**Chapter – 15 Waves**

l. **Wave motion**:

(i) A wave motion is a kind of disturbance which is transferred from one part of the medium to the next due to the repeated periodic motion of medium particles about their mean position.

(ii) The disturbance travels through the medium with a certain definite velocity without any change in its form.

(iii) **Longitudinal waves**: A longitudinal wave is a wave in which the particles of the medium oscillate in simple harmonic motion along the direction of propagation of the wave. The most common example of a longitudinal wave is a sound wave.

Sound waves in gases and liquids are longitudinal waves. The propagation of compression and rarefaction in a long spring is also an example of a longitudinal wave.

(iv) **Transverse waves**: A transverse wave is a wave in which the particles of medium execute simple harmonic motion in a direction perpendicular to its direction of propagation. Waves of plucked strings, electromagnetic waves, light waves are the examples of transverse waves. **In solids, sound waves can be transverse or longitudinal. Transverse waves in a medium essentially require shear modulus**

(v) There are also some such waves in nature which are neither transverse nor longitudinal but a combination of both. Such waves are known as **ripples**, for example, waves on the surface of a liquid

(vi**) Only a transverse wave can be polarised** but not a longitudinal one. Hence, transverse or longitudinal nature of a wave can be decided on the basis of polarisation.

(vii**) Mechanical waves:**

(a) These waves require a material medium for their propagation.

(b) These waves transfer energy and momentum through the limited motion of the particles with the medium remaining at its own place.

(c) For the propagation of mechanical waves it is essential that the medium must possess **elasticity, inertia and low resistance for motion.**

(d) Water waves, sound waves, waves in a spring or a stretched string are examples of mechanical waves.

(viii) **Non-mechanical waves**: These waves do not require any medium for their propagation. All electromagnetic waves such as light radiation, heat radiation, γ-rays, X- rays, microwaves and so on are non-mechanical.

(ix) **Mechanical waves can be either longitudinal or transverse**. Hence, if a wave is longitudinal, it is mechanical, but if a wave is mechanical it may or may not be longitudinal

(x) AII non-mechanical waves are transverse in nature. Hence, if a wave is non-mechanical, it is transverse, but if a wave is transverse, it may or may not be non-mechanical

(xi) It is worth noting that **each kind of wave has two types of disturbances. Electromagnetic waves have electric and magnetic fields, sound waves have pressure variations and particle displacement, while stretched strings have particle displacements and variations of tension**

2. **Mechanical waves in different media:**

|  |  |  |
| --- | --- | --- |
| S.No. | Type of media | Type of mechanical wave |
| 1 | Strings | Mechanical waves are always transverse when the string is under a tension. |
| 2 | Gases and liquids | Mechanical waves are always longitudinal as liquids and gases cannot sustain shear. |
| 3 | Solids | Mechanical waves (may be sound waves) can be either transverse or longitudinal  depending on the mode of excitation. |
| 4 | Vibrating tuning  fork | Waves in the prongs are transverse while in the stem are longitudinal. |
| 5 | Rocks during  earthquakes | S (shear) and P (pressure) waves are produced simultaneously which travel  through the rock in the crust with different speeds [Vs ≈ 5 km/s while Vp ≈ 9 km/s]. S-waves are transverse while P-waves are longitudinal. |

3. **Wave characteristics:**

**(i) Displacement and amplitude (A):**

(a) The instantaneous displacement of any particle of the medium, in which the wave is propagating, is the displacement of that particle from its equilibrium position.

(b) The amplitude of the wave is the maximum value of the displacement.

(c) Amplitude is a vector quantity.

(d) When two waves of different amplitudes A1 and A2 superimpose each other with a phase difference of ϕ, then the resultant amplitude

(e) The maximum amplitude is , A1+A2 when ϕ= 00 and minimum amplitude is A1 - A2 when ϕ= 1800

**(ii) Oscillation and time period (T):**

(a) Oscillation is defined as one complete to and fro motion of the vibrating particle

(b) The time which a vibrating particle takes to complete its one oscillation is known as time period or the time after which a wave repeats itself is also called as **time period.**

(c) In case of a transverse progressive wave, the time taken by the crest or trough to change again into a crest or trough is known as time period.

(d) In case of a longitudinal progressive wave, the time taken by the compression or rarefaction to change again into compression or rarefaction is called as time period.

**(iii) Frequency ( *f* ) :**

(a) It is defined as the number of oscillations made by a vibrating particle in one second.

(b) Frequency may also be defined as the number of waves crossing any point of the medium in one sec.

(c) The reciprocal of the time period is called as frequency

(d) **Frequency depends upon the source and not the medium.**

(e) **Frequency** does not change when a wave travel from one medium to other.

**(iv) Wavelength (λ) :**

(a) The wavelength of a wave is the distance in the direction of propagation in which the wave repeats itself.

(b) It may also be defined as the distance travelled by a wave in the time the particle of the medium completes one oscillation.

(c) The distance between two consecutive points which are in the same state of vibration or phase (or differ in phase by 2π radian or T sec) is also defined as the wavelength.

(d) (I) **In case of transverse progressive waves:** λ = distance between two consecutive crests or troughs.

(II) **In case of longitudinal progressive waves**: λ = distance between two consecutive compressions or

rarefactions.

(e) **Wavelength depends upon:**

- the nature of medium (same source will produce waves of different wavelengths in different media).

- the source producing the waves (in a given medium sources of different frequencies will produce waves of

different wavelengths).

**(v) Wave velocity (*v*) :**

(a) The distance travelled by the wave in one second is known as wave velocity.

(b) v =λ/T = f λ (c) v =*w*/k

(d) When a given wave passes from one medium to another, its frequency does not change. So, from equation v =λ/T = f λ we can write: v1/v2 = λ1/λ2

(e) While using equation v = f λ , one must be careful to decide which out of v , f & λ is constant.

**(vi) Phase (ϕ)**

(a) Phase is that which gives the state of the vibrating particle as regards its position and direction of motion.

(b) Phase of a vibrating particle may be expressed as the angle turned by it since it last passed through its mean position.

(c) It may be expressed as the fraction of the time period that has elapsed since it passed through its mean position ∆ϕ = 2π t/ T

(d) If we consider two points at positions x1 and x2 on a wave at a given instant, then the phase difference between the two points

**A path difference of λ corresponds to a phase difference of 2π radian.**

(e) If two sources emit waves of frequencies f1 and f2 simultaneously, then the phase difference between these two waves after a time ∆t is given by:

**4. Plane progressive wave and its properties:**

(i) A progressive wave is due to continuous periodic vibration of all the particles of the medium.

(ii) A progressive wave transfers energy from one part of space to the other.

(iii) In a progressive wave all the particles vibrate with the same amplitude and with same time period.

(iv) In a progressive wave every particle differs in phase from the neighbouring particle and the phase difference between two consecutive crests or troughs in the case of transverse waves is 2π rads or T.

(v) In a progressive wave all the particles pass through the equilibrium positions successively but with the same speed (=A*w*).

(vi) In a transverse progressive wave the distance between consecutive crests or troughs is equal to λ and in longitudinal progressive wave the distance between two consecutive compressions or rarefactions is equal to λ.

(vii) In a progressive wave, no particle is permanently at rest.

(viii) In a complete vibration, at no instant all the particles will be in their mean position simultaneously in a progressive wave. At a particular instant, the particles of the medium fall on a sine curve.

(ix) In a progressive wave all the particles vibrate with same amplitude, same time period but every particle differs in phase from the neighbouring particle.

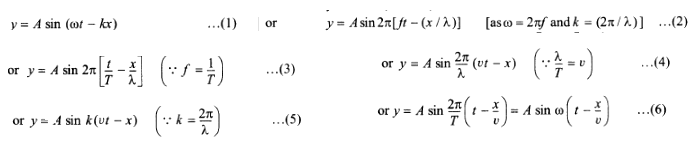
5. **Equation of plane progressive wave and related important points:**

(i) If a travelling wave is a sin or cos function of (at - bx) or (at + bx), the wave is said to be harmonic or plane progressive wave.

(ii) One dimensional progressive wave in its most general form is given by: y= A sin(*w*t +kx +ϕ)

where A, w, ϕ and k completely describe a plane progressive wave.

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



(iv) (a) If the sign between t and x terms is negative the wave is propagating along positive x-axis and vice-versa.

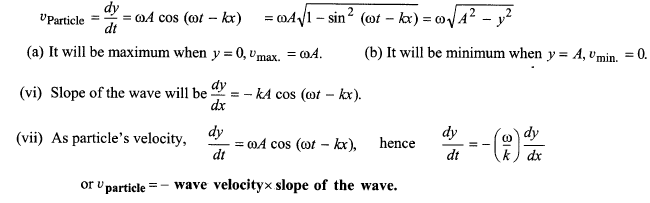
(b) The coefficient of sin or cos function, i.e., A gives the amplitude of the wave while its argument (wt ± kx) denotes phase.

(c) The coefficient of t gives angular frequency w =2πf = 2π/T

(d) The coefficient of x gives propagation constant or wave number k = 2π/λ

(e) The ratio of coefficient of t to that of x gives wave or phase velocity, i.e., v = (w/k) and is constant for a given medium

**(v) Particle velocity:**



6. **Velocity of transverse mechanical waves:**

(i) Velocity of a transverse wave propagating along a string having tension T and mass per unit length m, is

given by: v = √(T/m)

If A is the cross-section of the wire, m = ρA. so, v = √(T/ ρA) = √(S/ρ) [ as T /A = stress S ]

(ii) It has also been established that if a transverse mechanical wave instead of propagating along a string, is propagating through solid media (e.g., S-seismic waves in rocks) its velocity is given by: v = √(η/ρ) , where η is modulus of rigidity and ρ density of the solid.

7. **Audible, infrasonic and ultrasonic waves:**

(i) Mechanical waves can be transmitted in all the three states of matter namely solids, liquids and gases.

(ii) In **liquids and gases**, these waves are always longitudinal waves.

(iii) **In solids,** these waves can be either transverse or longitudinal.

(iv) According to their frequencies, **longitudinal mechanical waves** are classified into three categories:

(a**) Audible or sound waves:**

(I) These are longitudinal mechanical waves.

(II) Their frequencies lie between 20 Hz and 20,000 Hz.

(III) These are generated by vibrating bodies such as vocal cords, stretched strings or membranes.

(IV) In air at NTP (v= 330m/sec) their wavelength range is 16.5 m to 1.65 cm.

**(b) Infrasonic waves:**

(I) These are also longitudinal mechanical waves.

(II) Their frequencies lie below 20 Hz.

(III) These waves are created by earthquakes (P-waves), volcanic eruption, ocean waves.

**(c) Ultrasonic waves:**

(I) Longitudinal mechanical waves having frequency more than 20 kHz are known as ultrasonic waves.

(II) Human ear cannot detect these waves. Mosquitoes, fish, dogs and bats can detect these waves. Bats not only detect but also produce ultrasonic.

(III) These waves can be produced by the high frequency vibrations of a quartz crystal under an alternating electric field (piezoelectric effect)

(IV) These waves can also be produced by the vibrations of a ferromagnetic rod under an alternating magnetic field (Magnetostriction effect).

(V) Ultrasonic waves are used for navigation under water (SONAR).

(VI) They are used in ultrasonography (in photographing or scanning soft tissues of body).

(VU) Ultrasonics are used in bloodless surgery and wave therapy.

(VID These are also used to repel mosquitoes or attract fishes,

8. **Velocity of sound:**

(i) Velocity of sound is the characteristic of the medium in which a wave propagates.

(ii) Velocity of sound in a medium is given by: v = √(E/ρ), where E is the modulus of elasticity and ρ is the density of the medium.

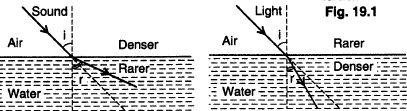
(iii) Velocity of sound is maximum in solids and minimum in gases since solids are most elastic and gases are least elastic.

(iv) For example, as Es >EL >Egas therefore Vs>VL >Vgas

(v)If we hear a distant momentary sound through a metallic pipe we will hear it twice, first in metal and then in air provided the time interval between two sounds is greater than (1/10) sec (persistence of ear).

(vi) (a) Velocity of sound in water (Vw) is more than the velocity of sound in air (Va); thus **water is a rarer medium** for sound waves. **When a beam of sound travels from air to water, it bends away from the normal since water is a rarer medium for sound waves.**

(b) **Velocity of light in water is less than the velocity of light in air**; thus water is a denser medium for light waves. **When a beam of light travels from air to water, it bends towards the normal since water is a denser medium for light.**



(vii) (a) In case of propagation of sound in solids (rods), elasticity involved is Young's modulus and velocity of sound is given by: Vsolid = √(Y/ρ)



(b) If the solid is an unbounded medium, the velocity of longitudinal waves is given by:

(c) In case of propagation of sound in liquids and gases, elasticity involved is bulk modulus and velocity of sound is given by: VL or G = √(B/ρ)

(viii) **Newton's formula**: Newton assumed that when sound propagates through air, temperature remains constant, i.e.,the process is isothermal.

So, B = P. therefore Vair = √(P/ρ)

At NTP for air, P = 1.01 x 105 N/m2  ρ = 1.3 kg/m3 which gives Vair = 279 m/s

This value is very much less than the value obtained experimentally (: 332 m/s).

(ix) **Laplace correction:** Laplace modified Newton's formula assuming that propagation of sound in air is an adiabatic process, i.e., B =γP , which gives Vair = 331 m/s m/s

(x) The velocity of sound in air at NTP is 332 m/s, which is much lesser than that of light and radio waves (=3 x 108 m/s). This is the reason that:

(a) if we set our watch by the sound of a distant siren it will be slow.

(b) if we record the time in a race by hearing the sound from the starting point it will be lesser than actual.

(c) in a cloud lightning, though light and sound are produced simultaneously but light precedes thunder.

9. **Effect of various factors on the velocity of sound:**

**(i) Effect of density:**

(a) For given values of γ and P, the velocity of sound in a gaseous medium is inversely proportional to the square root of the density of the gas, i.e., v α √(1/ρ) or v√ρ = constant

or V1/V2 = √(ρ2/ρ1)





(ii) **Effect of temperature:**

So, for a given gas, i.e., γ and M = constant, , V α √T ,i.e., with rise in temperature velocity of sound in a gas increases.

(b) The velocity of sound in a given gas will become n times if temperature is changed from T to T ' such that T'=n2T.



(c) When change in temperature is small,

i.e., for small temperature variations at 00C the velocity of sound changes by 0.61 m/s when temperature changes by l0C.



(iii) **Effect of pressure**: At constant temperature, the velocity of sound is independent of change of pressure since,

(iv) **Effect of relative humidity:** The velocity of sound in moist air is more than the velocity of sound in dry air, since the density of moist air is less than that of dry air at the same temperature.

(v) **Effect of wind:** The velocity of sound in the direction of the wind is more than the velocity of sound in a direction opposite to direction of the wind.

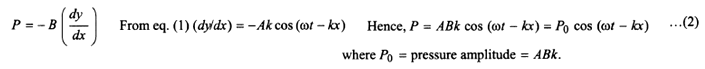
(vi) **Amplitude, frequency, phase, Loudness, pitch, quality have no effect on the velocity of sound.**

10. **Displacement and pressure waves:**

(i) A sound wave (longitudinal mechanical wave) may be described either in terms of longitudinal displacement suffered by the particles of the medium (called displacement wave) or in terms of the excess pressure generated due to compression and rarefaction (called pressure wave).

(ii) The displacement wave is described by: y = A sin (wt –kx) - [1]

(iii) The excess pressure (stress) is given by:



(iv) The pressure wave is 900 out of phase with respect to the displacement wave, i.e., displacement will be maximum when the pressure is minimum and vice-versa.

(v) The amplitude of the pressure wave is given by:



11. **Energy, power and intensity of sound wave:**



(i) If ρ is the density of the medium, kinetic energy of the wave per unit volume is given by:

Its maximum value will be equal to energy per unit volume [as(KE)max. = (PE)max = E ], i.e., **energy density U.**



(ii) Hence, the energy associated with a volume S ∆x will be:



(iii) Now, as **intensity** is defined as average energy transmitted per unit normal area per sec, i.e., power per unit area, so

(iv) As in case of sound wave displacement, amplitude is related to pressure amplitude through the relation

P0 = ρvAw so ,

(v) It follows from equations (4) and (5) that for a given source and medium, I α A2  or I α P o 2

(vi) The SI unit of intensity is W/m2. However as human ear responds to sound intensities over a wide range, i,e., from 10-12 W/m2 to I W/m2, so instead of specifying intensity of sound in W/m2, we use a logarithmic scale of intensity called sound level defined as,

where Io is the **threshold of human ear**, i.e.,l0-12 W/m2?. The sound level defined in this way is expressed in decibel (dB).

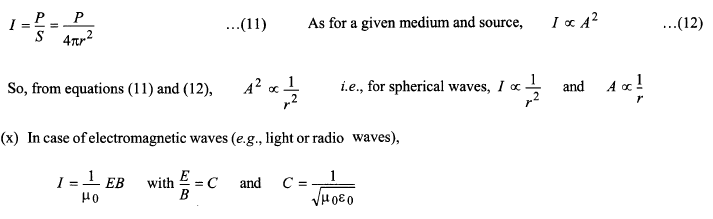
A sound of intensity Io has an

while sound at the upper range of human hearing called threshold of pain has an intensity of 1 W/m2 or **120 dB**

(vii) We also use dB as a relative measure to compare different sounds with one another, rather than with reference intensity.

Also Intensity (I) or Energy Flux = U x V = energy density x velocity

(ix) **With increase in distance from the source**, the total energy or power transmitted remains the same but intensity decreases. For an isotropic point source of power P, intensity I at a distance r from it will be:

**Superposition of Waves (Interference ,Beats and Stationary Waves)**

l. **Reflection and refraction of waves:**

(i) When sound waves are incident on a boundary separating two media, a part of incident waves returns back into the initial medium (reflection) while the remaining is partly absorbed and partly transmitted into the second medium (refraction).

(ii) In case of reflection and refraction of sound, the frequency of the waves remains unchanged, i.e., wi =wr =wt =w

(iii) The incident ray, the reflected ray, normal and the refracted ray are always in the same plane.

(iv) In case of reflection of sound; angle of incidence i = angle of reflection r.

(v) In case of refraction of sound; (sini /sin t) = Vi/Vt .

(vi) In case of reflection from a denser medium or rigid support or fixed end there is inversion of the reflected displacement wave, i.e., if the incident wave is given by: y = Ai sin(wt –kx) ;

then the reflected wave will be: y = - Ar sin(wt + kx) = Ar sin(wt + kx +π )

**i.e., the phase of the displacement wave changes by π in case of reflection from a denser medium or rigid support or fixed end, while in case of reflection from rarer medium there is no inversion of wave or phase change. The transmitted wave is never inverted.**

**(vii) Important points:**

(a) The concept of rarer or denser medium for a wave is through its speed (and not density of medium). For example, water is rarer for sound and denser for light than air, as for sound Vw > Va, while for light Vw < Va.

(b) In case of reflection of longitudinal pressure waves, there occurs a phase change of π on reflection from a free or open end and no change in phase from rigid boundaries.

2. **Echo:**

(i) An echo can be cited as an example of reflection of sound from a distant object such as hill or cliff. It is basically a sound of short duration reflected back to the observer 0.1 sec or more after the production of original sound.

(ii) If there is a sound reflector at a distance d from the source, the time interval between original sound and its echo at the site of source will be: t =d/v + d/v =2d/v



Now as persistence of ear is (l/10) sec, echo of a sharp or momentary sound will be heard if,

(iii) **If a person standing between two parallel hills fires a gun** and hears the first echo after t1 sec, the second echo after t2 see, and v is the velocity of sound, then the distance between the two hills is given by:



(iv) A man standing in front of a mountain at a certain distance beats a drum at regular intervals. The drumming rate is gradually increased and he finds that the echo is not heard when the rate becomes n1 per minute, He then moves nearer to the mountain by *x* m and finds that the echo is again not heard when the drumming rate becomes n2 per minute. Then, the distance between the mountain and the initial position is given by the equations:

(v) If a motor car approaching a cliff with a velocity u m/s sounds the horn and the echo is heard after t sec, then the distance between the cliff and the point where the horn is sounded is given by:



The distance between the cliff and the point where the echo is heard is given by:

(vi) A road runs midway between two parallel rows of buildings. If a motorist moving with a speed u m/s sounds the horn and hears the echo after t sec, then the distance between the two rows of buildings is, d= [√(v2-u2)]t, where v is the velocity of sound.

(vii) A road runs parallel to a long line of smooth cliffs. If a motorist moving with speed u m/s sounds the horn and hears the echo after t sec, then the distance between the road and the cliffs is given by: d= [√(v2-u2)]t/2, where v is the velocity of sound.

**3. Principle of superposition:**

(i) If two or more waves arrive simultaneously in a medium, the particles of the medium are subjected to two or more simultaneous displacements and a new wave is produced. **This phenomenon of intermixing of two or more waves to produce a new wave is called superposition of waves.**

(ii) In case of superposition of waves, the resultant wave function at any point is the algebraic sum of the wave-functions of individual waves, i.e., y=y1 + y2 + y3 +...

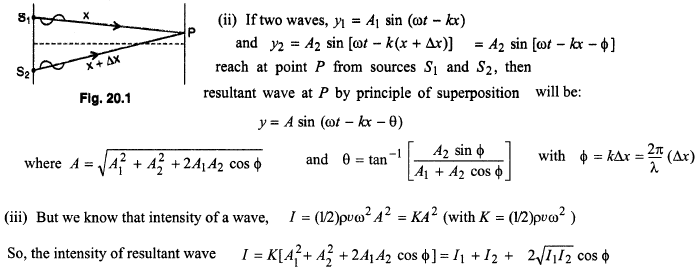
This principle is called principle of superposition.

(iii) Principle of superposition holds good as long as the amplitude of wave is not too large, i.e., the restoring force is proportional to the displacement.

(iv) This principle can be applied to many types of waves including wave pulse, waves or strings, surface water waves, sound waves, light waves and radio (i. e., electromagnetic) waves.

(v) This principle can be applied to study the phenomenon of interference, beats and stationary waves.

4. **Interference of sound waves:**

(i)When two or more sound waves arrive at a point simultaneously almost along the same line, the resultant intensity of sound at that point is different from the sum of intensities due to each wave separately. **This modification of intensity due to superposition of two or more waves is called interference.**

(iv) **Resultant intensity I at P is not just the sum of intensities due to separate waves** (I1 +I2) but different and depends on phase difference ϕ, i.e., position of point P. Hence,

(a) **Intensity will be maximum when cos ϕ : max**. = +1, i.e., ϕ = 0, 2π,4π,…. or ϕ =2nπ (where n= 0,1,2..)

or ∆x =nλ

i.e., intensity will be maximum at those points where path difference is integral multiple of wavelength λ, and maximum intensity is greater than the sum of two intensities (I1 +I2).

These points are called points of **constructive interference or interference maxima**

(b) **Intensity will be minimum** when cos ϕ = min. = - l, i.e., ϕ = π, 3π,4π,…. or ϕ =(2n-1) π (where n= 1,2..)

or ∆x =(2n-1) λ/2

i.e., intensity will be minimum at those points where path difference is odd integral multiple of Q" l2)and minimum intensity is lesser than the sum of two intensities (1r + 12 ). These points are called points of destructive interference or interference minima.

**5. Some important points concerning interference of sound waves:**

(i) All maxima are equally separated from each other and equally loud. Same is also true for minima.

(ii) Maxima and minima occur alternately.



(iv) In interference the intensity in maxima exceeds the sum of individual intensities by an amount 2√(I1I2)

while in minima lacks (I1 +I2 )by the same amount 2√(I1I2). This implies that in interference energy is neither created nor destroyed but is only redistributed.

(v) For producing sustained interference effects, waves must be **coherent.** The waves arriving at the point of interference must have constant phase difference.

**6. Beats:**

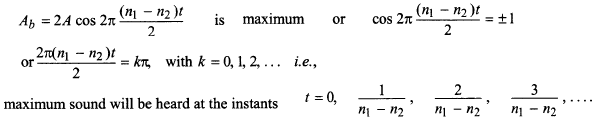
(i) When two notes (or two sound waves) of nearly equal frequency travelling in same direction superpose each other at a given point, then the intensity of the resulting sound rises and falls periodically. This periodic rise and fall in the intensity of sound at a given point is called as **beats.**

(ii) If two wave trains each of amplitude A travelling in the same direction but of slightly different frequencies n1 and n2 superpose each other, then the resultant wave is given by:



(iii) The frequency of the resultant harmonic wave is nav. = (n1 + n2)/2 while the frequency of the amplitude of resultant wave is nA = (n1 - n2)/2

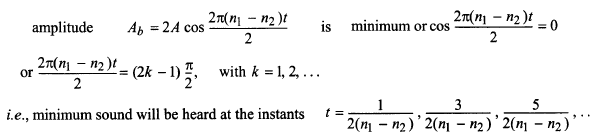
(iv) (a) The intensity of sound will be maximum when amplitude



(b) Time interval between two successive maxima = 1/(n1 - n2)

(c) The number of maxima per sec or beat frequency = (n1 - n2)

(v) (a) The intensity of sound will be minimum when

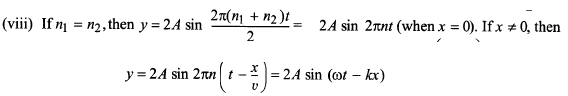


(b) Time interval between two successive minima = 1/(n1 - n2)

(c) The number of minima per sec or beat frequency = (n1 - n2)

(vi)Intensity of sound at a given point is not constant but varies periodically with time, i.e., interference is not sustained. As the persistence of ear is about (l/10) sec, beats will be detected by the ear only when frequency (n1 - n2) < 10 Hz.

(vii) If beat frequency is more than 10, beats produced will be more than 10 per sec but heard zero, as there will be continuous sound of intensity Iavg. = [(Imax + I min)/2] = I1 +I2 instead of waxing and waning of sound.



This shows that resultant wave will have an amplitude 2A and I α 4A2 or I = 4Io which is constant. Hence, beats will no more be produced and we will hear a sound of uniform intensity.

**7. Some important points concerning beats:**

(i) Phenomenon of beats is used by musicians in tuning their instruments. They sound their instruments along with a standard source and tune them till beats are no more heard. In this situation, frequency of the instrument becomes equal to that of standard source.

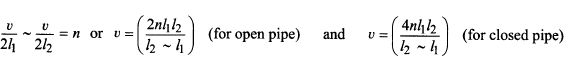
(ii) Phenomenon of beats can be used to determine the frequency of a tuning fork as follows:

(a) If a tuning fork of unknown frequency (nA) is sounded with a tuning fork of known frequency ( nB), then number of beats heard = nA ~ nB .If n is the beat frequency, then n = nA ~ nB and frequency of the tuning fork nA = nB ± n.

(b) Now the fork A is loaded with wax and sounded with the fork B; if the beat frequency decreases then nA > nB otherwise nA < nB. lf instead of loading the fork A with wax, fork A is filed and sounded with the fork B, then decrease in beat frequency implies nA < nB and increase in beat frequency means nA > nB. Remember that loading a fork with wax decreases its frequency while filing a fork increases its frequency.



(iii) If two sound waves of wavelengths λA and λB produce n beats, then the velocity of sound is given

(iv) If two open resonating air columns (closed) produce n beats per second, then velocity of sound is given by:

**8. Stationary or standing waves:**

(i) When two identical waves having same frequency and same amplitude travelling along the same straight line with same speed but in opposite direction are superposed, a new type of wave is formed known as a **stationary wave.**

(ii) Every particle of the medium is subjected to two disturbances one due to the wave travelling in one direction and the other due to the wave travelling in opposite direction.



[It should be noted here that if reflection takes place from a rigid boundary, then equation of reflected wave will be y2 = - A sin (wt +kx) ,as there occurs a phase change of π on reflection from a rigid boundary. In this case equation of resultant wave will be: y = -2A sin kx cos wt]

(iii) Because the above equation satisfies the wave equation, so it represents a wave. Since, it is not in the form of F (ax ± bt), so it is not a travelling or progressive wave but represents a standing wave.

(iv) Amplitude of resultant wave As = 2A cos kx is not constant but varies w.r.t. position periodically.

(v) The points for which the amplitude is minimum are called **nodes** and for these, cos kx = 0 or kx = (2n -l)(π/2) or kx = π/2 ,3π/2 ,5π/2 …. or x = λ/4 ,3λ/4 ,5λ/4 …

**This shows that in a stationary wave the distance between two adjacent nodes is (λ/2) and they are equally spaced.**

(vi) The points for which the amplitude is maximum are called **antinodes** and for these cos kx = ±1

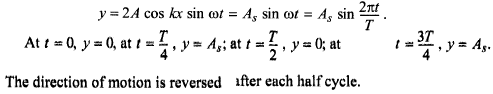
or kx = 0, π ,2π ,3π …. or x = 0, λ/2 , 2λ/2 ,3λ/2 …

**This shows that the distance between two adjacent antinodes is also equal to (λ/2) and they are equally spaced. Moreover, Amax. = ± 2a.**

(vii) In a stationary wave nodes and antinodes are formed alternately and the distance between them is equal to λ/4.

(viii) Due to persistence of vision these waves appear in the form of loops. All the particles in a loop are in the same phase. But the particles in adjacent loops differ in phase by π.

(ix) All the particles pass through mean position simultaneously twice in a complete vibration but with different velocity (given by *w*As where As, varies with position).

(x)

(xi) Stationary waves may be transverse or longitudinal, In strings (under tension) the waves are transverse stationary. In organ pipes the waves are longitudinal stationary.

(xii) In case of longitudinal waves pressure waves and displacement waves differ in phase by (π/2). **At nodes where the displacement is minimum, the pressure will be maximum and at antinodes where the displacement is maximum the pressure will be minimum.**

(xiii) (a) **As in stationary waves nodes are permanently at rest, no energy cannot be transmitted across them, i.e, energy of one region (segment) is confined in that region**.

(b) However, this energy oscillates between elastic potential energy and kinetic energy of the particles of the medium. When the particles are at their extreme positions KE is minimum and elastic PE is maximum. When the particles pass through the mean position KE will be maximum and PE will be minimum. The total energy confined in the segment remains constant.

**Vibration of strings, rods and air columns**

**l. Velocity of transverse mechanical waves:**

(i) If T is the tension in the string and m is linear density of the string, then velocity of transverse wave propagating along the string is given by:

v = √(T/m) ...(1)

(ii) Velocity of transverse wave propagating along a string depends only on the characteristics of the string but is independent of the frequency of the propagating wave.

(iii) If ρ be the density of the material of the string and A be its cross-sectional area, then m = Aρ and eq. (1)

can be rewritten as follows:

v = √(T/Aρ) =√(S/ρ) [ where S = stress = tension /area ]

(iv) If tension in different strings is kept constant, then v2/v1 = √(A1/A2) = √(r1/r2)

[r1 and r2 are the radii of two strings]

**This equation shows that velocity in a thinner wire is more than in a thicker wire.**

(v) If linear density ρ is kept constant, , v α √T , i.e., we can write

(vi) If a wire held fixed at the two ends by rigid supports is just taut at t10C then the velocity of the transverse wave at t20Cis given by:

(where dt is equal to the difference of temperatures t1 and t2).

(vii) (a) If a wire of uniform cross-section is stretched between two supports, fixed at one end and a load M is hung over a pulley at the other end, then the velocity of transverse wave is given by: v = √(Mg/m)



(b) If the suspended weight is immersed in a liquid of density σ, then the velocity of wave is given by:

where σ' is the density of the material of the load suspended.



(viii) If a transverse mechanical wave instead of propagating along a string, is propagating through solid media, its velocity is given by v= √(η/ρ), where η is the rigidity modulus and ρ is the density of the solid.

2. **Fundamental frequency of a stretched string:**

(i) The waves generated in a string stretched between two rigid supports are **transverse stationary waves.**

(ii) The string will vibrate in such a way that fixed points of the string behave as nodes because the string is not free to move at these points.

(iii) The free end or the point where the string is plucked behaves as an antinode because the displacement

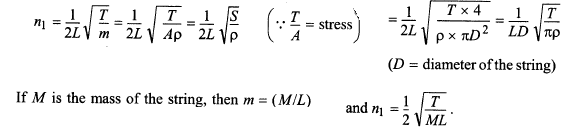
will constant be maximum at these points

(iv) In the simplest possible mode of vibration, a **node** will be formed- at both the fixed ends and an antinode in between them. This is called a fundamental mode of vibration and the frequency is known as **fundamental frequency**

(v) In the fundamental mode of vibration the length of the string L = λ/2 or λ =2L

(vi) (a) The fundamental frequency is given by n1= v/λ =v/2L = (1/2L) √(T/m)

(b) Fundamental frequency may also be expressed as:



3. **Mersenne's laws of vibrations of strings:**

**(i) Law of tension**

(a) If L and m are kept constant, the fundamental frequency of a stretched string is directly proportional to the square root of the tension in the string, i.e., n α √T or (n2/ n1) = √(T2/T1)

(b) If tension is made 4,9, 16 times and so on, then the fundamental frequency gets doubled, tripled,quadrupled and so on.

(c) If the tension in the string increases by 21%, 44% …. then the fundamental frequency increases by 10% , 20%.....

**(ii) Law of length:**

(a) If T and m are kept constant, the fundamental frequency of stretched string is inversely proportional to the length of the string, i.e., n α (1/L) or n1L1 = n2L2.

(b) If the length of string increases by 25% then the fundamental frequency decreases by 20%.

n1L1 = n2(1.25L1) or n2 =0.8 n1

(iii) **Law of mass:** If T and L are kept constant, the fundamental frequency of a stretched string is inversely proportional to the square root of linear density of the string, i.e.,

n α √(1/m) or n2m = constant or n12m1 = n22m2.

(iv) When n and m are kept constant, then

4. **Harmonics and overtones:**

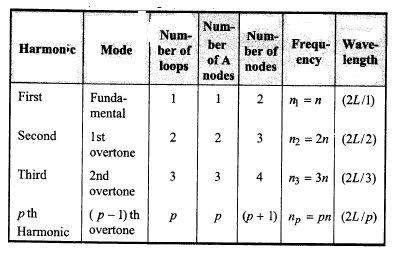
(i) The lowest possible frequency with which a stretched string can vibrate is called its fundamental frequency and corresponding mode of vibration is known as **fundamental mode or first harmonic**

(ii) The higher modes of vibration, whose frequencies are integral multiples of fundamental frequency are known as **overtones.**



(iii) The frequency of pth harmonic or ( p - l)th overtone is given by:

(iv) Table showing characteristics of different harmonics or overtones:



**5. Some more important points concerning vibrations of a stretched string:**

(i) In case of vibrations of composite string made up by joining two strings of different lengths, cross-sections and densities, having same tension throughout, the joint is a node and the string vibrates with the lowest common frequency.

(ii) Vibrations of rods or strings free at one end can be dealt similarly by taking the point of plucking or free end as an antinode while point of touching or clamping as a node.

(iii) **Interval** implies the ratio of two frequencies. If the interval is 1, the two vibrating bodies are said to exist in **unison** (n2 =n1). If the interval is 2, n2 is said to be an octave higher and so if interval is 2n , n2 will be n-octave higher. Similarly, n- octave lower implies n2 = (n1/2n ). For example, 3-octave higher implies n2 =23 n1=8n1 , while 3-octave lower implies n2 = n1/23 = n1/8

(iv) Tension in the string may be different due to different origins. For example,

(a) If it is due to suspended mass M, T = Mg.

(b) If the suspended mass of density ρ is immersed in a liquid of density σ, then T' = Mg' = Mg [ 1 - σ/ρ ]

(c) If T is due to elasticity of wire, then T = YA∆L/L and if the strain (∆L/L) is due to thermal expansion, then T = YA α ∆θ.

**6. Vibrations of a closed organ pipe:**

(i) The waves formed in a vibrating air column of a closed organ pipe are **longitudinal stationary waves.**

(ii) In a closed organ pipe, the closed end is always a node while the open end is always an antinode.

(iii) In the simplest mode of vibration, a node will be formed at the closed end and an antinode is formed at the open end.

(iv) In the simplest mode of vibration, the length of the air column is equal to λ1/4 or L = λ1/4 or λ1 =4L

(v) The fundamental frequency of the closed air column is given by: **n1 = (v/4L) = v/λ1** .This is also called as the **first harmonic**.

(vi) In the next mode of vibration, the length of the air column is equal to L = (3)λ3/4 or λ3 = 4L/3 . This mode of vibration is known as **third harmonic or first overtone**. Its frequency is given by:

n3 = v/λ3 = 3v/4L = 3n1

(vii) In the next mode of vibration, the length of the air column is equal to L = 5λ5/4 or λ5 = 4L/5. This mode is called as **fifth harmonic or second overtone.** Its frequency is given by:

n5 = v/λ5 = 5v/4L = 5n1

(viii) Thus, **only odd harmonics are found in a closed organ pipe. Even harmonics are absent.**

(ix) The maximum possible wavelength is 4L and the other wavelengths are given by [4L/(2k-1) ] , where k= 1,2,3 ...,

**(x) The frequencies of different overtones are given by [ (2k+1)v/4L ] where k =1,2,3, ., . .**

(xi) The modes of vibration of closed organ pipes are identical to that of a rod clamped at one end and a string fixed at one end and free at the other. **In organ pipes waves are always longitudinal, in rods waves may be longitudinal or transverse while in strings waves are always transverse stationary waves.**

**7. Vibrations of an open organ pipe:**

(i) The waves formed in the vibrating air column of an open organ pipe are also longitudinal stationary waves.

(ii) In the simplest mode of vibration, an antinode will be formed at either end with a node in between them.

(iii) The wavelength is maximum in the simplest possible mode and is given by: (λ/2) = L or λ = 2L.

(iv) **The fundamental frequency of the open pipe is given by**: n1 = v/λ = v/2L . This is also known as first harmonic.

(v) In the next mode of vibration, the length of the air column is equal to L = 2λ2/2 or λ2 = L . This mode is called as **second harmonic** or **first overtone**. Its frequency is given by:

n2 = v/λ2 = 2v/2L = 2 n1

(vi) In the next mode of vibration, the length of the air column is equal to L = 3λ2/2 or λ3 = 2L/3.This mode is called as **third harmonic or second overtone**. Its frequency is given by:

n3 = v/λ3 = 3v/2L = 3 n1

**(vii) Thus, all harmonics are found in an open organ pipe.**

**(viii) The maximum possible wavelength is equal to 2L and the other wavelengths are given by: (2L/k), where k = 1,2,3 …..**

**(ix) The frequencies of different overtones are given by: [ (k+1)v/(2L) ] where k = l, 2, 3,. ...**

**8. Some more important points concerning vibrations of closed and open air columns:**

(i) The fundamental frequencies in case of closed and open air columns are respectively, given by:

nc = v/(4Lc) and no = v/(4Lo) where Lc and Lo represent the lengths of closed and open air columns respectively.

(ii) Only odd harmonics are found in a closed organ pipe and nl : n3 : n5 = 1 :3 :5 ;but in case of an open organ pipe all the harmonics are present and nl : n2 : n3 = 1 : 2 : 3

(iii) If a closed organ pipe and open organ pipe have the same length,



i.e., if the lengths of closed and open organ pipes are equal, then the fundamental frequency of the open pipe is equal to twice the fundamental frequency of the closed pipe.

(iv) If closed pipe and open pipe have same fundamental frequency, then v/(4Lc) = v/(2Lo) or Lo =2Lc, i.e., the length of the open pipe is equal to twice the length of closed pipe, if their fundamental frequencies are equal.

(v) (a) Due to finite momentum of air molecules the reflection does not take place exactly at the open end but a little bit above it, i.e., antinode is not formed exactly at the open end but a little bit above it. This leads to an end correction which is found equal to e = 0.6r, where r is the radius of the pipe.

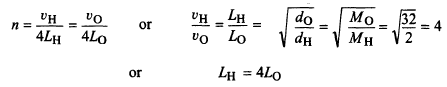
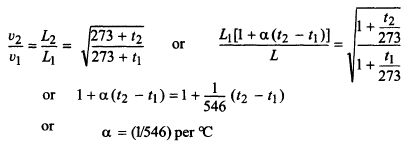
(b) Due to end correction, fundamental frequency in case of a closed organ pipe will be nc = v/[4(Lc + e)] and in case of open organ pipe, it will be no = v/[2(Lo + e)].

**(c) For given values of v and L, narrower the pipe higher will be the frequency or pitch and shriller will be the sound.**

(vi) For any organ pipe either closed or open, if v is constant n α (1/L),i.e., with decrease in length of the vibrating air column, frequency or pitch will increase. **This is why the pitch increases gradually as empty vessel fills gradually.**

(vii) If n is constant for an organ pipe, then v α λ, or v α L, i.e., if the ratio of speed of sound in a pipe to its length remains constant, then the frequency remained unchanged.

(viii) If fundamental frequencies of two closed organ pipes filled with hydrogen and oxygen gases are equal, then



(ix) If a closed organ pipe at different temperatures possesses same fundamental frequency of its vibration, then

Thus, if α = (1/546) per0C (coefficient of linear expansion of the material of the pipe), then the frequency of closed organ pipe remains constant at all temperatures.

(x) If the length of the pipe remains constant,



(b) then with change in the gas enclosed in the pipe, v will change and so n will change[ '.' v α √(γ/M)

(c) then with increase in moisture as v will increase, frequency will also increase.

(xi) A person will hear maximum sound at nodes, but not at antinodes. Since, perception of sound is due to pressure variations and as at node displacement is minimum, pressure will be maximum; while at antinodes as displacement is maximum, pressure will be minimum.

(xii) (a) **When a longitudinal compression reaches a rigid boundary**, it will press the boundary with maximum pressure and will be reflected back as compression as the boundary is not free to move. This in turn implies that in case of reflection of pressure waves from a rigid boundary, the boundary will be a node and there will be no change in phase.

(b) If the reflection of sound is from an open end, the pressure at the end will be equal to the atmospheric pressure and will not change unless the pressure of the whole surrounding atmosphere is changed. The attempt by the wave to compress air at the open end causes rarefaction, which travels back in opposite direction Thus, the longitudinal pressure wave is reflected from an open end with a phase change of π.

**9. Resonating air column experiment:**

(i) At first resonance, L1 + e = λ/4 At second resonance, , L2 + e = 3λ/4

therefore L2 – L1 = λ/2 or λ = 2 [L2 – L1]

(ii) Velocity of sound, v= nλ = 2 n[L2 – L1] ,where n is the frequency of the tuning fork.

(iii) End correction, e = [L2 – 3L1] /2.

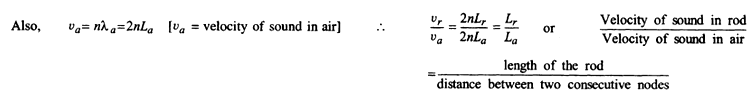
**10. Kundt's tube:**

(i) Kundt's tube enables us to determine the velocity of sound in solids in the form of rods and also in gases.

(ii) If Lr be the length of rod, λr be the wavelength of sound waves produced in it and velocity of sound in the rod be vr, then

Lr = λr/2 or λr = 2Lr and vr = nλr = 2nLr

If the mean distance between two nodes be La and wavelength be λa, then La = (λa)/2 or λa = 2La .



(iii) **Comparison of velocity of sound in different gases:** Here, the tube is filled first with one gas and the mean distance between two heaps (nodes) is determined. Let it be L1. Again, the experiment is done with other gas. Let the distance between two nodes in this case be L2.



Then . where v1 and v2 are the velocities of sound in the two gases.



(iv)**Determination of velocity of sound in a gas**:

where va, is the velocity of sound in air and L1, L2 are the mean distances between the nodes in air and gas respectively.

**Musical Sound and Doppler Effect**

1. **Musical sound and noise:**

(i) A musical sound consists of a quick succession of regular and periodic **rarefactions and compressions** without any sudden change in amplitude.

(ii) A **noise** consists of slow succession of irregular and aperiodic rarefactions and compressions accompanied by sudden change in amplitude.

(iii) A **tone** is a musical sound of a single frequency.

(iv) A **note** is a musical sound consisting of two or more tones.

(v) A note contains many tones. The tone with lowest frequency is called **fundamental tone**.

(vi ) Excepting the fundamental tone, the remaining tones in a note are called **overtones**.

(vii) If the frequencies of various overtones are integral multiples of the fundamental frequency, then overtones along with the fundamental are called **harmonics**.

2. **Characteristics of musical sound:**

**(i) Pitch:**

(a) Pitch of a note is the sensation conveyed to our brain by the sound waves falling on our ears which depends directly on the frequency of incident sound waves.

(b) Pitch is the characteristic of sound which distinguishes between a **shrill or grave sound**

Higher the frequency, more shrill the sound and higher the pitch. Lower the frequency, more, grave the sound and lower the pitch.

(c) The humming of a mosquito or buzzing of a bee has high pitch but low loudness while the roar of a lion has large loudness but low pitch.

(d) Pitch of female voice is higher than that of male due to presence of more harmonics.

(e) In a record player, if a 45 RPM record is played at 78 RPM, pitch will increase and sound will become shriller. If the same record is played at 33 RPM, pitch will decrease and so sound will become grave.

(f) Frequency refers to the number of waves produced by the source in one second and pitch depends upon the number of waves received by the ear in one second. These two may not be the same when the source and observer are in motion. **Thus, in Doppler effect, there is an actual change in pitch but an apparent change in frequency only.**

(g) In a tape-recorder, bass and treble refer to low and high pitch respectively. So, at bass low pitch, i.e., grave sounds such as of tabla or dholak become loud while at treble, high pitch, i.e., shrill sounds such as of flute or ghoonghroo become predominant.

**(ii) Loudness :** (a) Sensation received by our ears due to intensity of sound is known as loudness.

(b) Weber-Fechner established experimentally that Lα K log(I), i.e., higher is the amplitude of vibration , greater will be the intensity **I α A2** and louder will be the sound as in **shout** and lesser the intensity, feeble will be the sound as in **whispering**.

(c) The loudness being a sensation, depends upon the sensitivity of the listener's ears. Therefore loudness of a sound of given intensity may be different for different listeners.

(d) Also, two sounds of equal intensity but different frequency may not appear to be equally loud even to the same listener because the sensitivity of the ear is different for different frequencies.

(e) The unit of loudness is **phon** which is equal to the intensity level in dB of equally loud sound of I kHz (for which ear is most sensitive.

**(iii) Qualify or timbre:**

(a) Sensation received by our ears due to waveform is known as quality or timbre

(b) Two sound waves of same intensity and same frequency will differ in their quality if their waveforms are different

(c) As waveform depends on overtones present, quality of sound depends on number of overtones and their relative intensities.

(d) We can recognise a person without seeing him, by listening to his sound as it has a definite quality.

(e) If same note is played on different instruments say sitar and veena at same loudness and same frequency, they produce different sensation on our ears due to their different quality.

**3. Musical interval:**

(i) The ratio of the frequencies of two tones is known as **interval** between the two tones.

(ii) (a) The combined effect of two tones is **musical** if the interval can be expressed as a ratio of two small numbers as (2/1 ,3/2 ,…) and

(b) The combined effect of two tones is a noise if the interval is given by the ratio of large numbers as 21/20 ,22/21,…

**(iii) Some intervals:** Interval =n1/n2 (n1>n2)

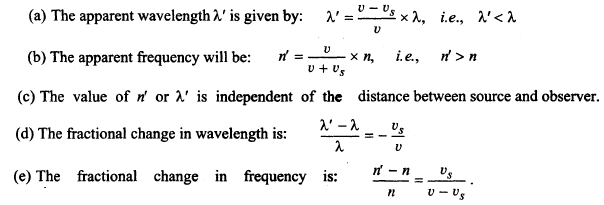
(a) For unison, n1 = n2 (b) For octave, n1 = 2n2  (c) For fifth. n1 = 3n2/2

(d)for major tone n1 = 9n2/8(e) For minor tone, n1 = 10n2/9 (f) For semi tone n1 = 16n2/15

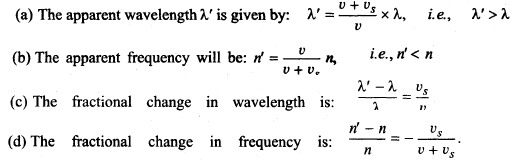
(iv) Diatonic scale: It consists of eight tones. The successive tones have either of the following three intervals, namely 9/8,10/9 and 16/15 i.e., successive tones in a diatonic scale have definite intervals.

4. **Doppler effect :** When a source of sound or an observer or both are in motion relative to air, there is an apparent change in the frequency of sound as heard by the observer. This phenomenon is called Doppler effect

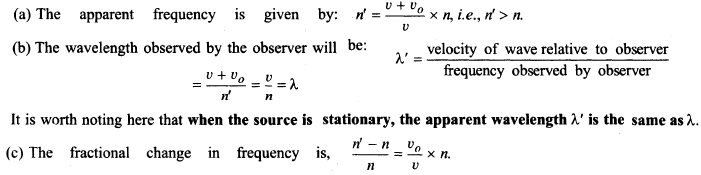
Case I: **Moving source approaches a stationary observer:**



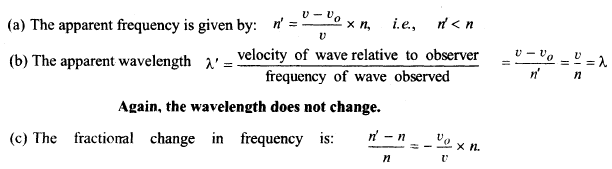
**Case II: Moving source recedes from a stationary observer:**



**Case III: Observing moving towards a stationary source:**



**Case IV: Observer moving away from stationary source:**



**Case V: Source and observer moving towards each other**



**Case VI: Source and observer moving away from each other**



The apparent frequency is i.e. n’ <n

**Case VII: Source moving towards observer and observer moving away from source:**



The apparent frequency is

**Case VIII: Source moving away from observer and observer moving towards source**



The apparent frequency is

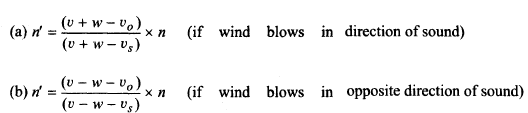
**5. Some other important points concerning Doppler effect:**

(i) **Doppler effect in sound is not symmetrical** :Consider two cases, one in which source is moving towards stationary observer and the other in which observer is approaching towards stationary source. Although the relative velocity is same and the apparent frequency increases, but the changes in frequencies are different in the two cases. **Thus, the Doppler effect is not symmetrical with respect to the motion of the source and the motion of the observer. The change in frequency is more when the source is in motion.**

(ii) If the relative velocity between source and observer becomes zero, **then n' = n, i.e., no Doppler effect takes place.**

(iii) When the distance between S and O, as a result of relative motion between them, decreases the observed frequency is more than the frequency emitted and when the distance between S and O increases then the observed frequency is less than the emitted frequency.

(iv)**Effect of motion of the medium**: When the wind blows in the direction of sound, then in all above formulae v is replaced by (v + w), where w is the velocity of wind. If the wind blows in the opposite direction to sound then u is replaced by (v - w). For example, when the source and observer both are in motion, then



**(v) When a moving source passes a stationary observer, then change in frequency is given by:**



**(vi) When a moving observer passes a stationary source, then change in apparent frequency will be:**



**(vii) Source moving towards or away from hill or wall:**

**(a) Moving towards:**

(I) For an observer A situated in between the source S and hill, the observed frequency of the waves received directly will be (source approaching)



and the observed frequency of reflected waves will also be:

**(II)But for the observer B situated behind the moving source**, the observed frequency of the waves received directly from the source will be (source receding):



But the observed (apparent) frequency of the reflected waves will be:

**(b) Moving away:**

**(I) For an observer A situated in between the source, S and hill,** the observed frequency of the waves received directly will be (source receding):



and the observed frequency of reflected waves will also be:

**(II)But for the observer B located behind the moving source**, the observed frequency of the waves received directly from the source will be (source approaching):

and the observed frequency of the reflected waves will be:

**(viii) Moving target(fig 22.1):**

(a) Suppose a sound source S and observer O are at rest (stationary). The frequency of sound emitted by the source is n and velocity of waves is v. A target is moving towards the source and observer with a velocity u. Here, the formula is derived by applying Doppler equations twice, first with the target as observer and then with the target as source.



Apparent frequency, for the real observer O, is given by:



(b) If the target is moving away from the observer, then

(c) If target velocity is much less than the speed of sound, u<< v, then



**(ix) SONAR (Sound Navigation Ranging):** In this sound waves (ultrasonic) are used (microwaves are absorbed by water). Sound waves are emitted by a source. These waves travel in water with velocity v. The waves reflected by targets (like submarine) are detected. The frequency of the reflected waves arriving at the detector will be (for vsub < v)

where the + sign is used for approaching submarine and the - sign is used for receding submarine. If vsub is not negligible, then for approaching submarine

**(x) Transverse Doppler effect:**

**(a) The Doppler effect in sound does not take place in the transverse direction.**

(b) For the position of source, S shown on left in the Fig. 22.2, the component of velocity of source towards the observer is vscosθ. Thus, the source is effectively approaching the observer with velocity vscosθ. For this situation, the approach frequency will be:

Note that n' will now be a function of angle θ, i.e., n' will no more be constant.

(c) For the situation shown on right, the source is moving away from the observer with velocity component vscos θ. Therefore, the apparent frequency for this position will be:

(d) If θ = 900, then vscos θ=0 and there is no shift in the frequency, i.e., for source at position T and moving transverse to the line joining S and O, Doppler effect does not occur.

**6. Doppler effect for light:**

(i) Doppler effect holds not only for sound waves but also for electromagnetic waves, including microwaves, radio waves and visible light.

(ii) There are two major differences in the Doppler effect for sound and for light:

(a) **Doppler effect for light is symmetrical,** i.e., whether the source is moving towards a stationary observer or the observer is moving towards the stationary source, the Doppler shift for light is the same for a given relative velocity.

**(b) There occurs a transverse Doppler shift for light.**

**(iii) The red shift:**

(a) When a light source is receding (moving away) from an observer with a relative velocity v, then the apparent frequency is less than the frequency emitted by the source, given by:



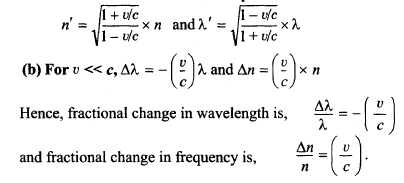
(b) Thus, when the S and O are separating away the apparent wavelength increases or **shifts towards the red end of the spectrum:**



(c) For v<<c

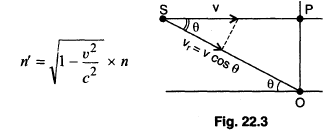
or fractional increase in wavelength is ∆λ/λ = v/c

It can also be shown that fractional decrease in frequency is ∆n/n = - v/c

**(iv) The blue shift:**

**(a) when a light source is approaching an observer with a relative velocity v**, then the apparent frequency observed by the observer is more than the frequency emitted by the source or the apparent wavelength decreases, i.e., shifts towards the blue end of the spectrum

**(v) Transverse Doppler effect for light:**

(a) In the adjoining Fig. 22.3,a light source S travels with velocity v past an observer at O. As the source passes through point P, the radial component vr = v cosθ becomes zero as θ becomes 900. According to special theory of relativity, there exists a transverse Doppler effect for light and apparent frequency is:



(b) For (v/c) << I this becomes :

(c) It is worth noting that **for sound waves there is no transverse Doppler effect.**

**(vi) RADAR (Radio Detection And Ranging):**

(a) It is a system for locating distant objects by means of reflected radio waves, usually of microwave frequencies.

(b) Doppler Radar employs the Doppler effect for light to distinguish between stationary and moving targets. The change in frequency between transmitted and received waves is measured. If v is the velocity of the approaching target, then the change in frequency is:

Here, the factor 2 arises due to reflection of waves,



For a receding target,

**Home Assignment- Waves**

1. What do you mean by wave motion?
2. Distinguish between Transverse and longitudinal wave motion?
3. Define wave function?
4. Define superposition principle?
5. What is the difference between constructive and destructive interference ?
6. Write an expression for the speed of wave in the following cases explaining the terms used :

- on string - in a fluid - in a solid - in and ideal gas – in an adiabatic ideal gas

1. Write the general rules that apply to reflected waves ?
2. Derive*y* =*A* sin(*kx* - w*t +ϕ*) for sine wave explain different terms and using the different variations of the given equation?
3. What do you mean by a standing wave and derive an equation for it?
4. What do you mean by a node and an antinode?
5. Derive the necessary conditions for positions of nodes and antinodes for a standing wave y=(2a sinkx) coswt for a string ?
6. What do you mean by beats ?
7. Find mathematically the expression for frequency of beats and frequency of change in intensity?
8. What do you mean by Doppler effect ?
9. Derive an expression for the change in frequency due to Doppler effect in the following cases :

- Source Moving & Observer Stationary - Observer Moving & Source Stationary

* + - Both Source and Observer Moving

1. Define wave motion ?
2. What are the two necessary properties of a medium for mechanical waves?
3. What do you mean by a wave function and write a general form of wave function?
4. Does the equation *y= A sin(wt ± kx) +Bcos(wt ± kx)* represent a wave function? If yes then find the amplitude and initial phase?
5. What is the relation between particle velocity and wave velocity ?
6. Write characteristics of wave motion?
7. Derive an expression for speed of transverse waves on a stretched string?
8. Derive an expression for speed of longitudinal waves in a fluid?
9. What do you mean by Laplace correction?
10. What are the different factors affecting velocity of sound in detail?
11. Write some applications of reflection of sound waves?
12. What is the expression for frequency of vibrations on a stretched string?
13. Write an expression for the first overtone in a closed organ pipe?
14. Write the general expression for doppler’s effect in sound?
15. Prove that doppler’s effect in sound is asymmetric?
16. Two tuning forks when sounded together produce 3 beats/sec.On loading one of them with a little wax ,20 beats are heard in 4 secs. Find it’s frequency, if that of other is 386 Hz.
17. Calculate the velocity of sound in a gas, in which two wavelengths 2.04m and 2.08m produce 20 beats in 6 secs?
18. Find the velocity of the source of sound, when the frequency appears to be (a)double (b)Half , the original frequency to a stationary listener?
19. The two parts of a sonometer wire divided by a movable knife edge differs by 2mm and produce one beat per sec when sounded together. Find their frequencies if the whole length of the wire is one metre?
20. Two tuning forks A & B give 9 beats in 3 secs. A resounds with a closed column of air 15cm long and B with an open column 30.5cm long. Calculate their frequencies?
21. What are fundamental notes and overtones?
22. Can beats be observed in two light sources of nearly equal frequencies?
23. Where will a person hear maximum sound , at node or antinode?
24. A standing wave is represented by *y = 2A sinkx coswt*. If one of the component waves is *Y1 = A sin(wt-kx)* , what is the equation of the second component wave ?
25. Sound waves from a point source are propagating in all directions. What will be the ratio of amplitudes at a distances of 9m and 25m from the source?
26. Why is sound heard in CO2 more intense in comparison to sound heard in air?
27. What is essential condition for the formation of beats ?
28. Set up a relation between the speed of sound in a gas and RMS velocity of the gas molecules?

**NCERT**

1. Given below are some examples of wave motion. State in each case if the wave motion is transverse, longitudinal

or a combination of both:

* 1. Motion of a kink in a longitudinal spring produced by displacing one end of the spring sideways.
  2. Waves produced in a cylinder containing a liquid by moving its piston back and forth.
  3. Waves produced by a motorboat sailing in water.
  4. Ultrasonic waves in air produced by a vibrating quartz crystal.

1. Estimate the speed of sound in air at standard temperature and pressure. The mass of 1 mole of air is 29.0 ×10–3 kg.
2. A stone dropped from the top of a tower of height 300 m high splashes into the water of a pond near the base of the tower. When is the splash heard at the top given that the speed of sound in air is 340 m/s ? (*g* = 9.8 m/s–2)
3. A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound meets a water surface, what is the wavelength of (a) the reflected sound, (b) the transmitted sound? Speed of sound in air is 340 m/s and in water 1486 m/ s.
4. A transverse harmonic wave on a string is described by *y(x, t) =* 3.0 sin (36 t + 0.018 *x* + π/4) where *x* and *y* are in cm and *t* in s. The positive direction of *x* is from left to right.
   1. Is this a travelling wave or a stationary wave ?If it is travelling, what are the speed and direction of its propagation ?

(b) What are its amplitude and frequency? (c) What is the initial phase at the origin?

(d) What is the least distance between two successive crests in the wave?

1. A wire stretched between two rigid supports vibrates in its fundamental mode with a frequency of 45 Hz. The mass of the wire is 3.5 × 10–2 kg and its linear mass density is 4.0 × 10–2 kg/m.

What is (a) the speed of a transverse wave on the string, and (b) the tension in the string?

1. Explain why (or how):
   1. in a sound wave, a displacement node is a pressure antinode and vice versa,
   2. bats can ascertain distances, directions, nature, and sizes of the obstacles without any “eyes”,
   3. a violin note and sitar note may have the same frequency, yet we can distinguish between the two notes,
   4. solids can support both longitudinal and transverse waves, but only longitudinal waves can propagate in gases, (e) the shape of a pulse gets distorted during propagation in a dispersive medium.
2. A train, standing at the outer signal of a railway station blows a whistle of frequency 400 Hz in still air. (i) What is the frequency of the whistle for a platform observer when the train (a) approaches the platform with a speed of 10 m/s, (b) recedes from the platform with a speed of 10 m/s? (ii) What is the speed of sound in each case ? The speed of sound in still air can be taken as 340 m/s.

**Exemplar**

1. A sonometer wire is vibrating in resonance with a tuning fork. Keeping the tension applied same, the length of the wire is doubled. Under what conditions would the tuning fork still be is resonance with the wire?
2. A tuning fork A, marked 512 Hz, produces 5 beats per second, where sounded with another unmarked tuning fork B. If B is loaded with wax the number of beats is again 5 per second. What is the frequency of the tuning fork B when not loaded?
3. The displacement of an elastic wave is given by the function *y* = 3 sin ω*t* + 4 cos ω*t* ,where *y* is in cm and *t* is in second. Calculate the resultant amplitude.
4. At what temperatures (in oC) will the speed of sound in air be 3 times its value at OoC?
5. When two waves of almost equal frequencies *n*1 and *n*2 reach at a point simultaneously, what is the time interval between successive maxima?
6. In the given progressive wave *y* = 5 sin (100π*t* – 0.4π*x* ),where *y* and *x* are in m, *t* is in s. What is the (a) amplitude (b) wave length (c) frequency (d) wave velocity (e) particle velocity amplitude.

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**Objectives Wave motion**

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

(a) interference (b) diffraction (c) reflection (d) polarization

2. Which of the following statements is incorrect?

(a) Sound travels in straight lines. (b) Sound travels as waves.

(c) Sound is a form of energy. (d) Sound travels faster in vacuum than in air.

3.Define Mach Number.: (a) It is the ratio of the stress to strain (b) It is the ratio of the strain to stress

(c) It is the ratio of the velocity of an object to the velocity of sound

(d) It is the ratio of the velocity of sound to the velocity of an object

4.If Co and C denote the sound velocity and root mean square velocity of molecules in a gas, then:

(a) Co > C (b) Co = C (c) Co > C √(γ/3) (d) Co & C are not related

5.A light pointer fixed to one prong of a tuning fork touches a vertical plate. The fork is set vibrating and the plate is allowed to fall freely. Eight complete oscillations are counted when the plate falls through l0 cm. What is the frequency of the tuning fork? (a) 112 Hz (b) 56 Hz (c) 8/7 Hz (d) 7/8 Hz

6. Sound waves in air are always longitudinal, because

(a) density of air is very small (b) air is a mixture of several gases

(c) air does not have a modulus of rigidity (d) of the inherent characteristics of sound waves in air



7. The equation for the displacement of a stretched string is given by:

Where, y and x are in cm and t in sec. The (i) frequency (ii) velocity of the wave (iii) maximum particle velocity are: (a) 50 Hz, 50 m/s, 20π m/s (b) 50 Hz, 20 m/s, 50 m/s

(c) 50 Hz, 50 m/s, 2 π m/s (d) 50 Hz, 50 m/s, 4π m/s

8. Which one of the following does not represent a travelling wave?

9. Which of the following expressions is that of a simple harmonic progressive wave





10.If the equation of a progressive wave is given by:

Then, which of the following is correct?

(a) v = 5cm/sec (b) λ=l8m (c) A =0.04cm (d) f = 50Hz

11. Oxygen is 16 times heavier than hydrogen. The equal volumes of hydrogen and oxygen are mixed. The ratio of speed of sound in the mixture to that in hydrogen is:

(a) √8 (b) √(1/8) (c) √(2/17) (d) √(32/17)

12. A transverse wave is travelling along a string from left to right. The adjoining A figure 19.2 represents the shape of the string at a given instant. At this instant, among the following, choose the wrong statement.

(a) Points D, E and F have upwards positive velocity. (b) Points A, B and H have downwards negative velocity.

(c) Points C and G have zero velocity. (d) Points A and E have minimum velocity.

13. The amplitude of a wave disturbance propagating in the positive Y-direction is given by

Where, x and y are in m. If the shape of the wave disturbance does not change during the propagation, what is the velocity of the wave?

(a) I m/sec (b) 1.5 m/sec (c) 0.5 m/sec (d) 2 m/sec

14.A sound wave of wavelength 90 cm in glass is refracted into air. If the velocity of sound in glass is 5400 m/sec, the wavelength of the wave in air is: (a) 55 cm (b) 5.5 cm (c) 55 m (d) 5.5 m

15. A small piece of cork in a ripple tank oscillates up and down as ripples pass it. If the ripples travelling at 0.3 m/s have a wavelength of 1.5π cm and the cork vibrates with an amplitude of 5 mm, the maximum velocity of the cork is: (a) 20 cm/sec (b) 20 m/sec (c) 0.02 m/sec (d) 200 cm/sec

16. For the wave shown in figure19.3 given below, the frequency and wavelength, if its speed is 320 m/sec, are: (a) 8 cm,400 Hz (b) 80 cm, 40 Hz (c) 8 cm,4000 Hz (d) 40 cm, 8000 Hz

17. lf x = a sin(wt + π/6) and x’ = a cos wt, then what is the phase difference between the two waves?

(a) π/3 (b) π/6 (c) π/2 (d) π

18. Three waves of equal frequencies having amplitudes l0 μm, 4μm and 7μm arrive at a given point with successive phase difference of π/2. The amplitude of the resulting wave (in μm) is given by:

(a) 7 (b) 6 (c) 5 (d) 4

19. A transverse wave is described by the equation y =yo sin2π(ft –x/λ), the maximum particle velocity is equal to four times the wave velocity if: (a) λ = πyo/4 (b) λ = πyo/2 (c) λ = πyo  (d) λ = 2πyo

20. Figure 19.5 given below shows four progressive waves A, B ,C and D with their phases expressed with respect to the wave A. It can be calculated from the figure that:

(a) the wave C is ahead by a phase angle of π/2 and the

wave B lags behind by a phase angle of π/2

(b) the wave C lags behind by a phase angle of π/2 and the

wave B is ahead by a phase angle of π/2

(c) the wave C is ahead by a phase angle of π and the wave

B lags behind by a phase angle of π.

(d) the wave C lags behind by a phase angle of π and the

wave B is ahead by a phase angle of π.

21. The speed of sound in hydrogen at NTP is 1270 m/s. Then, the speed in a mixture of hydrogen and oxygen in the ratio 4 : I by volume will be: (a) 317 m/s (b) 635 m/s (c) 830 m/s (d) 950 m/s

22. Velocity of sound waves in air is 330 m/s. For a particular sound in air, a path difference of 40 cm is equivalent to a phase difference of l.6π. The frequency of the wave is:

(a) 165 Hz (b) 150 Hz (c) 660 Hz (d) 330 Hz



23. A simple harmonic wave is represented by the relation:

If the maximum particle velocity is three times the wave velocity, the wavelength λ, of the wave is:

(a) πao/3 (b) 2πao/3 (c) πao (d) πao/2

24. Two particles P and Q describe SHM of same amplitude a, frequency *v* along the same straight line. The maximum distance between the two particles is a√2. The initial phase difference between the particles is:

(a) zero (b) π/2 (c) π/6 (d) π/3

25. A sound wave travelling with a velocity v in a medium A reaches a point on the interface of medium A and medium B. If the velocity in the medium B be 2v,the angle of incidence for total internal reflection of the wave will be: (a) > 150 (b) > 300 (c) >450 (d) >900

26. A note has a frequency l28Hz. The frequency of a note two octaves higher than it is:

(a) 256 Hz (b) 64Hz (c) 32Hz (d) 384 Hz

27. An echo is heard when minimum distance of the reflecting surface is:

(a) l0 cm (b) 17 m (c) 34m (d) 340 m

28. The waves produced by a motor boat sailing in water are:

(a) transverse (b) longitudinal (c) longitudinal and transverse (d) stationary

29. The ratio of velocity of sound in hydrogen and oxygen at STP is:

(a) 16: I (b)8:l (c) 4: I (d)2:1

30. A student sees a jet plane flying from east to west. When the jet is seen just above his head, the sound of jet appears to reach him making angle 600 with the horizontal from east. If the velocity of sound is *v,* then that of the jet plane is: (a) 2*v* (b) √3 *v*/2 (c) 2*v*/√3 (d) *v/*2

31. A person hears the sound of a jet aeroplane after it has passed over his head. The angle of the jet plane with the horizontal when the sound appears to be coming vertically downwards is 600. If the velocity of sound is *v*, then the velocity of the jet plane should be: (a) 2*v* (b) *v*/√3 (c) *v*√3 (d) *v*

32. A man stands between two parallel cliffs (not in middle). When he claps his hands, he hears two echoes one after 1 second and the other after 2 seconds. If the velocity of sound in air is 330 m/s, the width of the valley is: (a) 330 m (b) 445 m (c) 660 m (d) 990 m

33.A thin plane membrane separates hydrogen at 70 C from hydrogen at 470 C, both being at the same pressure. If a collimated sound beam travelling from the cooler gas makes an angle of incidence of 300 at the membrane, the angle refraction is:

(a) sin-1[√(7/32 )] (b) sin-1[√(2/7 )] (c) sin-1[√(4/7 )] (d) sin-1[√(7/4 )]

34. In a sports meet, the timing of a 200 metre straight dash is recorded at the finish point by starting an accurate stop watch on hearing the sound of starting gun fired at the starting point. The time recorded will be more accurate: (a) in winter (b) in summer (c) in all seasons (d) none of these

35. If Vm, is the velocity of sound in moist air,Vd is the velocity of sound in dry air, under identical conditions of pressure and temperature (a) Vm>Vd  (b) Vm<Vd (c) Vm=Vd (d) Vm.Vd=1

36. lf the temperature raised by I K from 300 K, then the percentage change in the speed of sound in the gaseous mixture is (R = 8.31 J/mol-K): (a) 0.167% (b) 2% (c) 1% (d) 0.334%

37. What is the maximum possible sound level of sound waves in air? Given that density of air = 1.3 kg/m 3, v = 332 m/ s and atmospheric pressure = 1.01 x 105 N/m2

(a)120dB (b)60dB (c)190dB (d)50dB

38. A bomb explodes on the moon. How long will it take for the sound to reach the earth?

(a) 10 sec (b)1000 sec (c) 1 day (d)none of these

39. A particle on the trough of a wave at any instant will come to the mean position after a time: (T = time period) (a) T/2 (b)T/4 (c) T (d)2T

40. In a medium in which a transverse progressive wave is travelling, the phase difference between two points with a separation of 1.25 cm is (π/y).If the frequency of wave is 1000 Hz, its velocity will be:

(a)104 m/s (b) 125 m/s (c) 100 m/s (d) 10 m/s

41. A heavy rope is suspended from a rigid support. A wave pulse is set up at the lower end; then:

(a) the pulse will travel with uniform speed (b) the pulse will travel with increasing speed

(c) the pulse will travel with decreasing speed (d) the pulse cannot travel through the rope

42.If the density of air at NTP is 1.293 kg/m3 and γ=1.41, then the velocity of sound in air at NTP is:

(a)102.3 m/s (b) 252.3 m/s (c) 332.3 m/s (d) 432.3 m/s

43.The phase difference between two points separated by 0.8 m in a wave of frequency 120 Hz is 0.5π. The wave velocity is : (a) 144 m/s (b) 256 m/s (c) 384 m/s (d) 720 m/s

44. Light can travel in vacuum but not sound, because:

(a) speed of sound is very much slower than light (b) light waves are electromagnetic in nature

(c) sound waves are electromagnetic in nature (d) light waves are not electromagnetic in nature

45.Which of the following is not a transverse wave?

(a) X-rays (b) γ-rays (c) Visible light waves (d) Sound wave in a gas

46. A sings with a frequency (n ) and B sings with a frequency (1/8) that of A. If the energy remains the same and the amplitude of ,A is *a* then amplitude of B is: (a) a (b) 2a (c) 8a (d) l6a

47. A vibrating tuning fork generates a wave given by y = 0.l sin π (0.1x - 2t), where x and y are in metre and t in second. The distance travelled by the wave while the fork completes 30 vibrations is:

(a) 600 m (b) 20 m (c) 30 m (d) 200 m

48. 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 (b) 3.6 x 10-6 (c) 3.6 x l0-11 (c) 3.6 x l0-4

49. A plane sound wave is travelling in a medium. With reference to a frame A, its equation is y = a cos (wt - kx). With reference to a frame B, moving with a constant velocity *v* in the direction of propagation of the wave, equation of the wave will be: (a) y = a cos [(w+kv)t – kx] (b) y = -a cos [(w-kv)t – kx](c) y = a cos [(w-kv)t – kx](d) y = a cos [(w+kv)t + kx]

50. The velocity of sound waves in an ideal gas at temperatures T1 (K) and T2 (K) are respectively ,v1 and v2. The rms velocities of gas molecules at these two temperatures are wl  and w2 respectively; then



51.It is found that an increase in pressure of 100 kPa causes a certain volume of water to decrease by

5 x l0-3 per cent of its original volume. Then, the speed of sound in water is about:

(a) 330 m/s (b) 1400 m/s (c) 2400 m/s (d) 660 m/s

**Objective Superposition of Waves**

52. 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 beats when sounded again. The frequency of A is 256 Hz. The frequency of B will be: (a) 250 Hz (b) 252 Hz (c) 260 Hz (d) 262 Hz

53. If two sound waves: y1 = 0.3 sin 596π (t – *x*/330) and y2 = 0.5 sin 604π (t – *x*/330) are superposed.

What will be : (i) the frequency of the resultant wave (ii) the frequency at which the amplitude of resultant wave varies? (a) 600,8 (b) 300,2 (c) 300,4 (d) 600,4

54. In the Q. 53, what will be the (i) frequency at which beats are produced and (ii) the ratio of maximum and minimum intensities of beats? (a) 4,16 (b) 2,4 (c) 4,8 (d) 2, 16

55. There are three sources of sound of equal intensity with frequencies 400, 401 and 402 vibrations/sec . The number of beats heard per second is: (a) 0 (b)1 (c)2 (d)3

56. 56 tuning forks are so arranged in series that each fork gives 4 beats per sec with the previous one. The frequency of the last fork is 3 times that of the first. The frequency of the first fork is:

(a) 110 (b) 56 (c) 60 (d) 52

57. Two sinusoidal plane waves of the same frequency having intensities I0 and 4I0 are travelling in the same direction. The resultant intensity at a point at which waves meet with a phase difference of zero radian is:

(a) I0 (b) 5 I0 (c) 9 I0 (d) 3 I0

58. Two interfering waves have intensities in the ratio 9:1.Then, the ratio of maximum to minimum amplitude is: (a) l0:8 (b) 4:2 (c) 100:64 (d) 16 :4

59. Two interfering waves have intensities in the ratio 9:1.Then, the ratio of maximum to minimum intensity is: (a) l0:8 (b) 4:2 (c) 100:64 (d) 16 :4

60. Sound waves from a whistle of frequency 1100 Hz reach a point by two different paths. When the paths differ by l5 cm or 45 cm there is silence at that point. The speed of sound is:

(a) 1100 x 15cm/s (b) 1100 x 30cm/s (c) 1l00 x 45cm/s (d) 1100x 60cm/s

61. A tuning fork whose frequency as given by manufacturer is 5l2Hz is being tested with an accurate oscillator. It is found that the fork produces a beat of 2Hz when oscillator reads 514 Hz but produces a beat of 6 Hz when oscillator reads 5l0Hz. The actual frequency of fork is:

(a) 508 Hz (b) 512 Hz (c) 516 Hz (d) 518 Hz

62. 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 fewer beats per second than before? (a) 460 Hz (b) 470 Hz (c) 480 Hz (d) 490 Hz

63. A man standing between two cliffs, claps his hands and starts hearing a series of echoes at intervals of one second. If speed of sound in air is 340 m/s, then distance between the cliffs is:

(a) 340 m (b) 680 m (c) 1020 m (d) 1360 m

64. For production of beats the two sources must have:

(a) different frequencies and same amplitude (b) different frequencies

(c) different frequencies, same amplitude and same phase (d) different frequencies and same phase

65. A source of sound gives 5 beats per second when sounded with another source of frequency 100 per second. The second harmonic of the source, together with a source of frequency 205 per second, gives 5 beats per second. What is the frequency of the source?

(a) 95 Hz (b) 100 Hz (c) 105 Hz (d) 205 Hz

66. At a certain instant, a stationary transverse wave is found to have maximum kinetic energy. The appearance of string at that instant is:

(a) sinusoidal shape with amplitude A/3 (b) sinusoidal shape with amplitude A/2

(c) sinusoidal shape with amplitude A (d) straight line

67. If two waves of same frequency and same amplitude respectively, on superposition, produce a resultant disturbance of the same amplitude, the waves differ in phase by:

(a) π (b) 2 π /3 (c) π/3 (d) 3 π

68. Consider ten identical sources of sound all giving the same frequency but having phase angles which are random. If the average intensity of each source is I0, the average of resultant intensity I due to all these ten sources will be: (a) 100 I0 (b) 10 I0 (c) I0 (d) I0√10

69. The displacement of a particle executing periodic motion is given by: y = 4 cos2(t/2) sin(1000t). This expression may be considered to be a result of superposition of:

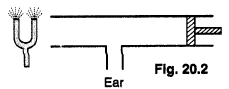
(a) two waves (b) three waves (c) four waves (d) five waves

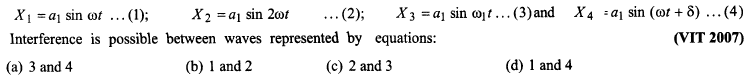
70. A number of tuning forks are arranged in the order of increasing frequency and any two successive tuning forks produce 4 beats per second, when sounded together. If the last tuning fork has a frequency octave higher than that of the first tuning fork and the frequency of the first tuning fork is 256Hz, then the number of tuning forks is: (a) 63 (b) 64 (c) 65 (d) 66

71. y =acos (kx - wt) superposes on another wave giving a stationary wave having node at *x* = 0. What is the equation of the other wave? (a) acos (kx + wt) (b) acos (kx - wt) (c) -acos (kx +wt) (d) -asin (kx + wt)

72. In a large room, a person receives direct sound waves from a source 120 metres away from him. He also receives waves from the same source which reach, being reflected from the 25 metres high ceiling, at a point halfway between them. The two waves interfere constructively for a wavelength of:

(a) 20, 20/3 ,20/5,etc (b) 10, 5,2.5,etc (c) 10, 20, 30,etc (d) 15, 25,35,etc

73. A vibrating tuning fork of frequency n is placed near the open end of a long cylindrical tube fig (20.2). The tube has a side opening and is also fitted with a movable reflecting piston. As the piston is moved through 8.75 cm , the intensity of sound changes from a maximum to minimum. If the speed of sound is 350 metre per second, then n is: (a) 500 Hz (b) 1000 Hz (c) 2000 Hz (d) 4000 Hz

74. Four independent waves are represented by the following equations:

75.Plane simple harmonic progressive waves of wavelengths 120 cm and speed 34800 cm/sec are incident normally on a plane surface which is a perfect reflector of sound. Stationary waves are formed. The ratio of amplitudes of vibrations at points distant (i) l0 cm (ii) 30 cm from the reflector is

(a) l : 2 (b) 1 : 0 (c) 1 : 1 (d) 1 :4

76. Two periodic waves of intensities I1 and I2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is:

77. Two waves are passing through a region in the same direction at the same time. If the equations of these waves are:

then the amplitude of the resulting wave for x0 = λ/ 2 is:



78. Two radio stations broadcast their programmes at the same amplitude A and at slightly different frequencies w1 and w2 respectively, where w2 – w1 = 103 Hz. A detector is receiving signals from the two stations simultaneously. It can only detect signals of intensity > 2A2. The time interval between successive maxima of the intensity of the signal received by the detector is:

(a) 103 sec (b) 10-3 sec (c) 10-4 sec (d) 104 sec

**Vibration of strings, rods and air columns**

79. A tuning fork is found to give five beats in three seconds when sounded in conjunction with a stretched string vibrating transversely under a tension of either 10.2 kgf or 9.9 kgf. The frequency of the fork is approximately: (a) 237 Hz (b) 235 Hz (c) 223 Hz (d) 225 Hz

80. A stone is hung in air from a wire which is stretched over a sonometer. The bridges of the sonometer are 40 cm apart when the wire is in unison with a tuning fork of frequency 256. When the stone is completely immersed in water, the length between the bridges is 22 cm for re-establishing unison. The specific gravity of the material of the stone is:

81. In brass the velocity of longitudinal wave is 100 times the velocity of the transverse wave. If Y = 1011 N/ m2, then stress in the wire is(a) 1013 N/ m2 (b) 109 N / m2 (c) 1011 N / m2 (d) 107 N / m2

82. A tuning fork of frequency n is held near the open end of a tube which is closed at the other end and the length of the tube is adjusted until resonance occurs. If the two shortest lengths that produce resonance are L1 and L2,the speed of the sound is:(a) n(L2 –L1) (b) n(L2 –L1)/2 (c) 2n(L2 + L1) (d) 2n(L2 –L1)

83. A loaded string of length one metre and weighing 0.5 gm is hanging from a tuning fork of frequency 200 Hz and is vibrating in four loops. For the transverse arrangement, the tension is: (in dyne)

(a) 1.25 x 105 (b) 2.5 x 105 (c) 5 x 105 (d) 10 x 105

84. In the Q. 83, for the longitudinal arrangement, the tension in dyne is:

(a) 1.25 x 105 (b) 2.5 x 105 (c) 5 x 105 (d) 10 x 105

85. Two wires of the same material and radii r and 2r respectively are welded together end to end. The combination is used as a sonometer wire and kept under tension T. The welded point is midway between the two bridges. When stationary waves are set up in the composite wire, the joint is a node. Then, the ratio of the number of loops formed in the thinner to thicker wire is:

(a) 2:3 (b) 1 :2 (c) 2: I (d) 5 :4

86. A uniform rope of length 12 m and mass 6 kg hangs vertically from a rigid support. A block of mass 2 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.06 metre is produced at the lower end of the rope. What is the wavelength of the pulse when it reaches the top of the rope?

(a) 0.06 metre (b) 0.03 metre (c) 0.12 metre (d) 0.09 metre

87. A uniform wife 20 metre long and weighing 50 newton hangs vertically. If g = l0 m/s2, then the speed of the transverse wave in m/s at the middle point of the wire is: (a) 4 (b) 10√2 (c) 10 (d) zero

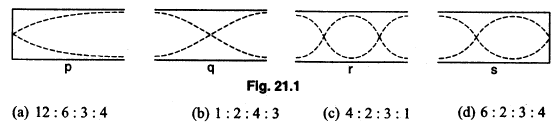
88. Two steel springs of equal lengths and diameters are vibrating in the fundamental mode. If the stretching loads are 2 kg and 4.5 kg, then the interval between their frequencies is:

(a) unison (b) fourth (c) fifth (d) octave

89. Two strings with masses per unit length of 25 gm/cm and 9 gm/cm are joined together in series. The reflection coefficients for the vibration waves are: (a) 9/25 (b) 3/5 (c) 1/16 (d) 9/16

90.The speed of longitudinal waves in a thin brass rod is 3480 m/s. If the rod is clamped at one end and gives a fundamental frequency of 435 Hz, the length of the rod is: (a) 0.5 m (b) 1 m (c) 2 m (d) 4 m

91. The end correction of a resonance column is 1.0 cm. If the shortest length resonating with a tuning fork is 15.0 cm, the next resonating length is: (a) 3l cm (b) 45 cm (c) 46 cm (d) 47 cm

92. The vibrations of four air columns are represented in the figure 21.1. The ratio of frequencies np : nq : nr : ns is:

93. The fundamental frequency of a sonometer wire carrying a block of mass I kg and density 1.8 is 260. When the block is completely immersed in a liquid of density 1.2, then what will be its new frequency?

(a) 300 Hz (b) 150 Hz (c) 450 Hz (d) None of these

94. In a resonance column experiment, the first resonance is obtained when the level of the water in the tube is at 20 cm from the open end. Resonance will also be obtained when the water level is at a distance of:

(a) 40 cm from the open end (b) 60 cm from the open end

(c) 80 cm from the open end (d) 100 cm from the open end

95. 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 l0 cm from the fixed end of the string. The speed of incident (and reflected) wave is: (a) 40 m/s (b) 20 m/s (c) 10 m/s (d) 5 m/s

96. A long glass tube is held vertically in water. A tuning fork is struck and held over the tube. Strong resonances are observed at two successive lengths 0.50 m and 0.84 m above the surface of water. If the velocity of sound is 340 m/s, then the frequency of the tuning fork is:

(a) 128 Hz (b) 256Hz (c) 384 Hz (d) 500 Hz

97. A glass tube of 1.0 m length is fitted with water. The water can be drained out slowly at the bottom of the tube. If a vibrating tuning fork of frequency 500 c/s is brought at the upper end of the tube and the velocity of sound is 330 m/s, then the total number of resonances obtained will be:(a) 4 (b) 3 (c) 2 (d) 1

98. When the string of a sonometer of length L between the bridges vibrates in the first overtone, the amplitude of vibration is maximum at: (a) L/2 (b) L/4 & 3L/4

(c) L/6 ,3L/6 & 5L/6 (d) L/8 ,3L/8 , 5L/8 & 7L/8

99. When the string of a sonometer of length L between the bridges vibrates in the second overtone, the amplitude of vibration is maximum at: a) L/2 (b) L/4 & 3L/4

(c) L/6 ,3L/6 & 5L/6 (d) L/8 ,3L/8 , 5L/8 & 7L/8

100. If the tension in the string of a sonometer changes by a small amount from T to T + ∆T, the fundamental frequency of vibration changes from n to n + ∆n, then:

(a) ∆n/n =∆T/T (b) ∆n/n =∆T/2T (c) ∆n/n =2∆T/T (d) ∆n/n = - ∆T/2T

101. If the length of the string between the bridges of a sonometer wire changes by a small amount from L to

L+ ∆L, the fundamental frequency of vibration changes from n to n + ∆n, then:

(a) ∆n/n =∆L/L (b) ∆n/n = - ∆L/L (c) ∆n/n = - ∆L/2L (d) ∆n/n = ∆L/2L

102. The extension in a string obeying Hooke's law is *x*. The speed of sound wave in a stretched string is *u*. If the extension in a string is increased to 1.5*x*, the speed of sound wave will be:

(a) 1.22u (b) 0.61u (c) 1.5 u (d) 0.75 u

103.A hollow metallic tube of length L and closed at one end produces resonance with a tuning fork of frequency n. The entire tube is then heated carefully, so that at equilibrium temperature its length changes by *l*. If the change in velocity V of sound is *v* the resonance will now be produced by a tuning fork whose frequency is:

104. A tube is closed at one end and closed at the other end by a vibrating diaphragm which may be assumed to be a node. When the frequency of the diaphragm is 2000 Hz, a stationary wave pattern with separation of 8 cm between adjacent nodes is set up. On decreasing the frequency gradually, stationary wave pattern disappears but another stationary wave pattern appears at a frequency of 1600 Hz. Then, the length of the tube between the diaphragm and the closed end is: (a) 16 cm (b) 20 cm (c) 40 cm (d) l0 cm

105. A stretched wire of some length under a tension is vibrating with its fundamental frequency. Its length is decreased by 45% and tension is increased by 2l%. Now its fundamental frequency:

(a) increases by 50% (b) increases by 100% (c) decreases by 50% (d) decreases by 25%

106. With the increase in temperature, the frequency of the sound from an organ pipe:

(a) decreases (b) increases (c) remains unchanged (d) changes erratically

107. The distance between the nodes in a resonating Kundt's tube increases if:

(a) some moisture gets into it (b) the atmospheric pressure decreases

(c) the temperature of the room decreases (d) the length of the rod decreases

108. If oil of density higher than that of water is used in place of water in a resonance tube its frequency will:

(a) increase (b) decrease (c) remain the same (d) depend upon the density of oil

109. In a vibrating organ pipe, the flame flickers most at:

(a) displacement nodes (b) displacement antinodes

(c) midway between nodes and antinodes (d) none of the above

110. With a stationary wave, a person hears a louder sound at:(a) the node (b) the antinodes

(c) midway between node and antinodes (d) neither the node nor the antinodes

**Musical Sound and Doppler Effect**

111. The intensity of a sound wave gets reduced by 20% on passing through a slab. The reduction in intensity on passage through two such consecutive slabs is: (a) 40% (b) 36% (c) 30% (d) 50%

112. If the pressure amplitude in a sound wave is tripled, then the intensity of sound is increased by a factor: (a) 3 (b) 6 (c) 9 (d)√3

113. 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 the two sounds are equal. The amplitude of the note of B is:

(a) same as that of A (b) twice that of A (c) four times that of A (d) eight times that of A

114.The amplitude of sound is doubled and the frequency is reduced to one-fourth. The intensity of sound at the same point will be: (a) increased by a factor of 2 (b) increased by a factor of 4

(c) decreased by a factor of 2 (d) decreased by a factor of 4

115. A two fold increase in the intensity of a wave implies an increase of:

(a) 2 dB (b) 10 dB (c) 3.01 dB (d)0.5dB

116. An increase in intensity level of one decibel implies an increase in intensity of:

(a) 1% (b) 3.01% (c) 26% (d) 0.1%

117. The intensity of a sound wave while passing through an elastic medium falls down to l0% as it covers one metre distance through the medium. If the initial intensity of the sound wave was 100 decibel, its value after it has passed through 3 metre thickness of the medium will be:

(a) 70 dB (b) 72.9 dB (c) 81 dB (d)60 dB

118. An observer is moving with velocity *vo* towards a stationary sound source emitting waves of frequency n. If *v* is the velocity of sound waves, then the wavelength of the sound waves as detected by the observer will be : (a) *vo* /n (b) *v*/n (c) ( *v* +*vo* )/n (d) ( *v* - *vo* )/n

119. A rocket ship is receding from the earth at a speed of 0.2 c. The ship emits the signal of frequency 4 x 107 Hz. The apparent frequency to an observer on the surface of the earth in Hz is:

(a) 3.2 x 107 (b) 4.8 x 107 (c) 4 x 107 (d) 5.3 x 107

120. An engine is moving on a circular path of radius 100 metre with a speed of 20 metre per second. What will be the frequency observed by an observer standing stationary at the centre of circular path when the engine blows a whistle of frequency 500 Hz? (a) More than 500 Hz (b) Less than 500 Hz

(c) 500 Hz (d) No sound is heard

121. A source of sound emitting a tone of frequency 200 Hz moves towards an observer with a velocity u equal to the velocity of sound. If the observer also moves away from the source with the same velocity u, the apparent frequency heard by the observer is: (a) 50Hz (b) 100Hz (c) 150 Hz (d) 200 Hz

122. 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 the sound in the medium is 350 m/s.)

(a) 750Hz (b) 857 Hz (c) 1143 Hz (d) 1333 Hz

123. Two factories are sounding their sirens at 800 Hz. A man goes from one factory to the other at a speed of 2 m/s. The velocity of the sound is 320 m/s. The number of beats heard by the person in one second will be: : (a) 2 (b) 4 (c) 8 (d) 10

124. Two trains. one coming towards and another going away from an observer both at 4 m/s produce a whistle simultaneously of frequency 300 Hz. Find the number of beats produced:

(a) 5 (b) 6 (c) 7 (d) 12

125. The apparent frequency of the whistle of an engine as heard by an observer, when the engine moves towards the observer with a speed v is n. If the engine is stationary and the observer moves towards the engine with the same speed v, the apparent frequency of the same whistle will be:(a) greater than n

(b) less than n (c) equal to n (d) less or more depending on frequency of the whistle

126. A radio wave of frequency 840 MHz is sent towards an aeroplane. The frequency of the radio echo is 2.9 kHz more than the original frequency. Then, the velocity of aeroplane is:

(a) 1000 m/s (b) 500 m/s (c) 1500 m/s (d) 2000 m/s

127. A whistle emitting a sound of frequency 440 Hz is tied to a string of 1.5 m length and rotated with an angular velocity of 20 rad/sec in the horizontal plane. Then, the range of frequencies heard by an observer stationed at a large distance from the whistle will be: (v =330 m/s)

(a) 400.0 Hz to 484.0Hz (b) 403.3 Hz to 480.0 Hz

(c) 400.0 Hz to 480.0 Hz (d) 403.3 Hz to 484.0 Hz

128. One train is approaching an observer at rest and another train is receding from him with the same velocity 4 m/s. Both the trains blow whistles of same frequency of 243 HZ. The beat frequency (in Hz) as heard by the observer is: (speed of sound in air = 320m/s) (a) 10 (b) 6 (c) 4 (d) 1

129. A siren 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)

(a) 733.3 Hz (b) 644.8 Hz (c) 481.2 Hz (d) 286.5 Hz

130. 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 335 m/s, the number of beats heard per second by the passengers in the bus will be: (a) 3 (b) 4 (c) 5 (d) 6

131. A car with a horn of frequency 620 Hz travels towards a large wall with a speed of 20 m/s. If the velocity of sound is 330 m/s, the frequency of echo of sound of horn as heard by the driver is:

(a) 700 (b) 660 (c) 620 (d) 550

132. A source of sound of frequency 90 vibrations/sec is approaching a stationary observer with a speed equal to l/10 the speed of sound. What will be the frequency heard by the observer?

(a) 80 vib/sec (b) 90 vib/sec (c) 100 vib/sec (d) 120 vib/sec

133. A man standing on a platform hears the sound of frequency 605 Hz coming at frequency 550 Hz from a train whistle coming towards the platform. If the velocity of sound is 330 m/s, then what is the speed of train

(a) 30 m/s (b) 35 m/s (c) 40 m/s (d) 45 m/s

134. The law applicable for determining the apparent change in frequency when a source and an observer are in motion is: (a) Doppler's law (b) Huygen's law (c) Newton's law (d) Galileo's law

135. A vehicle, with a horn 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 + n1) . Then, n1 is equal to: (take velocity of sound in air as 330 m/s)

(a) 10n (b) -n (c) 0.1n (d) 0

136. An isotropic stationary source is emitting waves of frequency n and wind is blowing due north. An observer ,A is on north of the source while observer B is on south of the source. If both the observers are stationary, then: (a) frequency received by A is greater than n

(b) frequency received by B is less than n (c) frequency received by A is equal to that received by B

(d) frequencies received by A and B cannot be calculated unless velocity of waves in still air and velocity of wind are known

137. A source and an observer are located at the same point. The source starts moving away from the observer at t = 0,with a constant acceleration a. If natural frequency of the source is no and speed of sound in air is *v*, then frequency received by the observer at time t will be:



138. Two sound sources are moving in opposite directions with velocities v1 and v2 (v1>v2). Both are moving away from a stationary observer. The frequency of both the sources is 900 Hz. What is the value of v1- v2 ,so that the beat frequency observed by the observer is 6 Hz? Speed of sound = 300 m/s. Given that v1 and v2 << v.

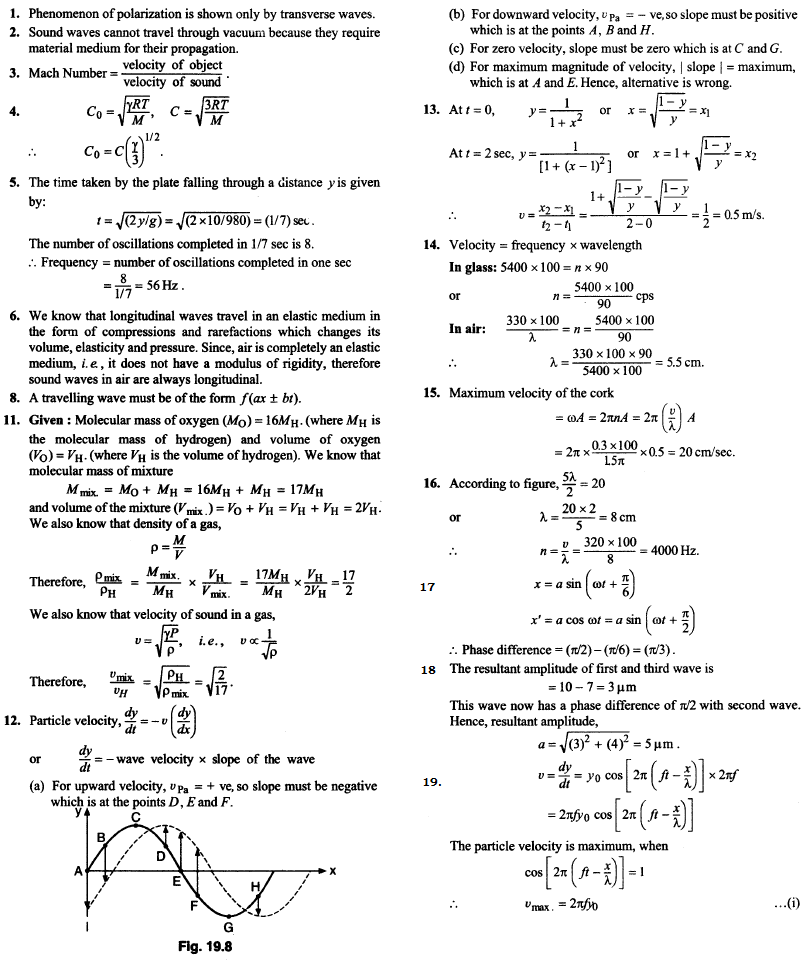
(a) I m/s (b) 2 m/s (c) 3 m/s (d)4 m/s

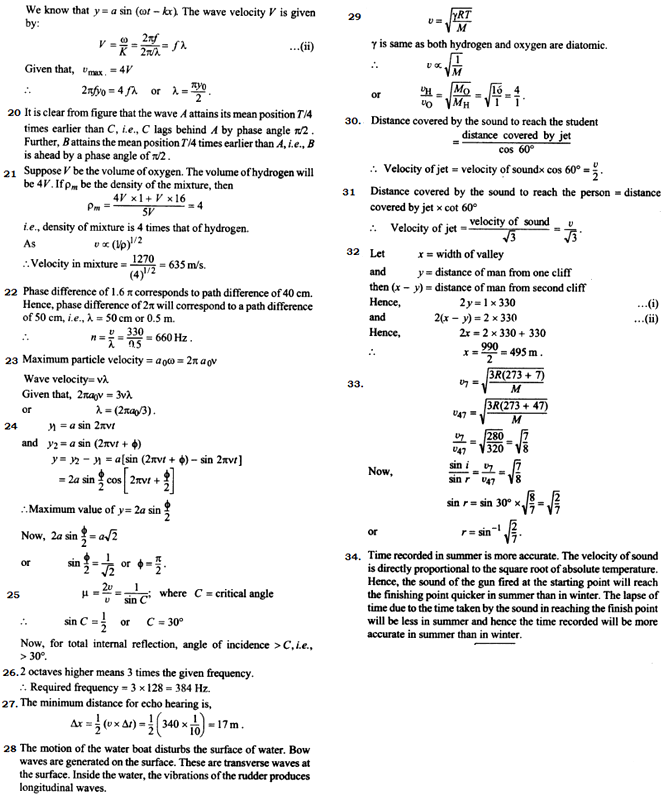
139. The frequency changes by l0% as the source approaches a stationary observer with constant speed vS. What should be the percentage change in frequency as the source recedes from the observer with the same speed? Given that vS << v: (v= speed of sound in air): (a) 14.3% (b) 20% (c) 16.7% (d) 10%

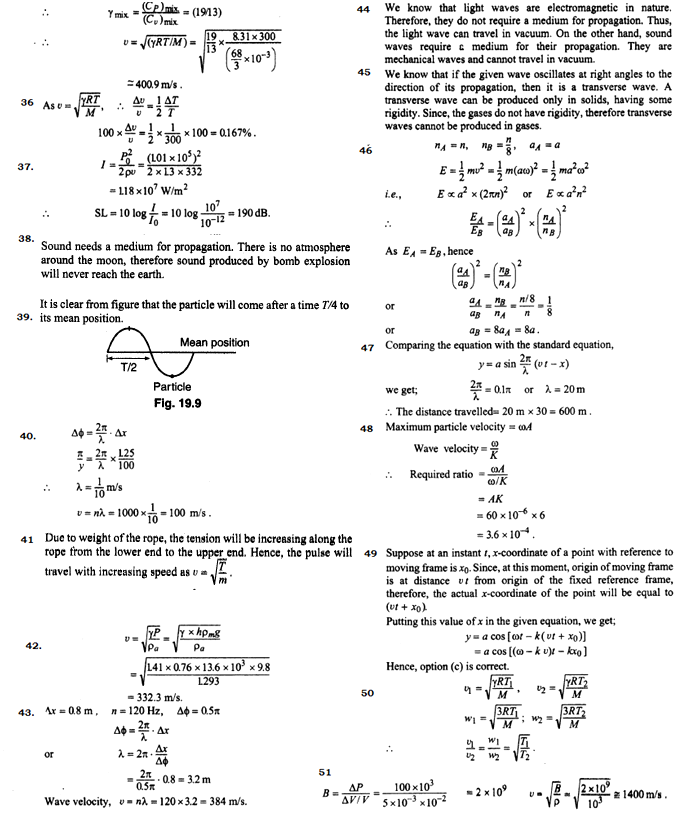
**Answers Objective ( Wave Motion)**

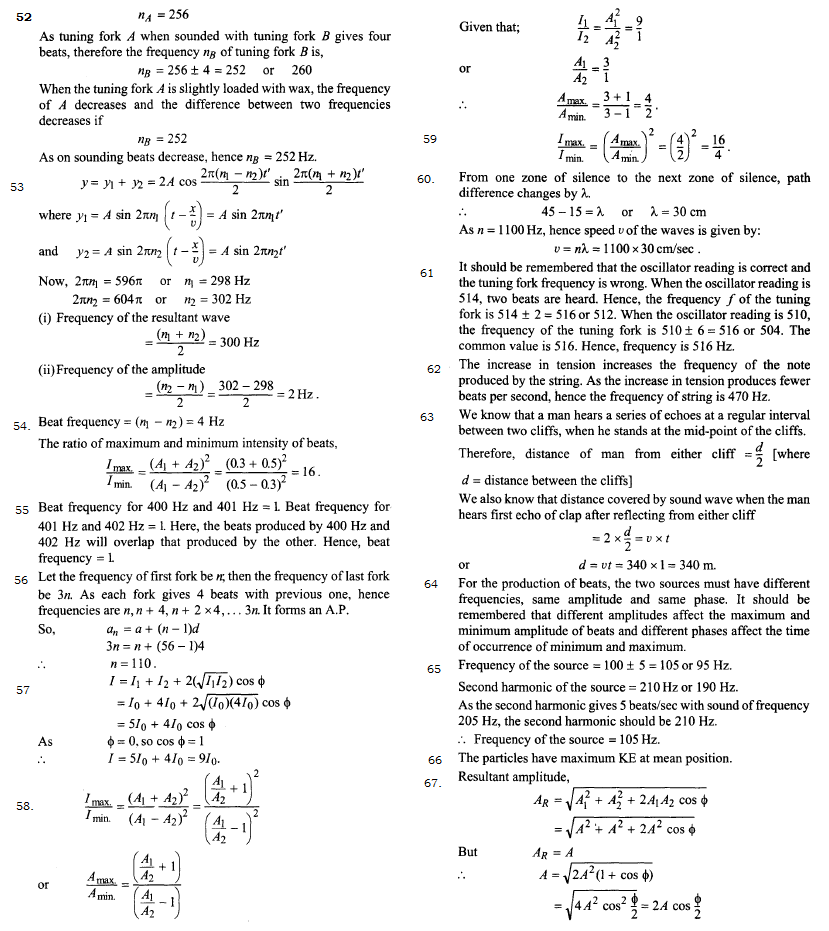
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| 1. C | 1. B | 1. A | 1. C | 1. C | 1. D |
| 1. B | 1. B | 1. B | 1. C | 1. C | 1. A |
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| 1. B | 1. C | 1. C | 1. C | 1. C | 1. C |
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| 1. B | 1. B | 1. C | 1. B | 1. B | 1. A |
| 1. A | 1. C | 1. B | 1. B | 1. A | 1. C |
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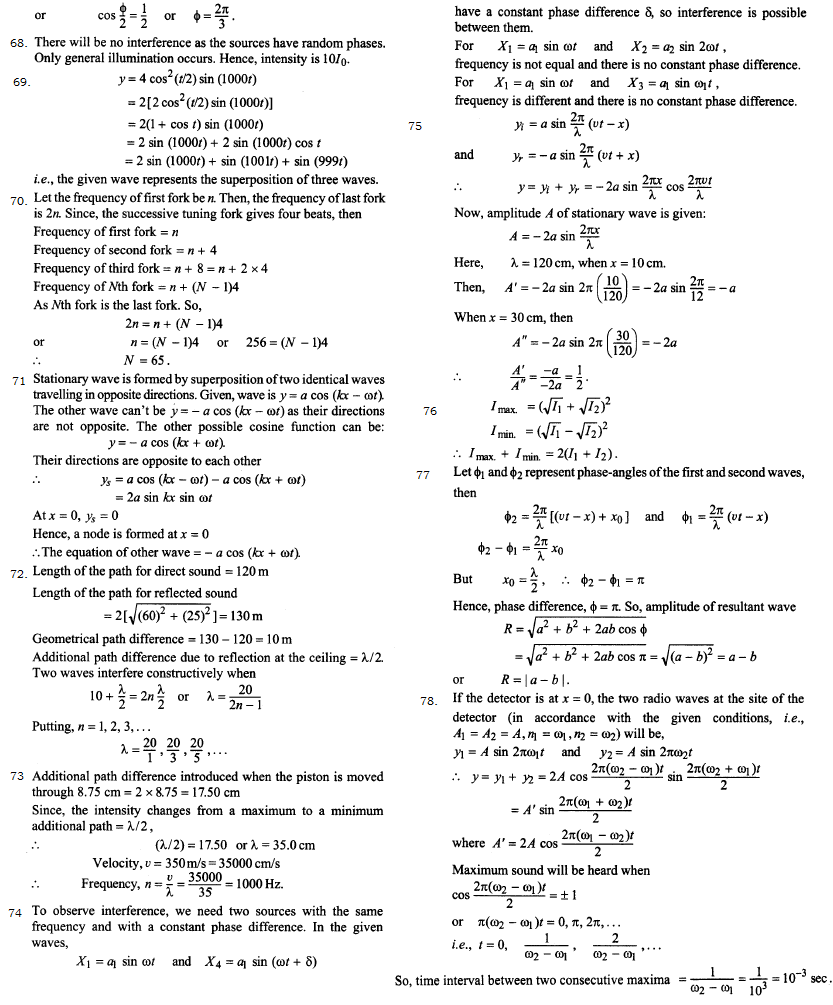
***Explanations & Answers for Objectives –Wave Motion***

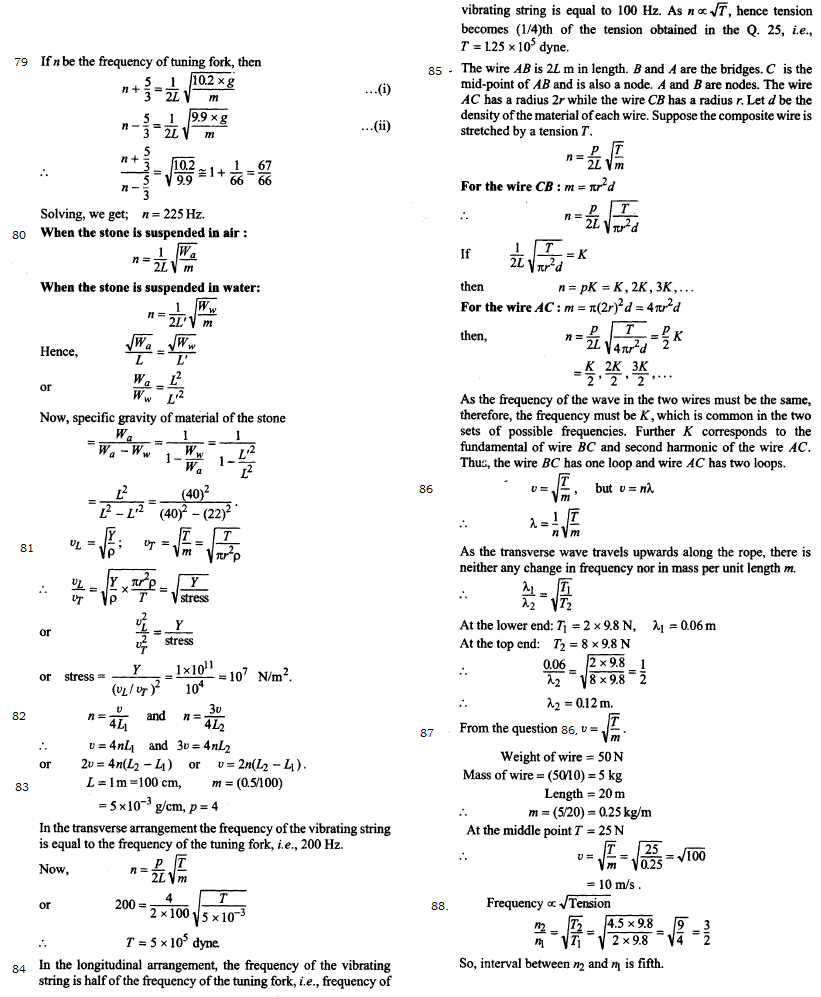
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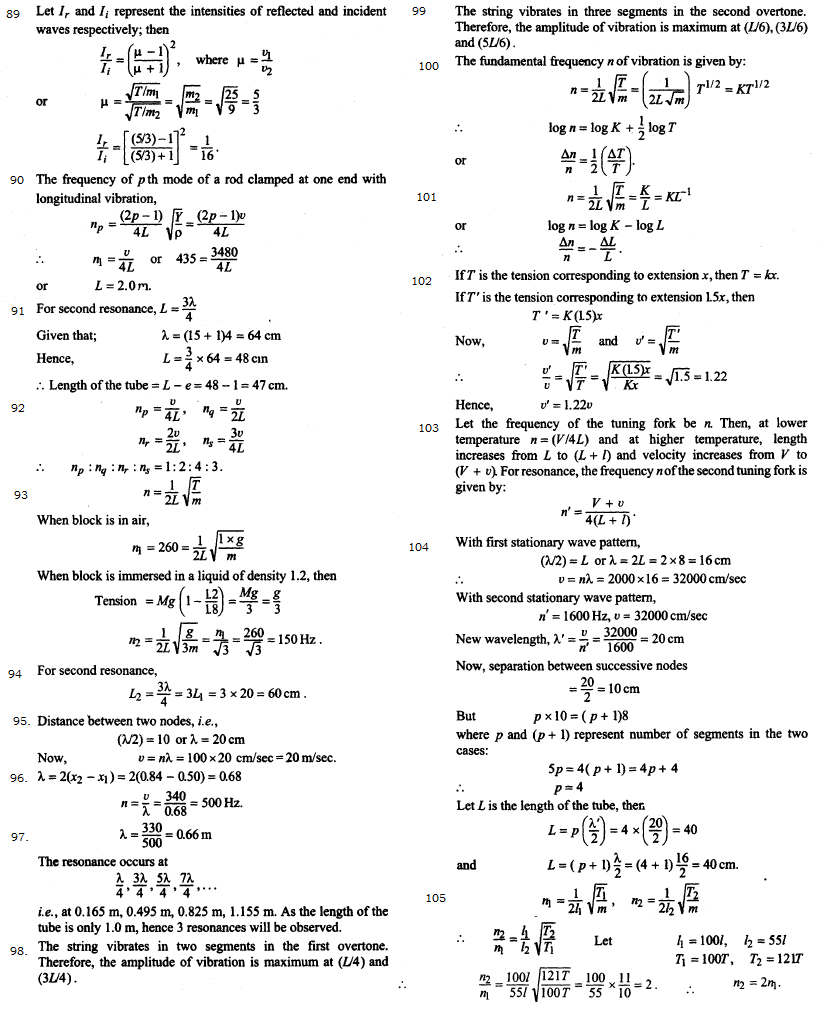
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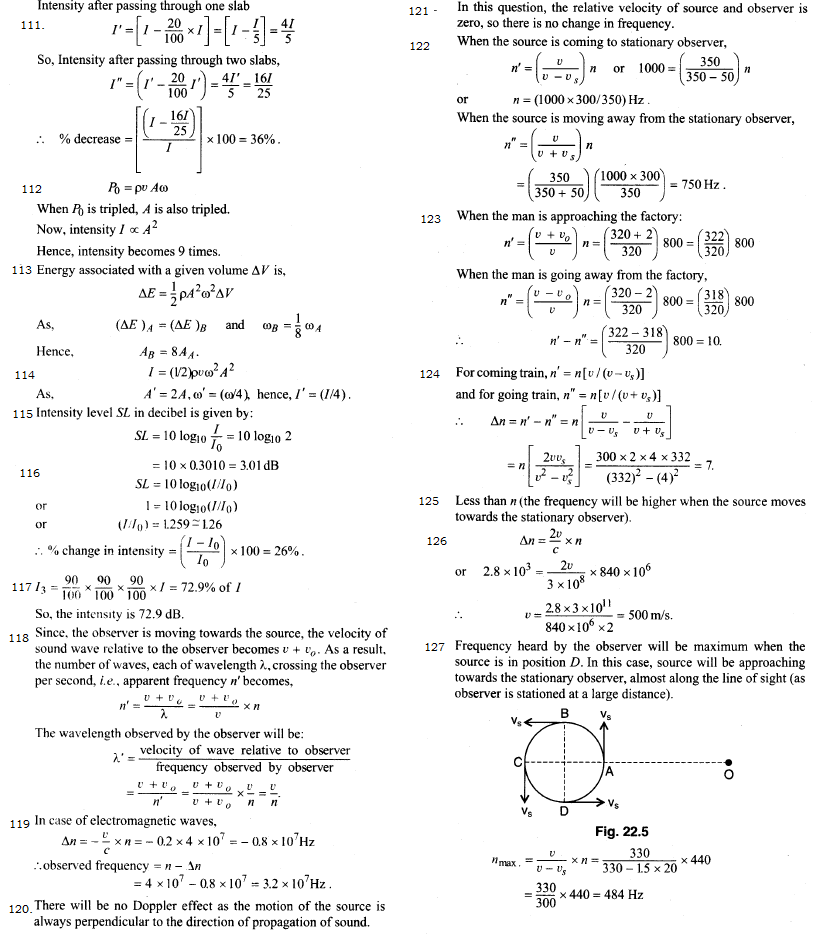
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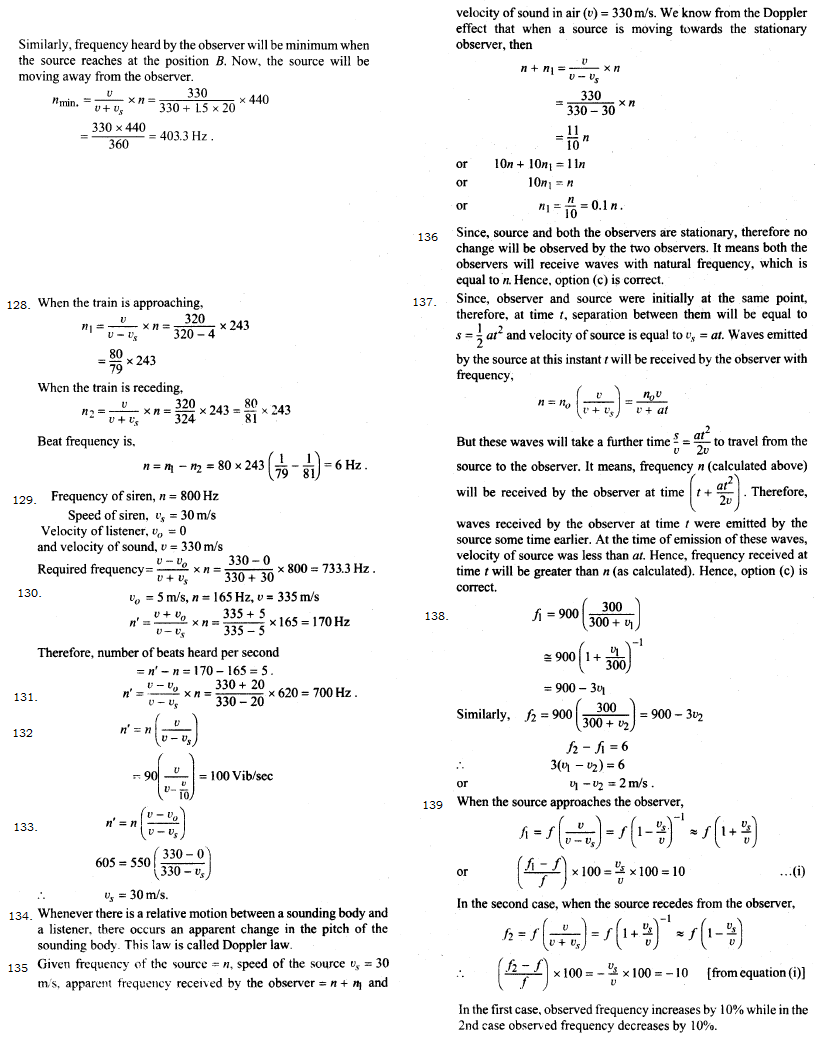
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