SECTION-01 - BE-01

BASICS OF SCIENCE AND ENGINEERING

PHYSICS

1. Units and Measurements
2. Classical Mechanics
3. Electric Current
4. Heat and Thermometry
5. Weave Motion, Optics and Acoustics

CHEMISTRY

6. Chemical Reactions and Equations
7. Acids, Bases and Salts
8. Metals and Non-Metals

COMPUTER PRACTICE

9. Computer Practice

ENVIRONMENT SCIENCES

10. Environmental Sciences

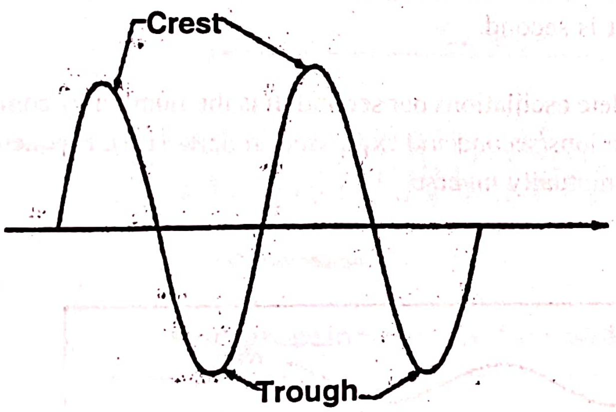
5. Wave Motion, Optics and Acoustics

Wave Motion

[1] According to transmit energy through vacuum :

(1) Mechanical Waves :

Mechanical waves require an elastic medium to propagate, wherein the particles of the medium experience oscillatory motion. Particles of elastic medium take part in the propagation of waves. The waves on the water surface, the waves on the string under tension, the waves formed by the spring, seismic waves, sound waves, etc. are mechanical waves. A mechanical wave is a wave that is an oscillation of matter and is responsible for the transfer of energy through a medium.



Crest and Trough in Transverse Waves

When a small stone is thrown on the stable (undisturbed) surface of the water, it causes a disturbance there and circular waves or ripples are formed which expand slowly and gradually and vanish after some time. The waves grow in size and appear to travel outward, yet there is no outward flow of water. Due to the disturbance, water particles are not displaced or move with the motion of the ring-shaped ripples on the water surface, but they move upward and downward around their mean position at their place. They induce other particles in contact with them to move around in the same manner. In this way, the disturbance expands. After the disturbance has passed, the water particles return to their original state. Similar ripples are also seen when a duck, floating on the surface of the water, passes through the water wagging its tail. If a small cork is kept floating on the water surface, it moves up and down as the wave passes over that region. Such waves are seen when the edge of a pencil is moved up and down in a container filled with water.

As shown in **Figure** the points on the maximum raised part of the water surface are called crests, and the points on the most lowered part of the water surface are called troughs. In this way, the wave moves in the water through the crests and troughs simultaneously.

Thus, a wave is not a physical entity moving in a medium. The medium itself does not move as a whole unit in a wave motion. Particles of the medium do not travel during wave motion, but the wave is generated only by the oscillations of the medium particle around its mean position. The effect of the disturbance arising in any one part of the medium is felt by different particles of the medium as the wave moves forward. The particle of the medium returns to its equilibrium position after the disturbance has passed. The disturbance produced at one point is transmitted to another point by vibration or oscillation of particles. When a particle is disturbed, it starts vibrating. The neighbouring particles are linked with this oscillating particle as such they also began to vibrate and the disturbance is carried out. However, the particles of the medium do not move bodily in the direction of propagation, the energy is transferred from one to another particle by the way of vibrations about their mean positions, without bodily propagation, which is called wave motion. During the wave motion, only energy and not the particles of the medium is transferred from one place to another by disturbance. Thus, in wave motion, material particles of the medium remain in their place and exchange energy through vibrations.

• **Distinguish between Transverse Waves and Longitudinal Waves :**

	Transverse Waves		Longitudinal Waves
1	During transverse wave motion, oscillations occur in a direction perpendicular to the direction of wave propagation.	1	During longitudinal wave motion, the particles of the medium oscillate along the direction of wave propagation.
2	The waves on the Water surface waves, waves on a stretched string, light (electromagnetic) waves etc. are illustrations of transverse waves.	2	Sound waves, waves from a tunning fork, ultrasonic waves etc are illustrations of longitudinal waves.
3	Longitudinal waves can not pass through the vacuum.	3	Transverse waves can propagate in a vacuum.
4	The velocity of longitudinal waves is higher in air, medium in fluid and higher in solids.	4	Their velocity is maximum in air or vacuum.
5	Transverse waves propagate through crests and troughs.	5	Longitudinal waves propagate through compressions and rarefactions in a medium.

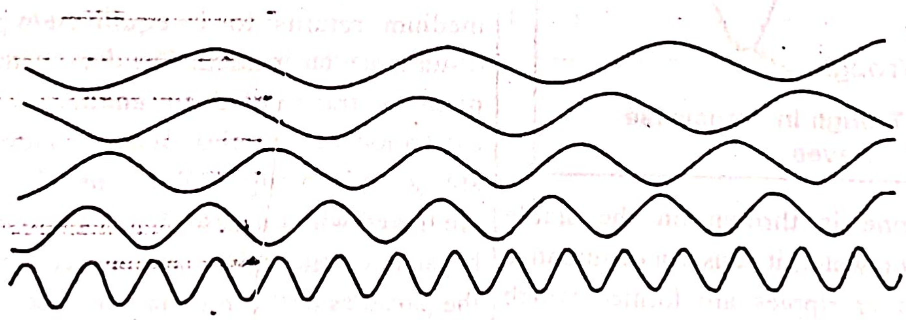
[2] Some Definitions Related to Waves :

Periodic Time (T) : It is the time required to complete one vibration. During the wave motion, the time required for one complete oscillation is called periodic time (T). Its unit is second.

Periodic time (T) = 1/frequency

Frequency (f or *f* or *n*) : Frequency is the number of complete oscillations per second. It is the number of complete vibrations performed by the particle in one second. Its unit is vibrations/second and expressed in hertz (Hz). Frequency is denoted by f or v or n. Periodic time (T) and frequency (f) are mutually inverse.

Frequency, $f = 1/T$



Waves with Different Frequencies

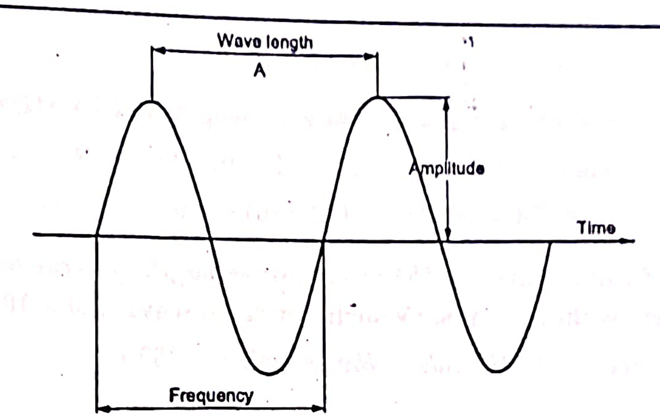
Figure shows the waves with different frequencies, in which the frequency of wave-1 to wave-5 gradually increases.The frequency of wave is lowest while that of wave-5 is highest.

Wave Length : The wavelength is the distance between two successive particles that vibrate in the same phase. In the wave motion, the distance betweem two consecutive particles having phase difference 2π radian or 180° is called the wavelength of that wave. Though wavelemgth is measured in meters, practically is very short and hence, usually expressed in Angstrom (Å) unit. **(Figures)**

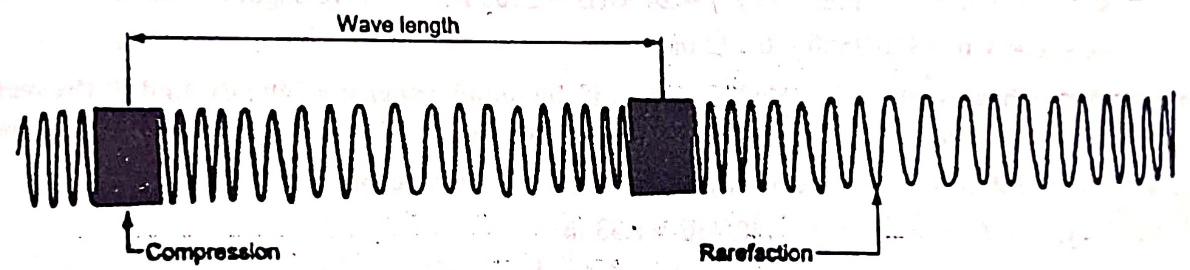
$1\,\mathring{A} = 10^{-10}\text{ m} = 10^{-8}\text{ cm.}$

During the wave motion, the positions of upward and downward maxima at a given time are called crest and trough respectively. Wavelength is the distance between two successive crestsand troughs for transverse waves and the distance between two successive compression and rarefaction longitudinal waves.

Speed of Sound Waves : The distance that a wave travels per second is called the speed of waves. Its unit is meter per second (ms^{-1}).



Frequency, Amplitude and Wavelength (Transverse Waves)



Compression-Rarefaction and Wavelength In Longitudinal Waves

Amplitude : The maximum displacement made by a particle in any direction from its mean equilibrium position during wave motion is called amplitude during the wave motion. The larger the amplitude, the greater the intensity of sound. See **Figure.**

[3] Relation Between Velocity, Wavelength snd Frequency :

A sound wave travels a distance of wavelength (λ) during the periodic time (T).

$$\text{So, the velocity of sound wave} = \frac{\text{Distance}}{\text{Time}} = \frac{\text{Wave length}}{\text{Periodic Time}}$$

$$\therefore\ v = \frac{\lambda}{T}$$

$$\therefore\ v = f\lambda \text{ because frequency, } f = \frac{1}{T}$$

$\therefore$ Sound velocity = wavelength × frequency

- **Numercial Problem Sums :**

1. **The frequency of a Tunning fork is 512 Hz. Calculate the wavelength of sound if the speed of sound emitted from it is 330 m/s.**

Solution : Velocity = 330 m/s Frequency = 512 Hz Wavelength λ = ?

$v = f\lambda$

Therefore, wavelength, $\lambda = v/f$ = 330/512 = 0.6445 m

2. **Obtain the velocity of radio waves having a 12.5 m wavelength and 24 MHz frequency.**

Solution : Velocity v = ? Frequency = 24 MHz = 24×10^6 Hz Wavelength λ = 12.5 m

Therefore, velocity, $v = f\lambda = (24 \times 10^6 \text{ Hz}) . (12.5 \text{ m}) = 3.0 \times 10^8$ m/s

3. **Calculate the frequency of radio waves of 353 meters wavelength are transmitted in the air from a radio station. Find the frequency of these waves. (Velocity of radio waves 3.0×10^5 km / s)**

Solution : Velocity = 3.0×10^5 km/s = 3.0×10^8 m/s Wavelength λ = 353 m

Frequency f = ? Hz

Now, velocity, $v = f\lambda$ $\therefore$ frequency $f = v / \lambda = 3.0 \times 10^8 / 353 = 0.8499 \times 10^6$ Hz = 0.8499 MHz

4. **A sound of 2500 Hz frequency is passing through the steel rod. If the velocity of sound in steel is 330 m/s, find its wavelength.**

Solution : Velocity v = 330 m/s Frequency f = 24 MHz = 2500 Hz Wavelength λ = ...

$v = n\lambda = \lambda = v/n$ = 330/2500 = 0.132 m

5. **A tuning fork vibrates with a 256 Hz frequency. If the sound velocity is 340 m/s, find (i) the wavelength of sound and (ii) the distance travelled by the sound waves during the 50 oscillations of the tuning fork.**

Solution : Velocity = 340 m/s Frequency f = 256 Hz Wavelength λ = ... m

Velocity, $v = f\lambda => \lambda = v f$ = 340/256 = 1.33 m

During 1 complete oscillation of the tuning fork, the sound wave travels a distance of its wavelength. So, the distance travelled by sound waves during 50 oscillations of tuning fork = 1.33×50 = 66.5 m

6. **Calculate the wavelength of sound with a frequency of 20 kHz and a velocity of 340 m/s in the air.**

Solution : Velocity v = 340 m/s F r ef = 20 KHz = 20000 Hz Wavelength λ = ?

Velocity, $v = f\lambda => \lambda = v/f$ = 340/20000 = 0.017 m

7. **Find the wavelength of a sound wave having a frequency of 440 Hz and a velocity of 330 m/s.**

Solution : Velocity v = 330 m/s Frequency f = 440 Hz Wavelength λ = ?

Velocity, $v = f\lambda => \lambda = v/f$ = 330/440 = 0.75 m

8. **A tuning fork of 480 Hz generates sound waves having velocity in air 330 m/s. Calculate its wavelength.**

Solution : Velocity v = 330 m/s Frequency f = 480 Hz Wavelength λ = ?

Velocity, $v = f\lambda => \lambda = v/f$ = 330/480= 0.6875 m

9. **How much distance will the sound waves travel during 200 oscillations made by a tuning fork of 512 Hz frequency, if the velocity of sound is 330 m/s ?**

Solution : Velocity = 330 m/s Frequency = 512 Hz Wavelength λ= ?

Velocity, $v = f\lambda => \lambda = v/f$ = 330/512 = 0.6455 m

The distance travelled by sound waves during one complete oscillation of tuning fork = λ = 0.6455 m

The distance travelled by sound waves during 200 oscillation of tuning fork = $200\lambda = 200 \times 0.6455$ m = 129.1m

10. Compute the velocity of a radio wave with a wavelength of 1200 cm and frequency of 25×10^3 kHz.

Solution : Frequency, = 25×10^3 kHz = 25×10^6 Hz Wavelength, λ =1200 cm = 12 m

Velocity, $v = f\lambda = (25 \times 10^6 \text{ Hz}) \cdot (12 \text{ m}) = 3.0 \times 10^8$ m/s

11. The frequency of a tuning fork is 660 Hz. If the speed of sound is 0.33 km/s, how much distance will the wave cover when the tuning fork completes 75 vibrations ?

Solution : Velocity v = 0.33 km/s = 0.33×10^3 m/s Frequency, f = 660 Hz

Wavelength, λ = ?

Velocity, $v = f\lambda \Rightarrow \lambda = v/f = 0.33 \times 10^3 / 660 = 0.5$ m

The distance travelled by sound wave during one oscillation of tuning fork = λ = 0.5 m

The distance covered by sound waves during 75 complete vibrations of tuning fork = $75\lambda = 75 \times 0.5$ m = 37.5m

[4] Sound and Light Waves :

- **Properties of Sound Waves :**

(1) Sound waves are longitudinal waves.

(2) Like light waves, sound waves can also be absorbed, reflected, refracted, etc. by the surface. The echo of a sound is due to its reflection from the surface.

(3) A medium is required for sound wave propagation. Sound cannot propagate in a vacuum.

(4) When a sound wave travels from one medium to another its frequency remains constant, but the velocity changes. And so its wavelength also varies.

Properties of Light Waves :

1. Light rays are the disturbances propagating in electric and magnetic fields combine.
2. A light ray is nothing but electromagnetic waves composed of photons (which has both particle and wave nature). Electromagnetic waves do not require a medium for propagation as they can travel through a vacuum.
3. Since light waves are of the Tranverse type of non-mechanical waves, the direction of oscillations is perpendicular to the direction of propagation of the waves during the wave motion. i.e. The direction of electric field oscillations (Wave components), the direction of magnetic field oscillations and the direction of propagation are mutually perpendicular. Moreover, the electric and magnetic field vectors vibrations. Equi-phased at a long distance from the origin.
4. For example, sunlight travels through space (vacuum) and reaches us.
5. Light is a form of energy i.e. they possess energy, so it can be converted into electrical energy, mechanical energy, chemical energy or heat energy.
6. There is a sensation in your eyes when light comes any object. And so we can see that object.
7. In a homogeneous medium, a light ray travels in a straight line.
8. The straight path of light connecting any two points on the passage of light is called a light-ray.
9. Light travels at extremely high speeds. The speed of light in a vacuum is 3×10^8m/s. The speed of light varies in different mediums.
10. Absorption, Reflection, Refraction, Dispersion, Interference, Diffraction and Polarization can occur for a light beam.

[5] Ultrasonics :

- **Classification of Sound :**

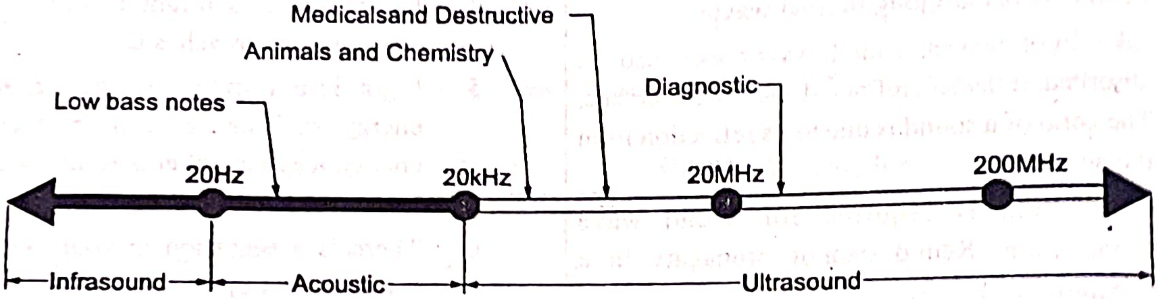
- Sound is classified according to its frequency in three ways :

(1) Infrasonic sound (2) Audible sound (3) Ultrasonic sound.

(1) Infrasonic sound : The sound that has a frequency less than 20 Hz is called infrasonic sound. Such waves we cannot hear. Waves generated during an earthquake are infrasonic sound waves. Pigeons, crows, crows, owls, bees, dolphins etc. can hear infrasonic sounds.

(2) **Audible sound :** Sound with a frequency of 20 Hz to 20 kHz (20,000 Hz) induces sensations in the human ear. The range of this frequency is called the audible range.

(3) **Ultrasonic sound :** Sound waves with a frequency of more than 20 kHz (20,000 Hz) are called ultrasonic or supersonic sounds. A Normal healthy person cannot hear an infrasonic and ultrasonic range of sound waves. But some animals, birds, reptiles and insects like horses, scorpions, mice, snakes, some mosquitoes, flies, wasps etc. can hear it. Bats can produce ultrasonic waves of 120 kHz, cats 12 KHz and dogs 50 KHz. We can not hear the sound of a dog whistle which is made for the Dog Squad. The bat continuously produces short ultrasonic pulses with a frequency of 20 kHz to 60 kHz. The inner ear of a bat is very delicate and sensitive. They can get an idea of the direction and distance from the reflection of the short ultrasonic pulse they produce. Because of this, they can move freely even in the dark. Even marine animals like whales and dolphins can identify the place, direction and object in the water with the help of the ultrasound they produce.



Classification of Sound Waves in terms of their Frequency Range

Properties of Ultrasonic waves :

1. Ultrasonic waves are sound waves with a frequency higher than 20000 Hz, which sounds inaudible to humans.
2. The wavelength of ultrasonic waves is short (< 1.7 m). So its penetrating power is higher.

$$\lambda \le v / f \therefore \lambda \le \frac{340 \text{ ms}^{-1}}{20000 \text{ s}^{-1}} \quad \therefore \lambda \le 1.7 \text{ cm}$$

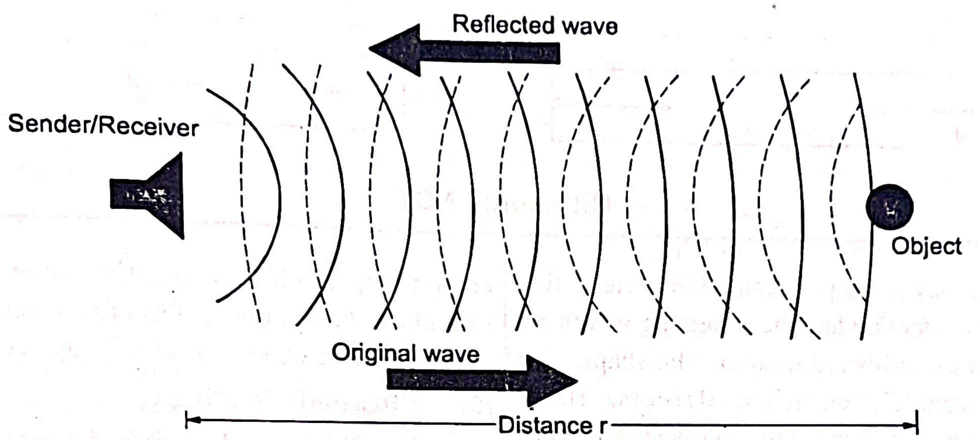
3. They are also longitudinal type sound waves, which are propagated by compression and rarefaction.
4. As ultrasonic waves are mechanical waves, a medium is required for their transmission. So, they cannot pass through a vacuum.
5. The speed of ultrasonic waves in any medium is equal to the speed of sound waves in that medium. As the frequency of the ultrasonic waves increases, so does the velocity. In dense media, its velocity is higher. Ultrasonic waves travel at a constant speed in a homogeneous medium.
6. Ultrasonic waves produce a heating effect when they pass through a medium, producing intense heat.
7. Ultrasonic waves are reflected, refracted and absorbed just like normal sound waves.
8. Ultrasonic waves act as catalysts in accelerating some chemical processes.
9. Ultrasonic waves produce standing wave patterns and cause cavitation and form a type of acoustic grating when they are passed through a liquid.
10. Ultrasonic waves are very high energy waves. The energy of ultrasonic waves can be sent over long distances, without significant loss of energy.

[6] Applications of Ultrasonic Waves :

Ultrasonic waves are used in many fields such as engineering, industrial, chemical, scientific research and medical, communication and technology etc.

(1) Ultrasonic waves as a Warning Signal :

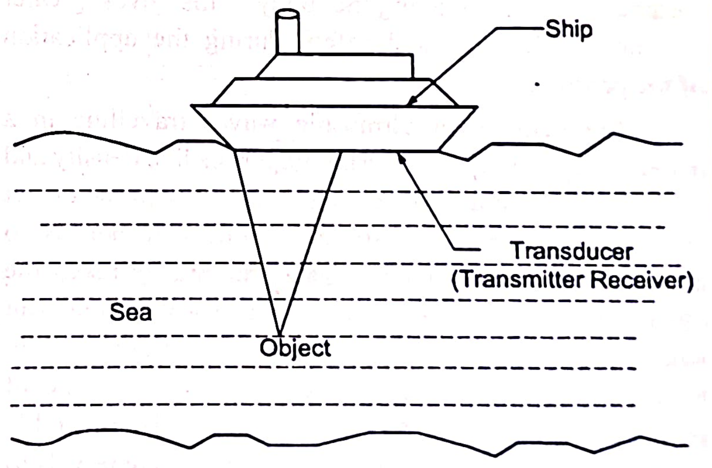
The frequency of ultrasonic waves is much more powerful than that of normal waves of sound. So ultrasonic waves can be sent in the form of a sharp beam in a certain direction over very long distances. Obstacles like submarines, icebergs, planes or missiles are reflected in the path of these waves. Analysing the reflected ray, the type and dimensions of the obstacle can be judged. SONAR (Sound Navigation and Ranging) is a method used to detect submarines, icebergs and other objects at sea. It is shown in **Figure** for understanding.



SONAR (Sound Navigation and Ranging)

(2) Measurement of Depth of Ocean :

The method used to measure the depth of (Sea or River) water is called Depth sounding or Echo sounding. Using the SONAR method, the ultrasonic generator transmits ultrasonic waves of frequency of 40 kHz to 50 kHz into seawater and send it to the bottom from which it returns and is reflected back as shown in **Figure.** Depth can be calculated by measuring the time taken by ultrasonic waves for to and fro travelling.The required time for transmission and reflection of ultrasonic waves and their velocity depending upon the salinity of the sea water.



Depth Sounding

The method for measuring this time is to capture the reflected ultrasonic rays on the crystal plate of the transducer and this results in vibration of the crystal plate producing a negligible emf. The time between the electromotive force (emf) generated by the ultrasonic waves and the emf generated by these reflected ultrasonic waves is recorded on the oscilloscope. The depth of the ocean can be found from the following formula :

$$\text{Depth} = \frac{1}{2}\,(\text{Velocity} \times \text{To-\&-FroTime taken by the wave}) \qquad \therefore S = \frac{v \times t}{2}$$

where,

S = Depth of Sea, v = Velocity of Ultrasonic Waves and t = The total time required for to-&-fro travelling by ultrasonic waves between sea surface and bottom.

(3) Measurement of Dimensions :

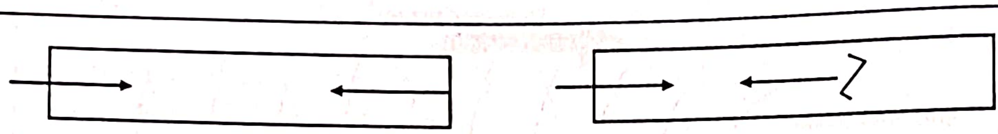
A beam of ultrasonic waves of appropriate and known frequency and speed is obtained by focusing the surface of the object on the surface of the object with a piezoelectric transducer, reflecting from the other end and returning the beam. The parameters (length, width, height/depth, etc.) of the distance between the two surfaces can be known from the time taken during this.

Here, dimension, thickness = velocity Time Time

∴ Dimension, D = vt

This way the thickness of the material can be measured without breaking or drilling.

(4) Non Destructive Testing and Detection of Flaws in Metals/Alloys :



Ultrasonic NDT

The ultrasonic waves are propagated into the testing piece or metal under inspection and the reflecting waves are analyzed. This gives us information about the shape, size and location of cracks, cavities, defects, flaws (imperfections), concavity, convexity, flatness and sub-surface defects, bond defects and other microstructural defects in metals, alloys, ceramics, glass, plastic etc. Metal casting, forging and welding specimen are tested by this method without damaging the body. This gives greater assurance, reliability and safety during the application of the product.

The velocity of ultrasonic waves travelling in a material depends upon material properties like density and elasticity. Ultrasonic waves are passed through the object to be tested using an ultrasonic transducer. If there is no defect in the object then the ultrasonic waves reach the other surface and from there it is 100% reflected. But when irregularities like cavitation, rupture, rupture, split, break, crack or bond error etc. come in the way of propagation, the wave is reflected from there **[Figure]**. If a cavity or crack-like defect is not there, the wave travels to the opposite surface and is reflected back from there. **[Figure]**. The error can be detected by recording the reflection of ultrasonic waves with the help of an oscilloscope. Currently, ultrasonic NDT is authentically used for the investigation of castings and other metal parts. Ultrasonic testing is used in small parts of vehicles and machines, as well as railway tracks.These days, the trains running on railway track sare equipped with ultrasound equipment, which is constantly scanning the railway line to find cracks or other defects that cannot be seen with the naked eye and which cause railway accidents.

(5) Ultrasonic Drilling :

(1) When a hole is drilled in a brittle object such as china clay with the help of a normal drill, it cracks and breaks. The ultrasonic drill vibrates instead of rotating so that high-power ultrasonic waves can ultrasonic frequency vibrating quickly and easily drill holes in such brittle objects or metals in the desired shape. A glass rod, vibrating with ultrasonic frequency, can make holes in steel or glass plates.

(2) Drilling can be done on a microscopic area of stone rocks by concentrating powerful ultrasonic waves of higher frequency. Similarly, by co centrating powerful ultrasonic waves over a larger area, a blast occurs which break the rocks.

(3) High-frequency ultrasonic waves generated from a special type of drill-bit can easily drill holes into the required shapes and sizes in diamonds and hard metals. Ultrasonic waves are also used to grind and polish diamonds.

(6) Ultrasonic Machining and Cutting :

When using the machining technique for conventional cutting, it is difficult to turn the machine round for unusual and complex shapes as well as the cut edges of hard objects become rough. The advantage of the ultrasonic machining technique is that it can easily cut hard materials such as soft steel, ceramics, glass, semiconductors, hard alloys and tungsten carbide. It has become possible because, in the ultrasonic machining technique, ultrasonic waves are passed through the liquid instead of using a conventional blade. So that a smooth edge is obtained after cutting.

(7) Ultrasonic Soldering and Welding :

In the conventional soldering method, oxy-hydrogen or oxyacetylene is used in electric welding or gas welding. For micro-soldering, molten droplets of tin are placed on the printed circuit board. High-frequency ultrasonic waves are used for microscopic welding. It is difficult to solder metal like aluminium because of the oxide layer on it; ultrasonic soldering can penetrate this oxide layer and perform soldering.

With the help of heat and pressure produced by intense vibrations of ultrasonic waves, a thin sheet of metal can be welded with a thick piece. The advantage of ultrasonic welding is that it puts very little pressure on the space for welding, which does not change the structure of the substance. Similarly, ultrasonic techniques are used to weld similar or different pieces of plastic together. A fairly flat welding of two plates of the same metal, as aluminium, can be done.

(8) Metallurgical Applications :

(i) When molten metal is in the process of cooling, ultrasonic waves pass through it to get the trapped air out, thus stopping the formation of pores.

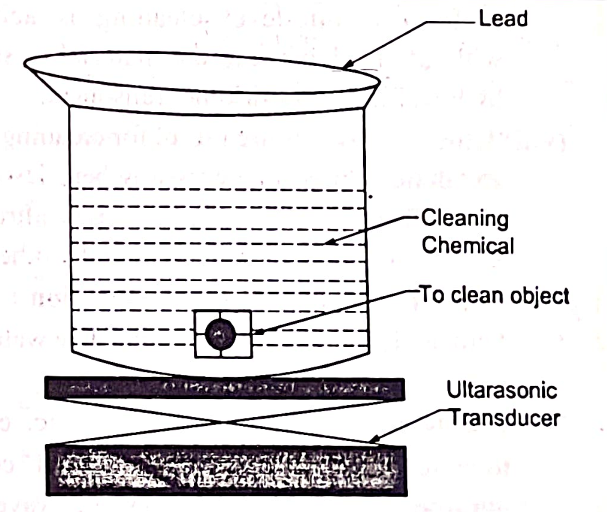
(ii) In alloy formation, ultrasonic waves are used to prepare a molten mixture of different metals in proper proportion.

(9) In Scientific Researach, Material Structure and Study of Atomic/Molecular Structure :

1. Viscosity of fluids can be measured with ultrasonic waves.
2. Ultrasonic waves are useful for determining the properties of solids materials such as compressibility, specific heat and elasticity.
3. The composition and structure of matter can be studied by ultrasonic waves. Ultrasonic waves are used to study atomic or molecular structure and crystal structure. In particular, ultrasonic waves are used to determine the elastic symmetries of objects such as crystals, as well as the molecular structure.
4. Ultrasonic waves are used in 'Acoustic Microscope' which is used to study up to microscopic objects. With the help of basic microstructural characteristics such as size, porosity and structure of the material and the associated defects like cracks, wear etc. can be studied.

(10) Ultrasonic Cleaning :

A cleaning fluid (such as water, detergent solution or other organic compounds) is taken into a tank as shown in **Figure.** The tank is connected to an ultrasonic transducer. A specimen for cleaning (e.g. lenses, ball bearings, quartz crystals, dental bridges, etc.) is immersed in the tank, and the lid closed. When ultrasonic waves are passed through the liquid in the tank, they form cavitation (many small bubble cavities or vacuum spaces at the places of rarefaction because of separated fluid particles) and pull outdust, soot or corrosion, etc. from the surface of the solid sample. The unwanted particulate matter, corrosion, dyes, particles or oils from the specimen surface is released by ultrasonic vibrations. This way quick and thorough cleaning is done.



Ultrasonic Cleaning

(i) Ultrasonic Waves can clean dust, oxide-layer (rust), grease, pollution, etc. from solid surfaces. Low-frequency ultrasonic waves are useful for cleaning the devices made of metal, glass, ceramic or crystal, electric parts, electronic circuits, jewellery, delicate and minute (very small) mechanical parts used in watches, machines, vehicles, aeroplanes etc. where even cleaning with a small brush is not possible.

(ii) Ultrasonic waves are used for washing clothes, especially silk clothes, as well as for cleaning utensils. Nowadays Ultrasonic transducers are installed in cleaning tanks (like washing machines etc...) So that perfect uniform complete molecular-level cleaning is achieved without damaging the material.

(iii) Ultrasonic waves are used to remove fog from the airport. Ultrasonic waves can clear dust and soot/mesh from a chimney or boiler.

(iv) Sonic Pocket Toothbrush cleans teeth without toothpaste. Powered by an "AA type" battery, this toothbrush vibrates 16,000 times a minute and cleans teeth and gums using the ultrasonic technique.

(v) High-frequency ultrasonic waves are used for fiber cleaning, cloth cleaning in the textile industry.

(vi) Ultrasonic waves can be used to clean dust, oxide-rust, grease, pollution etc. on the surface of an object.

(vii) In large cleaning tanks, in industries, complete uniform atomic-level cleaning is achieved without any damage to the material or surface by installing an ultrasonic transducer.

(viii) Ultrasonic waves are useful for cleaning small and delicate parts like wristwatches, jewellery, scientific instruments etc. In textiles, ultrasonic waves are used to wash fibres and clothes.

(11) Ultrasonic Pest Control and Sterilization :

1. Ultrasonic waves are used to sterilize water and milk.
2. Insects such as flies, mosquitoes etc. cannot tolerate, runaway and even die at certain ultrasound frequencies. Ultrasonic waves are used to kill or destroy insects.
3. Rats, cats, dogs and some reptiles can hear ultrasonic sounds but cannot tolerate its higher frequency. They either die or run away.

(12) In Agriculture field :

1. Ultrasonic waves act as pesticides and insecticides in crops in agriculture.

2. Ultrasonic waves can accelerate certain chemical reactions. So in agriculture, when a seed is passed through a fixed frequency of an ultrasonic wave for a certain period of time, it germinates faster and yields more.

(13) In Medical field :

1. Ultrasonic waves are used in testing by imaging in the medical field that is called sonography, by which the internal parts of the body can be seen. Sonography by ultrasonic waves is advantageous compared to x-rays, as frequent use of ultrasonic waves has no side effects. Also, x-rays only image bones, while 2D/3D imaging of soft tissues/muscles/organs such as kidneys, liver, spleen, pancreas inside the body which cannot be seen by X-rays can be done by ultrasonic waves.
2. Ultrasonic waves are also useful for warming muscles for various therapies. They are specially used for ultrasonic massaging in physiotherapy.
3. Ultrasonic waves are used to sterilize operation theatre and operation equipment. It is useful for sterilization of operation tools including socks, glovesand masks and disinfection of intravenous sets/blood transfusion sets etc.
4. High-frequency ultrasonic waves are used to locate and remove (burn) brain-tumourcells by concentrating sharp ultrasonic waves of high frequency which can destroy diseased cells and tissues.
5. Ultrasonic waves create microscopic bubbles in gallstones, kidney stones and cancer tumour cells. When such bubbles burst, they create intense shockwaves that destroy the cancer cells or stones in very small pieces. Thus, stones can be removed without surgery by ultrasonic waves.
6. Cataracts can be removed by ultrasonic waves without surgery. Ultrasonic waves are especially useful for bloodless surgery in eye surgery, brain surgery and internal organ surgery. It is used to remove the infected teeth.
7. Ultrasonic waves (sonography) are used to detectthe growth of the unborn child in the mother's body so that any defect or abnormality in the baby's development during each stage of pregnancy can be detected from the earliest stage.
8. Ultrasonic sonography is also performed to diagnose abdominal diseases.

9. Ultrasonic waves are useful for the therapeutic treatment of diseases like joint pains, rheumatism arthritis and neuroma. In severe muscle pain, ultrasonic waves of a certain frequency are applied by an ultrasonic gun on the muscle or joint that gives immediate relief from pain and spasm.
10. (Ultra) Sonography is used to check the bloodflow in the body and also know the function of the valve in the heart through 2D / 3D Echo Cardiography. Some major heart defects and diseases like cardiomyopathy (heart enlargement), perfusion pericardial (fluid retention around the heart), blood clots in the heart, valve defects etc. can be detected and diagnosed by echo-cardiography using ultrasonic waves.
11. Doppler and colour Doppler, using ultrasonic waves, can also be used to find out the direction of blood flow.

(14) Sono Chemistry :

1. Ultrasonic waves, as catalysts, are used to accelerate some chemical reactions such as oxidation, hydrolysis, polymerization, de-polymerization, crystallization as well as certain chemical processes, even at low temperatures.
2. Ultrasonic mixing is currently widely used. When two unmixable liquids (For example, under normal circumstances, such as oils and water) are mixed together, it is known to be an emulsion. If two unmixable liquids are filled in a container, their emulsion is formed on passing ultrasonic waves through them. When energetic ultrasonic waves pass through the two or more liquids in a container, cavities are formed at the places of rarefactions because of separated water particles. When the cavity vanishes, high pressure is produced. Many bubbles are formed in such cavities. They suck undissolved gases and vapours and form an emulsion.
3. Ultrasonic Waves are useful for emulsification which depends upon (1) Air bubbles or dissolved gas in the liquid (2) External pressure. Alloys like iron-lead or aluminium-cadmium, zinc-lead etc. can be obtained in uniform composition by the ultrasonic emulsification method. Some emulsions such as paints, polishes, foodstuffs, and pharmaceutical products are prepared with ultrasonic mixing techniques.
4. Ultrasonic waves are used to convert jelly-like substances, such as aluminium hydroxide [$Al(OH)_3$], into liquid form.
5. With the help of ultrasonic waves the dissolved substances in the liquid can be brought closer together. This is called coagulation. (from liquid to semisolid).
6. Loose particles of dust, mist or smoke can be easily removed having coagulated by ultrasonic waves. In the dairy industry, ultrasonic waves are used to convert fat droplets into small particles and mix them well in milk to form homogeneous milk.
7. Ultrasonic pasteurization and sterilization of milk results in the destruction of harmful bacteria and other micro-organisms present in the milk.

(15) Thermal Effect by Heat Generation :

Heat is generated from a substance when very strong ultrasonic waves are passed through it.

(16) Flow Monitoring :

Flow detection by ultrasonic waves does not affect the flowing material. Ultrasonic waves are used to test the conduction of coolant in a nuclear power plant. Also, they can be used to measure

(17) Electronic field :

Ultrasonic technology is widely used for testing, cleaning and soldering of electronic circuit components. Surface Acoustic Wave (SAW) filters operating on the ultrasonic version are a type of electrical component, important for useful electronics equipment such as cellular phones and high-capacity TV receivers.

(18) In Aerospace Engineering :

When the velocity of the sound source is greater than that of the sound itself, the sound produced is called "Sonik Boom". Such a sonic boom, supersonic aircraft etc. are studied in aerospace engineering.

Multiple Choice Questions (MCQs)

1. Sound waves in the air are ________ waves.
(A) longitudinal (B) standing
(C) transverse (D) circular
Ans. : (A)

2. When a sound wave travels from air to dense medium, its ______ and ______ do not change but ______ does.
(A) wavelength, amplitude, velocity
(B) wavelength, velocity, frequency
(C) phase, velocity, frequency
(D) speed, frequency, phase
Ans. : (B)

3. The __________ object produces sound.
(A) Rotational motion (B) vibration
(C) circulation motion (D) Linear motion
Ans. : (B)

4. For the sound waves, _______, larger the wavelength.
(A) greater the amplitude (B) lower the amplitude
(C) high the frequency (D) low the frequency
Ans. : (C)

5. The speed of sound is maximum in _______, while the speed of light is maximum in ______.
(A) Gaseous medium (B) Solid medium
(C) Liquid medium (D) vacuum
Ans. : (B, D)

6. Sound waves are of the _____ type which propagates in the medium through _____ and ______.
(A) Longitudinal, crest, rarefaction
(B) Transverse, compression, trough
(C) Longitudinal, rarefaction, compression
(D) Transverse, trough, crest
Ans. : (C)

7. Light waves are of the................type which is propagated in the medium by .... and ....
(A) Longitudinal, crest, rarefaction
(B) Transverse, compression, trough
(C) Longitudinal, rarefaction, compression
(D) Transverse, trough, crest
Ans. : (D)

8. The frequency of ultrasonic waves is ________.
(A) >20 Hz (B) >20 KHz
(C) < 20 Hz (D) 20 Hz to20 KHz
Ans. : (B)

9. Ultrasonic waves are ______ for humans.
(A) Audible (B) inaudible
(C) visible (D) permeable
Ans. : (B)

10. When the humidity in the atmosphere increases, the velocity of the sound waves passing through it _________.
(A) decreases (B) increases
(C) becomes zero (D) remains constant
Ans. : (B)

11. The velocity of the sound waves passing through the medium depends on its ________.
(A) viscosity (B) pressure
(C) density (D) elastisity
Ans. : (D)

12. When the temperature of the atmosphere goes down, the velocity of the sound wave passing through it ____.
(A) decreases (B) increases
(C) becomes zero (D) remains constant
Ans. : (A)

13. Sound waves with a frequency of fewer than 20 Hz are called _____.
(A) audio sound (B) infrasonic waves
(C) ultrasonic waves (D) supersonic waves
Ans. : (B)

14. The amplitude of sound waves in air with frequency 10 Hz is................
(A) 1 second (B) 10second
(C) 100second (D) 0.1 second
Ans. : (D)

15. S.O.N.A.R. = ...
(A) Small Navigation And Random
(B) Small Navigation And Ranging
(C) Sound Navigation And Ranging
(D) Signal Navigation And Ranging
Ans. : (C)

16. A ship from the sea sends an ultrasound, which reflects back off the coast after 3.42 seconds. If the speed of ultrasound in seawater is 1300 m/s, the distance from the ship to the coast would be......... .

(A) 3.0 km (B) 2.661 km

(C) 2.223 km (D) 2.810 km

Distance = ½ (velocity × time) = ½ (1300)(3.42) = 2223 m = 2.223 km

Ans. : (C)

17. The wavelength of the ultrasonic waves is .... the normal sound waves.

(A) more than (B) less than

(C) equal to (D) more or less than

Ans. : (C)

18. Waves with a frequency less than 20 Hz are called .... waves.

(A) ultrasonic (B) infrasonic

(C) audible (D) transverse

Ans. : (B)

19. During .... wave motion, the direction of vibrations of the particles is perpendicular to the direction of propagation of the waves, whereas, during .... wave motion, the direction of vibrations of the particles is parallel to the direction of propagation of the waves.

(A) Light, sound

(B) Longitudinal, transverse

(C) Electromagnetic, ultrasonic

(D) All options are correct

Ans. : (D)

20. In the transverse wave motion the particles ....

(A) oscillate perpendicular to the direction of propagation.

(B) oscillate parallel to the direction of propagation.

(C) Perform random motion.

(D) propagate with compression and rarefaction.

Ans. : (A)

21. Which of the following is not the example of longitudinal wave motion ?

(A) Ultrasonic waves

(B) Sound waves

(C) Waves on the water surface

(D) Tsunami and seismic waves

Ans. : (C)

22. The unit of frequency is

(A) seconds(s) (B) Herts(Hz)

(C) (1/s) (D) (B) & (C) both

Ans. : (D)

23. Wave equation y = ... sin (........ t ± .... *x*)

(A) X, Ω, K (B) A, ω, k

(C) A, ω, K (D) α, ω, K

Ans. : (B)

24. A single coloured light or monochromatic light has ....

(A) all colours merged.

(B) totally black light.

(C) pure white light

(D) light rays of single wavelength

Ans. : (D)

25. The .... of the .... substance is taken as the magnetostrictive material.

(A) sphere, paramagnetic (B) rod, diamagnetic

(C) rod, ferromagnetic (D) bar, glass

Ans. : (C)

26. The piezoelectric transducer oscillator produces ultrasonic waves with .... effect.

(A) magnetostriction (B) piezoerlectric

(C) electromagnetic (D) photoelectric

Ans. : (B)

27. Magnetostriction frequency is, f = ... Hz

(A) $\frac{n}{2l}\sqrt{Y\rho}$ (B) $\frac{n}{2l}\sqrt{\frac{Y}{\rho}}$

(C) $\frac{n}{2l}\sqrt{\frac{\rho}{Y}}$ (D) $\frac{n}{l}\sqrt{\frac{Y}{\rho}}$

Ans. : (B)

28. The ultrasonic frequency generated by a piezoelectric transducer oscillator is f_ℓ = ... Hz.

(A) $\frac{P}{2l}\sqrt{Y\rho}$ (B) $\frac{P}{2l}\sqrt{\frac{Y}{\rho}}$

(C) $\frac{P}{2l}\sqrt{\frac{\rho}{Y}}$ (D) $\frac{P}{l}\sqrt{\frac{Y}{\rho}}$

Ans. : (B)

29. ________ type of circuit is used in magnetostriction transducer.

(A) LC-tank (B) AC-tank

(C) DC-tank (D) π-filter

Ans. : (A)

30. During ________ wave motion, the direction of vibrations of the particles is perpendicular to the direction of propagation of the waves, whereas, during ______ wave motion, the direction of vibrations of the particles is parallel to the direction of propagation of the waves.

(A) Light, sound

(B) Longitudinal, transverse

(C) Electromagnetic, ultrasonic

(D) All options are correct

Ans. : (D)

31. When a vibrating sound source, makes a nearby stationary sound source start vibrating along with it, the phenomenon is called..................

(A) resonance (B) echo

(C) reverberation (D) polarisation

Ans. : (A)

32. Mechanical waves require ______ medium.

(A) inelastic (B) elastic

(C) Fluidor solid (D) air or vacuum

Ans. : (B)

33. Which of the following is not an example of mechanical waves ?

(A) Waves on the water surface

(B) Waves of a string or spring

(C) Sound waves

(D) Electromagnetic waves

Ans. : (D)

34. Which of the following is not the example of longitudinal wave motion ?

(A) Ultrasonic waves

(B) Sound waves

(C) Waves on the water surface

(D) Tsunami and seismic waves

Ans. : (C)

35. Which of the following is not a prerequisite for interference ?

(A) Coherent source

(B) Zero phases difference

(C) Very close and sharp source

(D) The distance between two slits must be less than the wavelength

Ans. : (D)

36. Which of the following is not a prerequisite for destructive interference ?

(A) Phase difference $(2n \pm 1)\,\pi$

(B) Path difference $\frac{(2n-1)\,\lambda}{2}$

(C) Superposition of crest of one wave and trough of another.

(D) Superposition of crest on crest and trough on a trough.

Ans. : (D)

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