v_d$

Hence, velocity o f sound in moist air is greater than the velocity of sound in dry air That is why sound travels faster on a rainy day than on a dry day.

Note:

In case of Helium and Hydrogen, humidity increases the density. Therefore, velocity of sound in humid He and H_2 is less than velocity of sound in dry *He* and H_2 respectively.

(e) Effect of wind velocity.

The velocity of sound in air is affected by the velocity of wind because wind drifts the medium (air) along its direction of motion. The velocity of sound in a particular direction is therefore, the algebraic sum of the velocity of sound and the component of wind velocity in that direction. For example, in Fig. let

v = velocity of sound emitted by a source S in the direction of a listener L.

W = velocity of the wind along SA making an angle θ with the direction of propagation of sound.

The wind velocity W can be resolved into two rectangular components:

(i) W cos θ along SL i.e. along v

(ii) W sin θ perpendicular to v.

The component W sin θ, being perpendicular to v has got no effect on v.

Since v and W cos 0 act in the same direction (i.e., along SL),

Resultant velocity of sound along

$$SL = v + W\cos\theta \qquad ...(18)$$

RECALL YOUR MEMORY:

1. The formula for velocity of sound does not involve frequency or wavelength. Hence sound of any frequency or wavelength travels through a given medium with the same velocity.
2. The amplitude normally does not affect the velocity of sound. However, if the amplitude is too large, the velocity of sound increases slightly.
3. Velocity of sound in a gas depends also an atomicity of the gas, which determines $\gamma = C_p/C_v$ For monoatomic gases, y = 5/3, For diatomic gases, y = 7/5 and so on.
4. All other factors like phase, loudness, pitch, quality etc. have practically no effect on velocity of sound.
5. Kundt's tube is used to measure the velocity of sound in any medium, solid, liquid or gas.

NOTES:

1. In case of liquids, E = B = bulk modulus of elasticity

For water, $B = 2.23 \times 10^9\ N/m^2, \rho = 10^3\ kg/m^3$

$$v_{water} = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{2.23\times10^9}{10^3}}\ 1500\ m/s$$

Clearly, $v_{water} = 4v_{air}$

That is why two swimmers stationed particular distance apart in water hear a given sound quicker than when they are same distance apart in air.

2. In case of solids (in the form of rods), E = Y , the Young's modulus of elasticity.

$$\therefore \quad v = \sqrt{\frac{Y}{\rho}}$$

For a steel rod, $Y = 21 \times 10^{11}\ N/m^2$, $p = 7.8 \times 10^3\ kg/m^3$

$$\therefore \quad v_{steel} = \sqrt{\frac{2.1\times10^{11}}{7.8\times10^3}} = 5189\ m/s$$

We find $v_{steel} \approx 4v_{water} \approx 16v_{air}$

Thus sound waves have greatest speed in solid media and least speed in gaseous media.

Problem:

A wave pulse is travelling on a string of linear mass density 1.0 g/cm under a tension of 1 kg wt. Calculate time taken by the pulse to travel a distance of 50 cm on the string. Take g = 10 m/s^2.

Sol.

Here, m = 1 g/cm = 10^{-3} kg/10^{-2} m = 10^{-1} kg/m,

T = 1 kg wt. = 10 N

$v = \sqrt{T/m} = \sqrt{10/10^{-1}} = 10$ m/s

Time taken, $t = \frac{\text{distance}}{\text{velocity}} = \frac{0.5}{10} = 0.05$ s

Problem:

A tuning fork of frequency 220 Hz produces sound waves of wavelength 1.5 m in air at NTP. Calculate the increase in wavelength, when temperature of air is 27^{0}C.

Sol.

Here, v = 220 Hz, λ_1 = 1.5 m, T_1 = 0^{0}C = 273 K,

$v_1 = v\lambda_1$ = 220 x 1.5= 330 m/s,

$T_{2=27}{}^0C = 27 + 273 = 300$ K

$v_2 = v_1\sqrt{\frac{T_2}{T_1}} = 330\sqrt{\frac{300}{273}} = 345.9$ m/s

$\lambda_1 = \frac{v_2}{n} = \frac{345.9}{220} = 1.57$ m

Increase in wavelength $= \lambda_2 - \lambda_1$

$= 1.57 - 1.50 = 0.07$ m

Problem:

How far does the sound travel in air, when a tuning fork of frequency 256 Hz makes 32 vibrations? Velocity of sound in air = 320 m/s.

Sol.

Here, s = ?, v = 256 Hz, n = 32; v = 320 m/s

Time taken to complete 32 vibs. $t = \frac{32}{256} = \frac{1}{8}$ s

$s = v \times t = 320 \times \frac{1}{8} = 40$ m.

Problem:

The speed of a wave in a medium is 960 ms^{-1}. If 3600 waves are passing through a point in medium in 1 minute. What is the wavelength of waves?

Sol.

Here,υ = 960 m/s,

v = 3600/60 = 60 waves/sec

λ = ? From $\lambda = \upsilon/v = 960/60 = 16$ m.

Problem:

In a sonometer experiment the density of material of the wire used is 7.5 x 10^3 kg/m^3. If the stress of the wire is 3.0 x 10^8 N/m^2, find out the speed of transverse waves in the wire.

Sol.

Here, ρ = 7.5 x 10^3 kg/m^3

Stress = 3.0 x 10^8 N/m^2

If A is area of cross section of the wire, then tension in wire,

T = stress x area = 3.0 x 10^8 A N

Mass per unit length of wire,

m = A x 1 x ρ = A x 7.5 x 10^3 kg/m

$$\upsilon = \sqrt{\frac{T}{m}} = \sqrt{\frac{3.0 \times 10^8 A}{A \times 7.5 \times 10^3}} = \sqrt{4 \times 10^4} = 200 \text{ m/s.}$$

Problem:

At a pressure of 10^5 N/m^2, the volumetric strain of water is 5 x 10^{-5}. Calculate the speed of sound in water. Density of water is 10^3 kg/m^3

Sol.

Here, mP = 10^5 N/m, $\Delta V/V$ = 5 x 10^{-5}

υ = ? , ρ = 10^3 kg/m^3

$$K = \frac{\text{normal stress}(= \text{pressure})}{\text{volumetric strain}}$$

$$= \frac{10^5}{5 \times 10^{-5}} = 2 \times 10^9 \text{ N/m}^2$$

$$\upsilon = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{2 \times 10^9}{10^3}} = 1.414 \times 10^3 \text{ m/s.}$$

Problem:

Estimate the speed of sound in air at standard temperature and pressure. The mass of 1 mole of air is 29.0 x 10^{-3} kg, γ for air = 7/5.

Sol.

At S.T.P

P = 1 atmosphere = 1.01 x 10^5 N/m^2

As mass of 1 mole of air = 29.0 x 10^{-3} kg

and ots volume is 22.4 litre = 22.4 x 10^{-3} m^3

∴ density of air,

$$\rho = \frac{M}{V} = \frac{29.0 \times 10^{-3}}{22.4 \times 10^{-3}} = 1.29 \text{ kg/m}^3$$

$$\text{As, } v = \sqrt{\frac{\gamma P}{\rho}}$$

$$\therefore \quad v = \sqrt{\frac{7}{5} \times \frac{1.01 \times 10^5}{1.29}} = 331.1 \text{ m/s}$$

Problem:

At what temperature will the speed of sound be double its value at 273 K?

Sol.

T_2 = ? T_1 = 273 K, $v_2 = 2v_1$

$$\text{As} \quad \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = 2, \ T_2 = 4T_1 = 4 \times 273$$

$$T_2 = 1092 \text{ K}$$

Problem:

What is the ratio of velocity of sound in hydrogen (γ = 7/5) to that in helium (γ = 5/3) at the same temperature?

Sol.

$$\text{As} \quad v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

$$\therefore \frac{v_H}{v_{He}} = \sqrt{\frac{\gamma_H}{\gamma_{He}} \times \frac{M_{He}}{M_H}} = \sqrt{\frac{(7/5)4}{(5/3) \times 2}} = \frac{\sqrt{42}}{5}$$

Intensity and sound level

If we hear the sound produced by violin, flute or harmonium, we get a pleasing sensation in the ear, whereas the sound produced by a gun, horn of a motor car etc. produce unpleasant sensation in the ear.

The loudness of a sound depends on intensity of sound wave and sensitivity of the ear.

The intensity is defined as the amount of energy crossing per unit area per unit time perpendicular to the direction of propagation of the wave.

Intensity is measured in W m^{-2}.

The intensity of sound depends on (i) Amplitude of the source (I α a^2), (ii) Surface area of the source (I α A), (iii) Density of the medium (I α ρ), (iv) Frequency of the source (I α n^2) and (v) Distance of the observer from the source (I α $1/r^2$)

The lowest intensity of sound that can be perceived by the human ear is called threshold of hearing. It is denoted by I_o.

For sound of frequency 1 KHz, $I_o = 10^{-12}$ W m^{-2}. The level of sound intensity is measured in decibel. According to Weber-Fechner law,

$$\text{decibel level } (\beta) = 10 \log_{10}\left[\frac{I}{I_0}\right]$$

where I_o is taken as 10^{-12} W m^{-2} which corresponds to the lowest sound intensity that can be heard. Its level is 0 dB. I is the maximum intensity that an ear can tolerate which is 1 W m^{-2} equal to 120 dB.

$$\beta = 10 \log_{10}\left(\frac{1}{10^{-12}}\right)$$

$$\beta = 10 \log 10 \ (10^{12})$$

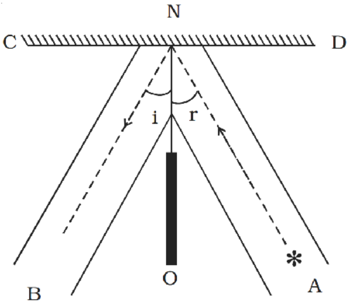
$$\beta = 120 \text{ dB.}$$

Table gives the decibel value and power density (intensity) for various sources.

Source of sound	Sound intensity (dB)	Intensity (W m^{-2})
Threshold of pain	120	1
Busy traffic	70	10^{-5}
Conversation	65	3.2 x 10^{-6}
Quiet car	50	10^{-7}
Quiet Radio	40	10^{-8}
Whisper	20	10^{-10}
Rustle of leaves	10	10^{-11}
Threshold of hearing	0	10^{-12}

14.3.1 Reflection of sound

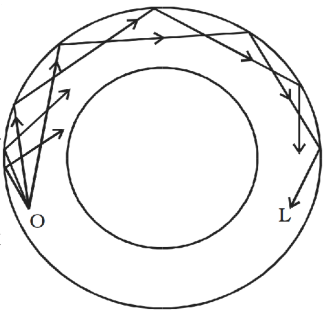
Take two metal tubes A and B. Keep one end of each tube on a metal plate as shown in Fig. Place a wrist watch at the open end of the tube A and interpose a cardboard between A and B. Now at a particular inclination of the tube B with the cardboard, ticking of the watch is clearly heard. The angle of reflection made by the tube B with the cardboard is equal to the angle of incidence made by the tube A with the cardboard.



Reflection of sound

14.3.2 Applications of reflection of sound waves

(i) Whispering gallery : The famous whispering gallery at St. Paul's Cathedral is a circular shaped chamber whose walls repeatedly reflect sound waves round the gallery, so that a person talking quietly at one end can be heard distinctly at the other end. This is due to multiple reflections of sound waves from the curved walls (Fig.).



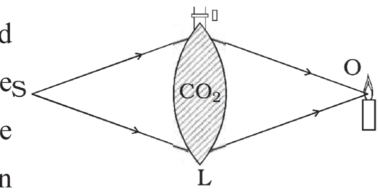
Multiple reflections in the whispering gallery

(ii) Stethoscope : Stethoscope is an instrument used by physicians to listen to the sounds produced by various parts of the body. It consists of a long tube made of rubber or metal. When sound pulses pass through one end of the tube, the pulses get concentrated to the other end due to several reflections on the inner surface of the tube. Using this doctors hear the patients' heart beat as concentrated rays.

(iii) Echo : Echoes are sound waves reflected from a reflecting surface at a distance from the listener. Due to persistence of hearing, we keep hearing the sound for 1/10 th of a second, even after the sounding source has stopped vibrating. Assuming the velocity of sound as 340 ms^{-1}, if the sound reaches the obstacle and returns after 0.1 second, the total distance covered is 34 m. No echo is heard if the reflecting obstacle is less than 17 m away from the source.

14.3.3 Refraction of sound

This is explained with a rubber bag filled with carbon-di-oxide as shown in Fig. The velocity of sound in carbon-di-oxide is less than that in air and hence the bag acts as a lens. If a whistle is used as a source S, the sound passes through the lens and converges at O which is located with the help of flame. The flame will be disturbed only at the point O.



Refraction of sound

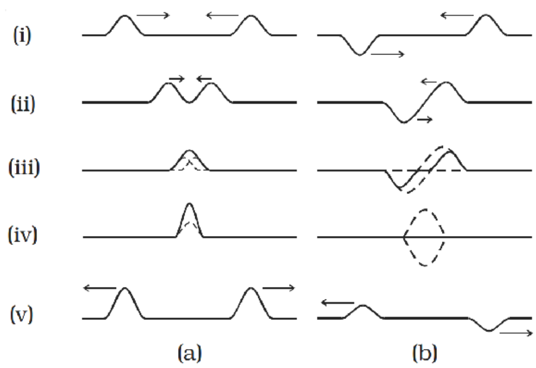
When sound travels from one medium to another, it undergoes refraction.

Applications of refraction of sound

It is easier to hear the sound during night than during day-time. During day time, the upper layers of air are cooler than the layers of air near the surface of the Earth. During night, the layers of air near the Earth are cooler than the upper layers of air. As sound travels faster in hot air, during day-time, the sound waves will be refracted upwards and travel a short distance on the surface of the Earth. On the other hand, during night the sound waves are refracted downwards to the Earth and will travel a long distance.

14.3.4 Superposition principle

When two waves travel in a medium simultaneously in such a way that each wave represents its separate motion, then the resultant displacement at any point at any time is equal to the vector sum of the individual displacements of the waves.



Superposition of waves

This principle is illustrated by means of a slinky in the Fig.(a).

1. In the figure, (i) shows that the two pulses pass each other,

2. In the figure, (ii) shows that they are at some distance apart

3. In the figure, (iii) shows that they overlap partly

4. In the figure, (iv) shows that resultant is maximum

Fig. b illustrates the same events but with pulses that are equal and opposite.

If $\vec{Y}_1$ and $\vec{Y}_2$ are the displacements at a point, then the resultant displacement is given by $\vec{Y} = \vec{Y}_1 + \vec{Y}_2$

If $|\vec{Y}_1|=|\vec{Y}_2|=$ a, and if the two waves have their displacements in the same direction, then $|\vec{Y}| = a + a = 2a$

If the two waves have their displacements in the opposite direction, then $|\vec{Y}| = a + (-a) = 0$

The principle of superposition of waves is applied in wave phenomena such as interference, beats and stationary waves.

Three important applications of superposition principle are:

(i) Stationary waves

(ii) Beats.

(iii) Interference of waves

We shall briefly describe the first two applications here. The third application will be discussed in later.

Note

The waves that obey the superposition principle are called Linear waves. The wave amplitude of linear waves is small. The waves which do not obey the superposition principle are called Nonlinear waves. They often have large amplitude.

14.4.1 Standing waves or stationary waves

When two sets of progressive wave trains of the same type (Le. both longitudinal or both transverse) having the same amplitude and same time period/ frequency/ wavelength travelling with same speed along the same straight line in opposite directions superimpose, a new set of waves are formed. These are called stationary waves or standing waves.

The resultant waves do not propagate in any direction, nor there is any transfer of energy in the medium. In the stationary waves, there are certain points of the medium, which are permanantly at rest i.e. their displacement is zero all throughout. These points are called Nodes. Similarly, there are some other points which vibrate about their mean position with largest amplitude. These points are called Antinodes.

Two types of stationary waves :

1. Longitudinal stationary waves are formed as a result of superimposition of two identical longitudinal waves travelling in opposite directions. For example, stationary waves produced in organ pipes and in air column of reasonance tube apparatus are longitudinal stationary waves.

2. Transverse stationary waves are formed as a result of superimposition of two identical transverse waves travelling in opposite directions. For example, stationary waves produced on the vibrating string of a sonometer are transverse stationary waves.

14.4.2 Standing waves and normal modes

Standing waves phenomena can be explained by the principle of superposition of waves. When two travelling waves of same amplitude, frequency and velocity but moving in opposite directions are superposed, the phenomenon of standing waves is observed Consider two waves with same amplitude, velocity and frequency but travelling in opposite directions as in figure (a) and (b).

$y_1 = A \sin(kx - \omega t)$ and

$y2 = A \sin(kx + \omega t + \phi_0)$

To understand these waves easily, let us discuss the special case when $\phi_0 = 0$. Using the principle of superposition, their resultant is $y = y_1 + y_2$

$y = A \sin(kx - \omega t) + A \sin(kx + \omega t)$

(or) $y = 2A \sin kx \cos \omega t$

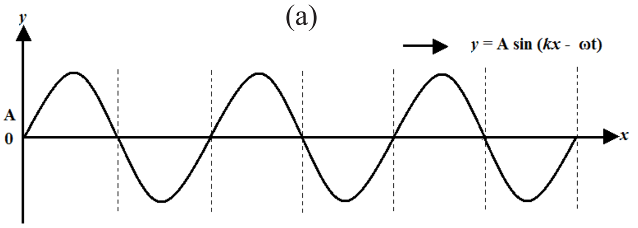
The wave function $y = 2A \sin kx \cos \omega t$ does not have the form of $f(ax \pm bt)$ and therefore, it does not describe a travelling wave. Hence it is known as standing wave. The wavelength and frequency of this resultant wave is equal to that of the individual waves which are superposed.

Since $y = 2A \sin kx \cos \omega t$ (or) $y = A_S \cos \omega t$, where $A_S = 2A \sin kx$, is called as amplitude of the wave is not constant but varies periodically with position.

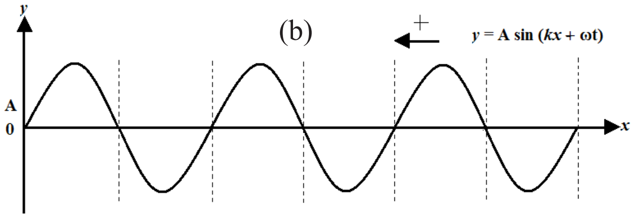
The equation $y = A_s \cos \omega t$ explains that particles of the medium execute simple harmonic motion.

All the particles vibrate with same frequency but their amplitudes are not equal. The amplitude of oscillation of particle depends on their position as $A_s = 2A \sin kx$. The given figure (c) represents the stationary wave form of $y = 2A \sin kx \cos \omega t$, at t = 0.

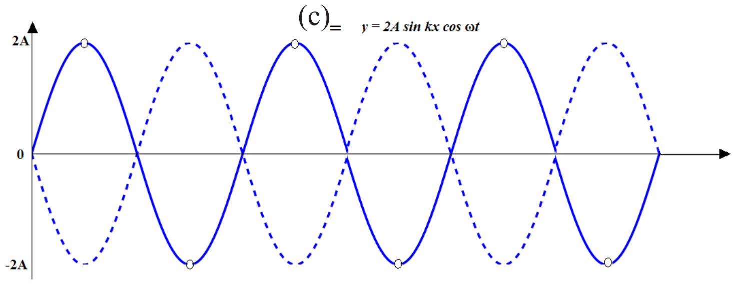
(a)



(b)



(c)



Position of nodes:

In particular, these are points where the amplitude $|2A \sin kx| = 0$. This will be the case when $\sin kx = 0$

∴ $kx = n\pi$, where n = 0,1,2,3,- - - - -

i.e $kx = 0, \pi, 2\pi, \ldots\ldots\ldots$(or)

$$x = 0, \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2} \ldots\ldots\ldots \left(\because k = \frac{2\pi}{\lambda}\right)$$

i.e., $x = n\left(\frac{\lambda}{2}\right)$, where n = 0, 1,2,3,- - - - -

Nodes:

These are the points at which particles never displace from their mean position as the two waves pass them simultaneously. These points are not physically clamped. In the Fig(c) certain points are marked as filled dots (●) whose displacements are zero at all times. Hence they represent nodes. The distance between two successive nodes is $\frac{\lambda}{2}$.

Position of Antinodes:

The points where the amplitude $|2A \sin kx| = 2A$, i.e. the points with maximum amplitude are called antinodes. In this case $\sin kx = \pm 1$.

∴ $kx = (2n - 1)\pi/2$,

where n = 1, 2, 3, ...

i.e

$$kx = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots\ldots(\text{or})$$

$$x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots\ldots\left(\because k = \frac{2\pi}{\lambda}\right)$$

i.e $x = (2n - 1)\frac{\lambda}{4}$, n = 1, 2, 3, -----

On the other hand, there are certain points in the Fig.(c) marked as empty dots (o), whose displacements periodically vary between zero and maximum in opposite directions. Such points are called antinodes.

The distance between two adjacent anti – nodes is also λ/2, while that between a node and an antinode is λ/4. The maximum amplitude of the individual wave

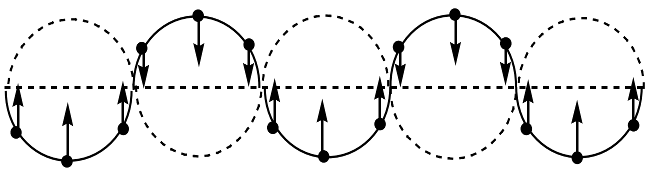
i.e $A_{max} = \pm 2A$

Standing waves can be transverse or longitudinal:

Example: In strings (under tension) if reflected wave exists, the waves formed are transverse stationary, while in organ pipes waves are longitudinal stationary.

Properties of stationary waves:

1. The nodes divide the medium into segments (or loops). All the particles in a segment vibrate in same phase, but in opposite phase (differ by phase π) with the particles in the adjacent segment. i.e., Two particles in consecutive loops always move in opposite direction.



Hence in a stationary wave two particles differ in phase either by 0 or π

2. With in a segment (or loop) all the particles pass through their mean positon simultaneously in same direction with their own maximum velocity ($A_s\omega$). In one time period particles cross theor mean postion twice. THe particle velocity in a stationary wave is

$$V_p = \frac{dy}{dt} = \frac{d}{dt}(A_s \cos \omega t) = -A_s \omega \sin \omega t$$

where A_s is amplitude of the particle.

3. The energy density in a stationary wave is twice that of the progressive wave.

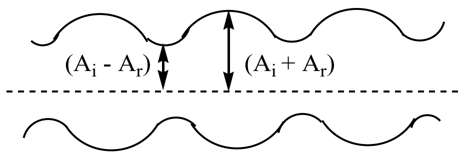
4. As in stationary wave nodes being permanently at rest, so no energy can be transmitted across them. i.e. energy of one region is confined in that region. This energy osillates between elastic potential energy and kinetic energy of the particles of the medium. When all the particles are at thier extreme position kinetic energy is minimum (zero), while elastic potential energy is maximum.

when all the particles pass through thier mean positon kinetic energy will be maximum, while elastic potetnial energy is minimum. Thus the total energy confined in a segment always remains the same. At a given position (except nodes), the distribution of kinetic energy and potential energy changes with time. At a given instant, the ratio of kinetic to potential energy for all the particles is same.

5. In a stationary wave if the amplitudes of the component waves are not equal, then nodes will not be permanently at rest ($A_{min} \neq 0$) and so some energy will pass across the node and that energy is transfered to another medium at boundary as a transmitting wave. Hence the wave will be partially standing.

6. The extent to which the resultant wave translates enrgy is proportional to $\frac{A_i - A_r}{A_i + A_r}$

where A_i and A_r are amplitudes of incident and reflected waves respectively. Lesser this value lesser ist he energy propagated at node. For $A_i = A_r$, the percentage of energy that crosses the loop is zero.



Terms related to the application of stationary wave.

1) **Note:** Any musical sound produced by the simple harmonic oscillations of the source is called note.

2) **Tone:** Every musical sound consists of a number of components of different frequencies Every component is know as a tone.

3) **Fundamental note and fundamental frequency:** The note of lowest frequency produceed by an instrument is called fundamental note. THe frequency of this note is called fundamental frequency.

4) **Harmoncs:** The frequencies which are integral multiple of the fundamental frequency are known as harmonics e.g. if n be the fundamental frequency, then

the frequencies n, 2n, 3n..... are termed as first, second, third....harmonics.

5) **Overtone:** Frequencies higher than the fundamental frequency are called overtones.

e.g. the tone with frequency immediately higher than the fundamental is defined as first overtone.

6) **Octave:** The tone whose frequency is double the fundamental frequency is defined as an Octave.

i) If $n_2 = 2n_1$, it means n_2 is an octave higher than n_1 or n_1 is an octabe lower than n_2.

ii) If $n_2 = 2_3 n_1$, it means n_2 is 3 – octave higher than n_1 or n_1 is 3 – octave lower than n_2

iii) Similarly if $n = 2^n n_1$(2_n is called an interval) it means n_2 is n – octave higher than n_1.

7) **Unison:** If the interval is one i.e. two frequencise are equal, then the vibrating bodies are said to be in unison.

8) **Resonance:** The phenomenon of making a body vibrate with its natural frequency under the influence of another vibrating body with the same frequency is called resonance.

14.4.3 Transverse modes of vibration of a string :

When a string under tension is set into vibration continuously, transverse harmonic waves will propagate along it. If the length of the string is finite, the reflected wave will also exist at its fixed end and travel back, The overlapping of incident and reflected waves, produce standing wave of large amplitude.The waves in a taut string of finite length are transverse stationary. It can be analytically obtained from the i principle of superposition of waves.

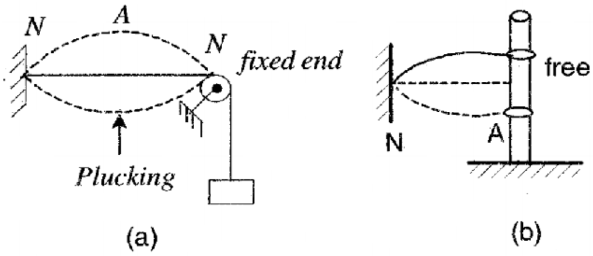
The incident and reflected transverse progressive waves with same amplitude (A), wavelength (X) and frequency (f) travelling in opposite direction along the stretched string are given by $y_i = A \sin(kx - \omega t)$ and y_r= Asin $(kx+\omega t)$,where k is propagation constant.

According to the principle of super position.

$$y = y_i + y_r$$

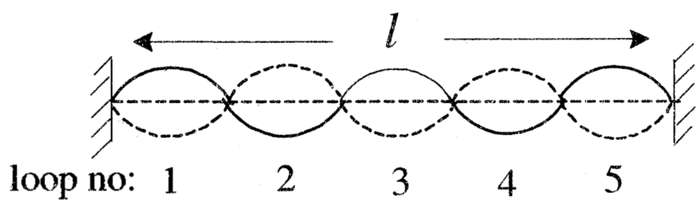
∴ $y = 2A \sin$ fee $\cos \omega t$ (or) $y = A_s \cos \omega t$,

where A_s = 2A sin he represents amplitude of particles in stationary wave. The string will vibrate in such away that fixed (or) clamped points of the string are nodes, as the string at these points is not free to move, while the point of plucking or free end is an antinode as here displacement will be maximum.



String fixed at both ends :s

A stretched string of length l is clamped between two points. It may vibrate in the form of one or more number of segments (or loops) which are called normal modes. These modes of vibration are known as harmonics. The wavelength associated with the standing waves can take on many different values and it is dependent on number of harmonics. The distance between adjacent nodes is $\lambda/2$, so that in a string fixed at both ends there must be exactly an integral number 'p' of half wavelengths $\lambda/2$.

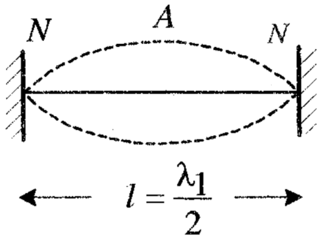


i.e., $(\lambda/2) = l$

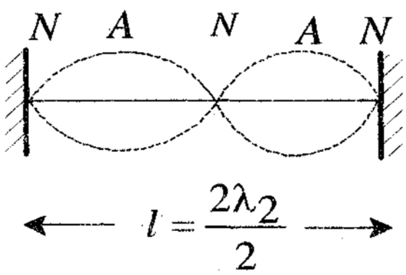
(or) $\lambda = \frac{2l}{p}$, where p = 1, 2, 3,........

But $V = f\lambda$ and $V = \sqrt{\frac{T}{\mu}}$, so that the natural frequencies of oscillation of the string are $f = P\, p\left(\frac{V}{2l}\right)$ p = 1, 2, 3, ...where μ is the linear density of the string and T is the tension in it.

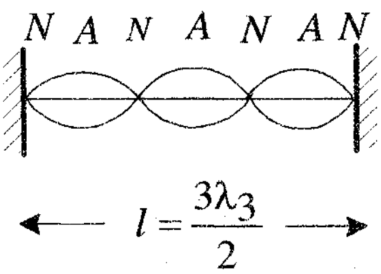
a) First harmonic (or) Fundamental mode p = 1



b) Second harmonic (or) First over tone p = 2



c) Third harmonic (or) Second overtone p = 3



If the string vibrate as one segment (p = 1) fig. (a), there is smallest frequency f_1 that corresponds to the largest wavelength

$$\lambda_1 = 2l \qquad f_1 = \frac{V}{2l} = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

This is known as fundamental (or) first harmonic frequency. In this mode, an antinode is formed at the middle of the string and two nodes are formed at the two ends.

If the string vibrates as two segments (p = 2) as shown figure (b) the frequency

$$f_1 = 2\left(\frac{V}{l}\right) = \frac{2}{2l}\sqrt{\frac{T}{\mu}} \quad \therefore f_2 = 2f_1$$

This frequency us called as second harmonic or first overrtone frequency.

The other standing wave frequencies are

$$f_3 = 3\left(\frac{V}{l}\right) = \frac{3}{2l}\sqrt{\frac{T}{\mu}}$$

Effect of Temperature on vibrating string:

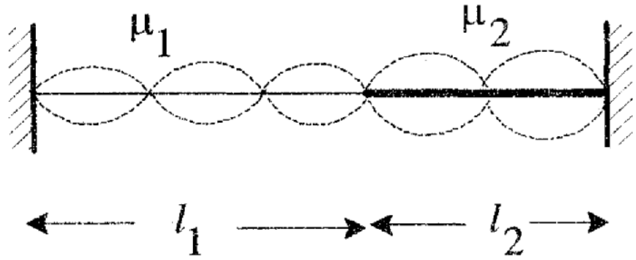
The frequency of vibration of a string under a load is $f \propto \sqrt{\frac{T}{ml}}$, where l is the length of string and m is the mass of it. For change of temperature Δθ the change in length $\Delta l = l\,\alpha\,\Delta\theta$, where α in the coefficiet of linear expansion of the wire. As tension and mass of the wire are constant, we have

$$\frac{\Delta f}{f} = \frac{1}{2}\frac{\Delta l}{l} = -\frac{1}{2}\alpha\Delta\theta \quad \text{or} \quad \Delta f = \frac{1}{2}\alpha f\Delta\theta$$

The negative sign indicated that with increase in temperature, frequency decreases.

Vibrations of compositie string:

Under vibrations of composite string (string made up by joining two strings of different length, cross section and density) having same tension through out, the joint is a node or antinode while lowest common fundamental frequency of the string will b $f_c = n_1f_1 = n_2f_2$.



Where f_1 and f_1 are the individual fundamental frequencies of strings 1 and 2 respectively, under same tension as that of the composite string. The higher harmonic frequencies will be integral multiple of common frequency f_c.

14.4.4 Laws of transverse vibrations of a stretched string:

When a string is fixed at both the ends, its fundamental frequency is $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$. so we can state the three laws of transverse vibrations.

i) First law or law of length:

The fundamental frequency of a vibrating string is inversely proportional to the length (l) of the string, when the tension (T) in the string and its linear denisty (μ) are constant.

i.e $f \propto \frac{1}{l}$, if T and μ are constant

(or)

$$fl = \text{constant (or) } \frac{f_1}{f_2} = \frac{l_1}{l_2}$$

ii) Second law (or) Law of tension:

The fundamental frequency of vibrating string is directly proportional to the square root of the tension(T)., when the length of the string (l) and its linear density are constant.

i.e $f \propto \sqrt{T}$, if l and μ are constant (or)

$$\frac{f}{\sqrt{T}} = \text{constant (or) } \frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}}$$

iii) Third law or Law of linear density:

The fundamental frequency of vibrating stringis inversely proportional to square root of linear density, when the length of the string (l) and tension (T) are constant.

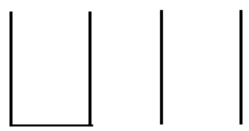
i.e $f \propto \frac{1}{\sqrt{\mu}}$, if l and T are constant (or)

$$f\sqrt{\mu} = \text{constant (or) } \frac{f_1}{f_2} = \sqrt{\frac{\mu_2}{\mu_1}}$$

These laws of vibration of string are known as M ersenne's law o f vibration o f string and according to these the frequency of a string can be changed by changing its length, tension or linear density. These three laws can be verified by sonometer experiment.

14.5.1 Longitudinal standing wave in an organ pipe

An organ pipe is a cylindrical tube of uniform cross section in which a gas or air is trapped as a medium. One end of an organ pipe is always open while the other may be closed or open giving rise to closed end or open end organ pipe respectively.



Suppose that a longitudinal wave is introduced at the open end of closed pipe. The longitudinal wave on reaching the closed end of the pipe gets reflected

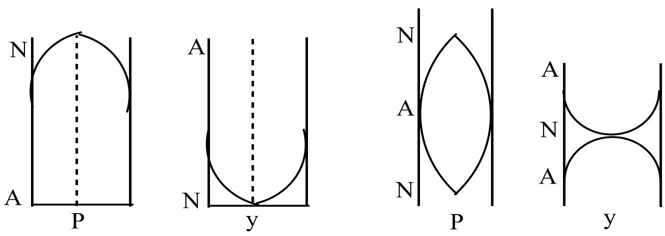
The reflected pressure wave differs in phase by π with the incident pressure wave. That is compression is reflected as compression and a rarefaction is reflected as rarefaction. Hence the superposition of incident and reflected pressure waves results in longitudinal standing waves

At closed end, always a pressure antinode is formed i.e., pressure fluctuation is maximum, and it will be a displacement node.

A longitudinal wave can also reflect at open end. If the longitudinal pressure wave encounters the open end of the pipe, a compression is reflected as a rarefaction and a rarefaction as a compression. Let us see how this reflection take place.

When a rarefaction reaches an open end, the surrounding air or gas rushes towards thisregion because of its low pressure and creates a compression that travels back along the pipe.

Similarly, when a compression reaches an open end, the gas or air in this region expands because of high pressure and creats a rarefaction and travel back along the pipe



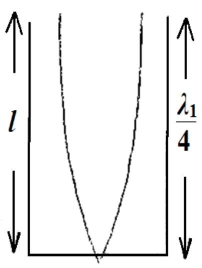
(a) Closed pipe (b) Open pipe

Hence the superposition of incident and reflected pressure waves result in longitudinal standing waves. The open end is always a pressure node, and it will be a displacement antinode.

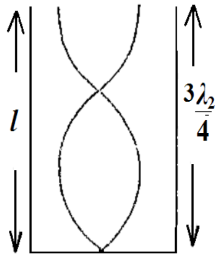
i) Standing wave in closed pipe:

In case of closed pipe, as closed end will always be displacement node while free end the antinode, the distance between the successive node and antinode is λ/4, where v is the speed of wave in the pipe.

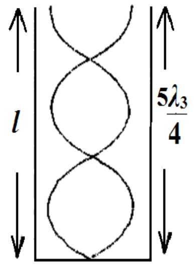
Closed pipe Open pipe



Fundamental note or first harmonic



First overtone or Third harmonic



Second overtone or Fifth harmonic

1) If λ_1 is the wavelength of wave produced in first harmonic, then $l = \lambda_1/4$.

The fundaental frequency (or) first harmonic frequency $f_1 = v/\lambda_1 = v/4l$

The nedt possible harmonic with node at the closed end and antinode at the open end is oly the third harmonic, since one more node and antinode should be included. The length of the pipe becomes equal to 3/4 of the wave length. If λ_3 is the wavelength of wave produced in the first overtone, then $l = 3\left(\frac{v}{4l}\right) = 3f_1$.

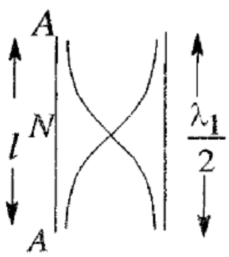
The third harmonic or first overtone frequency $f_3 = v/l_3 = 3\left(\frac{v}{4l}\right) = 3f_1$.

Similarly the next overtone in the closed pipe is only the fifth harmonic. It will have three nodes and three antinodes between the closed end and the open end of the pipe. The length 'l' of the pipe adjust itself to 5/4 of the wave length (λ_5) i.e., If λ_5 is the wavelength of wave produced in the second overtone, then $l = 5/4\ \lambda_5$

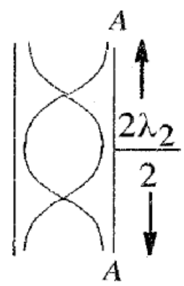
The fifth harmonic or second overtone frequency $f_5 = v/\lambda_5 = 5\left(\frac{v}{4l}\right) = 5f_1$. The frequencies of the higher harmonics can be derived in the same way.

$\therefore \quad f_c = n\left(\frac{v}{4l}\right)$ where n = 1, 3, 5......

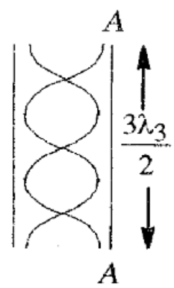
This mode of vibration frequency is similar to rod clamped at one end.



Fundamental note or First harmonic



First overtone or Second harmonic



Second overtone or Third harmonic

ii) Standing wave in open organ pipe:

In case of an open pipe at both ends there will be displacement antinodes. Let v be the speed of wave in that pipe.

The first harmonic or the fundamental has an antinode at each end, with a node included between them. Therefore the vibrating length (l) is equall to half the wavelength, then l = $\lambda_1/2$. The fundamental or first harmonic frequency is $f_1 = \frac{v}{\lambda_1} = \frac{v}{2l}$

The second harmonic or the first overtone will at least have one more node and an antinode than the fundamental. If λ_2 is the wavelength produced in first over tone, then $l = 2\frac{\lambda_2}{2}$

First overtone or second harmonic frequency $f_2 = \frac{v}{\lambda_2} = 2\left(\frac{v}{2l}\right)$

Similarly second overtone or third harmonic frequency $f_3 = \frac{v}{\lambda_3} = 3\left(\frac{v}{2l}\right)$ and so on.

Hence the frequency of vibration of an open pipe $f_0 = n\left(\frac{v}{4l}\right)$ where n = 1, 2, 3, 4......

iii) End correction of pipes:

Due to inertia of motion of particles in organ pipes reflection does not take place exactly at open end, but somewhat above it i.e. at a distance e = 0.6 r = 0.3 D called end correction or Helmholtz and Rayleigh correction, where r is radius of pipe, D is the diameter of pipe.

The effective length of the pipe is therefore, greater than the length of the pipe. So for closed pipe $L_c = l + 0.6\,r$, while for open pipe $L_0 = l + 1.2r$. Hnce the frequency of vibration of air column of closed organ pipe is given by

$$f_c = n\left(\frac{v}{4(l+0.6r)}\right),\ n = 1,3,5.....$$

and that of open pipe is givne by

$$f_0 = n\left(\frac{v}{2(l+1.2r)}\right),\ n = 1,2,3,4.....$$

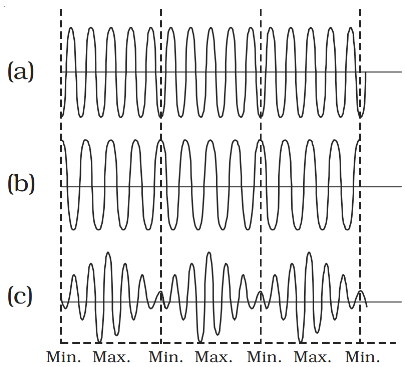
A wider tube has greater correction in the fundamental frequency.

14.5.2 Beats

When two waves of nearly equal frequencies travelling in a medium along the same direction superimpose upon each other, beats are produced. The amptitude of the resultant sound at a point rises and falls regularly.

The intensity of the resultant sound at a point rises and falls regularly with time. When the intensity rises to maximum we call it as waxing of sound, when it falls to minimum we call it as waning of sound.

The phenomenon of waxing and waning of sound due to interference of two sound waves of nearly equal frequencies are called beats. The number of beats produced per second is called beat frequency, which is equal to the difference in frequencies of two waves.



Analytical method

Let us consider two waves of slightly different frequencies n_1 and n_2 ($n_1 \sim n_2 < 10$) having equal amplitude travelling in a medium in the same direction.

At time t = 0, both waves travel in same phase.

The equations of the two waves are

$$y_1 = a \sin \omega_1 t$$

$$y_1 = a \sin (2\pi n_1)t \qquad ...(1)$$

$$y_2 = a \sin \omega_2 t$$

$$= a \sin (2\pi n_2)t \qquad ...(2)$$

When the two waves superimpose, the resultant displacement is given by

$$y = y_1 + y_2$$

$$y = a \sin (2\pi n_1) t + a \sin (2\pi n_2) t \qquad ...(3)$$

Therefore

$$y = 2a \sin 2\pi\left(\frac{n_1+n_2}{2}\right) t \cos 2\pi \left(\frac{n_1-n_2}{2}\right) t \qquad ...(4)$$

Substitute $A = 2a \cos 2\pi \left(\frac{n_1-n_2}{2}\right) t$ and $n = \left(\frac{n_1+n_2}{2}\right)$ in equation(4)

$\therefore \quad y = A \sin 2\pi nt$

This represents a simple harmonic wave of frequency $n = \left(\frac{n_1+n_2}{2}\right)$ and amplitude A which changes with time.

(i) The resultant amplitude is maximum (i.e) ± 2a, if

$$\cos 2\pi \left[\frac{n_1-n_2}{2}\right] t = \pm$$

$$\therefore \quad 2\pi \left[\frac{n_1-n_2}{2}\right] t = m\pi$$

(where m = 0, 1, 2 ...) or $(n_1 - n_2)\, t = m$

The first maximum is obtained at $t_1 = 0$

The second maximum is obtained at

$$t_2 = \frac{1}{n_1-n_2}$$

The third maximum at $t_3 = \frac{2}{n_1-n_2}$ and so on.

The time interval between two successive maxima is

$$t_2 - t_1 = t_3 - t_2 = \frac{1}{n_1-n_2}$$

Hence the number of beats produced per second is equal to the reciprocal of the time interval between two successive maxima.

(ii) The resultant amplitude is minimum (i.e) equal to zero, if

$$\cos 2\pi \left[\frac{n_1-n_2}{2}\right] t = 0$$

(i.e) $\quad 2\pi \left[\frac{n_1-n_2}{2}\right] t = \frac{\pi}{2} + m\pi = (2m+1)\frac{\pi}{2}$

or $\quad (n_1 - n_2)t = \frac{(2m+1)}{2}$ where m = 0, 1, 2 ...

The first maximum is obtained at $t_1' = \frac{1}{2(n_1-n_2)}$

The second maximum is obtained at $t_2' = \frac{3}{2(n_1-n_2)}$

The third maximum at $t_3' = \frac{5}{2(n_1-n_2)}$ and so on.

The time interval between two successive maxima is

$$t_2' - t_1' = t_3' - t_2' = \frac{1}{n_1-n_2}$$

Hence the number of beats produced per second is equal to the reciprocal of the time interval between two successive minima.

Uses of beats

(i) The phenomenon of beats is useful in tuning two vibrating bodies in unison. For example, a sonometer wire can be tuned in unison with a tuning fork by observing the beats. When an excited tuning fork is kept on the sonometer and if the sonometer wire is also excited, beats are heard, when the frequencies are nearly equal. If the length of the wire is adjusted carefully so that the number of beats gradually decreases to zero, then the two are said to be in unison. Most of the musical instruments are made to be in unison based on this method.

(ii) The frequency of a tuning fork can be found using beats. A standard tuning fork of frequency N is excited along with the experimental fork. If the number of beats per second is n, then the frequency of experimental tuning fork is N±n. The experimental tuning fork is then loaded with a little bees' wax, thereby decreasing its frequency. Now the observations are repeated. If the number of beats increases, then the frequency of the experimental tuning fork is N–n, and if the number of beats decreases its frequency is N + n.

14.5.3 Doppler effect

The whistle of a fast moving train appears to increase in pitch as it approaches a stationary observer and it appears to decrease as the train moves away from the observer. This apparent change in frequency was first observed and explained by Doppler in 1845.

The phenomenon of the apparent change in the frequency of sound due to the relative motion between the source of sound and the observer is called Doppler effect.

The apparent frequency due to Doppler effect for different cases can be deduced as follows.

(i) Both source and observer at rest

Suppose S and O are the positions of the source and the observer respectively. Let n be the frequency of the sound and v be the velocity of sound. In one second, n waves produced by the source travel a distance SO = v (Fig. a).

The wavelength is $\lambda = v/n$.

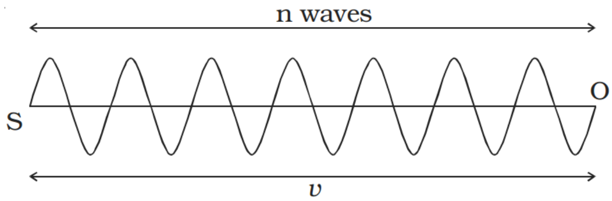


Fig (a)

(ii) **When the source moves towards the stationary observer**

If the source moves with a velocity v_s towards the stationary observer, then after one second, the source will reach S′ , such that SS′ = v_s. Now *n* waves emitted by the source will occupy a distance of $(v–v_s)$ only as shown in Fig. b.

Therefore the apparent wavelength of the sound is

$$\lambda = \frac{v - v_s}{n}$$

The apparent frequency

$$n' = \frac{v}{\lambda'} = \left(\frac{v}{v - v_s}\right) n \qquad ...(1)$$

As n′ > n, the pitch of the sound appears to increase.

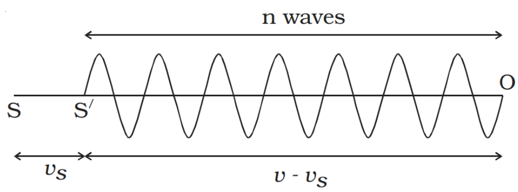


Fig. b

When the source moves away from the stationary observer

If the source moves away from the stationary observer with velocity vs, the apparent frequency will be given by

$$n' = \left(\frac{v}{v-(-v_s)}\right)n = \left(\frac{v}{v + v_s}\right) n \qquad ...(2)$$

As n′ < n, the pitch of the sound appears to decrease.

(iii) Source is at rest and observer in motion

S and O represent the positions of source and observer respectively. The source S emits n waves per second having a wavelength $\lambda = v/n$. Consider a point A such that OA contains n waves which crosses the ear of the observer in one second (Fig. a). (i.e) when the first wave is at the point A, the nth wave will be at O, where the observer is situated.

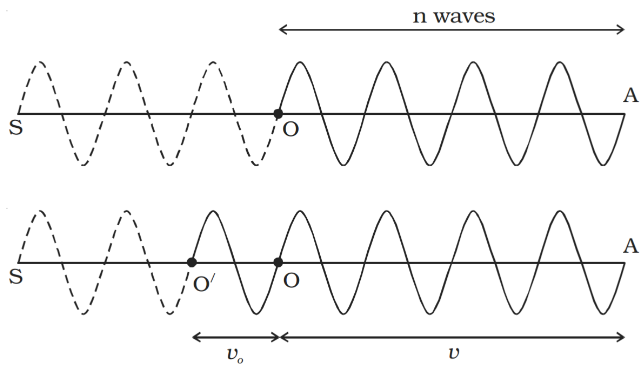


Fig (a) & (b)

When the observer moves towards the stationary source

Suppose the observer is moving towards the stationary source with velocity v_o. After one second the observer will reach the point O′ such that OO′ = v_o. The number of waves crossing the observer will be n waves in the distance OA in addition to the number of waves in the distance OO′ which is equal to $v_o \lambda$ as shown in Fig.b.

Therefore, the apparent frequency of sound is

$$n' = \frac{v_0}{\lambda} = n + \left(\frac{v_0}{v}\right)n$$

$$\therefore n' = \frac{v_0}{v}\left(\frac{v+v_0}{v}\right)n \qquad ...(3)$$

As $n' > n$, the pitch of the sound appears to increase.

When the observer moves away from the stationary source

$$n' = \left[\frac{v+(-v_0)}{v}\right]n$$

$$n' = \left(\frac{v-v_0}{v}\right)n \qquad ...(4)$$

As $n' < n$, the pitch of sound appears to decrease.

Note :

If the source and the observer move along the same direction, the equation for apparent frequency is

$$n' = \left(\frac{v-v_0}{v-v_S}\right)n \qquad ...(5)$$

Suppose the wind is moving with a velocity W in the direction of propagation of sound, the apparent frequency is

$$n' = \left(\frac{v+W-v_0}{v+W-v_S}\right)n \qquad ...(6)$$

The apparent frequency as detected by an observer in different situations are summarized in table:

	Stationary source	Source towards the observer	Source away from observer
Stationary Observer	f	$n\left(\frac{v}{v-v_S}\right)$	$n\left(\frac{v}{v+v_S}\right)$
Observer towards the source	$\left(\frac{v \overset{n}{+} v_0}{v}\right)$	$n\left(\frac{v+v_0}{v-v_S}\right)$	$n\left(\frac{v+v_0}{v+v_S}\right)$
Observer away from source	$\left(\frac{v \overset{n}{-} v_0}{v}\right)$	$n\left(\frac{v-v_0}{v-v_S}\right)$	$n\left(\frac{v-v_0}{v+v_S}\right)$

Applications of Doppler effect

(i) To measure the speed of an automobile

An electromagnetic wave is emitted by a source attached to a police car. The wave is reflected by a moving vechicle, which acts as a moving source. There is a shift in the frequency of the reflected wave. From the frequency shift using beats, the speeding vehicles are trapped by the police.

(ii) Tracking a satellite

The frequency of radio waves emitted by a satellite decreases as the satellite passes away from the Earth. The frequency received by the Earth station, combined with a constant frequency generated in the station gives the beat frequency. Using this, a satellite is tracked.

(iii) RADAR (RADIO DETECTION AND RANGING)

A RADAR sends high frequency radiowaves towards an aeroplane. The reflected waves are detected by the receiver of the radar station. The difference in frequency is used to determine the speed of an aeroplane.

(iv) SONAR (SOUND NAVIGATION AND RANGING)

Sound waves generated from a ship fitted with SONAR are transmitted in water towards an approaching submarine. The frequency of the reflected waves is measured and hence the speed of the submarine is calculated.

Exercise – 1

BASICS OF MECHANICAL WAVES

1. The speed of sound in oxygen (O_2) at a certain temperature is 460 ms^{-1}. The speed of sound in helium (He) at the same temperature will be (assume both gases to be ideal)
[1] 500 ms^{-1} [2] 650 ms^{-1}
[3] 330 ms^{-1} [4] 1420 ms^{-1}.

2. The relation between frequency 'n' wavelength 'λ' and velocity of propagation 'v' of wave is
[1] n = vλ [2] n = λ/v
[2] n = v/λ [4] n = 1/v.

3. The speed of sound in air is 332 m/s. The speed of sound in air in units of km per hour will be
[1] 1.1952 km/h [2] 11.952 km/h
[3] 119.52 km/h [4] 1195.2 km/h

4. The speed of sound in a gas of density ρ at a pressure P is proportional to
[1] $\left(\frac{p}{\rho}\right)^2$ [2] $\left(\frac{p}{\rho}\right)^{3/2}$ [3] $\sqrt{\frac{p}{\rho}}$
[4] $\sqrt{\frac{P}{\rho}}$ [5] $\left(\frac{\rho}{P}\right)^2$

5. A tuning fork makes 256 vibrations per second in air. When the velocity of sound is 330 m/s, then wavelength of the tone emitted is
[1] 0.56 m [2] 0.89 m
[3] 1.11 m [4] 1.29 m

6. Sound waves travel at 350 m/s through a warm air and at 3500 m/s through brass. The wavelength of a 700 Hz acoustic wave as it enters brass from warm air
[1] Decreases by a factor 20
[2] Decreases by a factor 10
[3] Increases by a factor 20
[4] Increases by a factor 10

7. When a sound wave of frequency 300 Hz passes through a medium the maximum displacement of a particle of the medium is 0.1 cm. The maximum velocity of the particle is equal to
[1] 60 π cm/sec [2] 30 π cm/sec
[3] 30 cm/sec [4] 60 cm/sec

8. Angle between wave velocity and particle velocity of a longitudinal wave is
[1] 90° [2] 60° [3] 0° [4] 120°

9. Velocity of sound waves in air is 330 m/sec. For a particular sound in air, a path difference of 40 cm is equivalent to a phase difference of 1.6 π. The frequency of this wave is
[1] 165 Hz [2] 150 Hz
[3] 660 Hz [4] 330 Hz

10. If the frequency of human heart beat is 1.25 Hz, the number of heart beats in 1 minute is
[1] 80 [2] 65 [3] 90
[4] 75 [5] 120

11. The relation between phase difference (Δϕ) and path difference (Δx) is
[1] $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ [2] $\Delta\phi = 2\pi\lambda\,\Delta x$
[3] $\Delta\phi = 2\pi\lambda/\Delta x$ [4] $\Delta\phi = 2\,\Delta x/\lambda$.

12. A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz. The speed of sound in a tissue is 1.7 km– s^{-1}. The wavelength of sound in the tissue is close to
[1] 4 x 10^{-4} m [2] 8 x 10^{-3} m
[3] 4 x 10^{-3} m [4] 8 x 10^{-4} m

13. An observer standing near the sea shore observes 54 waves per minute. If the wavelength of the water wave is 10m then the velocity of water wave is
[1] 540 ms^{-1} [2] 5.4 ms^{-1}
[3] 0.184 ms^{-1} [4] 9 ms^{-1}

14. The ratio of the speed of sound in nitrogen gas to that in helium gas, at 300 K is
[1] $\sqrt{2/7}$ [2] $\sqrt{1/7}$
[3] $\sqrt{3}/5$ [4] $\sqrt{6}/5$

15. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 second. The frequency of the wave is
[1] 1.47 Hz [2] 0.36 Hz
[3] 0.73 Hz [4] 2.94 Hz

16. The number of waves contained in unit length of the medium is called
[1] Elastic wave [2] Wave number
[3] Wave pulse
[4] Electromagnetic wave

17. The frequency of a rod is 200 Hz. If the velocity of sound In air is 340 ms^{-1} , the wavelength of the sound produced is
[1] 1.7 cm [2] 6.8 cm
[3] 1.7 m [4] 6.8 m

18. Frequency range of the audible sounds is
[1] 0 Hz – 30 Hz [2] 20 Hz – 20 kHz
[3] 20 kHz – 20,000 kHz
[4] 20 kHz – 20 MHz

19. A wave has velocity u in medium P and velocity 2u in medium Q. If the wave is incident in medium P at an angle of 30^0 then the angle of refraction will be
[1] 30° [2] 45° [3]60° [4] 90°

20. A stone is dropped into a lake from a tower 500 metre high . The sound of the splash will be heard by the man approximately after
[1] 11.5 seconds [2] 21 seconds
[3] 10 seconds [4] 14 seconds

21. When sound waves travel from air to water, which of the following remains constant
[1] Velocity [2] Frequency
[3] Wavelength [4] All the above

22. A stone is dropped in a well which is 19.6 m deep. Echo sound is heard after 2.06 sec (after dropping) then the velocity of sound is
[1] 332.6 m/sec [2] 326.7 m/sec
[3] 300.4 m/sec [4] 290.5 m/sec

23. A boat at anchor is rocked by waves whose crests are 100 m apart and velocity is 25 m/sec. The boat bounces up once in every
[1] 2500 s [2] 75 s
[3] 4 s [4] 0.25 s

24. Velocity of sound is maximum in
[1] Air [2] Water
[3] Vacuum [4] Steel

25. Which one of the following statements is true
[1] Both light and sound waves in air are longitudinal
[2] Both light and sound waves can travel in vacuum
[3] Both light and sound waves in air are transverse
[4] The sound waves in air are longitudinal while the light waves are transverse

26. Sound waves transfer
[1] Only energy not momentum
[2] Energy
[3] Momentum
[4] Both energy and momentum

27. At which temperature the speed of sound in hydrogen will be same as that of speed of sound in oxygen at 100°C

[1] -148°C [2] -212.5°C
[3] -317.5°C [4] -249.7°C

28. A tuning fork produces waves in a medium. If the temperature of the medium changes, then which of the following will change

[1] Amplitude [2] Frequency
[3] Wavelength [4] Time-period

29. The wave length of light in visible part (A y) and for sound are related as

[1] $\lambda_V > \lambda_S$ [2] $\lambda_S > \lambda_V$
[3] $\lambda_S = \lambda_V$ [4] None of these

30. Which of the following is different from others

[1] Velocity [2] Wavelength
[3] Frequency [4] Amplitude

31. The phase difference between two points separated by lm in a wave of frequency 120 Hz is 90°. The wave velocity is

[1] 180 m/s [2] 240 m/s
[3] 480 m/s [4] 720 m/s

32. The echo of a gun shot is heard 8 sec. after the gun is fired. How far from him is the surface that reflects the sound (velocity of sound in air = 350 m/s)

[1] 1400 m [2] 2800 m
[3] 700 m [4] 350 m

33. A man sets his watch by the sound of a siren placed at a distance 1 km away. If the velocity of sound is 330 m/s

[1] His watch is set 3 sec. faster
[2] His watch is set 3 sec. slower
[3] His watch is set correctly
[4] None of the above

34. Velocity of sound in air is

[1] Faster in dry air than in moist air
[2] Directly proportional to pressure
[3] Directly proportional to temperature
[4] Independent of pressure of air

35. Two monoatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by

[1] $\sqrt{\frac{m_1}{m_2}}$ [2] $\sqrt{\frac{m_2}{m_1}}$
[3] $\frac{m_1}{m_2}$ [4] $\frac{m_2}{m_1}$

36. When sound is produced in an aeroplane moving with a velocity of 200 m/s horizontally its echo is heard after 10 $\sqrt{5}$ seconds. If velocity of sound in air is 300 ms"1 the elevation of aircraft is

[1] 250 m [2] 250 $\sqrt{5}$ m
[3] 1250 m [4] 2500 m

37. When the temperature of an ideal gas is increased by 600 K, the velocity of sound in the gas becomes $\sqrt{3}$ times the initial velocity in it. The initial temperature of the gas is

[1] -73°C [2] 27° C
[3] 127° C [4] 327°C

38. The frequency of a sound wave is n and its velocity is v. If the frequency is increased to 4n, the velocity of the wave will be

[1] v [2] 2v [3] 4v [4] v/4

39. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.14 second. The frequency of the wave is

[1] 0.42 Hz [2] 2.75 Hz
[3] 1.79 Hz [4] 0.56 Hz
[5] 3.5 Hz

40. The speed of a wave in a certain medium is 960 m/s. If 3600 waves pass over a certain point of the medium in 1 minute, the wavelength is

[1] 2 metres [2] 4 metres
[3] 8 metres [4] 16 metres

41. Speed of sound at constant temperature depends on
[1] Pressure [2] Density of gas
[3] Above both [4] None of the above

42. A man standing on a cliff claps his hand hears- its echo after 1 sec. If sound is reflected from another mountain and velocity of sound in air is 340 m/sec. Then the distance between the man and reflection point is
[1] 680 m [2] 340 m
[3] 85 m [4] 170 m

43. What will be the wave velocity, if the radar gives 54 waves per min and wavelength of the given wave is 10 m
[1] 4 m/sec [2] 6 m/sec
[3] 9 m/sec [4] 5 m/sec

44. Sound velocity is maximum in
[1] H_2 (b) N_2
[3] He (d) O_2

45. The minimum distance of reflector surface from the source for listening the echo of sound is
[1] 28 m [2] 18 m
[3] 19 m [4] 16.5 m

46. The type of waves that can be propagated through solid is
[1] Transverse [2] Longitudinal
[3] Both (a) and (b) [4] None of these

47. A man stands in front of a hillock and fires a gun. He hears an echo after 1.5 sec. The distance of the hillock from the man is (velocity of sound in air is 330 m/s)
[1] 220 m [2] 247.5 m
[3] 268.5 m [4] 292.5 m

48. Velocity of sound in air
I. Increases with temperature
II. Decreases with temperature
III. Increase with pressure
IV. Is independent of pressure
V. Is independent of temperature
Choose the correct answer.
[1] Only I and II are true
[2] Only I and III are true
[3] Only II and III are true
[4] Only 1 and IV are true

49. The speed of a wave in a medium is 760 m/s. If 3600 waves are passing through a point, in the medium in 2 minutes, then its wavelength is
[1] 13.8 m [2] 25.3 m
[3] 41.5 m [4] 57.2 m

50. If at same temperature and pressure, the densities for two diatomic gases are respectively d_1 and d_2, then the ratio of velocities of sound in these gases will be
[1] $\sqrt{\frac{d_1}{d_2}}$ [2] $\sqrt{\frac{d_2}{d_1}}$
[3] $d_1 d_2$ [4] $\sqrt{d_1 d_2}$

51. The frequency of a tunning fork is 384 per second and velocity of sound in air is 352 m/s. How far the sound has traversed while fork completes 36 vibration
[1] 3 m [2] 13 m
[3] 23 m [4] 33 m

52. v_1 and v_2 are the velocities of sound at the same temperature in two monoatomic gases of densities ρ_1 and ρ_2 respectively. If $\rho_1 / \rho_2 = \frac{1}{4}$ then the ratio of velocities v_1 and v_2 will be
[1] 1 : 2 [2] 4 : 1
[3] 2 : 1 [4] 1 : 4

53. The temperature at which the speed of sound in air becomes double of its value at 0°C is
[1] 273 K [2] 546 K
[3] 1092 K [4] 0 K

54. If wavelength of a wave is $\lambda = 6000Å$. Then wave number will be
[1] $166 \times 10^3 m^{-1}$ [2] $16.6 \times 10^{-1} m^{-1}$
[3] $1.66 \times 10^6 m^{-1}$ [4] $1.66 \times 10^7 m^{-1}$

55. Velocity of sound measured in hydrogen and oxygen gas at a given temperature will be in the ratio

[1] 1 : 4 [2] 4 : 1
[3] 2 : 1 [4] 1 : 1

56. Find the frequency of minimum distance between compression & rarefaction of a wire. If the length of the wire is lm & velocity of sound in air is 360 m/s

[1] 90 sec^4 [2] 180 sec^{-1}
[3] 120 sec^1 [4] 360 sec^{-1}

57. The velocity of sound is us in air. If the density of air is increased to 4 times, then the new velocity of sound will be

[1] $\frac{V_s}{2}$ [2] $\frac{V_s}{12}$
[3] $12v_s$ [4] $\frac{3}{2}v_s^2$

58. It takes 2.0 seconds for a sound wave to travel between two fixed points when the day temperature is 10°C. If the temperature rise to 30°C the sound wave travels between the same fixed parts in

[1] 1.9 sec [2] 2.0 sec
[3] 2.1 sec [4] 2.2 sec

59. If v_m is the velocity of sound in moist air, v_d is the velocity of sound in dry air, under identical conditions of pressure and temperature

[1] $v_m > v_d$ [2] $v_m < v_d$
[3] $v_m = v_d$ [4] $v_m v_d = 1$

60. If the phase difference between two sound waves of wavelength λ is 60°, the corresponding path difference is

[1] $\frac{\lambda}{6}$ [2] $\frac{\lambda}{2}$
[3] 2λ [4] $\frac{\lambda}{4}$
[5] $\frac{6}{\lambda}$

61. A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500 m/s and in air is 300 m/s. The frequency of sound recorded by an observer who is standing in air is

[1] 200 H_z [2] 3000 H_z
[3] 120 H_z [4] 600 H_z

62. If the temperature of the atmosphere is increased, the following character of the sound wave is effected

[1] Amplitude [2] Frequency
[3] Velocity [4] Wavelength

63. An underwater sonar source operating at a frequency of 60 kHz directs its beam towards the surface. If the velocity of sound in air is 330 m/s, the wavelength and frequency of waves in air are:

[1] 5.5 mm, 60 kHz [2] 330 m, 60 kHz
[3] 5.5 mm, 20 kHz [4] 5.5 mm, 80 kHz

64. Two sound waves having a phase difference of 60° have path difference of

[1] 2λ [2] λ / 2
[3] λ / 6 [4] λ / 3

65. It is possible to distinguish between the transverse and longitudinal waves by studying the property of

[1] Interference [2] Diffraction
[3] Reflection [4] Polarisation

66. Water waves are

[1] Longitudinal
[2] Transverse
[3] Both longitudinal and transverse
[4] Neither longitudinal nor transverse

67. The phenomenon of sound propagation in air is

[1] Isothermal process [2] Isobaric process
[3] Adiabatic process [4] None of these

68. The waves in which the particles of the medium vibrate in a direction perpendicular to the direction of wave motion is known as

[1] Transverse wave [2]Longitudinal waves
[3] Propagated waves [4] None of these

69. A point source emits sound equally in all directions in a non-absorbing medium, Two points P and Q are at distance of 2_m and 3_m respectively from the source. The ratio of the intensities of the waves at P and Q is
[1] 9 : 4 [2] 2 : 3
[3] 3 : 2 [4] 4 : 9

70. Which of the following is the longitudinal wave
[1] Sound waves
[2] Waves on plucked string
[3] Water waves
[4] Light waves

71. The nature of sound waves in gases is
[1] Transverse [2] Longitudinal
[3] Stationary [4] Electromagnetic

72. Transverse waves can propagate in
[1] Liquids [2] Solids
[3] Gases [4] None of these

73. Ultrasonic signal sent from SONAR returns to it after reflection from a rock after a lapse of 1 sec, If the velocity of ultrasound in water is 1600 ms^{-1}, the depth of the rock in water is
[1] 300 m [2] 400 m
[3] 500 m [4] 800 m

74. Which of the following is not the transverse wave
[1] X-rays [2] γ-rays
[3] Visible light wave
[4] Sound wave in a gas

75. What is the phase difference between two successive crests in the wave
[1] π [2] $\pi/2$ [3] 2π [4] 4π

76. A wave of frequency 500 Hz has velocity 360 m/sec. The distance between two nearest points 60° out of phase, is
[1] 0.6 cm [2] 12 cm
[3] 60 cm [4] 120 cm

77. The following phenomenon cannot be observed for sound waves
[1] Refraction [2] Interference
[3] Diffraction [4] Polarisation

78. When an aeroplane attains a speed higher than the velocity of sound in air, a loud bang is heard. This is because
[1] It explodes
[2] It produces a shock wave which is received as the bang
[3] Its wings vibrate sc violently that the bang is heard
[4] The normal engine noises undergo a Doppler shift to generate the bang

79. A micro-wave and an ultrasonic sound wave have the same wavelength. Their frequencies are in the ratio (approximately)
[1] 106 : 1 [2] 104 : 1
[3] 102 : 1 [4] 10 : 1

80. A big explosion on the moon cannot be heard on the earth because
[1] The explosion produces high frequency sound waves which are inaudible
[2] Sound waves require a material medium for propagation
[3] Sound waves are absorbed in the moon's atmosphere
[4] Sound waves are absorbed in the earth's atmosphere

81. Sound waves of wavelength greater than that of audible sound are called
[1] Seismic waves [2] Sonic waves
[3] Ultrasonic waves [4] Infrasonic waves

82. 'SONAR' emits which of the following waves
[1] Radio waves [2] Ultrasonic waves
[3] Lightwaves [4] Magnetic waves

83. Which of the following do not require medium for transmission
(a) Cathode ray [2] Electromagnetic wave
(c) Sound wave [4] None of the above

84. Consider the following
I. Waves created on the surfaces of a water pond by a vibrating sources,
II. Wave created by an oscillating electric field in air,
III. Sound waves travelling under water.
Which of these can be polarized
[1] I and II [2] II only
[3] II and III [4] I,II and III

85. Speed of sound in mercury at a certain temperature is 1450 m/s. Given the density of mercury as 13.6 x 10^3 kg / m^3, the bulk modulus for mercury is
[1] 2.86 x 10^{10} N/m^3 [2] 3.86 x 10^{10} N/m^3
[3] 4.86 x 10^{10} N/m^3 [4] 5.86 x 10^{10} N/m^3

86. The ratio of densities of nitrogen and oxygen is 14:16. The temperature at which the speed of sound in nitrogen will be same at that in oxygen at 55°C is
[1] 35°C [2] 48°C
[3] 65°C [4] 14°C

87. The intensity of sound increases at night due to
[1] Increase in density of air
[2] Decrease in density of air
[3] Low temperature
[4] None of these

88. A wavelength 0.60 cm is produced in air and it travels at a speed of 300 ms^{-1}. It will be an
[1] Audiable wave
[2] Infrasonic wave
[3] Ultrasonic wave
[4] None of the above

Progressive Waves

1. A progressive wave y=A sin (kx-ωt) is reflected by a rigid wall at x=0. Then the reflected wave can be represented by
[1] y = A sin (kx + ωt) [2] y = A cos (kx + ωt)
[3] y = -A sin (kx - ωt) [4] y = -A sin (kx +ωt)
[5] y = A cos (kx - ωt)

2. Equation of a progressive wave is given by
$y = 0.2\cos \pi\ 0.04t + .02x - \frac{\pi}{6}$
The distance is expressed in cm and time in second. What will be the minimum distance between two particles having the phase difference of
[1] 4 cm [2] 8 cm
[3] 25 cm [4] 12.5 cm

3. A sound wave y = A_0 sin (ωt-kx) is reflected from a rigid wall with 64% of its amplitude. The equation of the reflected wave is
[1] $y = \frac{64}{100} A_0 \sin(\omega t + kx)$
[2] $y = -\frac{64}{100} A_0 \sin(\omega t + kx)$
[3] $y = \frac{64}{100} A_0 \sin(\omega t - kx)$
[4] $y = \frac{64}{100} A_0 \cos(\omega t - kx)$

4. The equation of a transverse wave is given by
y = 10 sin π (0.01x-2t)
where x and y are in cm and t is in second. Its frequency is
[1] 10 sec^{-1} [2] 2 sec^{-1}
[3] 1 sec^{-1} [4] 0.01 sec^{-1}

5. A wave travellig along the x-axis is described by the equation y(x,t) = 0.005 cos (ax-βt). If the wavelength and the time period of the wave are 0.08 m and 2.0s, respectively, then α and β in appropriate units are
[1] $\alpha = \frac{0.08}{\pi}, \beta = \frac{2.0}{\pi}$
[2] $\alpha = \frac{0.04}{\pi}, \beta = \frac{1.0}{\pi}$
[3] α=12.50 π , β= $\frac{\pi}{2.0}$
[4] α=25.00 π ,β= π

6. A wave of frequency 500 Hz has a velocity 300 m/s. The phase difference between the two points is 60°, then the path difference is
[1] 10 cm [2] 20 cm
[3] 30 cm [4] 50 cm

7. The function $\sin^2(\omega t)$ reprensents
[1] A periodic, but not simple harmonic motion

with a period $2\pi/\omega$

[2] A periodic, but not simple harmonic motion with a period π/ω

[3] A simple harmonic motion with a period $2\pi/\omega$

[4] A simple harmonic motion with a period π/ω

8. Two waves are given by $y_1 = a\sin(\omega t - kx)$ and $y_2 = a\cos(\omega t - kx)$ The phase difference between the two waves is

[1] $\pi/4$ [2] π
[3] $\pi/8$ [4] $\pi/2$

9. The wave function (in SI unit) for a light wave is given as $\Psi(x, t) = 10^3 \sin\pi(3\times10^6 x - 9\times10^{14} t)$ The frequency of the wave is equal to

[1] 4.5×10^{14}Hz [2] 3.5×10^{14}Hz
[3] 3.0×10^{10}Hz [4] 2.5×10^{10}Hz

10. A travelling acoustic wave of frequency 500Hz is moving along the positive x-direction with a velocity of $300 ms^{-1}$. The phase difference between two points x_1 and x_2 is 60°. Then the minimum separation between the two points is

[1] 1 mm [2] 1 cm
[3] 10 cm [4] 1 m

11. A wave is reflected from a rigid support. The change in phase on refledion will be

[1] $\pi/4$ [2] $\pi/2$
[3] π [4] 2π

12. If the wave equation $y = 0.08 \sin\frac{2\pi}{\lambda}(200t - x)$ then the velocity of the wave will be

[1] $400\sqrt{2}$ [2] $200\sqrt{2}$
[3] 400 [4] 200

13. The phase difference between two waves represented by $y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]$m
$y_2 = 10^{-6}\cos[100t + (x/50)]$m
where x is expressed in metres and t is expressed in seconds, is approximately

[1] 1.5 rad [2] 1.07 rad
[3] 2.07 rad [4] 0.5 rad

14. The equation of a wave travelling in a string can be written as $y = 3\cos\pi(100t - x)$. Its wavelength is

[1] 100 cm [2] 2 cm
[3] 5 cm [4] None of the above

15. A transverse wave is described by the equation $Y = Y_0 \sin\pi$ The maximum particle velocity is four times the wave velocity if

[1] $\lambda = \frac{\pi Y_0}{4}$ [2] $\lambda = \frac{\pi Y_0}{2}$
[3] $\lambda = \pi Y_0$ [4] $\lambda = 2\pi Y_0$

16. A wave motion is described by $y(x,t) = a\sin(kx - wt)$. Then the ratio of the maximum particle velocity to the wave velocity is

[1] ωa [2] $\frac{1}{ka}$
[3] $\frac{\omega}{k}$ [4] ka

17. The displacement y of a wave travelling in the x-direction is given by $y = 10^4 \sin\left(600t - 2x + \frac{\pi}{3}\right)$ metres, where x is expressed in metres and t in seconds. The speed of the wave-motion, in ms^{-1}, is

[1] 200 [2] 300
[3] 600 [4] 1200

18. When a wave travels in a medium, the particle displacement is given by the equation $y = a\sin 2\pi(bt - cx)$ where a,b and c are constants. The maximum particle velocity will be twice the wave velocity if

[1] $c = \frac{1}{\pi a}$ [2] $c = \pi a$
[3] $b = ac$ [4] $b = \frac{1}{ac}$
[5] $a = bc$

19. If $y = 5\sin(30\pi t - \frac{\pi}{7} + 30°)$ y → mm, t → second, x → m. For given progressive wave equation, phase difference between two vibrating particle having path difference 3.5 m would be

[1] $\pi/4$ [2] π
[3] $\pi/3$ [4] $\pi/2$

20. When a longitudinal wave propagates through a medium, the particles of the medium execute

simple harmonic oscillations about their mean positions. These oscillations of a particle are characterised by an invariant

[1] Kinetic energy
[2] Potential energy
[3] Sum of kinetic energy and potential energy
[4] Difference between kinetic energy and potential energy

21. In a plane progressive wave given by y $y = 25\cos(2\pi t - \pi x)$, the amplitude and frequency are respectively

[1] 25,100   [2] 25, 1
[3] 25, 2   [4] 50π, 2

22. The equation of the propagating wave is $y = 25\sin(20t + 5x)$, where y is displacement. Which of the following statements is not true

[1] The amplitude of the wave is 25 units
[2] The wave is propagating in positive x-direction
[3] The velocity of the wave is 4 units
[4] The maximum velocity of the particles is 500 units

23. The equation of a wave is given as $y = 0.07\sin(12\pi x - 3000\pi t)$. Where x is in metre and t in sec, then the correct statement is

[1] $\lambda = 1/6$m, $v = 250$m / s
[2] $a = 0.07$m, $v = 300$m / s
[3] n =1500, v - 200m / s
[4] None

24. A wave is represented by the equation $y = 0.5\sin(10t - x)$m . It is a travelling wave propagating along the + x direction with velocity

[1] 10 m/s   [2] 20 m/s
[3] 5 m/s   [4] None of these

25. The wave described by $y = 0.25\sin(10\pi x - 2\pi f)$ where x and y are in meters and t in seconds, is a wave travelling along the

(a) Positive x direction with frequency 1 Hz and wavelength $\lambda = 0.2$m
(b) Negative x direction with amplitude 0.25 m and wavelength $\lambda = 0.2$m
[3] Negative x direction with frequency π Hz
[4] Positive x direction with frequency it Hz. and wavelength $\lambda = 0.2$m

26. The equation of a transverse wave travelling on a rope is given by $y = 10\sin\pi(0.01x - 2.00t)$ where y and x are in cm and t in seconds. The maximum transverse speed of a particle in the rope is about

[1] 63 cm/s   [2] 75 cm/s
[3] 100 cm/s   [4] 121 cm/s

27. Which of the following is not true for this progressive wave $y = 4\sin 2\pi\left(\frac{t}{0.02} - \frac{x}{100}\right)$ where y and x are in cm & t in sec

[1] Its amplitude is 4 cm
[2] Its wavelength is 100 cm
[3] Its frequency is 50 cycles/sec
[4] Its propagation velocity is 50×10^3 cm/sec

28. A transverse wave is represented by the equation $y = y_0 \sin\frac{2\pi}{\lambda}(vt - x)$
For what value of λ, the maximum particle velocity equal to two times the wave velocity

[1] $\lambda = 2\pi y_0$ [2] $\lambda = \pi y_0/3$
[3] $\lambda = \pi y_0/2$ [4] $\lambda = \pi y_0$

29. A travailing wave in a stretched string is described by the aquation $y = A\sin(kx - \omega t)$. The maximum particle velocity is

[1] $A\omega$ [2] ω/k
[3] $d\omega/dk$ [4] x/t

30. A wave travels in a medium according to the equation of displacement given by $y(x, t) = 0.03\sin\pi(2t - 0.01x)$ where y and x are in metres and t in seconds. The wavelength of the wave is

[1] 200 m   [2] 100 m
[3] 20 m   [4] 10 m

31. The equation of a progressive wave is $y = 8\sin\left[\pi\left(\frac{t}{10} - \frac{x}{4}\right) + \frac{\pi}{3}\right]$. The wavelength of the wave is

[1] 8 m   [2] 4 m
[3] 2 m   [4] 10 m

32. A wave is given by $y = 3 \sin 2\pi \left(\frac{t}{0.04} - \frac{x}{0.01}\right)$ where y is in cm. Frequency of wave and maximum acceleration of particle will be
[1] 100 Hz, 4.7×10^3 cm / s^2
[2] 50 Hz, 7.5×10^3 cm / s^2
[3] 25Hz, 4.7×10^4 cm /s^2
[4] 25Hz, 7.4×10^4 cm / s^2

33. Equation of a progressive wave is given by
$$y = 4 \sin \left\{\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right\}$$
Then which of the following is correct
[1] u = 5m /sec [2] λ = 18m
[3] a = 0.04 m [4] n = 50Hz

34. With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the propagation direction are
[1] Energy, momentum and mass
[2] Energy
[3] Energy and mass
[4] Energy and linear momentum

35. The frequency of the sinusoidal wave $y = 0.40 \cos[2000t + 0.80x]$ would be
[1] 1000π Hz [2] 2000 Hz
[3] 20 Hz [4] $\frac{1000}{\pi}$ Hz

36. Which of the following equations represents a wave
[1] $Y = A(\omega t - kx)$ [2] $Y = A \sin \omega t$
[3] $Y = A \cos kx$ [4] $Y = A \sin (at-bx+c)$

37. The equation of a transverse wave is given by $y = 100 \sin \pi (0.04z-2t)$
where y and z are in cm and t is In seconds. The frequency of the wave in Hz is
[1] 1 [2] 2 [3] 25 [4] 10

38. The equation of a plane progressive wave is given by $y = 0.025\sin(100t + 0.25x)$. The frequency of this wave would be
[1] $\frac{50}{\pi}$ Hz [2] $\frac{100}{\pi}$ Hz
[3] 100 Hz [4] 50 Hz

39. The equation of a sound wave is
$y = 0.0015 \sin(62.4x + 316t)$
The wavelength of this wave is
[1] 0,2 unit [2] 0.1 unit
[3] 0.3 unit [4]Cannot be calculated

40. Equation of a progressive wave is given by $y = a\sin \pi \left[\frac{t}{2} - \frac{x}{4}\right]$, where t is in seconds and x is in meters. The distance through which the wave moves in 8 sec is (in meter)
[1] 8 [2] 16 [3] 2 [4] 4

41. A pulse or a wave train travels along a stretched string and reaches the fixed end of the string. It will be reflected back with
[1] The same phase as the incident pulse but with velocity reversed
[2] A phase change of 180° with no reversal of velocity
[3] The same phase as the incident pulse with no reversal of velocity
[4] A phase change of 180° with velocity reversed

42. The equation of a travelling wave is
$y = 60 \cos(1800t - 6x)$
where y is in microns, t in seconds and x in metres. The ratio of maximum particle velocity to velocity of wave propagation is
(a) 3.6×10^{-11} [2] 3.6×10^{-6}
(c) 3.6×10^{-4} [4] 3.6

43. The wave equation is $y = 0.30 \sin (314t-1.57x)$ where t, x and y are in second, meter and centimeter respectively. The speed of the wave is
[1] 100 m/s [2] 200 m/s
[3] 300 m/s [4] 400 m/s

44. A particle moving along x-axis has acceleration f, at time t, given by where f_0, and T are constants. The particle at t=0 has zero velocity. In the time interval between t=0 and the instant when f = 0 , the particle's velocity (vx) is
[1] f_0T [2] $\frac{1}{2} f_0T^2$
[3] f_0T^2 [4] $\frac{1}{2} f_0T$

45. When beats are produced by two progressive waves of the same amplitude and of nearly the same frequency, the ratio of maximum loudness to the loudness of one of the waves will be n. Where n is
[1] 3 [2] 1 [3] 4 [4] 2

46. Two waves of frequencies 20 Hz and 30 Hz. Travels out from a common point. The phase difference between them after 0.6 sec is
[1] Zero [2] $\frac{\pi}{2}$
[3] π [4] $\frac{3\pi}{4}$

47. Given that $y = A \sin\left[\left(\frac{2\pi}{\lambda}(ct - x)\right)\right]$, where y and x are measured in metres. Which of the following statements is true
[1] The unit of λ^{-1} is same as that of $\frac{2\pi}{\lambda}$
[2] The unit of λ is same as that of x but not of A
[3] The unit of c is same as that of $\frac{2\pi}{\lambda}$
[4] The unit of (ct - x) is same as that of $\frac{2\pi}{\lambda}$

48. A plane progressive wave is represented by the equation $y = 0.1 \sin\left(200\pi t - \frac{20\pi t}{17}\right)$ where y is displacement in m, t in second and x is distance from a fixed origin in meter.
The frequency, wavelength and speed of the wave respectively are
[1] 100 Hz, 1.7 m, 170 m/s
[2] 150 Hz, 2.4 m, 200 m/s
[3] 80 Hz, 1.1 m, 90 m/s
[4] 120 Hz, 1.25 m, 207 m/s

49. If the equation of transverse wave is $y = 5 \sin 2\pi\left[\frac{t}{0.04} - \frac{x}{40}\right]$, where distance is in cm and time in second, then the wavelength of the wave is
[1] 60 cm [2] 40 cm
[3] 35 cm [4] 25 cm

50. A wave is represented by the equation : y = a sin(0.01x - 2t) where a and x are in cm. velocity of propagation of wave is
[1] 10 cm/s [2] 50 cm/s
[3] 100 cm/s [4] 200 cm/s

51. A simple harmonic progressive wave is represented by the equation : y =8 sin 2π (0.1x - 2t) where x and y are in cm and t is in seconds. At any instant the phase difference between two particles separated by 2.0 cm in the x-direction is
[1] 18° [2] 36°
[3] 54° [4] 72°

52. The phase difference between two points separated by 0.8 m in a wave of frequency is 120 Hz is π/2. The velocity of wave is
[1] 720 m/s [2] 384 m/s
[3] 250 m/s [4] 1 m/s

53. If the equation of transverse wave is Y = 2 sin {π (kx - 2x)}, then the maximum particle velocity is
[1] 4 units [2] 2 units
[3] 0 [4] 6 units

54. A wave is represented by the equation y = 7 sin{π (2t - 2x)} where x is in metres and t in seconds. The velocity of the wave is
[1] 1 m/s [2] 2 m/s
[3] 5 m/s [4] 10 m/s

55. A particle on the trough of a wave at any instant will come to the mean position after a time (T = time period)
[1] T / 2 [2] T / 4
[3] T [4] 2T

56. A wave equation which gives the displacement along y - direction is given by y = 0.001 sin (100t + x) where x and y are in meter and t is time in second. This represented a wave
[1] Of frequency 100/π Hz
[2] Of wavelength one metre
[3] Travelling with a velocity of 50/π ms^{-1} in the positive X-direction
[4] Travelling with a velocity of 100 ms^{-1} in the negative X-direction

57. The equation of a simple harmonic wave is given by $y = 5\sin\frac{\pi}{2}(100t - x)$ where x and y

are in metre and time is in second. The period of the wave in second will be

[1] 0.04 [2] 0.01
[3] 1 [4] 5

58. The equation of a wave is represented by $y = 10^{-4}\sin\left[100t - \frac{x}{10}\right]$. The velocity of the wave will be

[1] 100 m/s [2] 250 m/s
[3] 750 m/s [4]1000 m/s

59. A wave travelling in positive X-direction with A = 0.2m has a velocity of 360 m/sec. if λ = 60m, then correct expression for the wave is

[1] $y = 0.2 \sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$

[2] $y = 0.2 \sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$

[3] $y = 0.2 \sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$

[4] $y = 0.2 \sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$

60. Which of the following equations represents a wave travelling along y-axis

(a) y = A sin (kx--ωt) [2] x = A sin (ky - ωt)
(c) y = A sin ky cos ωt [4] y = A cos ky sin ωt

61. Two waves represented by the following equations are travelling in the same medium

$y_1 = 5 \sin 2\pi (75t-0.25x)$,
$y_2 = 10 \sin 2\pi (150t-0.50x)$

The intensity ratio of the two waves is

[1] 1 : 2 [2] 1 : 4
[3] 1 : 8 [4] 1 : 16

INTERFERENCE AND SUPERPOSITION OF WAVES

1. Three sound waves of equal amplitudes have frequencies (v - 1), v, (v + 1) . They superpose to give beats. The number of beats produced per second will be

[1] 4 [2] 3 [3] 2 [4] 1

2. Two periodic waves of amplitude A_1 and A_2 pass through a region. If $A_1 > A_2$, the difference in the maximum and minimum resultant amplitude possible is

[1] 2^ (b) $2A_2$
[3] $A_1 + A_2$ (d) $A_1 - A_2$

3. If the phase difference between the two wave is 2π during superposition, then the resultant amplitude is

[1] Maximum
[2] Minimum
[3] Maximum or minimum
[4] None of the above

4. Two waves are represented by $y_1 = 4 \sin 404 \pi t$ and $y_2 = 3 \sin 400 \pi t$. Then

[1] Beat frequency is 4 Hz and the ratio of maximum to minimum intensity is 49 : 1
[2] Beat frequency is 2 Hz and the ratio of maximum to minimum intensity is 49 :1
[3] Beat frequency is 2 Hz and the ratio of maximum to minimum intensity is 1 : 49
[4] Beat frequency is 4 Hz and the ratio of maximum to minimum intensity is 1 : 49

5. If two waves of same frequency and same amplitude respectively, on superimposition produced a resultant disturbance of the same amplitude, the waves differ in phase by

[1] π [2] $2\pi / 3$
[4] $\pi / 2$ [4] Zero

6. A stationary point source of sound emits sound uniformly in all directions in a non-absorbing medium. Two points P and Q are at a distance of 4 m and 9 m respectively from the source. The ratio of amplitudes of the waves at P and Q is

[1] 3/2 [2] 4/9
[3] 2/3 [4] 9/4

7. 1 wo waves are propagating to the point P aiong a straight line produced by two sources A and B of simple harmonic and of equal frequency. The amplitude of every wave at P is 'a' and the phase of A is ahead by π /3 than that of B and the distance AP is greater than BP by 50 cm. Then the resultant amplitude at the point P will be, if the wavelength is 1 meter

[1] 2a [2] a $\sqrt{3}$
[3] a $\sqrt{2}$ [4] a

8. Two identical sinusoidal waves each of amplitude 5 mm with a phase difference of π / 2 are traveling in the same direction in a string. The amplitude of the resultant wave (in mm) is
[1] Zero [2] 5 $\sqrt{2}$
[3] 5 / $\sqrt{2}$ [4] 2.5

9. The minimum intensity of sound is zero at a point due to two sources of nearly equal frequencies, when
[1] Two sources are vibrating in opposite phase
[2] The amplitude of two sources are equal
[3] At the point of observation, the amplitudes of two S.H.M. produced by two sources are equal and both the S.H.M. are along the same straight line
[4] Both the sources are in the same phase6.

10. The wavelength of a wave in a medium is 0.5 m. The phase difference between the oscillations at two points in the $\frac{\pi}{5}$. What is the minimum distance between these points
[1] 0.05 m [2] 0.1 m
[3] 0.25 m [4] 0.15 m

11. If two waves having amplitudes 2A and A and same frequency and velocity, propagate in the same direction in the same phase, the resulting amplitude will be
[1] 3A [2] $\sqrt{5}$ A
[3] $\sqrt{2}$ A [4] A

12. Two periodic waves of intensities and 12 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is
[1] $(\sqrt{I_1}-\sqrt{I_2})^2$ [2] $2(I_1+I_2)$
[3] I_1+I_2 [4] $(\sqrt{I_1}+\sqrt{I_2})^2$

13. Two sound waves travel in the same direction in a medium. The amplitude of each wave is A and the phase difference between the two waves is 120°. The resultant amplitude will be
[1] $\sqrt{2}$ A [2] 2A
[3] 3 A [4] 4 A
[5] A

14. Law of superposition is applicable to only
[1] Light waves [2] Sound waves
[3] Transverse waves [4] All kinds of waves

15. The superposing waves are represented by the following equations :
$y_1 = 5\sin 2\pi(10t - 0.1x)$, $y_2 = 10\sin 2\pi(20t - 0.2x)$
Ratio of intensities $\frac{I_{max}}{I_{min}}$ will be
[1] 1 [2] 9 [3] 4 [4] 16

16. The displacement of a particle is given by
$x = 3\sin(5\pi t) + 4\cos(5\pi t)$
The amplitude of the particle is
[1] 3 [2] 4 [3] 5 [4] 7

17. Two waves
$y_1 = A_1 \sin(\omega t - \beta_1)$, $y_2 = A_2 \sin(\omega t - \beta_2)$
Superimpose to form a resultant wave whose amplitude is
[1] $\sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\beta_1 - \beta_2)}$
[2] $\sqrt{A_1^2 + A_2^2 + 2A_1A_2\sin(\beta_1 - \beta_2)}$
[3] $A_1 + A_2$
[4] $|A_1 + A_2|$

18. Beats are produced with the help of two sound waves of amplitudes 3 and 5 units. The ratio of maximum to minimum intensity in the beats is
[1] 2 : 1 [2] 5 : 3
[3] 4 : 1 [4] 16 : 1

19. The two interfering waves have intensities in the ratio 9 : 4. The ratio of intensities of maxima and minima in the interference pattern will be
[1] 1 : 25 [2] 25 : 1
[3] 9 : 4 [4] 4 : 9

20. If the ratio of amplitude of two waves is 4 : 3. Then the ratio of maximum and minimum

intensity will be

[1] 16 : 18 [2] 18 : 16
[3] 4 9 : 1 [4] 1 : 49

21. Equation of motion in the same direction is given by - y_1 = A sin (ωt-kx), y_2 = A sin (ωt-kx-θ) The amplitude of the medium particle will be

[1] $2A\cos\frac{\theta}{2}$ [2] 2A cos θ
[3] $\sqrt{2}\ A\cos\frac{\theta}{2}$ [4] $\sqrt{2}$ A cos θ

22. Two waves having the intensities in the ratio of 9 : 1 produce interference. The ratio of maximum to the minimum intensity, is equal to

[1] 2 : 1 [2] 4 : 1
[3] 9 : 1 [4] 10 : 8

23. The displacement of the interfering sound waves are $y_1 = 4\sin\omega t$ and $y_2 = 3\sin\left(\omega t + \frac{\pi}{2}\right)$ What is the amplitude of the resultant wave

[1] 5 [2] 7
[3] 1 [4] 0

24. Two waves are represented by $y_1 = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and y_2 = a cos ωt. What will be their resultant amplitude

[1] a [2] $\sqrt{2}$ a
[3] $\sqrt{3}$ a [4] 2a

25. The amplitude of a wave represented by displacement equation $y = \frac{1}{\sqrt{a}}\sin\omega t \pm \frac{1}{\sqrt{b}}\cos\omega t$ will be

[1] $\frac{a+b}{ab}$ [2] $\frac{\sqrt{a}+\sqrt{b}}{ab}$
[3] $\frac{\sqrt{a}\pm\sqrt{b}}{ab}$ [4] $\sqrt{\frac{a+b}{ab}}$

26. Two waves having equations $x_1 = a\sin(\omega t + \phi_1)$, $x_2 = a\sin(\omega t + \phi_2)$ If in the resultant wave the frequency and amplitude remain equal to those of superimposing waves. Then phase difference between them is

[1] π / 6 [2] 2π / 3
[3] π / 4 [4] π / 3

27. Equation of motion in the same direction are given by y_1 = 2a sin (ωt-kx), and y_2 = 2a sin (ωt-kx-θ) The amplitude of the medium particle will be

[1] 2 acos θ [2] $\sqrt{2}$ a cos θ
[3] 4a cos θ / 2 [4] $\sqrt{2}$ a cos θ / 2

28. Two waves coming from two coherent sources, having different intensities interfere tneir ratio of maximum intensity to the minimum intensity is 25. The intensities of the sources are in the ratio

[1] 25 : 1 [2] 25 : 16
[3] 9 : 4 [4] 5 : 1

29. Light from two coherent sources of the same amplitude A and wavelength λ illuminates the screen. The intensity of the central maximum is I_0. If the sources were incoherent, the intensity at the same point will be

[1] $4I_0$ [2] $2I_0$
[3] I_0 [4] $I_0/2$

30. In the experiment to determine the speed of sound using a resonance column

[1] Prongs of the tuning fork are kept in a vertical plane

[2] Prongs of the tuning fork are kept in a horizontal plane

[3] In one of the two resonances observed, the length of the resonating air column is close to the wavelength of sound in air

[4] In one of the two resonances observed, the length of the resonating air column is close to half of the wavelength of sound in air

31. The transverse displacement of a string fixed at both ends is given by $y = 0.06\sin\frac{2\pi x}{3}\cos(120\pi t)$ y and x are in metres and t in seconds. The wavelength and frequency of the two superposing waves are

[1] 2m, 120 Hz [2] $\frac{2}{3}$ m, 60 Hz
[3] $\frac{3}{2}$ m, 120 Hz [4] 3m, 60 Hz

BEATS

1. Two tuning forks when sounded together produced 4 beats/sec. The frequency of one fork is 256. The number of beats heard increases when the fork of frequency 256 is loaded with wax. The frequency of the other fork is
[1] 504 [2] 520
[3] 260 [4] 252

2. Beats are the result of
[1] Diffraction
[2] Destructive interference
[3] Constructive and destructive interference
[4] Superposition of two waves of nearly equal frequency

3. Two adjacent piano keys are struck simultaneously. The notes emitted by them have frequencies n_1 and n_2. The number of beats heard per second is
[1] $\frac{1}{2}(n_1 - n_2)$ [2] $\frac{1}{2}(n_1 + n_2)$
[3] $(n_1 \sim n_2)$ [4] $(n_1 - n_2)$

4. Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20 N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is
[1] 5 [2] 7
[3] 8 [4] 3

5. Two tuning forks of frequencies n_1 and n_2 produces n beats per second. If n_2 and n are known, n_1 may be given by
[1] $\frac{n_2}{n} + n_2$ [2] $n_2 n$
[3] $n_2 \pm n$ [4] $\frac{n_2}{n} - n_2$

6. If two tuning forks A and B are sounded together, they produce 4 beats per second. A is then slightly loaded with wax, they produce 2 beats when sounded again. The frequency of A is 256. The frequency of B will be
[1] 250 [2] 252
[3] 260 [4] 262

7. A tuning fork of frequency 250 Hz produces a beat frequency of 10 Hz when sounded with a sonometer vibrating at its fundamental frequency. When the tuning fork is filed, the beat frequency decreases. If the length of the sonometer wire is 0.5 m, the speed of the transverse wave is
[1] 260 ms^{-1} [2] 250 ms^{-1}
[3] 240 ms^{-1} [4] 500 ms^{-1}
[5] 520 ms^{-1}

8. Two tuning forks have frequencies 450 Hz and 454 Hz respectively. On sounding these forks together, the lime interval between successive maximum intensities will be
[1] 1/4 sec [2] 1/2 sec
[3] 1 sec [4] 2 sec

9. Two sound waves with wavelengths 5.0 m and 5.5 m respectively, each propagate in a gas with velocity 330 m/s We expect the following number of beats per second
[1] 1 [2] 6
[3] 12 [4] 0

10. A sound source of frequency 170 Hz is placed near a wall. A man walking from a source towards the wall finds that there is a periodic rise and fall of sound intensity. If the speed of sound in air is 340 m/s. then distance (in metres) separating the two adjacent positions of minimum intensity is
[1] 1/2 [2] 1
[3] 3/2 [4] 2

11. Pulse rate of a normal person is 75 per minute. The time period of heart is
[1] 0.8 seconds [2] 0.75 seconds
[3] 1.25 seconds [4] 1.75 seconds

12. The length of the wire between two ends of a sonometer is 100 cm. What should be the positions of two bridges below the wire so that the three segments of the wire have their fundamental frequencies in the ratio 1 : 3 : 5
[1] $\frac{1500}{23}$ cm, $\frac{500}{23}$ cm
[2] $\frac{1500}{23}$ cm, $\frac{300}{23}$ cm

[3] $\frac{300}{23}$cm, $\frac{1500}{23}$cm
[4] $\frac{1500}{23}$cm, $\frac{2000}{23}$cm

13. Two sources P and Q produce notes of frequency 660 Hz each. A listener moves from P to Q with a speed of $1 ms^{-1}$. If the speed of sound is 330 m/s, then number of beats heard by the listener per second will be
[1] 4 [2] 8
[3] 2 [4] zero

14. A source of unknown frequency gives 4 beats/s, when sounded with a source of known frequency 250 Hz, The second harmonic of the source of unknown frequency gives five beats per second, when sounded with a source of frequency 513 Hz, The unknown frequency is
[1] 260 Hz [2] 254 Hz
[3] 246 Hz [4] 240 Hz

15. The beats are produced by two sound sources of same amplitude and of nearly equal frequencies. The maximum intensity of beats will be that of one source
[1] Same [2] Double
[3] Four times [4] Eight times

16. Beats are produced by two waves given by y_1 = a sin 2000 and y_2 = a sin 2008 M . The number of beats heard per second is
[1] Zero [2] One
[3] Four [4] Eight

17. A tuning fork whose frequency as given by manufacturer is 512 Hz is being tested with an accurate oscillator. It is found that the fork produces a beat of 2 Hz when oscillator reads 514 Hz but produces a beat of 6 Hz when oscillator reads 510 Hz. The actual frequency of fork is
[1] 508 Hz [2] 512 Hz
[3] 516 Hz [4] 518 Hz

18. A tuning fork of frequency 480 Hz produces 10 beats per second when sounded with a vibrating sonometer string. What must have been the frequency of the string if a slight increase in tension produces lesser beats per second than before
[1] 460 Hz [2] 470 Hz
[3] 480 Hz [4] 490 Hz

19. The disc of a siren containing 60 holes rotates at a constant speed of 360 rpm. The emitted sound is in unison with a tuning fork of frequency
[1] 10 Hz [2] 360 Hz
[3] 216 Hz [4] 6 Hz

20. A source of sound gives five beats per second when sounded with another source of frequency $100 s^{-1}$. The second harmonic of the source together with a source of frequency $205 s^{-1}$ gives five beats per second. What is the frequency of the source
[1] $105 s^{-1}$ [2] $205 s^{-1}$
[3] $95 s^{-1}$ [4] $100 s^{-1}$

21. When two sound waves are superimposed, beats are produced when they have
[1] Different amplitudes and phases
[2] Different velocities
[3] Different phases
[4] Different frequencies

22. When a tuning fork produces sound waves in air, which one of the following is same in the material of tuning fork as well as in air
[1] Wavelength [2] Frequency
[3] Velocity [4] Amplitude

23. Two vibrating tuning forks produce progressive waves given by $Y_1 = 4 \sin 500 \pi t$ and $Y_2 = 2 \sin 506 \pi t$. Number of beats produced per minute is
[1] 360 [2] 180
[3] 3 [4] 60

24. Two tuning forks, A and B, give 4 beats per second when sounded together. The frequency of A is 320 Hz. When some wax is added to B

and it is sounded with A, 4 beats per second are again heard. The frequency of B is
[1] 312 Hz [2] 316 Hz
[3] 324 Hz [4] 328 Hz

25. Two tuning forks have frequencies 380 and 384 Hz respectively. When they are sounded together, they produce 4 beats. After hearing the maximum sound, how long will it take to hear the minimum sound
[1] 1/2 sec [2] 1/4 sec
[3] 1/8 sec [4] 1/16 sec

26. When a guitar string is sounded with a 440 Hz tuning fork, a beat frequency of 5 Hz is heard. If the experiment is repeated with a tuning fork of 437 Hz, the beat frequency is 8 Hz. The string frequency (Hz) is
[1] 445 [2] 435
[3] 429 [4] 448

27. Two waves of wavelengths 50 cm and 51 cm produced 12 beats per second. The velocity of sound is
[1] 306 m/s [2] 331 m/s
[3] 340 m/s [4] 360 m/s

28. When a tuning fork vibrates, the waves produced in the fork are
[1] Longitudinal [2] Transverse
[3] Progressive [4] Stationary

29. The frequency of tuning forks A and B are respectively 3% more and 2% less than the frequency of tuning fork C. When A and B are simultaneously excited, 5 beats per second are produced. Then the frequency of the tuning fork 'A' (in Hz) is
[1] 98 [2] 100
[3] 103 [4] 105

30. An unknown frequency x produces 8 beats per seconds with a frequency of 250 Hz and 12 beats with 270 Hz source, then x is
[1] 258 Hz [2] 242 Hz
[3] 262 Hz [4] 282 Hz

31. Two strings X and Y of a sitar produce a beat frequency 4 Hz. When the tension of the string Y is slightly increased the beat frequency is found to be 2 Hz. If the frequency of X Is 300 Hz, then the original frequency of Y was
[1] 296 Hz [2] 298 Hz
[3] 302 Hz [4] 304 Hz

32. The wavelengths of two waves are 50 and 51cm respectively. If the temperature of the room is 20°C, then what will be the number of beats produced per second by these waves, when the speed of sound at 0°C is 332 m/sec
[1] 14 [2] 10
[3] 24 [4] None of these

33. Maximum number of beats frequency heard by a human being is
[1] 10 [2] 4
[3] 20 [4] 6

34. Two sound waves of slightly different frequencies propagating in the same direction produce beats due to
[1] Interference [2] Diffraction
[3] Polarization [4] Refraction

35. On sounding tuning fork A with another tuning fork B of frequency 384 Hz, 6 beats are produced per second . After loading the prongs of A with some wax and then sounding it again with B. 4 beats are produced per second. What is the frequency of the tuning fork A
[1] 388 Hz [2] 380 Hz
[3] 378 Hz [4] 390 Hz

36. It is possible to hear beats from the two vibrating sources of frequency
[1] 100 Hz and 150 Hz
[2] 20 Hz and 25 Hz
[3] 400 Hz and 500 Hz
[4] 1000 Hz and 1500 Hz

37. A tuning fork gives 4 beats with 50 cm length of a sonometer wire. If the length of the wire is shortened by 1 cm. the number of beats is still

the same. The frequency of the fork is
[1] 396 [2] 400
[3] 404 [4] 384

38. Two sound waves of wavelengths 5m and 6m formed 30 beats in 3 seconds . The velocity of sound is
[1] 300 ms^{-1} [2] 310 ms^{-1}
[3] 320^{-1} [4] 330 ms^{-1}

39. The wavelength of a wave is 99 cm and that of other is 100cm. Speed cf sound is 396 m/s. The number of beats heard is
[1] 4 [2] 5 [3] 1 [4] 8

40. A tuning fork arrangement (pair) produces 4 heats/sec with one fork of frequency 288 cps. A little wax is placed on the unknown fork and it then produces 2 beats/sec. The frequency of the unknown fork is
[1] 286 cps [2] 292 cps
[3] 294 cps [4] 288 cps

41. A tuning fork vibrates with 2 beats in 0.04 second. The frequency of the fork is
[1] 50 Hz [2] 100 Hz
[3] 80 Hz [4] None of these

42. When temperature increases, the frequency of a tuning fork
[1] Increases
[2] Decreases
[3] Remains same
[4] Increases or decreases depending on the material

43. A tuning fork of known frequency 256 Hz makes 5 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was
[1] 256 + 5 Hz [2] 256 + 2Hz
[3] 256- 2 Hz [4] 256 - 5Hz

44. Two sources produce sound waves of equal amplitudes and travelling along the same direction producing 18 beats in 3 seconds. If one source has a frequency of 341Hz, the frequency of the other source may be
[1] 329 or 353 Hz [2] 335 or 347 Hz
[3] 338 or 344 Hz [4] 332 or 350 Hz

45. Two sources of sound placed close to each other, are emitting progressive waves given by $y_1 = 4 \sin 600\pi t$ and $y_2 = 5\sin 608\pi t$. An observer located near these two sources of sound will hear
[1] 4 beats per second with intensity ratio 25 :16 between waxing and waning
[2] 8 beats per second with intensity ratio 25 : 16 between waxing and waning
[3] 8 beats per second with intensity ratio 81 : 1 between waxing and waning
[4] 4 beats per second with intensity ratio 81 : 1 between waxing and waning

STATIONARY WAVES

1. The distance between the nearest node and stationary wave is
[1] $\lambda/1$ [2] $\lambda/2$
[3] $\lambda/4$ [4] 2λ

2. In stationary wave
[1] Strain is maximum at nodes
[2] Strain is maximum at antinodes
[3] Strain is minimum at nodes
[4] Amplitude is zero at all the points

3. The phase difference between the two parti both the sides of a node is
[1] 0° [2] 90°
[3] 180° [4] 360°

4. Two travelling waves $y_1 = A \sin[k(x-c\,t)]$ and $y_2 = A \sin[k(x+ct)]$ are superimposed on string. The distance between adjacent nodes is
[1] $c\,t/\pi$ [2] $c\,t/2\pi$
[3] $\pi\ 2k$ [4] π/k

5. Consider the three waves z_1, z_2 and z_3 as
z_1 = A sin (kx - ωt) , z_2 = A sin (kx + ωt) and
z_3 = A sin (ky - ωt) . Which of the following represents a standing wave
[1] $z_1 + z_2$ [2] $z_2 + z_3$
[3] $z_3 + z_1$ [4] $z_1 + z_2 + z_3$

6. When a stationary wave is formed then its frequency is
[1] Same as that of the individual waves
[2] Twice that of the individual waves
[3] Half that of the individual waves
[4] None of the above

7. The equation of stationary wave along a stretched string is given by y = 5sin $\frac{\pi x}{3}$ cos 40π t, where x and y are in cm and t in second. The separation between two adjacent nodes is
[1] 1.5 cm [2] 3 cm
[3] 6 cm [4] 4 cm

8. In a stationary wave all the particles
[1] On either side of a node vibrate in same phase
[2] In the region between two nodes vibrate in same phase
[3] In the region between two antinodes vibrate in same phase
[4] Of the medium vibrate in same phase

9. At nodes in stationary waves
[1] Change in pressure and density are maximum
[2] Change in pressure and density are minimum
[3] Strain is zero
[4] Energy is minimum

10. Stationary waves
[1] Transport energy
[2] Does not transport energy
[3] Have nodes and antinodes
[4] Both (b) and (c)

11. A wave represented by the given equation y = a cos(kx-ωt) is superposed with another wave to form a stationary wave such that the point x = 0 is a node. The equation for the other wave is
(a) y = a sin(kx + ωt) [2] y = -a cos(kx + ωt)
(c) y = -a cos(kx - ωt) [4] y = -a sin (kx - ωt)

12. At a certain instant a stationary transverse wave is found to have maximum kinetic energy. The appearance of string at that instant is
[1] Sinusoidal shape with amplitude A/3
[2] Sinusoidal shape with amplitude A/2
[3] Sinusoidal shape with amplitude A
[4] Straight line

13. The equation y = 0.15sin5xcos300t , describes a stationary wave. The wavelength of the stationary wave is
[1] Zero [2] 1.256 metres
[3] 2.512 metres [4] 0.628 metre

14. In stationary waves, antinodes are the points where there is
[1] Minimum displacement and minimum pressure change
[2] Minimum displacement and maximum pressure change
[3] Maximum displacement and maximum pressure change
[4] Maximum displacement and minimum pressure change

15. In stationary waves all particles between two nodes pass through the mean position
[1] At different times with different velocities
[2] At different times with the same velocity
[3] At the same time with equal velocity
[4] At the same time with different velocities

16. A wave of wavelength 2m is reflected from a surface. If a node is formed at 3m from the surface, then at what distance from the surface another node will be formed
[1] 1 m [2] 2 m
[3] 3 m [4] 4 m

17. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance

1.21 A between them. The wavelength of the standing wave is

[1] 1.21 Å [2] 2.42 Å
[3] 6.05 Å [4] 3.63 Å

18. In stationary waves, distance between a node and its nearest antinode is 20 cm. The phase difference between two particles having a separation of 60 cm will be

[1] Zero [2] $\pi/2$
[3] π [4] $3\pi/2$

19. Two waves are approaching each other with a velocity of 16m/s and frequency n. The distance between two consecutive nodes is

[1] $\frac{16}{n}$ [2] $\frac{n}{16}$
[3] $\frac{8}{n}$ [4] $\frac{n}{8}$

20. Which two of the given transverse waves will give stationary waves when get superimposed

$z_1 = a\cos(kx - \omega t)$ ....(A)
$z_2 = a\cos(kx + \omega t)$ ....(B)
$z_3 = a\cos(ky - \omega t)$ ....(C)

[1] A and B [2] A and C
[3] B and C [4] Any two

21. A standing wave is represented by
$Y = A\sin(100t)\cos(0.01x)$
where Y and A are in millimetre, t is in seconds and x is in metre. The velocity of wave is

[1] 10^4 m / s [2] 1 m / s
[3] 10^{-4} m /s
[4] Not derivable from above data

22. A wave of frequency 100 Hz is sent along a string towards a fixed end. When this wave travels back after reflection, a node is formed at a distance of 10 cm from the fixed end of the string. The speed of incident (and reflected) wave are

[1] 40 m/s [2] 20 m/s
[3] 10 m/s [4] 5 m/s

23. In stationary waves

[1] Energy is uniformly distributed
[2] Energy is minimum at nodes and maximum at antinodes
[3] Energy is maximum at nodes and minimum at antinodes
[4] Alternating maximum and minimum energy producing at nodes and antinodes

24. Two waves are approaching each other with a velocity of 20m/s and frequency n. The distance between two consecutive nodes is

[1] $\frac{20}{n}$ [2] $\frac{10}{n}$
[3] $\frac{5}{n}$ [4] $\frac{n}{10}$

25. Energy is not carried by which of the following waves

[1] Stationary [2] Progressive
[3] Transverse [4] Electromagnetic

26. A string vibrates according to the equation $y = 5\sin\frac{2\pi x}{3}\cos 20\pi t$, where x and y are in cm and t in sec. The distance between two adjacent nodes is

[1] 3 cm [2] 4.5 cm
[3] 6 cm [4] 1.5 cm

27. Two sinusoidal waves with same wavelengths and amplitudes travel in opposite directions along a string with a speed 10 ms^{-1}. If the minimum time interval between two instants when the string is flat is 0.5 s, the wavelength of the waves is

[1] 25 m [2] 20 m
[3] 15 m [4] 10 m

28. "Stationary waves" are so called because in them

[1] The particles of the medium are not disturbed at all
[2] The particles of the medium do not execute SHM
[3] There occurs no flow of energy along the wave
[4] The interference effect can't be observed

VIBRATION OF STRING

1. If we study the vibration of a pipe open at both ends, then the following statement is not true
[1] Pressure change will be maximum at both ends
[2] Open end will be antinode
[3] Odd harmonics of the fundamental frequency will be generated
[4] All harmonic of the fundamental frequency will be generated

2. A 1 cm long string vibrates with fundamental frequency of If the length is reduced to cm keeping the tension unaltered, the new fundamental frequency will be
[1] 64 [2] 256
[3] 512 [4] 1024

3. Standing waves are produced in a 10 m long stretched string. If the string vibrates in 5 segments and the wave velocity is 20 m/s, the frequency is
[1] 2 Hz [2] 4 Hz
[3] 5 Hz [4] 10 Hz

4. The velocity of waves in a string fixed at both ends is 2 m/s. The string forms standing waves with nodes 5.0 cm apart. The frequency of vibration of the string in Hz is
[1] 40 [2] 30
[3] 20 [4] 10

5. Which of the following is the example of transverse wave
[1] Sound waves
[2] Compressional waves in a spring
[3] Vibration of string
[4] All of these

6. A stretched string of lm length and mass $5x10^{-4}$kg is having tension of 20N. If it is plucked at 25cm from one end then it will vibrate with frequency
[1] 100 Hz [2] 200 Hz
[3] 256 Hz [4] 400 Hz

7. Two similar sonometer wires given fundamental frequencies of 500Hz. These have same tensions. By what amount the tension be increased in one wire so that the two wires produce 5 beats/sec
[1] 1% [2] 2%
[3] 3% [4] 4%

8. A string is producing transverse vibration whose equation is $y = 0.021\sin(x + 30t)$, Where x and y are in meters and t is in seconds. If the linear density of the string is $1.3x10^{-4}$ kg/m, then the tension in the string in N will be
[1] 10 [2] 0.5
[3] 1 [4] 0.117

9. If the tension of sonometer's wire increases four times then the fundamental frequency of the wire will increase by
[1] 2 times [2] 4 times
[3] 1/2 times [4] None of the above

10. If vibrations of a string are to be increased by a factor of two, then tension in the string must be made
[1] Half [2] Twice
[3] Four times [4] Eight times

11. Four wires of identical length, diameters and of the same material are stretched on a sonometre wire. If the ratio of their tensions is 1 : 4 : 9 : 16 then the ratio of their fundamental frequencies are
[1] 16 : 9 : 4 : 1 [2] 4 : 3 : 2 : 1
[3] 1: 4 : 2 : 1 6 [4] 1 : 2 : 3 : 4

12. A tuning fork vibrating with a sonometer having 20 cm wire produces 5 beats per second. The beat frequency does not change if the length of the wire is changed to 21 cm. the frequency of the tuning fork (in Hertz) must be
[1] 200 [2] 210
[3] 205 [4] 215

13. A stretched string of length /, fixed at both ends can sustain starionary waves of wavelength λ,

given by

[1] $\lambda = \frac{n^2}{2l}$ [2] $\lambda = \frac{l^2}{2n}$

[3] $\lambda = \frac{2l}{n}$ [4] $\lambda = 2l\,n$

14. If you set up the seventh harmonic on a string fixed at both ends, how many nodes and antinodes are set up in it

[1] 8, 7 [2] 7, 7

[3] 8, 9 [4] 9, 8

15. If you set up the ninth harmonic on a string fixed at both ends, its frequency compared to the seventh harmonic

[1] Higher [2] Lower

[3] Equal [4] None of the above

16. Frequency of a sonometer wire is n. Now its tension is increased 4 times and its length is doubled then new frequency will be

[1] n/2 [2] 4n

[3] 2n [4] n

17. A device used for investigating the vibration of a fixed string or wire is

[1] Sonometer [2] barometer

[3] Hydrometer [4] None of these

18. A string on a musical instrument is 50 cm long and its fundamental frequency is 270 Hz. If the desired frequency of 1000 Hz is to be produced, the required length of the string is

[1] 13.5 cm [2] 2.7 cm

[3] 5.4 cm [4] 10.3 cm

19. The tension in a piano wire is ION. What should be the tension in the wire to produce a note of double the frequency

[1] 5 N [2] 20 N

[3] 40 N [4] 80 N

20. To increase the frequency from 100 Hz to 400 Hz the tension in the string has to be changed by

[1] 4 times [2] 16 times

[3] 20 times [4] None of these

21 In order to duuble the frequence of the funamental note emitte by a strethed string, the length is reduced to 3/4th of the original length and the tension is reduced is changed. the factor by which the tension is to be changed,is

[1]3/8 [2]2/3

[3]8/9 [4]9/4

22 A string of 7 m length has a mass of 0.035 kg . If tension in the string is 60.5, then speed of a wave on the string is

[1]77m/s [2102m/s

[3]110m/s [4]165m/s

23 A second harmonic has to be generated in a string of length I stretched between twp rigid supports. The point where the string has to be plucked and touched are

[1]Plucked at 1/4 and touched at 1/2

[2]Plucked at 1/4 and touched at 31/4

[3]Plucked at 1/2 and touched at 1/4

[4]plucked at 1/2 and touched at 31/4

24 Transverse waves of same frequency are generated in two steel wires A and B. The diameter of A is twice of B and the tenion in A is half that is B. The ratio of velocities of wave in A and B is

[1]$1:3\sqrt{2}$ [2]$1:2\sqrt{2}$

[3]1:2 4]$\sqrt{2}:1$

25 A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire

When this mass is replaced by a mass M, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of M is

[1]25kg [2]5kg

[3]12.5kg 1/25kg

26 he tension of a stretched string is increased by 69%. In order to keep to keep its frequency of vibration constant, its length must be increased by

[1] 20% [2] 30%

[3] $\sqrt{69\%}$ [4] 69%

27 The length of a sonometer wire tuned to a frequency of 250 Hz is 0.60 meter. The frequency of tuning fork with which the vibrating wire will be in tune when the length is made 0.40 meter is

[1] 250 Hz [2] 375Hz

[3] 256Hz [4] 384Hz

28 Length of a string tied to two rigid supports is 40 cm. Maximum length (wavelength in m) of a stationary wave produced on it is

[1] 20 [2] 80

[3] 40 [4] 120

29 A string in musical instrument is 50 cm long and its fundamental frequency is 800 Hz. If a frequency of 1000 Hz is to be produced,then required length of sting is

[1] 62.5 cm [2]50 cm

[3] 40 cm [4] 37.5 cm

30 Two wires are in unison.If the tension in one of the wires is increased by 2%, 5 beats are produced per second. The intial frequency of each wire is

[1] 200 Hz [2] 400Hz

[3] 500Hz [4] 1000Hz

31 Two unirom string A and B made of steel are made to vibrate under the same tension. if the first overtone of A is equal to the second overtone of B and if the radius of A is twice that of B,the ratio of the lengths of the strings is

[1] 1;2 [2] 1:3

[3] 1:4 [4] 1:6

32 If the length of a stretched string is shortened by 40% and the tension is increased by 44%,then the ratio of the final and initial fundamental frequencies is

[1] 2:1 [2] 3:3

[3] 3:4 [4] 1:3

33 Two wires are fixed in a sonometer. Their tension are in the ratio 8:1. The lengths are in the ratio 36:35. The diameters are in the ratio 4:1. Densities of the materials are in the ratio 1:2. If the lower frequency in the setting is 360 Hz. the best frequency when the two wires are sounded together is

[1] 5 [2] 8

[3] 6 [4] 10

34 The first overtone of a stretched wire of given length is 320 Hz. The first harmonic is

[1]320 Hz [2] 160 Hz

[3] 480 Hz [4] 640 Hz

35 A transverse sinusoidal wave moves along a string in the positive x-direction at a speed of 10cm/s. The wavelength of the wave is 0.5 m and its amplitude is 10 cm. At a particular time t, the snap-shot of the wave is shown in figure. The velocity of point P when its displacement is 0.05

[1] $\frac{\sqrt{3}\pi}{50}\hat{j}\,m/s$ [2] $-\frac{\sqrt{3}\pi}{50}\hat{j}\,m/s$

[3] $\frac{\sqrt{3}\pi}{50}\hat{i}\,m/s$ [4] $-\frac{\sqrt{3}\pi}{50}\hat{i}\,m/s$

36 A tuning fork of frequency 392 Hz, resonates with 50 cm length of a string under tension (T). If length of the string is decreased by 2%, keeping the tension constant, the number of beats heard when the string and the tuning fork made to vibrate simultaneously is

[1] 4 [2] 6

[3] 8 [4] 12

37 The sound carried by air from a sitar to a listener is a wave of the following type

[1] Longitudinal stationary
[2] Transverse progressive
[3] Transverse stationary
[4] Longitudinal progressive

38 In Melde's experiment in the transverse mode, the frequency of the tuning fork and the frequency of the waves in the string are in the ratio
[1] 1:1 [2] 1:2
[3] 2:1 [4] 4:1

39 The frequency of transverse vibrations in a stretched string is 200 Hz. If the tension is increased four times and the length is reduced to one-fourth the original value, the frequency of vibration will be
[1] 25 Hz [2] 200 Hz
[3] 400 Hz [4] 1600 Hz

40 Three similar wires of frequency n_1,n_2 and n_3 are joined to make one wire. Its frequency will be
[1] $n = n_1 + n_2 + n_3$
[2] $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$
[3] $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}}$
[4] $\frac{1}{n^1} = \frac{1}{n_1^2} + \frac{1}{n_2^2} + \frac{1}{n_3^2}$

41 A steel rod 100 cm long is clamed at its mid-point. The funda-mental frequency of longitudianl virations of the rod is given to be 2.5 kHz. What is the speed of sound in steel
[1] 5.06 km/s [2] 6.06km/s
[3] 7.06 km/s [4] 8.06 km/s

42 Two wires are producing fundamental notes of the same frequency. Change in which of the following factors of one wire will not produce beats between them
[1] Amplitude of the vibrations
[2] Material force
[3] Stretching force
[4] Diameter of the wires

43 Calculate the frequency of the second harmonic formed on a string of length 0.5 m and mass $2*10^{-4}$ kg when stretched with a tension of 20N
[1] 274.4 Hz [2] 74402 Hz
[3] 44.72 Hz [4] 447.2 Hz

44 The fundamental frequency of a string stretched with a weight of 4 kg is 256 Hz. The weight required to produce its octave is
[1] 4 kg wt [2] 8 kg wt
[3] 12 kg wt [4]16 kg wt

45 Two vibrating strings of the same material but lengths L and 2L have radii 2r and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes,the one of length L with frequency n_1 and the other with frequency n_2. The ratio $n_{1/}n_2$ is given by
[1] 2 [2] 4
[3] 8 [4] 1

46 If the tension and diameter of a sonometer wire of fundamental frequency n are doubled and density is halved then its fundamental frequency will become
[1] $\frac{n}{4}$ [2] $\sqrt{2}\,n$
[3] n [4] $\frac{n}{\sqrt{2}}$

47 In a sonometer wire, the tension is maintained by suspending a 50.7 kg mass from the free end of the wire. The suspended mass has a volume of 0.0075 m^3. The fundamental frequency of the wire is 260 Hz. If the suspended mass is completely submerged in water,the fundamental frequency will become (take g =10 ms^{-2})
[1] 240 Hz [2] 230 Hz
[3] 220 Hz [4] 200Hz

48 A string is rigidly tied at two ends and its equation of vibration is given by $y = \cos 2\pi$ t $\sin 2\pi$. Then minimum length of string is

[1] 1 m [2] $\frac{1}{2}$m

[3] 5 m [4] 2πm

49 Fundamental frequency of sonometer wire is n. If the length , tension and diameter of wire are tripled, the new fundamental frequency is

[1] $\frac{n}{\sqrt{3}}$ [2] $\frac{n}{3}$

[3] $n\sqrt{3}$ [4] $\frac{n}{3\sqrt{3}}$

50 A string of length 2 m is fixed at both ends. If this string vibrates in its fourth normal mode with a frequency of 500 Hz then waves would travel on its with a velocity of

[1] 125 m/s [2] 250 m/s

[3] 500 m/s [4] 1000 m/s

51 The fundamental frequency of a sonometer wire is n. If its radius is doubled and its tension become half,the material of the wire remains same, the new fundamental frequency will be

[1] n [2] $\frac{n}{\sqrt{2}}$

[3] $\frac{n}{2}$ [4] $\frac{n}{2\sqrt{2}}$

52 In an experiment with sonometer a tuning fork of frequency 256 Hz resonates with a length of 25 cm and another tuning fork resonates with a length of 16 cm. Tension of the string remaining constant. The frequency of the second tuning fork is

[1] 163.84 Hz [2] 400 Hz

[3] 320 Hz [4] 204.8 Hz

53 A string is stretched between fixed points separated by 75.0cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. Then the lowest resonant frequency for this string is

[1] 1.05 Hz [2] 1050 Hz

[3] 10.5 Hz [4] 105 Hz

54 The speed of a wave on a string is 150 m/s when the tension is 120 N. The percentage increse in the tension in order to raise the wae speed by 20% is

[1] 44% [2] 40%

[3] 20% [4] 10%

55 Two stretched strings of same material are vibrating under same tension in fundamental mode. The ratio of their frequencies is 1:2 and ratio of the length of the vibrating segments is 1:4. Then the ratio of the radii of the srtings is

[1] 2:1 [2] 4:1

[3] 3:2 [4] 8:1

56 When the length of the vibrating segment of a sonometer wire is increased by 1% the percentage change in its frequency is

[1] $\frac{100}{101}$ [2] $\frac{99}{100}$

[3] 1 [4] 2

57 A 20 cm long strring, having a mass of 1.0 g, is fixed at both the ends. The tension in the string is 0.5 N. The string is set into vibrations using an external vibrator of frequency 100 Hz. Find the separation (in cm) between the successive nodes on the string.

[1] 15 cm [2] 5 cm

[3] 25 cm [4] 22 cm

58 On which principle does Sonometer works

[1] Hooke's Law [2] Elasticity

[3] Resonance [4] Newton's Law

59 A string vibrates with a frequency of 200Hz. When its length is doubled and tension is altered, it begins to vibrate with a frequency of 300 Hz. The ratio of the new

tension to the original tension is

[1] 3:1 [2] 1:3

[3] 9:1 [4] 1:9

60 A string is hanging from a rigid support. A transverse pulse is excited at its free end. The speed at which the pulse travels a distance x is proportional to

[1] x [2] $\frac{1}{x}$

[3] $\frac{1}{\sqrt{x}}$ [4] x^2

[5] $\sqrt{x}$

61 Two identical palin wires have a fundamental frequency of 600 cycle per second when kept under the same tension. What frational increase in the tension of one wires will lead to the occurrence of 6 beats per second when both wires vibrate simultaneouslu

[1] 0.01 [2] 0.02

[3] 0.03 [4] 0.04

62 A sonometer wire supports a 4 kg load and vibrate in fundamental mode with a tunini fork of frequency 416 Ha. The length of the wire between the bridges is now doubled. In order to maintain fundamental mode,the load should be changed to

[1] 1 kg [2] 2 kg

[3] 4 kg [4] 8 kg

63 A wave in a string has an amplitude of 2 cm. The wave travels in the +ve direction of x axis with a speed of 128 m/sec and it is noted that 5 complete waves fit in 4 m length of the string. The equation describing the wave is

[1] y = (0.02) m sin (7.85 x + 1005t)

[2] y = (0.02) m sin (15.7 x - 2010t)

[3] y = (0.02) m sin (15.7 x + 2010t)

[4] y = (0.02) m sin (7.85 x - 1005t)

64 Two stretched strings have lengths l and 2l while tensions are T and 4T respectively. If they are made of same material the ratio of their frequency is

[1] 2:1 [2] 1;2

[3] 1:1 [4] 1:4

65 The equation of a wave on a string of linear mass density 0.04 kg m^{-1} is given by $y = 0.02(m)\sin\left[2\pi\left(\frac{t}{0.04(s)} - \frac{x}{0.50(m)}\right)\right]$. The tension in the string is

[1] 6.25 N [2] 4.0 N

[3] 12.5 N [4] 0.5 N

66 A standing wave is produced in a string fixed at both ends. In this case

[1] All particles vibrate in phase

[2] All antinodes vibrate in phase

[3] All alternate antinodes vibrate in phase

[4] All particles between two consecutive antinodes vibrate in phase

67 A uniform wire of length L, diameter D and density ρ is stretched under a tension T. The correct relation between its fundamental frequency 'f", the length L and the diameter D is

[1] $f \alpha \frac{1}{LD}$ [2] $f \alpha \frac{1}{L\sqrt{D}}$

[3] $f \alpha \frac{1}{D^2}$ [4] $f \alpha \frac{1}{LD^2}$

68 The condition under which a microwave oven heats up a food item containing water molecules most efficiently is

[1] Infra-red waves produce heating in a microwave oven

[2] The frequency of the microwave must match the resonant frequency of the water molecules

[3] The frequency of the microwawves has no relation with natural frequency of water molecules

[4] Microwaves are heat waves,so always produce heating

Organ Pipe (Vibration of Air Column)

1 The length of two open organ pipes are l and $(l+\Delta l)$ respectively. Neglecting end correction, the frequency of beats between them will be approximately

[1] $\frac{\upsilon}{2l}$ [2] $\frac{\upsilon}{4l}$

[3] $\frac{\upsilon \Delta l}{2l^2}$ [4] $\frac{\upsilon \Delta l}{l}$

(Here υ is the speed of sound)

2 A tube closed at one end and containing air is excited. It produces the fundamental note of frequency 512 Hz. If the same tube is open at both the ends the fundamental frequency that can be produced is

[1] 1024 Hz [2] 512 Hz

[3] 256 Hz [4] 128 Hz

3 A closed pipe and an open pipe have their first overtones identical in frequency. Their lengths are in the ratio

[1] 1:2 [2] 2:3

[3]3:4 [4] 4:5

4 The first overtone in a closed pipe has a frequency

[1] Same as the fundamental frequency of an open tube of same length

[2] Twice the fundamental frequency of an open tube of same length

[3] Same as that of the first overtone of an open tube of same length

[4] None of the above

5 An empty vessel is partially filled with water, then the frequency of vibration of air column in the vessel

[1] Remains same

[2] Decreases

[3] Increases

[4] First increases then decreases

6 The fundamental frequencies of an open and a closed tube, each of same length L with υ as the speed of sound in air, respectively are

[1] $\frac{\upsilon}{2l}$ and $\frac{\upsilon}{L}$ [2] $\frac{\upsilon}{L}$ and $\frac{\upsilon}{2L}$

[3] $\frac{\upsilon}{2L}$ and $\frac{\upsilon}{4L}$ [4] $\frac{\upsilon}{4L}$ and $\frac{\upsilon}{2L}$

7 An air column in a pipe,which is closed at one end, will be in resonance with a vibrating body of frequency 166 Hz,if the length of the air column is

[1] 2.00 m [2] 1.50 m

[3] 1.00 m [4] 050 m

8 If the velocity of sound in air is 350 m/s. Then the fundamental frequency of an open organ pipe of length 50cm,will be

[1] 350 Hz [2] 175 Hz

[3] 900 Hz [4] 750 Hz

9 If the length of a closed organ pipe is 1m and velocity of sound is 330 m/s,then the frequency for the second note is

[1] $4\times\frac{330}{4}$Hz [2] $3\times\frac{330}{4}$Hz

[3] $2\times\frac{330}{4}$Hz [4] $2\times\frac{4}{330}$Hz

10 The fundamental note produced by a closed organ pipe is of frequency f. The fundamental note produced by an open organ pipe of same length will be of frequency

[1] f/2 [2] f

[3] 2f [4] 4f

11 If the velocity of sound in air is 336 m/s. The maximum length of a closed pipe that would produce a just audible sound will be

[1] 3.2 cm [2] 4.2 m

[3] 4.2 cm [4] 3.2 m

12 An organ pipe P_1 closed at one end vibrating in its first overtone and another pipe P_2 open at both ends vibrating in its third overtone are in resonance with a given tuning fork. The ratio of lengths of P_1 and P_2 is

[1] 1:2 [2] 1:3

[3] 3:8 [4] 3:4

13 A resonanc air column of length 20 cm resonates with a tuning fork of frequency 250 Hz.
The speed of sound in air is
[1] 300m/s [2] 200 m/s
[3] 150 m/s [4] 75 m/s

14 A cylindrical tube, open at both ends,has a fundamental frequency f_0 in air. The tube is dipped vertically into water such that half of its length is inside water. The fundamental frequency of the air column now is
[1] $3f_0 / 4$ [2] f_0
[3] $f_0 / 2$ [4] $2f_0$

15 If the length of a closed organ pipe is 1.5 m and velocity of sound is 330 m/s, then the frequencyfor the second note is
[1] 220 Hz [2] 165 Hz
[3] 110 Hz [4] 55 Hz

16 A pipe 30 cm long is open at both ends. Which harmonic mode of the pipe is resonantly excited by a 1.1 kHz source? (Take speed of sound in air = 330 ms^{-1})
[1] First [2] Second
[3] Third [4] Fourth

17 Two closed organ pipes,when sounded simultaneously gave 4 beats per sec. If longer pipe has a length of 1m, Then length of shorter pipe will be, (υ = 300 m/s)
[1] 185 5 cm [2] 94.9 cm
[3] 90 cm [4] 80 cm

18 A source of sound placed at the open end of a resonance column sends an acoustic wave of pressure amplitude ρ_0 inside the tube. If the atmospheric pressure is ρ_A ,then the ratio of maximum and minimum pressure at the closed end of the tube will be
[1] $\frac{(\rho_A + \rho_0)}{(\rho_A - \rho_0)}$ [2] $\frac{(\rho_A + 2\rho_0)}{(\rho_A - 2\rho_0)}$
[3] $\frac{\rho_A}{\rho_0}$ [4] $\frac{\left(\rho_A + \frac{1}{2}\rho_0\right)}{\left(\rho_A - \frac{1}{2}\rho_0\right)}$

19 Two closed pipes produce 10 beats per second when emitting their fundamental nodes.If their lengths are in ratio of 25:26. Then their fundamental frequency in Hz,are
[1] 270,280 [2] 260,270
[3] 260,250 [4] 260,280

20 A closed organ pipe and an open organ pipe are tuned to the same fundamental frequency. What is the ratio of lengths
[1] 1:2 [2] 2:1
[3] 2:3 [4] 4:3

21 An open pipe resonates with a tuning fork of frequency 500 Hz. It is observed that two successive nodes are formed at distance 16 and 46 cm from the open end. The speed of sound is air in the pipe is
[1] 230 m/s [2] 300 m/s
[3] 320 m/s [4] 360 m/s

22 Find the fundamental frequency of a closed pipe, if the length of the air column is 42 m. (speed of sound in air = 332 m/sec)
[1] 2 Hz [2] 4 Hz
[3] 7 Hz [4] 9 Hz

23 If υ is the speed of sound in air then the shortest length of the close pipe which resonates to a frequency n
[1] $\frac{\upsilon}{4n}$ [2] $\frac{\upsilon}{2n}$
[3] $\frac{2n}{\upsilon}$ [4] $\frac{4n}{\upsilon}$

24 The frequency of fundamental tone in an open organ pipe of length 0.48 m is 320 Hz. Speed of sound is 320 m/sec. Frequency of fundamental tone in closed organ pipe will be
[1] 153.8 Hz [2] 160.0 Hz
[3] 320.0 Hz [4] 143.2 Hz

25 If fundamental frequency of closed pipes is 50 Hz then frequency of 2nd overtone is
[1] 100 Hz [2] 50 Hz
[3] 250 Hz [4] 150 Hz

26 Two open organ pipes of length 25 cm and 25.5 cm produce 10 beat/sec. The velocity of sound will be

[1] 255 m/s [2] 250 m/s
[3] 350 m/s [4] None of these

27 What is minimum length of a tube, open at both ends,that resonate with tuning fork of frequency 350 Hz ? (velocity of sound in air = 350 m/s)

[1] 50 cm [2] 100 cm
[3] 75 cm [4] 25 cm

28 Two open organ pipes give 4 beats/sec when sounded together in their fundamental nodes. if the length of the pipe are 100 cm and 102.5 cm respectively, then the velocity of sound is:

[1] 496 m/s [2] 328 m/s
[3] 240 m/s [4] 160 m/s

29 The harmonics which are present in a pipe open at one end are

[1] Odd harmonics
[2] Even harmonics
[3]Even as well as odd harmonics
[4] None of these

30 An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz, then the fundamental frequency of open pipe is

[1] 480 Hz [2] 300 Hz
[3] 240 Hz [4] 200 Hz

31 Tube A has both ends open while tube B has one end closed, otherwise they are identical. The ratio of fundamental frequency of tube A and B is

[1] 1:2 [2] 1:2
[3] 2:1 [4] 4:1

32 If the temperature increases,then what happens to the frequency of the sound produced by the organ pipe

[1]Increases [2] Decreases
[3] Unchanged [4] Not definite

33 Apparatus used to find our the velocity of sound in gas is

[1] Melde's apparatus
[2] Kundt's tube
[3] Quincke's tube
[4] None of these

34 An organ pipe is closed at one end and open at the other. What is the ratio of frequency of the 3rd and 4th fundamental modes of vibration

[1] 3/4 [2] 5/7
[3] 3/5 [4] 9/11

35 The stationary wave $y = 2a \sin kx \cos \omega t$ in a closed organ pipe is the result of the superposition of $y = a\sin(\omega t - kx)$ and

[1] $y = -a\cos(\omega t + kx)$
[2] $y = -a\sin(\omega t + kx)$
[3] $y = a\sin(\omega t + kx)$
[4] $y = a\cos(\omega t + kx)$

36 Stationary waves are set up in air column. Velocity of sound in air is 330 m/s and frequency is 165 Hz. Then distance between the nodes is

[1] 2 m [2] 1 m
[3] 0.5 m [4] 4 m

37 An open pipe of length / vibrates in fundamental mode. The pressure variation is maximum at

[1] 1/4 from ends
[2] The middle of pipe
[3] The ends of pipe
[4] At 1/8 from ends of pipe

38 Fundamental frequency of pipe is 100 Hz and other two frequency are 300 Hz and 500 Hz then

[1] Pipe is open at both the ends
[2] Pipe is closed at both the ends
[3] One end open and another end is closed
[4 None of the above

39 Fundamental frequency of an open pipe of length 0.5 m is equal to the frequency of the first overtone of a closed pipe of length l. The value of l_c is(m)

[1] 1.5 [2] 0.75 [3] 2 [4] 1

40 In a closed organ pipe the frequency of fundamental note is 50 Hz. The note of which of the following frequency will not be emitted by it

[1] 50 Hz [2] 100 Hz
[3] 150 Hz [4] None of the above

41 On producing the waves of frequency 1000 Hz in a Kundt's tube, the total distance between 6 successive nodes is 85cm. Speed of sound in the gas filled in the tube is

[1] 330 m/s [2] 340 m/s
[3] 350 m/s [4] 300 m/s

42 What is the base frequency if a pipe gives notes of frequency 425,255 and 595 and decide whether it is closed at one end or open at both ends

[1] 17,closed [2] 85,closed
[3] 17,open [4] 85,

43 A student determines the velocity of sound with the help of a closed organ pipe. If the observed length for fundamental frequency is 24.7 m, the length for third harmonic will be

[1] 74.1 cm [2] 72.7 cm
[3] 75.4 cm [4] 73.1 cm

44. An open pipe of length 33 cm resonates with frequency of 100 Hz. If the speed of sound is 330 m/s, then this frequency is]

[1] Fundamental frequency of the pipe
[2] Third harmonic of the pipe
[3] Second harmonic of the pipe
[4] Fourth harmonic of the pipe

45. In a resonance tube the first resonance with a tuning fork occurs at 16 cm and second at 49 cm. If the velocity of sound is 330 m/s, the frequency of tuning fork is

[1] 500 [2] 300
[3] 330 [4] 165

46. Two closed organ pipes of length 100 cm and 101 cm produce 16 beats in 20 sec. When each pipe is sounded in its fundamental mode calculate the velocity of sound

[1] 303 ms-1 [2] 332 ms-1
[3] 323.2 ms"1 [4] 300 ms-1

47. In open organ pipe, if fundamental frequency is n then the other frequencies are

[1] n, 2n, 3n, 4n [2] n, 3n, 5n
[3] n, 2n, 4n, 8n [4] None of these

48. If in an experiment for determination of velocity of sound by resonance tube method using a tuning fork of 512 Hz, first resonance was observed at 30.7 cm and second was obtained at 63.2 cm, then maximum possible error in velocity of sound is (consider actual speed of sound in air is 332 m/s)

[1] 204 cm/sec [2] 110 cm/sec
[3] 58 cm/sec [4] 80 cm/sec

49. An organ pipe, open from both end produces 5 beats per second when vibrated with a source of frequency 200 Hz. The second harmonic of the same pipes produces 10 beats per second with a source of frequency 420 Hz. The frequency of source is

[1] 195 Hz [2] 205 Hz
[3] 190Hz [4] 210 Hz

50. In one metre long open pipe what is the harmonic of resonance obtained with

a tuning fork of frequency 480 Hz

[1] First [2] Second
[3] Third [4] Fourth

51. An organ pipe open at one end is vibrating in first overtone and is in resonance with another pipe open at both ends and vibrating in third harmonic. The ratio of length of twopipes is

[1] 1: 2 [2] 4 : 1
[3] 8 : 3 [4] 3 : 8

52. In a resonance pipe the first and second resonances are obtained at depths 22.7 cm and 70.2 cm respectively. What will be the end correction

[1] 1.05 cm [2] 115.5 cm
[3] 92.5 cm [4] 113.5 cm

53. An open tube is in resonance with string (frequency of vibration of tube is n_0). If tube is dipped in water so that 75% of length of tube is inside water, then the ratio of the frequency of tube to string now will be

[1] 1 [2] 2 [3] $\frac{2}{3}$ [4] $\frac{3}{2}$

54. Two closed organ pipes A and B, have the same length. A is wider than B. They resonate in the fundamental mode at frequencies n_A and n_B respectively, then

[1] $n_A = n_B$
[2] $n_A > n_B$
[3] $n_A < n_B$
(d) Either (b) or (c) depending on the ratio of their diameters

55. In a closed organ pipe, the 1 st resonance occurs at 50 cm. At what length of pipe, the 2nd resonance will occur

[1] 150 cm [2] 50 cm
[3] 100 cm [4] 200 cm

56. If in a resonance tube a oil of density higher than that of water is used then the resonance frequency would be

[1] Increased [2] Decreased
[3] Slightly increased [4] Remain the same

57. The frequency of the fundamental note in an organ pipe is 240 Hz. On blowing air, frequencies 720 Hz and 1200 Hz are heard. This indicates that organ pipe is

[1] A pipe closed at one end
[2] A pipe open at both ends
[3] Closed at both ends
[4] Having holes like flute

58. If L_1 and L_2 are the lengths of the first and second resonating air columns in a resonance tube, then the wavelength of the note produced is

[1] $2(L_2+L_1)$ [2] $2(L_2-L_1)$
[3] $2\left(L_2 - \frac{L_1}{2}\right)$ [4] $2\left(L_2 + \frac{L_1}{2}\right)$

59. A hollow cylinder with both sides open generates a frequency f in air. When the cylinder vertically immersed into water by half its length the frequency will be

[1] f [2] $2f$ [3] $f/2$ [4] $f/4$

60. While measuring the speed of sound by performing a resonance column experiment, a student gets the first resonance condition at a column length of 18 cm during winter. Repeating the same experiment during summer, she measures the column length to be x cm for the second resonance. Then

[1] $x > 54$ [2] $54 > x > 36$

61. A glass tube of length 1.0 m is completely filled with water. A vibrating tuning fork of frequency 500 Hz is kept over the mouth of the tube and the water is drained out slowly at the bottom of the tube. If velocity of sound in air is 330 ms^{-1} , then the total number of resonances that occur will be

[1] 2 [2] 3 [3] 1
[4] 5 [5] 4

62. An organ pipe P closed at one end vibrates in its first harmonic. Another organ pipe Q open at both ends vibrates in its third harmonic. When both are in resonance with a tuning fork, the ratio of the length of P to that of Q is

[1] 1/ 2 [2] 1/ 4 [3] 1/ 6
[4] 1/ 8 [4] 1/3

63. A closed organ pipe and an open organ pipe of same length produce 2 beats/second while vibrating in their fundamental modes. The length of the open organ pipe is halved and that of closed pipe is doubled. Then, the number of beats produced per second while vibrating in the fundamental mode is

[1] 2 [2] 6
[3] 8 [4] 7

64. A tuning fork of frequency 330 Hz resonates with an aircolumn of length 120 cm in a cylindrical tube, in the fundamental mode. When water is slowly poured in it, the minimum height of water required for observing resonance once again is (velocity of sound 330ms"1)

[1] 75 cm [2] 60 cm [3] 50 cm
[4] 30 cm [5] 45 cm

65. Air is blown at the mouth of an open tube of length 25cm and diameter 2cm. If the velocity of sound in air is 330ms”1, then emitted frequencies are (in Hz)

[1] 660, 1320, 2640 [2] 660, 1000, 3300
[3] 302, 664, 1320 [4] 330, 990, 1690
[5] 320, 660, 990

66. A cylindrical tube, open at both ends, has a fundamental frequency, f, in air. The tube is dipped vertically in water so that half of it is in water. The fundamental frequency of the air-column is now

[1] f [2] $f/2$ [3] $3f/4$ [4] $2f$

67. The fundamental frequency of a closed pipe is equal to the frequency of the second harmonic of an open pipe. The ratio of their lengths is

[1] 1 : 2 [2] 1 : 4
[3] 1 : 8 [4] 1 : 16

68. A pipe of length 85 cm is closed from one end. Find the number of possible natural oscillations of air column in the pipe whose frequencies lie below 1250 Hz. The velocity of sound in air is 340 m/s

[1] 12 [2] 8 [3] 6 [4] 4

69. The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (velocity of sound = 340 ms^{-1})

[1] 7 [2] 6 [3] 4 [4] 5

70. A student is performing an experiment using a resonance column and the tuning fork of frequency 244s^{-1}. He is told that the air in the tube has been replaced by another gas (assume that the column remains filled with the gas). If the minimum height at which resonance occurs is (0.350 ± 0.005) m, the gas in the tube is (Useful information) :
$\sqrt{167RT} = 640J^{1/2}$ $mole^{-1/2}$.
$\sqrt{140RT} = 590J^{1/2}$ $mole^{-1/2}$ The molar masses M in grams are given in the options. Take the value of $\frac{\sqrt{10}}{M}$ for each gas as given there)

[1]Neon $(M = 20, \sqrt{\frac{10}{20}} = \frac{7}{10})$

[2]Nitrogen $(M = 28, \sqrt{\frac{10}{28}} = \frac{3}{5})$

[3] Oxygen $(M = 32, \sqrt{\frac{10}{32}} = \frac{9}{16})$

[4] Argon $(M = 36, \sqrt{\frac{10}{36}} = \frac{17}{32})$

Doppler's Effect

1. Doppler shift in frequency does not depend upon
[1] The frequency of the wave produced
[2] The velocity of the source
[3] The velocity of the observer
(4) Distance from the source to the listener

2. A motor cycle starts from rest and accelerates along a straight path at 2 m/s^2. At the starting point of the motor cycle there is a stationary electric siren. How far has the motor cycle gone when the driver hears the frequency of the siren at 94% of its value when the motor cycle was at rest (Speed of sound = 330 ms^{-1})
[1] 49 m [2] 98 m
[3] 147 m [4] 196 m

3. A band playing music at a frequency f is moving towards a wall at a speed υ_b . A motorist is following the band with a speed υ_m . If υ be the speed of the sound, the expression for beat frequency heard by motorist is

[1] $\frac{\upsilon + \upsilon_m}{\upsilon + \upsilon_b} f$ [2] $\frac{\upsilon + \upsilon_m}{\upsilon - \upsilon_b} f$
[3] $\frac{2\upsilon_b(\upsilon + \upsilon_m)}{\upsilon^2 - \upsilon_b^2} f$ [4] $\frac{2\upsilon_m(\upsilon + \upsilon_b)}{\upsilon^2 - \upsilon_m^2} f$

4 The frequency of a whistle of an engine is 600 cycles/sec is moving with the speed of 30 m/sec towards an observer. The apparent frequency will be (velocity of sound = 330m/s)
(1) 600 cps [2] 660 cps
[3] 990 cps [4] 330 cps

5. A train moving at a speed of 220ms^{-1} towards a stationary object, emits a sound of frequency 1000Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is (speed of sound in air is 330ms^{-1})
[1] 3500Hz [2] 4000Hz
[3] 5000 Hz [4] 3000Hz

6. A train moving at a speed vs towards a stationary observer on a platform emits sound of frequency/ and velocity v . Then the apparent frequency heard by him is
[1] $f\left(1 + \frac{\upsilon}{\upsilon_s}\right)$ [2] $f\left(1 - \frac{\upsilon_s}{\upsilon}\right)$
[3] $f\left(1 + \frac{\upsilon_s}{\upsilon}\right)$ [4] $f\left(1 - \frac{\upsilon}{\upsilon_s}\right)$

7. An observer moves towards a stationary source of sound of frequency n. The apparent frequency heard by him is 2n. If the velocity of sound in air is 332 m/sec, then the velocity of the observer is
[1] 166 m/sec [2] 664 m/sec
[3] 332 m/sec [4] 1328 m/sec

8. An observer is moving towards the stationary source of sound, then
[1] Apparent frequency will be less than the real frequency
[2] Apparent frequency will be greater than the real frequency
[3] Apparent frequency will be equal to real frequency
[4] Only the quality of sound will change

9. A whistle sends out 256 waves in a second. If the whistle approaches the observer with velocity 1/3 of the velocity of sound in air, the number of waves per second the observer will receive
[1] 384 [2] 192
[3] 300 [4] 200

10. A person feels 2.5% difference of frequency of

a motor-car horn. If the motor-car is moving to the person and the velocity of sound is 320m/sec, then the velocity of car will be

[1] 8 m/s (approx.) [2] 800 m/s
[3] 7 m/s [4] 6 m/s (approx.)

11. The Doppler shift in the frequency received by a stationary receiver when the source is moving towards It, was measured to be $\Delta\nu_{air}$ when both receiver and source are In air, and it was measured to be $\Delta\nu_{water}$ water when both are under water. Then

[1] $\Delta\nu_{air} > \Delta\nu_{water}$
[2] $\Delta\nu_{air} < \Delta\nu_{water}$
[3] $\Delta\nu_{air} = \Delta\nu_{water}$
[4] $\Delta\nu_{water} = 0, \Delta\nu_{air} < 0$

12. A car moving at a velocity of 17 ms^{-1} towards an approaching bus that blows a horn at a frequency of 640 Hz on a straight track. The frequency of this horn appears to be 680 Hz to the car driver. If the velocity of sound in air is 340 ms^{-1}, then velocity of the approaching bus is

[1] 2 ms^{-1} [2] 4 ms^{-1}
[3] 8 ms^{-1} [4] 10 ms^{-1}

13. A source is moving towards a stationary observer, so that the apparent frequency increases by 50%. If velocity of sound is 330ms^{-1}, then velocity of source is

[1] 220ms^{-1} [2] 180ms^{-1}
[3] 150ms^{-1} [4] 110ms^{-1}

14. Doppler phenomena is related with

[1] Pitch (Frequency)
[2] Loudness
[3] Quality
[4] Reflection

15. Two sources A and B are sending notes of frequency 680 Hz. A listener moves from A and B with a constant velocity u. If the speed of sound in air is 340 ms^{-1}, what must be the value of u so that he hears 10 beats per second

[1] 2.0 ms^{-1} [2] 2.5 ms^{-1}
[3] 3.0 ms^{-1} [4] 3.5 ms^{-1}

16. A source of sound is travelling towards a stationary observer. The frequency of sound heard by the observer is of three times the original frequency. The velocity of sound is υ m/sec. The speed of source will be

[1] $\frac{2}{3}\upsilon$ [2] υ
[3] $\frac{3}{2}\upsilon$ [4] 3υ

17. A sound source is moving towards a stationary observer with 1/10 of the speed of sound. The ratio of apparent to real frequency is

[1] 10/9 [2] 11/10
[3] $(11/10)^2$ [4] $(9/10)^2$

18. Two trains, each moving with a velocity of 30 ms^{-1}, cross each other. One of the train gives a whistle whose frequency is 600 Hz. If the speed of sound is 330 ms^{-1} , the apparent frequency for passengers sitting in the other train before crossing would be

[1] 600 Hz [2] 630 Hz
[3] 920 Hz [4] 720 Hz

19. Suppose that the speed of sound in air at a given temperature is 400 m/sec. An engine blows a whistle at 1200 Hz frequency. It is approaching an observer at the speed of 100 m/sec. What is the apparent frequency as heard by the observer

[1] 600 Hz [2] 1200 Hz
[3] 1500 Hz [4] 1600 Hz

20. A train is moving at 30ms^{-1}in still air. The frequency of the locomotive whistle is 500 Hz and the speed of sound is 345ms^{-1}. The apparent wavelength of sound in frond of and behind the locomotive are respectively

[1] 0.80m, 0.63m [2] 0.63m, 0.80m
[3] 0.50m, 0.85m [4] 0.63m, 0.75m

21 The Doppler's effect is applicable for

[1] Light waves [2] Sound waves
[3] Space waves [4] Both [1] and [2]

22. A police car with a siren of frequency 8 kHz is moving with uniform velocity 36 km/hr towards a tall building which reflects the sound waves. The speed of sound in air is 320m/s. The frequency of the siren heard by the car driver is

[1] 8.50 kHz [2] 8.25 kHz
[3] 7.75 kHz (4) 7.50 kHz

23. A source of sound S is moving with a velocity 50 m/s towards a stationary observer. The observer measures the frequency of the source as 1000 Hz. What will be the apparent frequency of the source when it is moving away from the observer after crossing him? The velocity of sound in the medium is 350m/s

[1] 750 Hz [2] 857 Hz
[3] 1143 Hz (4) 1333 Hz

24. A source and listener are both moving towards each other with speed $\frac{\upsilon}{10}$, where υ is the speed of sound. If the frequency of the note emitted by the source is f, the frequency heard by the listener would be nearly

[1] 1.11 f [2] 1.22 f
[3] f (4) 1.27 f

25. A table is revolving on its axis at 5 revolutions per second. A sound source of frequency 1000 Hz is fixed on the table at 70 cm from the axis. The minimum frequency heard by a listener standing at a distance from the table will be (speed of sound = 352 m/s)

[1] 1000 Hz [2] 1066 Hz
[3] 941 Hz (4) 352 Hz

26. A train approaches a stationary observer, the velocity of train being $\frac{1}{20}$ of the velocity of sound. A sharp blast is blown with the whistle of the engine at equal intervals of a second. The interval between the successive blasts as heard by the observer is

[1] $\frac{1}{20}s$ [2] $\frac{1}{20}$min
[3] $\frac{19}{20}$S [4] $\frac{10}{20}$min

27. A motor car blowing a horn of frequency 124vib/sec moves with a velocity 72 km/hr towards a tall wall. The frequency of the reflected sound heard by the driver will be (velocity of sound in air is 330 m/s)

[1] 109 vib/sec [2] 132 vib/sec
[3] 140 vib/sec [4] 248 vib/sec

28. A source of sound of frequency n is moving towards a stationary observer with a speed S. If the speed of sound in air is V and the frequency heard by the observer is n_1, the value of n_1/n is

[1] [V + S] / V [2] V / [V + S]
[3] [V - S] / V [4] V / [V - S]

29. A vehicle with a hom of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n+n_1$ Then (if the sound velocity in air is 300 m/s)

[1] $n_1= 10n$ [2] $n_1= 0$
[3] $n_1= 0.1n$ [4] $n_1= -0.1n$

30. A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer in Hz is

[1] 409 [2] 429
[3] 517 [4] 500

31. An observer is moving away from source of sound of frequency 100 Hz. His speed is 33 m/s. If speed of sound is 330 m/s, then the observed frequency is

[1] 90 Hz [2] 100 Hz
[3] 91 Hz [4] 110 Hz

32. An observer standing at station observes frequency 219 Hz when a train approaches and 184 Hz when train goes away from him. If velocity of sound in air is 340 m/s, then velocity of train and actual frequency of whistle will be

[1] 15.5 ms^{-1}, 200 Hz
[2] 19.5 ms^{-1}, 205 Hz
[3] 29.5 ms^{-1}, 200 Hz
[4] 32.5ms^{-1}, 205 Hz

33. At what speed should a source of sound move so that stationary observer finds the apparent frequency equal to half of the original frequency

[1] v / 2 [2] 2v
[3] v / 4 [4] v

34. A source of sound is approaching an observer with speed of 30 ms^{-1} and the observer is approaching the source with a speed 60 ms^{-1}. Then the fractional change in the frequency of sound in air (330 ms^{-1}) is

[1] 1/ 3 [3] 3/10
[3] 2 /5 [4] 2 / 3

35. The driver of a car travelling with speed 30 metres per second towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 metres per second, the frequency of the reflected sound as heard by the driver is

[1] 720 Hz [3] 555.5 Hz
[2] 550 Hz [4] 500 Hz

36. Two sirens situated one kilometer apart are producing 44 sound of frequency 330 Hz. An observer starts moving from one siren to the other with a speed of 2 m/s. If the speed of sound be 330 m/s, what will be the beat frequency heard by the observer

[1] 8 [2] 4
[3] 6 [4] 1

37. An observer moves towards a stationary source of sound, with a velocity one-fifth of the velocity of sound. What is the percentage increase in the apparent frequency

[1] 5% [2] 20%
[3] Zero [4] 0.5%

38. The apparent frequency of a note, when a listener moves towards a stationary source, with velocity of 40 m/s is 200 Hz. When he moves away from the same source with the same speed, the apparent frequency of the same note is 160 Hz. The velocity of sound in air is (in m/s)

[1] 360 [2] 330
[3] 320 [4] 340

39. source of sound of frequency 256 Hz is moving rapidly towards a wall with a velocity of 5 m/s. The speed of sound is 330 m/s. If the observer is between the wall and the source, then beats per second heard will be

[1] 7.8 Hz [2] 7.7 Hz
[3] 3.9 Hz [4] Zero

40. A man sitting in a moving train hears the whistle of the engine. The frequency of the whistle is 600 Hz

[1] The apparent frequency as heard by him is smaller than 600 Hz
[2] The apparent frequency is larger than 600 z

[3] The frequency as heard by him is 600 Hz
[4] None of the above

41. A source of sound of frequency 500 Hz is moving towards an observer with velocity 30 m/s. The speed of sound is 330 m/s. The frequency heard by the observer will be
[1] 550 Hz [2] 458.3 Hz
[3] 530 Hz [4] 545.5 Hz

42. A source of sound of frequency 90 vibrations/sec is approaching a stationary observer with a speed equal to 1/10 the speed of sound. What will be the frequency heard by the observer
[1] 80 vibrations/sec [2] 90 vibrations/sec
[3] 100 vibrations/sec [4] 120 vibrations/sec

43. A whistle of frequency 500 Hz tied to the end of a string of length 1.2 m revolves at 400 rev/min. A listener standing some distance away in the plane of rotation of whistle hears frequencies in the range
(speed of sound = 340 m/s)
[1] 436 to 586 [3] 426 to 574
[3] 426 to 584 [4] 436 to 674

44. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1 . If the train's speed is reduced to 17 m/s, the frequency registered is f_2 . If the speed of sound is 340 m/s then the ratio f_1/f_2
[1] 18/19 [2] 1/2
[3] 2 [4] 19/18

45. If source and observer both are relatively at rest and if speed of sound is increased then frequency heard by observer will
[1] Increases
[2] Decreases
[3] Can not be predicted
[4] Will not change

46. A source and an observer move away from each other with a velocity of 10 m/s with respect to ground. If the observer finds the frequency of sound coming from the source as 1950 Hz, then actual frequency of the source is (velocity of sound in air = 340 m/s)
[1] 1950 Hz [2] 2068 Hz
[3] 2132 Hz [4] 2486 Hz

47. A source is moving towards an observer with a speed of 20 m/s and having frequency of 240 Hz. The observer is now moving towards the source with a speed of 20 m/s. Apparent frequency heard by observer, if velocity of sound is 340 m/s, is
[1] 240 Hz [2] 270 Hz
[3] 280 Hz [4] 360 Hz

48. A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz while the train approaches the siren. During his return journey in a different train B he records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that of train A is
[1] 242/252 [2] 2
[3] 5/6 [4] 11/6

49. A whistle revolves in a circle with an angular speed of 20 rad/sec using a string of length 50 cm. If the frequency of sound from the

whistle is 385 Hz, then what is the minimum frequency heard by an observer, which is far away from the centre in the same plane (v = 340 m/s)

[1] 333 Hz [2] 374 Hz
[3] 385 Hz [4] 394 Hz

50. A ilren emitting sound of frequency 800 Hz is going away from a static listener with a speed of 30 m/s, frequency of the sound to be heard by the listener is (take velocity of sound as 330 m/s)

[1] 733.3 Hz [2] 644.8 Hz
[3] 481.2 Hz [4] 286.5 Hz

51. A car sounding a horn of frequency 1000 Hz passes an observer. The ratio of frequencies of the horn noted by the observer before and after passing of the car is 11:9. If the speed of sound is v, the speed of the car is

[1] $\frac{1}{10}v$ [2] $\frac{1}{2}v$
[3] $\frac{1}{5}v$ [4] v

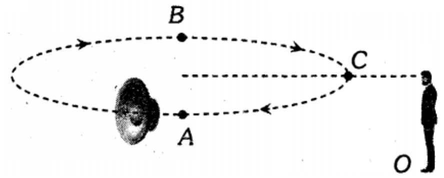
52. What should be the velocity of a sound source moving towards a stationary observer so that apparent frequency is double the actual frequency (Velocity of sound is v)

[1] v [2] 2v
[3] $\frac{v}{2}$ [4] $\frac{v}{4}$

53. A bus is moving with a velocity of 5 m/s towards a huge wall, the driver sounds a horn of frequency 165 Hz. If the speed of sound in air is 355 m/s, the number of beats heard per second by a passenger on the bus will be

[1] 6 [2] 5
[3] 3 [4] 4

54. A small source of sound moves on a circle as shown in the figure and an observer is standing on O . Let n_1, n_2 and n_3 be the frequencies heard when the source is at A, B and C respectively. Then



[1] $n_1 > n_2 > n_3$ [2] $n_2 > n_3 > n_1$
[3] $n_1 = n_2 > n_3$ [4] $n_2 > n_1 > n_3$

55. A source and an observer approach each other with same velocity 50 m/s, If the apparent frequency is 435 sec^{-1}, then the real frequency is

[1] 320 s^{-1} [2] 360 sec^{-1}
[3] 390 sec^{-1} [4] 420 sec^{-1}

56. A source emits a sound of frequency of 400 Hz, but the listener hears it to be 390 Hz. Then

[1] The listener is moving towards the source
[2] The source Is moving towards the listener
[3] The listener is moving away from the source
[4] The listener has a defective ear

57. Doppler effect is applicable for

[1] Moving bodies
[2] One Is moving and other are stationary
[3] For relative motion
[4] None of these

58. A source and an observer are moving towards each other with a speed equal to $\frac{v}{2}$ where v is the speed of sound. The source is emitting sound of frequency n. The frequency heard by the observer will be

[1] Zero [2] n
[3] $\frac{n}{3}$ [4] 3n

59. When an engine passes near to a stationary observer then its apparent frequencies occurs in the ratio 5/3. If the velocity of engine is (Velocity of sound is 340 m/s)
[1] 540 m/s [2] 270 m/s
[3] 85 m/s [4] 52.5 m/s

60. A police car horn emits a sound at a frequency 240 Hz when the car is at rest. If the speed of the sound is 330 m/s, the frequency heard by an observer who is approaching the car at speed of 11 m/s, is
[1] 248 Hz [2] 244 Hz
[3] 240 Hz [4] 230 Hz

61. A person carrying a whistle emitting continuously a note of 272 Hz is running towards a reflecting surface with a speed of 18 km/hour. The speed of sound in air is $345ms^{-1}$. The number of beats heard by him is
[1] 4 [2] 6
[3] 8 [4] 3

62. The speed of sound in air is 340 m/s. The speed with which a source of sound should move towards a stationary observer so that the apparent frequency becomes twice of the original
(a) 640 m / s (b) 340 m / s
(c) 170 m / s (d) 85 m / s

63. A bat flies at a steady speed of $4 ms^{-1}$ emitting a sound of $f = 90x10^3Hz$. It is flying horizontally towards a vertical wall. The frequency of the reflected sound as detected by the bat will be (Take velocity of sound in air as $330 ms^{-1}$)
[1] $88.1x10^3Hz$ [2] $87.lxlO^3Hz$
[3] $92.lxlO^3Hz$ [4] $89.1xl0^3Hz$

64. A speeding motorcyclist sees traffic jam ahead of him. He slows down to 36 km/hour, He finds that traffic has eased and a car moving ahead of him at 18 km/hour Is honking at a frequency of 1392 Hz. If the speed of sound is 343 m/s, the frequency of the honk as heard by him will be
[1] 1412 Hz [2] 1454 Hz
[3] 1332 Hz [4] 1372 Hz

MUSICAL SOUND

1. Which of the following has high pitch in their sound
[1] Lion [2] Mosquito
[3] Man [4] Woman

2. A spherical source of power 4 IV and frequency 800 Hz is emitting sound waves. The intensity of waves at a distance 200 m is
[1] $8 x10^{-6} W / m^2$ [2] $2 x10^{-4} W / m^2$
[3] $lxlO^{-4} W / m^2$ [4] $4 W / m^2$

3. If the pressure amplitude in a sound wave is tripled, then the intensity of sound is increased by a factor of
[1] 9 [2] 3
[3] 6 [4] $\sqrt{3}$

4. If the amplitude of sound is doubled and the frequency reduced to one-fourth, the intensity of sound at the same point will be
[1] Increased by a factor of 2

[2] Decreased by a factor of 2
[3] Decreased by a factor of 4
[4] Unchanged

5. Intensity level of a sound of intensity I is 30 dB. The ratio $\frac{I}{I_0}$ is (Where I_0 is the threshold of hearing
[1] 3000 [2] 1000
[3] 300 [4] 30

6. Decibel is unit of
[1] Intensity of light
[2] X-rays radiation capacity
[3] Sound loudness
[4] Energy of radiation

7. Quality of a musical note depends on
[1] Harmonics present
[2] Amplitude of the wave
[3] Fundamental frequency
[4] Velocity of sound in the medium

8. When we hear a sound, we can identify its source from
[1] Amplitude of sound
[2] Intensity of sound
[3] Wavelength of sound
[4] Overtones present in the sound

9. A man x can hear only up to 10 kHz and another man y up to 20 kHz. A note of frequency 500 Hz is produced before them from a stretched string. Then
[1] Both will hear sounds of same pitch but different quality
[2] Both will hear sounds of different pitch but same quality
[3] Both will hear sounds of different pitch and different quality
[4] Both will hear sounds of same pitch and same quality

10. The amplitude of two waves are in ratio 5 : 2. If all other conditions for the two waves are same, then what is the ratio of their energy densities
[1] 5 : 2 [2] 10 : 4
[3] 2.5 : 1 [4] 25 : 4

11. A is singing a note and at the same time B is singing a note with exactly one-eighth the frequency of the note of A. The energies of two sounds are equal, the amplitude of the note of B is
[1] Same that of A
[2] Twice as that of A
[3] Four times as that of A
[4] Eight times as that of A

12. The loudness and pitch of a sound depends on
[1] Intensity and velocity
[2] Frequency and velocity
[3] Intensity and frequency
[4] Frequency and number of harmonics

13. If T is the reverberation time of an auditorium of volume V then
[1] $T \propto \frac{1}{V}$ [2] $T \propto \frac{1}{V^2}$
[3] $T \propto V^2$ [4] $T \propto V$

14. The intensity of sound from a radio at a distance of 2 metres from its speaker is $1\times10^{-2}\mu W/m^2$. The intensity at a distance of 10 meters would be
[1] (a) $0.2\times10^{-2}\mu W/m^2$ [2] $1\times10^{-2}\mu W/m^2$
[3] $4\times10^{-4}\mu W/m^2$ [4] $5\times10^{-2}\mu W/m^2$

15. The physical quantity that remains unchanged when a sound wave goes from one medium to another is
[1] Amplitude [2] Speed
[3] Wavelength [4] Frequency
[5] Phase

16. How many times more intense is a 60 dB sound than a 30 dB sound
[1] 100 [2] 4
[3] 1000 [4] 2

17. The time of reverberation of a room A is one second. What will be the time (in seconds) of reverberation of a room, having all the dimensions double of those of room A
[1] $\frac{1}{2}$ [2] 1
[3] 2 [4] 4

18. A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of
[1] 1000 [2] 10000
[3] 10 [4] 100

19. If separation between screen and source is increased by 2% what would be the effect on the intensity
[1] Increases by 4% [2] Increases by 2%
[3] Decreases by 2% [4] Decreases by 4%

20. The musical interval between two tones of frequencies 320 Hz and 240 Hz is
[1] 80 [2] $\left(\frac{4}{3}\right)$
[3] 560 [4] 320 x 240

Answer Keys

Basics of mechanical waves

Q	1	2	3	4	5	6	7	8	9	10
A	**4**	**3**	**4**	**4**	**4**	**4**	**1**	**3**	**3**	**4**
Q	11	12	13	14	15	16	17	18	19	20
A	**1**	**1**	**4**	**3**	**1**	**2**	**3**	**2**	**4**	**1**
Q	21	22	23	24	25	26	27	28	29	30
A	**2**	**2**	**3**	**4**	**4**	**4**	**4**	**3**	**2**	**4**
Q	31	32	33	34	35	36	37	38	39	40
A	**3**	**1**	**2**	**4**	**2**	**4**	**2**	**1**	**3**	**4**
Q	41	42	43	44	45	46	47	48	49	50
A	**4**	**4**	**3**	**1**	**4**	**3**	**2**	**4**	**2**	**1**
Q	51	52	53	54	55	56	57	58	59	60
A	**4**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**1**
Q	61	62	63	64	65	66	67	68	69	70
A	**4**	**3**	**1**	**3**	**4**	**3**	**3**	**1**	**1**	**1**
Q	71	72	73	74	75	76	77	78	79	80
A	**2**	**2**	**4**	**4**	**3**	**2**	**4**	**2**	**1**	**2**
Q	81	82	83	84	85	86	87	88		
A	**4**	**2**	**2**	**2**	**1**	**4**	**1**	**3**		

Progressive Waves

Q	1	2	3	4	5	6	7	8	9	10
A	**4**	**3**	**2**	**3**	**4**	**1**	**2**	**4**	**1**	**3**
Q	11	12	13	14	15	16	17	18	19	20
A	**3**	**4**	**2**	**2**	**2**	**4**	**2**	**1**	**4**	**3**
Q	21	22	23	24	25	26	27	28	29	30
A	**2**	**2**	**1**	**1**	**1**	**1**	**4**	**4**	**1**	**1**
Q	31	32	33	34	35	36	37	38	39	40
A	**1**	**4**	**2**	**4**	**4**	**4**	**1**	**1**	**2**	**2**
Q	41	42	43	44	45	46	47	48	49	50
A	**4**	**3**	**2**	**4**	**3**	**1**	**1**	**1**	**2**	**4**
Q	51	52	53	54	55	56	57	58	59	60
A	**4**	**2**	**1**	**1**	**2**	**4**	**1**	**4**	**3**	**2**
Q	61									
A	**2**									

Interference and Superposition of Waves

Q	1	2	3	4	5	6	7	8	9	10
A	**3**	**2**	**1**	**2**	**2**	**4**	**4**	**2**	**3**	**1**
Q	11	12	13	14	15	16	17	18	19	20
A	**1**	**2**	**5**	**4**	**2**	**3**	**1**	**4**	**2**	**3**
Q	21	22	23	24	25	26	27	28	29	30
A	**1**	**2**	**1**	**3**	**4**	**2**	**3**	**3**	**4**	**1**
Q	31									
A	**4**									

Beats

Q	1	2	3	4	5	6	7	8	9	10
A	**3**	**4**	**3**	**2**	**3**	**2**	**1**	**1**	**2**	**2**
Q	11	12	13	14	15	16	17	18	19	20
A	**1**	**4**	**1**	**2**	**3**	**3**	**3**	**2**	**2**	**1**
Q	21	22	23	24	25	26	27	28	29	30
A	**4**	**2**	**2**	**3**	**3**	**1**	**1**	**1**	**3**	**1**
Q	31	32	33	34	35	36	37	38	39	40
A	**1**	**1**	**1**	**1**	**4**	**2**	**1**	**1**	**1**	**2**
Q	41	42	43	44	45					
A	**1**	**2**	**4**	**2**	**4**					

Stationary Waves

Q	1	2	3	4	5	6	7	8	9	10
A	**3**	**1**	**3**	**4**	**1**	**1**	**2**	**2**	**1,4**	**4**
Q	11	12	13	14	15	16	17	18	19	20
A	**2**	**4**	**2**	**4**	**4**	**4**	**1**	**4**	**2**	**1**
Q	21	22	23	24	25	26	27	28		
A	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**3**		

Vibration of String

Q	1	2	3	4	5	6	7	8	9	10
A	**1**	**4**	**3**	**3**	**3**	**2**	**2**	**4**	**1**	**3**
Q	11	12	13	14	15	16	17	18	19	20
A	**4**	**3**	**3**	**1**	**1**	**4**	**1**	**1**	**3**	**2**
Q	21	22	23	24	25	26	27	28	29	30
A	**4**	**3**	**1**	**2**	**1**	**2**	**2**	**2**	**3**	**3**
Q	31	32	33	34	35	36	37	38	39	40
A	**2**	**1**	**4**	**2**	**1**	**3**	**4**	**1**	**4**	**2**
Q	41	42	43	44	45	46	47	48	49	50
A	**1**	**1**	**4**	**4**	**4**	**3**	**1**	**2**	**4**	**3**
Q	51	52	53	54	55	56	57	58	59	60
A	**4**	**2**	**4**	**1**	**4**	**3**	**2**	**3**	**3**	**5**
Q	61	62	63	64	65	66	67	68		
A	**2**	**5**	**4**	**3**	**1**	**3**	**1**	**2**		

Organ Pipe (Vibration of Air Column)

Q	1	2	3	4	5	6	7	8	9	10
A	**3**	**1**	**3**	**4**	**3**	**3**	**4**	**1**	**2**	**3**
Q	11	12	13	14	15	16	17	18	19	20
A	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**3**	**1**
Q	21	22	23	24	25	26	27	28	29	30
A	**2**	**1**	**1**	**2**	**3**	**1**	**1**	**2**	**1**	**4**
Q	31	32	33	34	35	36	37	38	39	40
A	**3**	**1**	**2**	**2**	**2**	**2**	**2**	**3**	**2**	**2**
Q	41	42	43	44	45	46	47	48	49	50
A	**2**	**2**	**1**	**3**	**1**	**3**	**1**	**4**	**2**	**3**
Q	51	52	53	54	55	56	57	58	59	60
A	**1**	**1**	**2**	**3**	**1**	**4**	**1**	**2**	**1**	**1**
Q	61	62	63	64	65	66	67	68	69	70
A	**2**	**3**	**4**	**5**	**1**	**1**	**2**	**3**	**2**	**4**

Doppler's Effect

Q	1	2	3	4	5	6	7	8	9	10
A	**4**	**2**	**3**	**2**	**3**	**3**	**3**	**2**	**1**	**1**
Q	11	12	13	14	15	16	17	18	19	20
A	**1**	**2**	**4**	**1**	**2**	**1**	**1**	**4**	**4**	**4**
Q	21	22	23	24	25	26	27	28	29	30
A	**4**	**1**	**1**	**2**	**3**	**3**	**3**	**4**	**2**	**4**
Q	31	32	33	34	35	36	37	38	39	40
A	**1**	**3**	**4**	**2**	**1**	**2**	**2**	**1**	**4**	**3**
Q	41	42	43	44	45	46	47	48	49	50
A	**1**	**3**	**1**	**4**	**4**	**2**	**2**	**2**	**2**	**1**
Q	51	52	53	54	55	56	57	58	59	60
A	**1**	**3**	**2**	**2**	**1**	**3**	**3**	**4**	**3**	**1**
Q	61	62	63	64						
A	**3**	**3**	**3**	**1**						

Musical Sound

Q	1	2	3	4	5	6	7	8	9	10
A	**2**	**1**	**1**	**3**	**2**	**3**	**1**	**4**	**4**	**4**
Q	11	12	13	14	15	16	17	18	19	20
A	**4**	**3**	**4**	**3**	**4**	**3**	**3**	**4**	**4**	**2**