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TOPIC 1

WAVE THEORY

Categories of Waves

Waves come in many shapes and forms. While all waves share some basic characteristic properties and behaviours, some waves can be distinguished from others based on some observable (and some non-observable) characteristics. It is common to categorize waves based on these distinguishing characteristics.

Longitudinal versus Transverse Waves versus Surface Waves

One way to categorize waves is on the basis of the direction of movement of the individual particles of the medium relative to the direction that the waves travel. Categorizing waves on this basis leads to three notable categories: transverse waves, longitudinal waves, and surface waves.

Transverse Wave

- A transverse wave is a wave in which particles of the medium move in a direction perpendicular to the direction that the wave moves. Suppose that a slinky is stretched out in a horizontal direction across the classroom and that a pulse is introduced into the slinky on the left end by vibrating the first coil up and down. Energy will begin to be transported through the slinky from left to right.
- As the energy is transported from left to right, the individual coils of the medium will be displaced upwards and downwards. In this case, the particles of the medium move perpendicular to the direction that the pulse moves. This type of wave is a transverse wave. Transverse waves are always characterized by particle motion being perpendicular to wave motion.

Longitudinal Wave

- A longitudinal wave is a wave in which particles of the medium move in a direction parallel to the direction that the wave moves. Suppose that a slinky is stretched out in a horizontal direction across the classroom and that a pulse is introduced into the slinky on the left end by vibrating the first coil left and right. Energy will begin to be transported through the slinky from left to right.
- As the energy is transported from left to right, the individual coils of the medium will be displaced leftwards and rightwards. In this case, the particles of the medium move parallel to the direction that the pulse moves. This type of wave is a longitudinal wave. Longitudinal waves are always characterized by particle motion being parallel to wave motion.
- A sound wave travelling through air is a classic example of a longitudinal wave. As a sound wave moves from the lips of a speaker to the ear of a listener, particles of air vibrate back and forth in the same direction and the opposite direction of energy transport. Each individual particle pushes on its neighbouring particle so as to push it forward.
- This back and forth motion of particles in the direction of energy transport creates regions within the medium where the particles are pressed together and other regions where the particles are spread apart. Longitudinal waves can always be quickly identified by the presence of such regions. This process continues along the *chain* of particles until the sound wave reaches the ear of the listener.

Surface Wave

- While waves that travel within the depths of the ocean are longitudinal waves, the waves that travel along the surface of the oceans are referred to as surface waves. A surface wave is a wave in which particles of the medium undergo a circular motion. Surface waves are neither longitudinal nor transverse. In longitudinal and transverse waves, all the particles in the entire bulk of the medium move in a parallel and a perpendicular direction (respectively) relative to the direction of energy transport. In a surface wave, it is only the particles at the surface of the medium that undergo the circular motion. The motion of particles tends to decrease as one proceeds further from the surface.

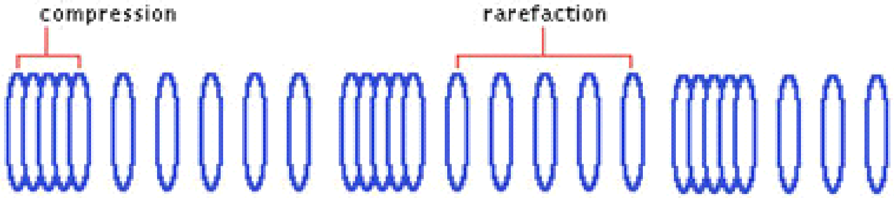

Figure 1: Longitudinal Wave

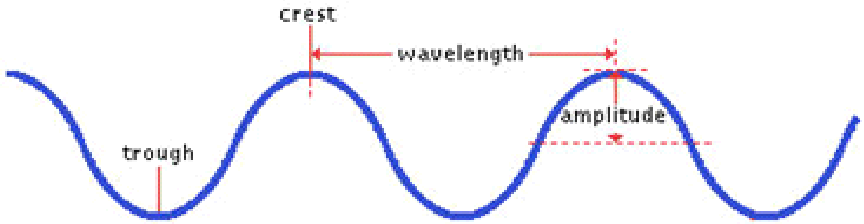

Figure 2: Transverse Wave

Conclusion

- Waves travelling through a solid medium can be either transverse waves or longitudinal waves. Yet waves travelling through the bulk of a fluid (such as a liquid or a gas) are always longitudinal waves. Transverse waves require a relatively rigid medium in order to transmit their energy. As one particle begins to move it must be able to exert a pull on its nearest neighbour. If the medium is not rigid as is the case with fluids, the particles will slide past each other. This sliding action that is characteristic of liquids and gases prevents one particle from displacing its neighbour in a direction perpendicular to the energy transport. It is for this reason that only longitudinal waves are observed moving through the bulk of liquids such as our oceans. Earthquakes are capable of producing both transverse and longitudinal waves that travel through the solid structures of the Earth. When seismologists began to study earthquake waves they noticed that only longitudinal waves were capable of travelling through the core of the Earth. For this reason, geologists believe that the Earth's core consists of a liquid - most likely molten iron.
- Any wave moving through a medium has a source. Somewhere along the medium, there was an initial displacement of one of the particles. For a slinky wave, it is usually the first coil that becomes displaced by the hand of a person. For a sound wave, it is usually the vibration of the vocal chords or a guitar string that sets the first particle of air in vibrational motion.
- At the location where the wave is introduced into the medium, the particles that are displaced from their equilibrium position always moves in the same direction as the source of the vibration. So if you wish to create a transverse wave in a slinky, then the first coil of the slinky must be displaced in a direction perpendicular to the entire slinky. Similarly, if you wish to create a longitudinal wave in a slinky, then the first coil of the slinky must be displaced in a direction parallel to the entire slinky.

Electromagnetic versus Mechanical Waves

- Another way to categorize waves is on the basis of their ability or inability to transmit energy through a vacuum (i.e., empty space).
- Categorizing waves on this basis leads to two notable categories: electromagnetic waves and mechanical waves.

Electromagnetic Wave

- An electromagnetic wave is a wave that is capable of transmitting its energy through a vacuum (i.e., empty space). Electromagnetic waves are produced by the vibration of charged particles.

- Electromagnetic waves that are produced on the sun subsequently travel to Earth through the vacuum of outer space.
- Were it not for the ability of electromagnetic waves to travel to through a vacuum, there would undoubtedly be no life on Earth. All light waves are examples of electromagnetic waves.

Mechanical Wave

- A mechanical wave is a wave that is not capable of transmitting its energy through a vacuum. Mechanical waves require a medium in order to transport their energy from one location to another. A sound wave is an example of a mechanical wave.
- Sound waves are incapable of travelling through a vacuum. Slinky waves, water waves, stadium waves, and jump rope waves are other examples of mechanical waves; each requires some medium in order to exist.
- Slinky wave requires the coils of the slinky; a water wave requires water; a stadium wave requires fans in a stadium; and a jump rope wave requires a jump rope.

Important concepts related to waves

Amplitude

- Amplitude is the magnitude of change in the oscillating variable with each oscillation within an oscillating system.
- For example, sound waves in air are oscillations in atmospheric pressure and their amplitudes are proportional to the change in pressure during one oscillation.

Frequency

- Frequency refers to the number of cycles per second.
- Unit of frequency – Hz
- Frequency has an inverse relationship to the concept of wavelength; simply, frequency is inversely proportional to wavelength *ë* (lambda).
- The frequency *f* is equal to the phase velocity *v*of the wave divided by the wavelength *ë* of the wave:

$$f = \frac{v}{\lambda}$$

Wave Length

- The wavelength of a sinusoidal wave is the spatial period of the wave – the distance over which the wave's shape repeats.
- It is usually determined by considering the distance between consecutive corresponding points of the same phase, such as crests, troughs, or zero crossings, and is a characteristic of travelling waves and standing waves, as well as other spatial wave patterns.
- Wavelength is commonly designated by the Greek letter *lambda* (λ).

Time Period

- The period *T* is the time taken by the wave to complete one cycle of an oscillation.
- Relation between the time period and frequency – $T = \frac{1}{f}$

Pitch

- Pitch is one of the major auditory attributes of musical tones along withduration, loudness, timbre, and sound source location. And while it is a crucial and immediate aspect of perceived sound, it is not one that is easily defined.
- It is the perceived fundamental frequency of a sound. The American National Standards Institute (1994) defines it as "that auditory attribute of sound according to which sounds can be ordered on a scale from low to high."
- Pitches are compared as "higher" and "lower" in the sense that allows the construction of melodies.Pitch may be quantified as a frequency in cycles per second (hertz), however pitch is not a purely objective physical property, but a subjective psycho acoustical attribute of sound.

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TOPIC 2

SOUND

Sound Waves

- Sound wave is a longitudinal mechanical wave which is generated or produced by the transmission of the disturbances in the form of compressions or rarefactions.
- Sound is produced by vibrating objects.
- This train of packets of compressions and rarefactions on reaching the listeners ears produce variations of pressure on his or her ear-membranes. These pressure variations set up impulses on the auditory nerves which carry the message to the hearing centre of the brain.
- In fact sound is produced by the rapid vibration of the material bodies and its sensation is produced by a vibrating body provided its frequency of vibration lies within 20 Hz to 20,000 Hz called audibility limit (or range).
- The frequencies of less than 20 Hz (lower limit of audible frequencies) are called infrasonic and those above the upper limit of audible frequencies 20,000 Hz are called ultrasonic (supersonics) waves.
- The wave length of infrared electromagnetic wave is the highest.
- The roaring sound of cloud is due to the vibration of various echoes.
- The velocity of sound increases with the increase of temperature but there is no effect of pressure on it.
- A human can not hear the sound of more than 120 decibel.
- Because of moisture the density of the medium is reduced, so the velocity of sound is increased.
- If there is more humidity, the velocity of sound is increased.
- Resonance occurs if frequency of the two sources becomes equal.
- The velocity of sound is less on height because of less temperature.

Frequencies range of sound waves :

Infrasonic waves :

- The sound waves whose frequencies are less than 20 Hz (20 Hz down to 0.001 Hz) is called Infrasonic waves and such waves cannot be listened by the human ears.
- Such waves are produced inside the earth during occurrence of earthquake. The heart beats of the human body are also infrasonic.
- This frequency range is utilized for monitoring earthquakes, charting rock and petroleum formations below the earth and also in ballistocardiography and seismocardiography to study the mechanics of the heart.
- Infrasound is characterized by an ability to cover long distances and get around obstacles with little dissipation.
- Infrasound has been known to cause feelings of awe or fear in humans. Since it is not consciously perceived, it can make people feel vaguely that supernatural events are taking place.
- An infrasonic signal of 19 Hz is considered to be responsible for some ghost sightings because it is very close to the resonant frequency of the eye given as 18 Hz by NASA.
- Whales, elephants, hippopotamuses, rhinoceros, giraffes, okapi, and alligators are known to use infrasound to communicate over distances—up to hundreds of miles in the case of whales. It has also been suggested that migrating birds use naturally generated infrasound, from sources such as turbulent airflow over mountain ranges, as a navigational aid. Elephants, in particular, produce infrasound waves that travel through solid ground and are sensed by other herds using their feet, although they may be separated by

hundreds of kilometres.These calls may be used to coordinate the movement of herds and allow male elephants to find mates.

Audible waves :

- The sound waves whose frequencies lie between 20 Hz to 20, 000 (or 20 KHz) is called audible waves which can be heard by the human ears.

Ultrasonic (Supersonic) waves :

- The sound waves whose frequencies are more than 20,000 Hz is called ultrasonic wave and such waves can not be listened by the human ears.
- Ultrasonics were produced firstly by Galton and later these were produced in certain crystals of tourmaline, quartz, zinc oxide, etc. by Piezo electric method. Thus Piezo electric crystals of quartz, rochelle salt, tourmaline etc. are generator of ultrasonics.
- As the frequencies of ultrasonics are too large so these waves are very energetic and have shorter wavelengths.
- Children under the age of five and some animals, such as dogs can hear up to 25 kHz (1 kHz = 1000 Hz).
- Some animals like birds, bats, dogs, cats, dolphins, etc. not only hear or listen ultrasonics but also but also produce them for communication, sighting and navigation.
- Moths of certain families have very sensitive hearing equipment. These moths can hear the high frequency squeaks of the bat and know when a bat is flying nearby, and are able to escape capture.
- Rats also play games by producing ultrasound.
- In the dark, the bats can fly freely without dashing against any obstacle (or barrier) because during flight they constantly send forward ultrasonics signals and if any obstacle is there, they hear the echoes (reflected sound wave) of the ultrasonics and at once they change their course of flight. Bats can easily hear the ultrasonics of the frequencies of 10, 000 Hz.

Use of Ultrasonics

(a) Ultrasounds are able to travel along welldefined paths even in the presence of obstacles. Ultrasounds are used extensively in industries and for medical purposes.

(b) In medical science ultrasonics are used in bloodless surgical operations, in tumour and cavity detection of teeth etc. By ultrasonic radiation various neurological disease and arthritis are being cured.

(c) In western and developed countries milk is purified by passing contaminated milk through ultrasonics. Generally contaminated (impure) milk has bacteria which are destroyed on passing ultrasonics.

(d) Ultrasonics coagulates the dust particles in winter season thus the mists and fogs from the airports are diminished and this facilitates the aircrafts (aeroplane) in landing.

(e) Ultrasonics is also utilized in measuring the sea depth, some commodities spread inside the sea like large rocks, icebergs, bigger fishes etc. SONAR (Sound Navigation And Ranging) is a technique by which inside located objects of the sea are detected.It is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. Sonar consists of a transmitter and a detector and is installed in a boat or a ship, as shown in Sound is produced due to vibration of different objects.Naval forces use the SONAR on large scale to detect submarines and drowned ships etc.

(f) The police use high frequency whistles which dogs can hear but humans cannotto guide the dogs during investigations.

(g) Ultrasound is generally used to clean parts located in hard-to-reach places, for example, spiral tube, odd shaped parts, electronic components etc. Objects to be cleaned are placed in a cleaning solution and ultrasonic waves are sent into the solution. Due to the high frequency, the particles of dust, grease and dirt get detached and drop out. The objects thus get thoroughly cleaned.

(h) Ultrasounds can be used to detect cracks and flaws in metal blocks. Metallic components are generally used in construction of big structures like buildings, bridges, machines and also scientific equipment. The cracks or holes inside the metal blocks, which are invisible from outside reduces the strength of the structure. Ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. If there is even a small defect, the ultrasound gets reflected back indicating the presence of the flaw or defect.

Ordinary sound of longer wavelengths cannot be used for such purpose as it will bend around the corners of the defective location and enter the detector.

(i) Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echocardiography'.

(j) Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs ofthe human body. A doctor may image the patient's organs such as the liver, gall bladder, uterus, kidney, etc. Ithelps the doctor to detect abnormalities, such as stones in the gall bladder and kidney or tumours in different organs. In this technique the ultrasonic waves travel through the tissues of the body and get reflected from a region where there is a change of tissue density. These waves are then converted into electrical signals that are used to generate images of the organ. These images are then displayed on a monitor or printed on a film. This technique is called 'Ultrasonography'. Ultrasonography is also used for examination of the foetus during pregnancy to detect congenial defects and growth abnormalities.

(k) Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains.

<u>Doppler's effect</u>

v The Doppler effect (or Doppler shift), named after Austrian physicist Christian Doppler who proposed it in 1842 in Prague, is the change in frequency of a wave for an observer moving relative to the source of the wave.

v It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer.

v The received frequency is higher (compared to the emitted frequency) during the approach, it is identical at the instant of passing by, and it is lower during the recession.

<u>Sonic booms andshock waves</u>

- When the speed of any object exceeds the speed of sound it is said to be travelling at supersonic speed. Bullets, jet aircrafts etc. often travel at supersonic speeds.
- When a sound, producing source moves with a speed higher than that of sound, it produces shock waves in air. These shock waves carry a large amount of energy. The air pressure variation associated with this type of shock waves produces a very sharp and loud sound called the "sonic boom".
- The shock waves produced by a supersonic aircraft have enough energy to shatter glass and even damage buildings.

<u>ECHO</u>

- If we shout or clap near a suitable reflecting object such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1 second.
- To hear a distinct echo, the time interval between the original sound and the reflected one must be at least 0.1 second. If we take the speed of sound to be 344 m/s at a given temperature, say at 22^0C in air, the sound must go to the obstacle and reach back the ear of the listener on reflection after 0.1s. Hence, the total distance covered by the sound from the point of generation to the reflecting surface and back should be at least (344 m/s) × 0.1 s = 34.4 m.
- Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance, that is, 17.2 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections.

<u>Mach number :</u>

- Mach number (M) of an aircraft is an indicator which tells the speed of the aircraft relative to the speed of sound.
- The Mach number is named after Austrian physicist and philosopher Ernst Mach, a designation proposed by aeronautical engineer Jakob Ackeret.
- Because the Mach number is often viewed as a dimensionless quantity rather than a unit of measure, with Mach, the number comes *after* the unit; the second Mach number is "Mach 2" instead of "2 Mach" (or Machs).
- In French, the Mach number is sometimes called the "Sarrau number" after Émile Sarrau, who carried out researches on explosions in the 1870s and 1880s.

- Flight can be roughly classified in six categories:

Region	Subsonic	Transonic	Sonic	Supersonic	Hypersonic
Mach	< 1.0	0.8 – 1.2	1.0	1.2 – 5.0	5.0 – 10.0

Sound of human beings

- In humans, the sound is produced by the voice box or the *larynx*. The vibration of the vocal cords produces sound in human beings.If you put your fingers on the throat then you will find a hard bump that seems to move when you swallow. This part of the body is known as the voice box. It is at the upper end of the windpipe.
- Two vocal cords are stretched across the voice box or larynx in such a way that it leaves a narrow slit between them for the passage of air.
- The shape of the outer part of the ear is like a funnel. When sound enters in it, it travels down a canal at the end of which a thin membrane is stretched tightly. It is called the eardrum. Itperforms an important function. The eardrum senses the vibrations of sound, It sends the signals to the brain. This process is called hearing.

Features of sound waves

- To and fro motion of an object is known as vibration. This motion is also called oscillatory motion.
- The number of oscillations per second is called the frequency of oscillation. Frequency is expressed in hertz. Its symbol is Hz. A frequency of 1 Hz is one oscillation per second.
- Amplitude and frequency are two important properties of any sound.
- The frequency determines the shrillness or pitch of a sound. If the frequency of vibration is higher we say that the sound is shrill and has a higher pitch. If the frequency of vibration is lower, we say that the sound has a lower pitch.
- Loudness of sound is proportional to the square of the amplitude of the vibration producing the sound. For example, if the amplitude becomes twice, the loudness increases by a factor of 4.
- The loudness is expressed in a unit called decibel (dB).
- When the amplitude of vibration is large, the sound produced is loud. When the amplitude is small, the sound produced is feeble.
- Unpleasant sounds are called noise.
- Excessive or unwanted sounds lead to noise pollution. Noise pollution may pose health problems for human beings.
- Plantation on the roadside and elsewhere can reduce noise pollution.
- When the level of a sound is increased by 10dB, the subjective loudness roughly doubles, whereas the sound power actually increases by a factor of 10.
- The smallest detectable change in level is about 1dB.
- The system was named after Alexander Graham Bell [1847-1922], who is given credit for being the inventor of the telephone.
- Numerous studies have shown prolonged exposure to 85 decibels or more can cause permanent hearing loss. Other physiological damage can occur at lower levels.
- A single, explosive noise is capable of damaging hair cells, but hearing loss is usually the result of continual exposure to volumes over 80-85 decibels.

Strength of sound produced by different sources

S. No.	Source of sound	Strength of sound	Comparison with ordinary conversation
1.	Threshold of hearing	0 dB	Don't hear anything
2.	Broadcast studio interior or rustling of leaves	10 dB	1/32nd as loud as conversation
3.	Normal breathing	10 dB	1/32nd as loud as conversation
4.	Quiet house interior or rural nighttime	20 dB	1/16th as loud
5.	Quiet office interior or watch ticking,	30 dB	1/8th as loud
6.	Normal talk, quiet conversation, soft whisper, quiet suburb, speech in a broadcasting studio	30 dB	1/8th as loud
7.	Quiet rural area, equivalent to quiet office, living room, bedroom away from traffic, residential area [no traffic]; computer hard drives, soft whisper [five feet]	40 dB	1/4th as loud
8.	Quiet suburban area, dishwasher in next room, quiet radio, average home, light traffic at a distance of 100 feet, refrigerator, gentle breeze, average office, non-electric typewriter, ordinary spoken voice.	50 dB	1/2 as loud
9.	Office interior, air conditioner at twenty feet, conversation [at one meter], sewing machine, large transformer, ordinary or average street traffic	60 dB	Ordinary Conversation
10.	Vacuum cleaner at 10 ft.	70 dB	Twice as loud
11.	Busy traffic, equivalent to typewriter, average factory noise, busy traffic [at one meter], office tabulator, noisy restaurant [constant exposure], quiet vacuum cleaner, TV.	70 dB	Twice as loud
12.	Passing car at 10 ft. or garbage disposal at 3 ft	80 dB	4 times as loud
13.	Factory noise, heavy city traffic [25-50 feet], alarm clock at two feet, vacuum cleaner, heavy truck, loud-radio music, garbage disposal.	80 dB	4 times as loud
14.	Passing bus or truck at 10 ft. or food blender at 3 ft., police whistle, heavy traffic, truck traffic, noisy home appliances subway-rail train, pneumatic drill [or hammer] at one meter, walk-man ear phone [average volume], rock drill at 100 feet, some motorcycles at 25 feet, shouted conversation.	90 dB	8 times as loud
15.	Passing subway train at 10 ft. or gas lawn mower at 3 ft. Or noise produced by machine shop, chain saw, pneumatic drill, printing plant, jackhammer, speeding express train, some car horns at five meters, farm tractor, riveting machine, some noisy subways [about 20 feet]	100 dB	16 times as loud

16.	Night club with band playing, loud factory noise	110 dB	32 times as loud
17.	Supersonic jet sound/threshold of pain/Sound of an amplified rock concert in front of speakers, sand-blasting, thunderclap [immediate danger], a nearby airplane engine, some rock or hard-metal cacophony groups, pneumatic hammer at one meter, thunderclap over head [the sensation of hearing is replaced by that of pain]	120 dB	64 times as loud as conversation (twice as loud as night club)
18.	Sound of a diesel engine room	125 dB	
19.	Sound of a gunshot blast, jet plane take-off at close range [approximately 200 feet], air raid siren [any length of exposure time is dangerous and is at the threshold of pain]	140 dB	
20.	Rocket launching pad [hearing loss inevitable]	180 dB	

Effect of various factors on the speed of sound

Effect of Pressure:

At the same temperature the speed of sound in the gas doesn't vary with pressure.

Effect of temperature:

The speed of sound is directly proportional to the square root of its absolute temperature. In any medium as we increase the temperature the speed of sound increases. For example, the speed of sound in air is 331 m s^{-1} at 0 ºC and 344 m s^{-1} at 22 ºC.

Effect of humidity:

The density of dry air is more than that of moist air. Thus in moist air the speed of sound is more than dry air. This is the reason why in rainy season the siren of the train are listened up to a far distances sharply then summer season.

Effect of the speed of the medium:

If the medium has also the speed then the speed of sound increases in the same direction and decreases in opposite direction.

Speed of sound in different mediums

- Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation. Sound propagates through a medium at a finite speed.
- It cannot travel through vacuum.
- The sound of a thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels.

  The speed of sound in a medium depends also on temperature and pressure of the medium. The speed of sound decreases when we go from solid to gaseous state.

Gases		Liquids at 25°C		Solids	
Material	Speed (m/s)	Material	Speed (m/s)	Material	Speed (m/s)
Hydrogen (0°C)	1286	Glycerol	1904	Diamond	12000
Helium (0°C)	972	Sea water	1533	Pyrex glass	5640
Air (20°C)	343	Water	1493	Iron	5130
Air (0°C)	331	Mercury	1450	Aluminium	5100
		Kerosene	1324	Brass	4700
		Methyl alcohol	1143	Copper	3560
		Carbon tetrachloride	926	Gold	3240
				Lucite	2680
				Lead	1322
				Rubber	1600

QUICK REVIEW OF SOUND WAVES

1. The number of oscillations or vibrations per second is called the frequency of oscillation. The frequency is expressed in hertz (Hz).

2. Sound travels from one point to another in the form of waves.

3. In sound propagation, it is the energy of the sound that travels, not the particles of the medium.

4. The change in density from one maximum value to the minimum value and again to the maximum value makes one complete oscillation.

5. The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength.

6. The time taken by the wave for one complete oscillation of the density or pressure of the medium is called the time period, T.

7. The number of complete oscillations per unit time is called the frequency.

8. The speed (*v*), frequency (n) and wavelength of sound (**ë**)are related by the equation, *v* = n**ë**.

9. The speed of sound depends primarily on the nature and the temperature of the transmitting medium.

10. The law of reflection of sound states that the directions in which the sound is incident and reflected make equal angles with the normal to the reflecting surface and the three lie in the same plane.

11. For hearing a distinct sound, the time interval between the original sound and the reflected one must be at least 0.1 s.

12. The persistence of sound in an auditorium is the result of repeated reflections of sound and is called reverberation.

13. Sound properties such as pitch, loudness and quality are determined by the corresponding wave properties.

14. Loudness is a physiological response of the ear to the intensity of sound.

15. The amount of sound energy passing each second through unit area is called the intensity of sound.

16. The audible range of hearing for average human beings is in the frequency range of 20 Hz – 20 kHz.

17. Sound waves with frequencies below the audible range are termed "infrasonic" and those above the audible range are termed "ultrasonic".

18. Ultrasound has many medical and industrial applications.

19. The SONAR technique is used to determine the depth of the sea and to locate under water hills, valleys, submarines, icebergs, sunken ships etc.

20. Sound waves are longitudinal in nature.

21. Sound waves cannot be polarised.

22. Sound waves require a material medium to travel.The matter or substance through which sound is transmitted is called a medium. It can be solid, liquid or gas. Sound moves through a medium from the point of generation to the listener.

23. A microphone converts sound energy into electrical energy.

24. Loudspeaker converts electrical energy into sound energy.

25. Decibel is the unit of measuring the intensity of a sound.

26. In water, sound is recorded by the help of a hydrophone.

27. Bells are made of metals because of the elasticity of metals.

28. There is no effect of pressure on the velocity of the sound if the temperature is kept constant.

29. Speed of sound increases with an increase in temperature and the humidity of air.

30. The speed of sound in a gas is proportional to the square of its absolute temperature.

31. The speed of sound in air increases by 0.61 m/s by the increase of 1°C temperature.

32. The speed of sound is higher in rainy season than in summers.

33. The unit of frequency is hertz.

34. Sound waves exhibit interference.

35. Interference is a phenomenon in which two waves superimpose to form a resultant wave of greater or lower amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic and surface water waves.

36. One characteristic of every standing wave pattern is that there are points along the medium that appear to be standing still. These points, sometimes described as points of no displacement, are referred to as **nodes**. There are other points along the medium that undergo vibrations between a large positive and large negative displacement. These are the points that undergo the maximum displacement during each vibrational cycle of the standing wave. In a sense, these points are the opposite of nodes, and so they are called **antinodes**. A standing wave pattern always consists of an alternating pattern of nodes and antinodes.

37. Nodes and antinodes are formed in stationary waves.

38. The difference between a node and an antinode is ë/4.

39. The difference between two consecutive nodes (or antinodes) is ë/2.

40. A sound of single frequency is called a tone whereas a sound of multiple frequencies is called a note. Of the several frequencies present in a note, the sound of the lowest frequency is called the fundamental tone. Besides the fundamental, other tones present in a note are known as overtones. Of the overtones, those which have their frequencies simple multiple of fundamental frequency, are known as harmonics. All harmonics are overtone but all overtones are not harmonics.

41. Whenever there is relative motion between the source of sound and the listener, the actual frequency (or pitch) of the source of sound appears to be changed to the listener. This apparent change in frequency is called the Doppler's effect.

42. Doppler's effect is related with the change in frequency of sound and not its intensity.

43. Doppler's effect is also applicable on light waves.

44. If a light source is receeding away from the observer on earth, then the frequency of light will appear to be decreased (or wave- length increased) to the observer. Due to this, the spectral lines appear to displace towards the red end of the spectrum. This is called the 'recessional red shift.'

45. If a light source is coming towards the observer on earth, the frequency of light will appear to be increased (i.e. wavelength decreased) to the observer due to which the spectral lines will appear to displace towards the violet end of the spectrum.

46. In supersonic motions, the speed of an object is expressed relative to the speed of sound. Their ratio is called the Mach number.

47. Mach number = $\frac{\text{speed of object}}{\text{speed of sound}}$

1. Mach number is greater than 1 for supersonic motions.

2. Mach number is used to express the motion of jet planes or rockets.

3. Echo is produced by the reflection of sound.

4. When two sound sources of approximately same frequencies produce sound then beats are heard.

5. The number of beats per second is equal to the difference in frequencies per second of the sound sources.

6. The frequency of the sound produced by the supersonic planes is beyond the audible region.

7. The quality of the same note produced from two different musical instruments is different.

8. Hydrophone records sound inside water.

9. Megaphone spreads sound to far off places.

10. Sound waves cannot travel in vacuum.

11. Tape of a tape recorder is coated with a thin layer of iron oxide. It is a magnetic substance.

12. If the original frequency of an open pipe is n, then the frequency of the pipe closed at one end remains n/2.

13. If the light emitted from a star is found to be redder than the sun light then it means that the star is receding away from the earth.

14. The sound from a piano or a guitar can be distinguished on the basis of its quality.

15. Sonar is used for communication and ranging beneath the surface of the ocean.

16. The speed of sound in air at room temperature is 330 m/s.

17. Pitch of sound is determined by its frequency.

18. On reflection of a wave from a surface there is no change in its velocity, wavelength and frequency.

19. All particles between the two successive nodes vibrate in the same phase.

20. The phase of vibration of the particles on one side of a node is opposite from the phase of vibration of the particles on the other side.

21. Sonar works on the reflection of sound waves.

22. Audible frequency range of sound is from 20 to 20,000 hertz.

23. When sound travels from one medium to another then its frequency remains unchanged but its speed, amplitude and intensity change.

24. The amplitude of a wave does not depend upon its velocity, wave length or frequency.

25. The intensity of sound increases with the increase in density of the medium.

26. In a telephone receiver electrical energy converts into sound energy.

27. In a microphone sound energy converts into electrical energy.

28. The phase difference between the particles on either side of a note at the same distance is ð.

29. The sound of supersonic planes is not heard on earth because the velocity of supersonic plane is either equal to or more than the velocity of sound. Hence its frequency is outside and audibility range.

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