PHYSICS
UNIT - 1
Chapter 2 : ULTRASONICS

Sound waves having frequency above the audible range, i.e. greater than 20,000 Hz are called **ultrasonics or ultrasonic waves (USW)**

Production of Ultrasonic Waves

a) Magnetostriction Method

When a rod of ferromagnetic material such as iron or nickel is kept in a magnetic field parallel to its length, the rod suffers a change in its length. This phenomenon is called **magnetostriction**.
The change in length of the rod is independent of the direction of the applied magnetic field (whether parallel of anti-parallel) and depends only on the magnitude of the field and the material of the rod.

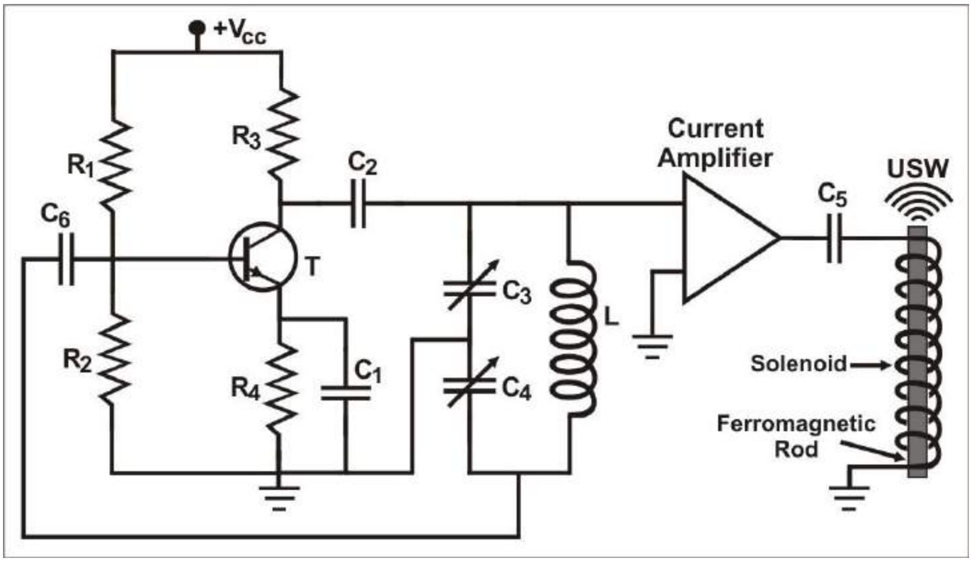
Use of magnetostriction to generate USW

If a ferromagnetic rod is placed in an alternating magnetic field of frequency f, the rod will change in length twice in each cycle resulting in vibrations of frequency $2f$. If f is greater than 10,000Hz, the rod will vibrate at a frequency greater than 20,000Hz, thus producing USW.
Further, if the amplitude of the USW produced is to be large, the rod must be made to vibrate at is natural frequency so that resonance will occur and the amplitude will be large.
The natural frequency f_n of a rod of length L made of material having density ρ and Young's modulus $Y$is given by the formula

$$f_n = \frac{1}{2L}\sqrt{\frac{Y}{\rho}}$$

Magnetostriction Oscillator

The circuit is basically a Colpitt's oscillator which generates a.c. signals of any desired frequency. When the circuit is switched on, the tank circuit, comprising of inductor L and variable capacitors C_3 and C_4, generates



small a.c. signals. These are amplified by the transistor T which is biased to work as a positive feedback amplifier. The current level of the signal is also amplified and it is then applied to a solenoid inside which a ferromagnetic rod is placed. The frequency of the circuit is adjusted using variable capacitors C_3 and C_4 to be exactly equal to half the natural frequency of the rod ($f_n/2$). The rod will then vibrate at its natural frequency $f_n$thereby producing USW of large amplitude.

Using this method USW of frequency upto about 100 KHz can be generated. (The length of the rod puts a limit on the maximum frequency of USW that can be generated by this method.)

b) Piezoelectric Method

When certain crystals (called piezoelectric crystals) such as quartz, tourmaline, Rock salt, Rochelle's salt, etc. are subjected to mechanical pressure along a certain direction called the mechanical axis, an electric potential is developed across the crystal along a perpendicular direction called the electrical axis. This phenomenon is called **direct piezoelectric effect**.

The polarity of the electric potential developed depends on whether the applied pressure is compressive or elongative.

Conversely, if an electric potential is applied to a piezoelectric crystal along its electrical axis, the crystal will either expand or contract along the mechanical axis, depending on the polarity of the applied potential. This phenomenon is called **inverse piezoelectric effect**.

Use of Inverse piezoelectric effect to generate USW

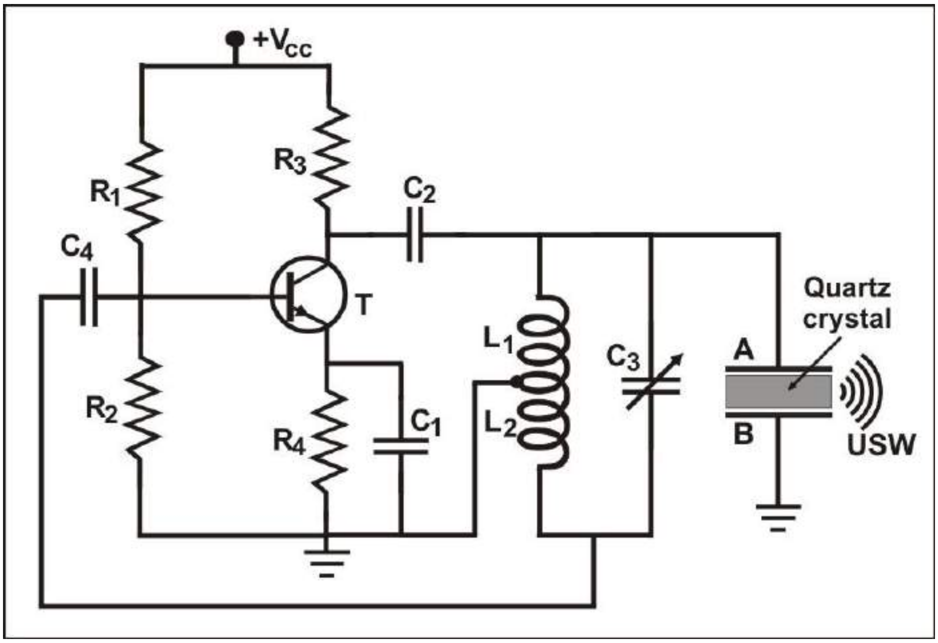
If an alternating electric potential of frequency f is applied to a piezoelectric crystal along its electrical axis, the crystal will expand and contract once in each cycle thus producing vibrations of frequency f. If f is greater than 20,000Hz, the crystal will also vibrate at the same frequency and thus produce USW. Further, if the frequency f matches with the natural frequency f_n of the crystal, the crystal will vibrate at resonance and produce USW of large amplitude.

The natural frequency f_n of a crystal of thickness t made of material having density ρ and Young's modulus Y is given by the formula

$$f_n = \frac{1}{2t}\sqrt{\frac{Y}{\rho}}$$

Piezoelectric Oscillator

The circuit is basically a Hartley's oscillator which generates a.c. signals of any desired frequency. When the circuit is switched on, the tank circuit, comprising of inductors L_1 and L_2 and variable capacitor C_3, generates small a.c. signals. These are amplified by the transistor T which is biased to work as a positive feedback amplifier. The amplified a.c. signal is then applied to a piezoelectric crystal C which is kept between two metal plates A and B. The frequency of the circuit is adjusted using variable capacitor C_3 to be exactly equal to the natural frequency of the crystal (f_n). The crystal will then vibrate at its natural frequency f_n thereby producing USW of large amplitude.



Using this method USW of frequency upto about 500MHz can be generated.

Detection of USW

a) Piezoelectric detector

The direct piezoelectric effect is used for detection of USW. A piezoelectric crystal is kept in the region containing USW. Due to the vibrations, an alternating voltage will develop across the crystal along its electrical axis. This voltage can be measured using a CRO. Thus USW can be detected.

b) Kundt's Tube method

Kundt's tube is a long sealed glass tube with lycopodium powder sprinkled on its inner walls. When USW are passed through the tube, standing waves consisting of alternate nodes and antinodes are formed in it. The lycopodium powder collects in the form of heaps at the nodal points and is blown off at the antinodal points. Thus by observing the powder pattern in the tube, the presence of USW can be detected.

c) Sensitive flame method

When a narrow sensitive flame is moved in a medium where USW are present, the flame remains stationary at the nodal points and flickers at the antinodal points. Thus by observing the flame, the presence of USW can be detected.

d) Thermal detector method

A platinum wire is kept in the region of USW. At the antinodal points the temperature rises slightly due to rapid to and fro motion. Hence the resistance of the wire at antinodal points slightly rises at the antinodal points. Whereas at the nodal points the resistance remains almost unchanged. This change in resistance along the length of the wire can be detected using a sensitive metre bridge arrangement. Hence the presence of USW can be detected.

Properties of USW

1) Since they have high frequency, USW are highly energetic.
2) Their speed of propagation increases with increase in frequency.
3) The wavelength of USW is very small and hence they show negligible diffraction effects.
4) They can travel over long distances without much loss of energy.
5) Intense USW produce cavitation in liquids through which they are passed.

Cavitation using USW

Microscopic air bubbles are always present in a liquid. When the pressure in the liquid is decreased, these air bubbles start growing in size and eventually they collapse. The pressure and temperature at the point where a bubble collapses becomes momentarily very high. This phenomenon is called cavitation.

When intense USW are passed through a liquid, alternate regions of compressions and rarefactions are produced in the liquid. In the regions of rarefactions the pressure is very low. Hence air bubbles in these regions grow in size and eventually collapse leading to cavitation.

Cavitation using USW is used in cleaning sensitive machine parts and jewellry.

Applications of Ultrasonic waves

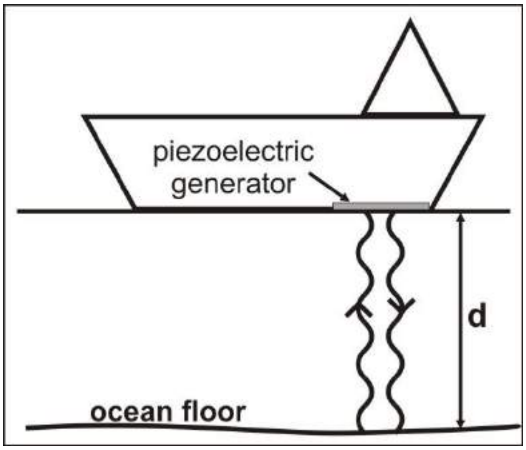
1) Detection of flaws in metal castings

An ultrasonic generator mounted on one face of the metal casting sends a pulse of USW into the metal casting. The waves get reflected from the position of the flaw as well as from the end of the metal casting. These reflected pulses are detected by the same generator. Thus by counting the number of reflected pulses received, the presence of flaws in the casting can be detected. (Number of flaws is one less than the number of reflected pulses received)

2) SONAR (Sound Navigation and Ranging)
This is a technique used to detect the presence of hidden underwater objects like submarines, icebergs, shipwrecks, etc. An ultrasonic generator mounted at the bottom of the ship sends a pulse of USW in all directions. A reflected pulse received from any particular direction indicates the presence of an underwater object in that direction. By measuring the time between sending and receiving of the pulse, the distance of the object can be determined. Also by using the phenomenon of Doppler effect, the speed and direction of motion of the object can be determined.

3) Echo-Sounding
This is a technique used to determine the depth of the ocean floor. An ultrasonic generator mounted at the bottom of the ship send a pulse of USW towards the ocean floor. The waves reflected from the ocean floor are received. The time (T) between sending and receiving of the waves is noted. By knowing the velocity (v) of USW in sea water, the depth of the ocean floor can be determined using the formula:

$$d = \frac{v.T}{2}$$

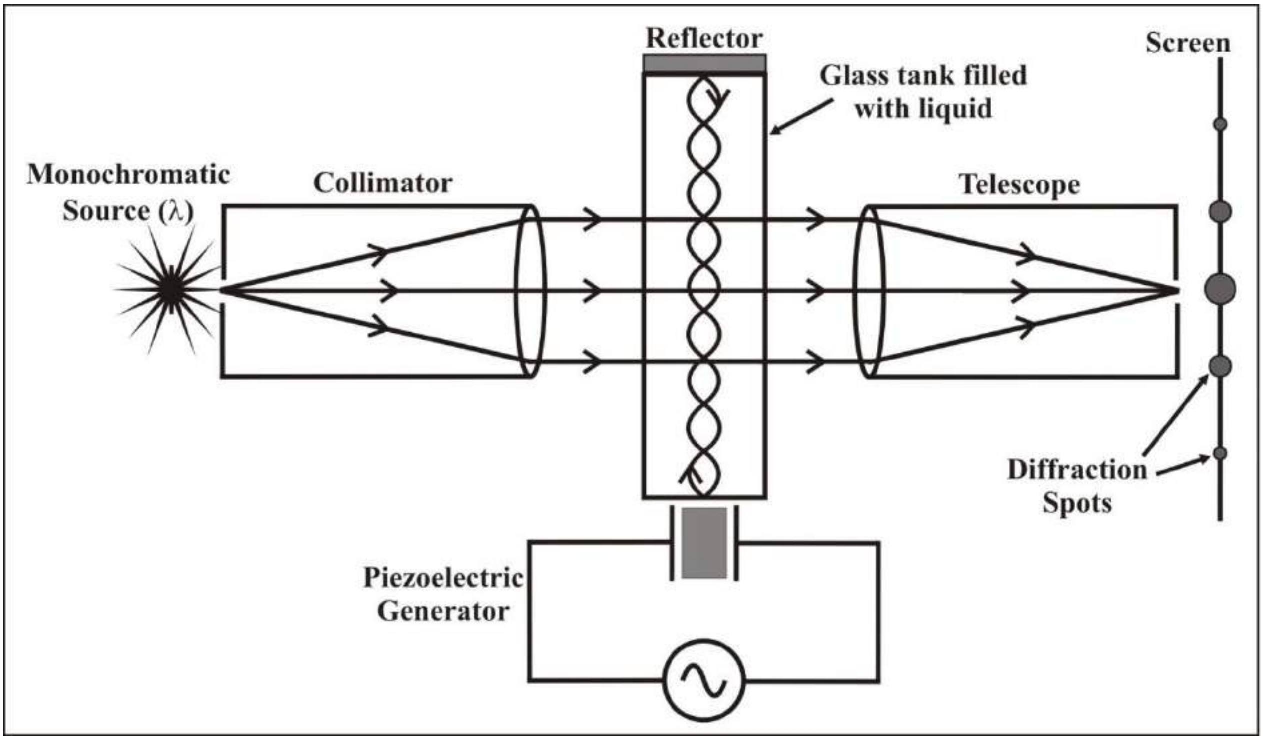


4) Ultrasonic soldering
To form a proper electrical joint the surfaces to be joined have to be cleaned to make them free from dust, grease, oxide films, etc. For this purpose flux is used.
However, aluminium cannot be soldered using normal soldering due to the formation of aluminium oxide film.
In ultrasonic soldering, an ultrasonic generator mounted on the soldering rod generates intense high frequency vibrations. This breaks down the oxide film and helps in the formation of a good joint. Thus in ultrasonic soldering flux is not required since the cleaning is done by the USW.

5) Ultrasonic Cleaning
The phenomenon of cavitation in liquids is used in ultrasonic cleaning (also called ultrasonic bath). The object to be cleaned is immersed in a detergent solution and intense high frequency USW are passed through the solution. Due to cavitation, high pressure points are created in the liquid which help in removing any contaminants present on the surface of the object, thus giving a thoroughly clean object. Ultrasonic bath is used in cleaning sensitive machine parts and jewellery.

6) Medical Uses
a) Ultrasound
Ultrasound is a technique involving USW and is used for imaging internal organs like kidney, liver, pancreas, etc. and to monitor the growth of the fetus in the womb. It works on the principle that USW get reflected from the boundaries of two different tissues. Ultrasound is better that X-ray because it is not harmful and also organs like kidney, liver, etc. cannot be seen on an x-ray.
b) Deep heat therapy
An ultrasonic generator is pressed against the affected area. Due to the high frequency vibrations in the muscle tissue, heat is generated. Heat relieves pain. Since USW can penetrate deep inside the body, pain in muscles even deep inside the body can be relieved using deep heat therapy.

Acoustic diffraction grating (determination of wavelength and velocity of USW in a liquid)



The experimental setup consists of a rectangular glass tank which is filled with the liquid in which velocity of USW is to be found. A piezoelectric generator mounted at the bottom of the tank send USW through the liquid (upwards). A reflector mounted at the top of the tank reflects the USW downwards thus forming a standing wave. The nodal points are more denser and hence behave like opaque regions for light, while antinodal points behave like transparent. Therefore, alternate periodic opaque and transparent regions are created in the liquid column. It thus behaves like a grating. (Such a grating is called acoustic grating since it is produced using sound waves.)

When a parallel beam of monochromatic light is incident normally on such a grating, a diffraction pattern consisting of a central bright spot and less brighter spots on either side of the central spot will be produced as shown in the figure.

<u>Analysis</u>

Applying the theory of diffraction we have for maxima,

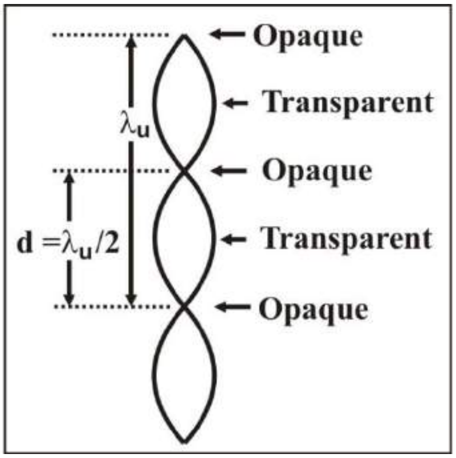
$d \, sin\theta = n \, \lambda$ …….eqn. 1

where d --- grating element

θ --- angle of diffraction maxima

n --- order if diffraction maxima

λ --- wavelength of monochromatic light used



In the acoustic grating, the grating element,

$d = \lambda_u/2$ (as shown in the figure

where λ_u --- wavelength of USW

Substituting the value of d in eqn. 1 we get,

$\frac{\lambda_u}{2} . sin\theta = n \, \lambda$

$\Rightarrow \lambda_u = \frac{2n\lambda}{sin\theta}$

Thus, by measuring the diffraction angle θ and by knowing the values of n and λ, the wavelength of USW λ_u can be determined.

Further, the velocity of USW in the liquid can be determined using the formula,

$v = f . \lambda_u$

where f is the frequency of the piezoelectric generator.

12.5 PROPERTIES OF ULTRASONIC WAVES

(i) The speed of propagation of ultrasonic waves depends upon their frequency. It increases with increase in frequency.

(ii) The wavelength of the waves is very small and the waves exhibit negligible diffraction effects.

(iii) They can travel over long distances as a highly directional beam and without appreciable loss of energy.

(iv) They are highly energetic. Owing to the high frequencies involved, ultrasonic waves may have intensities up to 10 kW/m^2. Normally, 1 to 2 kW/m^2 intensities are used.

(v) They produce cavitation effects in liquids.

12.6 CAVITATIONS

Microscopic bubbles of about 10^{-9} to 10^{-8} m sizes are always present in a liquid. A decrease in pressure above the liquid causes an intense evaporation in the bubbles and leads to their growth. The growth of bubbles leads to their collapse. The entire process of growth and collapse of bubbles occurs within one millisecond. During the collapse of a bubble, a shock wave is formed causing an abrupt increase in the temperature of the gas within the bubble.

When ultrasonic waves propagate thorough liquid media, they induce alternate regions of rarefaction and compression. A negative local pressure at the spot of rarefaction causes local boiling of the liquid accompanied by the bubble growth and collapse. This phenomenon is known as **cavitation**. When the minute bubbles collapse, the local pressure increases up to thousands of atmospheres and consequently local temperature increases by about as much as 10,000°C. The numerous shock waves combine to act as liquid hammer. In such conditions the liquid displays high crushing power.

12.12 INDUSTRIAL APPLICATIONS

Ultrasonic waves are extensively used in industry, medicine and marine applications.

1. Ultrasonic Drilling: Ultrasonic machining is a vibratory process that is now in common use for the mechanical treatment of hard and brittle solids such as ceramics, glasses, precious stones, semiconductors and hard alloys. The tool motion is produced by an acoustic concentrator to which the tool holder is threaded. The acoustic concentrator consists of a needle type magnetostriction vibrator, illustrated in Fig. 12.8. The vibrator is made of thin isolated ferromagnetic plates of high magnetostriction such as nickel. A coil is wound on the needle, through which an alternating current of frequency passes. The resulting magnetic field magnetizes the core and thus changes its length. The core of the vibrator vibrates at a frequency $2f$. By choosing the frequency f to be equal to half the natural vibration frequency of the vibrator, the system is held at resonance and the vibrations of the needle will be of large amplitudes. A tapered waveguide of appropriate dimensions and rigidly attached to the vibrator concentrates the vibrational energy and communicates it to the tool. The tool oscillates linearly with an amplitude of 0.013 to 0.1 mm at ultrasonic frequency of 20 kHz to 30 kHz.

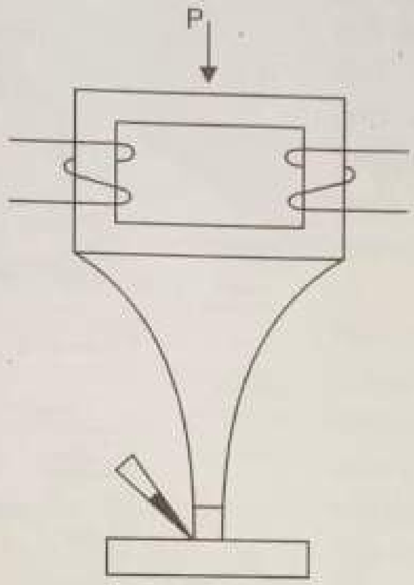


Fig. 12.8. *Schematic of a typical ultrasonic drill*

In operation, the needle vibrator is set in oscillation and the tool shank is pressed against the work piece. An aqueous suspension of a solid abrasive powder is then fed through a tube to the working zone. Abrasive particles bombard the work surface at high velocity and shear off small pieces of the material. This action rapidly chips away the work piece in a pattern controlled by the tool shape and contour.

2. Ultrasonic Welding: Practically, all metals and plastics can be welded using ultrasonic waves of suitable energy. The surfaces of the work pieces are cleaned and held together. They are subjected to ultrasonic oscillations at the spot where they are to be welded. The ultrasonic energy converts to heat at the contact area as a result of friction arising between the surfaces. As the temperature of surface layers exceeds the recrystallization point, the layers melt and bond together to form a strong joint. The merits of this process are that it does not cause stress at the spot of welding and that the structure of the materials remain unchanged.

3. Ultrasonic Soldering: Normally, surfaces are covered with contaminants, grease and oxide films. Such films prevent formation of a good joint. Therefore, prior to soldering, the surfaces are cleaned with active fluxes. The fluxes, when heated, dissolve the oxide films and uncover the clean metal surface which readily allow the molten solder to form a firm joint. This method however is not suitable for soldering aluminium. Active metals such as aluminium can be soldered without fluxes with the help of ultrasonic waves. In this case soldering is done by a special iron that vibrates at a frequency of tens of kilohertz.

4. Ultrasonic Cleaning: In the fabrication of electronic devices, it is highly essential to clean the surfaces of parts and components at different stages of production. Cleaning of the surfaces is commonly carried out in either organic solvents or weakly alkaline aqueous solutions containing surface-active agents. To scrub the surfaces more effectively, the phenomenon of cavitation is utilized. Ultrasonic cleaning baths are used for this purpose.

The hydraulic shock arising at the surface of a part due to cavitation destroys any layer of contaminants. Bubbles penetrate under the layer, tear it off and break it down into minute pieces. The surface-active agent pulls them away into the solution.

The chief advantage of this method is that it enables cleaning the surface of small products of intricate configuration. Jewelers make use of ultrasonic baths to clean jewellery.

5. Echo Sounder : Ultrasonic waves can be produced in the form of directed beams like beams of light. Further, ultrasonic waves can travel long distances in water. This property is utilized in measuring the depth of ocean. A ship equipped with an echo sounder sends out short pulses of ultrasonic waves towards the bed of the ocean (Fig. 12.9). These waves are reflected back from the bed and the receiver receives the reflected pulse. The time interval between the pulse sent and the pulse received is determined. Knowing the velocity υ of the waves through the seawater, the depth of the ocean, l can be computed with the help of the following formula.

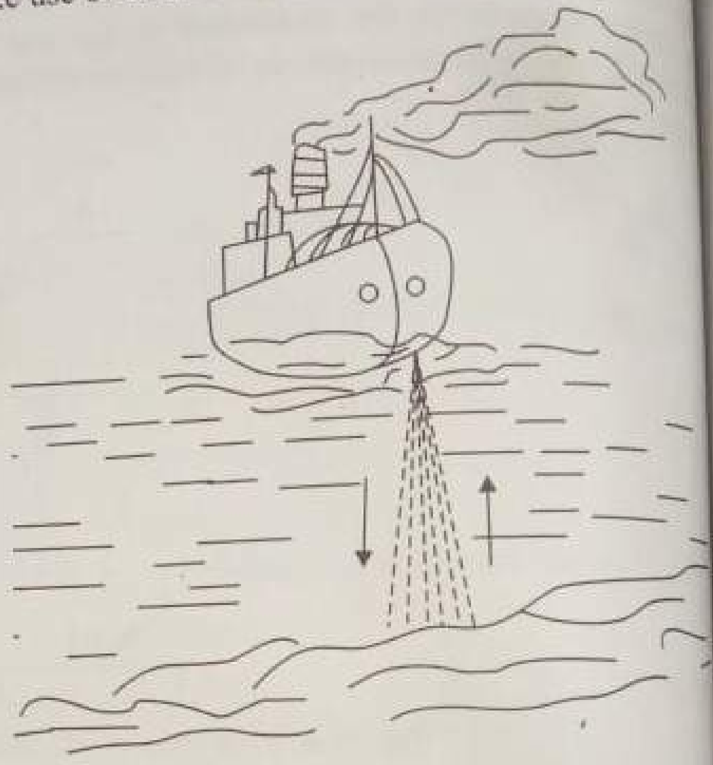


Fig. 12.9. *Depth sounding*

$$l = \frac{\upsilon t}{2} \tag{12.20}$$

where t is the time interval between the transmitted and reflected pulses.

6. SONAR: The word SONAR stands for **S**ound **N**avigation **A**nd **R**anging. The ultrasonic waves, which are highly directional, can be used for locating objects submerged under seawater and determining their distance. The idea of ultrasonic sonar was put forward first by the French physicist Paul Langevin and was successfully used by him during the first world war for detecting enemy submarines. The sonar acts in a way much similar to an echo sounder. In sonar, an ultrasonic beam is directed in different directions into the sea. In the absence of an obstacle, the ultrasonic pulses do not return to the ship. In the presence of an obstacle, pulses are reflected from the obstacle and are picked up by the receiver. Knowing the speed of the ultrasonic waves in seawater and time elapsed between the transmitted and reflected pulses, the distance of the object is determined using the formula (12.20).

- Sonar is used to guide submarines in the seas.
- It is used to detect the presence of submerged icebergs.
- It is used for direction signaling in submarines.

7. Fish-finder: Ultra sound can be used to locate shoals of fish utilizing the fact that the swimming bladder of fish is filled with air that scatters ultrasonic waves. Ultrasonic sonar is used for this purpose. At present ultrasonic locators are mainly used for detecting icebergs, fish shoals and the like.

Some of the sea animals such as whales and dolphins use ultrasound to locate their prey, avoid collision with obstacles and even to converse with each other. In the depths of the sea visibility is highly restricted because of the strong absorption of light by water. It may be therefore that these animals use ultrasound that is relatively less absorbed.

8. Emulsification: Immiscible liquids like water and oil can mix thoroughly and form stable emulsions when their mixture is subjected to strong ultrasonic waves. The ultrasonic emulsification is used in industry to mix molten metals and form alloys of uniform composition.

Example 12.5: *An ultrasonic source of 0.07 MHz sends down a pulse towards the seabed, which returns after 0.65 s. The velocity of sound in seawater is 1700 m/s. Calculate the depth of sea and wavelength of pulse.*

Solution: Depth of the sea, $l = \frac{\upsilon t}{2} = \frac{(1700\text{m/s})(0.65\text{s})}{2} = \mathbf{552.5\ m.}$

Wavelength of the pulse $\lambda = \frac{\upsilon}{f} = \frac{1700\text{m/s}}{0.07 \times 10^6 \text{s}^{-1}} = \mathbf{24\ mm.}$

12.13 ULTRASONIC TESTING

Ultrasonic testing is a versatile and widely used non-destructive testing (NDT) method. It utilizes high frequency acoustic waves generated by piezoelectric transducers. In NDT, ultrasonic waves of frequencies from 100 kHz to about 25 MHz are generally used. The ultrasonic waves are generated with the help of piezoelectric devices. When bursts of alternating voltage are applied to the transducer, the transducer emits ultrasonic beam. The ultrasonic beam is then transmitted from the transducer into the specimen under testing. If even a slight discontinuity exists inside the specimen, the ultrasonic waves are reflected back to the transducer. The transducer converts these reflected waves again into electrical signal. This signal is displayed on a screen of CRT. The characteristics of the pulses produced by the transducer are used for interpretation of the nature of the defect in the specimen.

Several methods have been developed for the ultrasonic testing. Among them, pulse-echo methods are most popular and widely used. In some of such methods, normal beam probes are used in which a transducer crystal is fixed parallel to the bottom plate of the probe. The ultrasonic beam produced by the probe propagates into the object perpendicular to the surface of contact and travels in the material in the form of longitudinal waves. Hence, these methods are known as normal beam pulse testing methods.

12.15 MEDICAL APPLICATIONS—SONOGRAPHY

Ultrasound is widely used in imaging of internal organs or structures of the human body. Ultrasound imaging, also called ultrasound scanning or **sonography**, involves exposing part of the body to high-frequency sound waves to produce pictures of the inside of the body. Ultrasound imaging provides valuable information regarding the size, location, and displacement of a given structure. Tumors and other regions of organ that differ in density from surrounding tissues can be detected. Ultrasound imaging is a noninvasive medical test that helps physicians diagnose and treat medical conditions.

Principle:

Sonography uses a probe containing one or more acoustic transducers to send pulses of sound into a body. Whenever a sound pulse encounters a boundary between two tissue structures, it is partly reflected from, and partially transmitted. The sound pulse reflected back to the probe is detected as an echo (Fig. 12.15). The reflection depends on the difference in acoustic impedance of the two tissues. The acoustic impedance of a medium is the speed of sound in the material × the density:

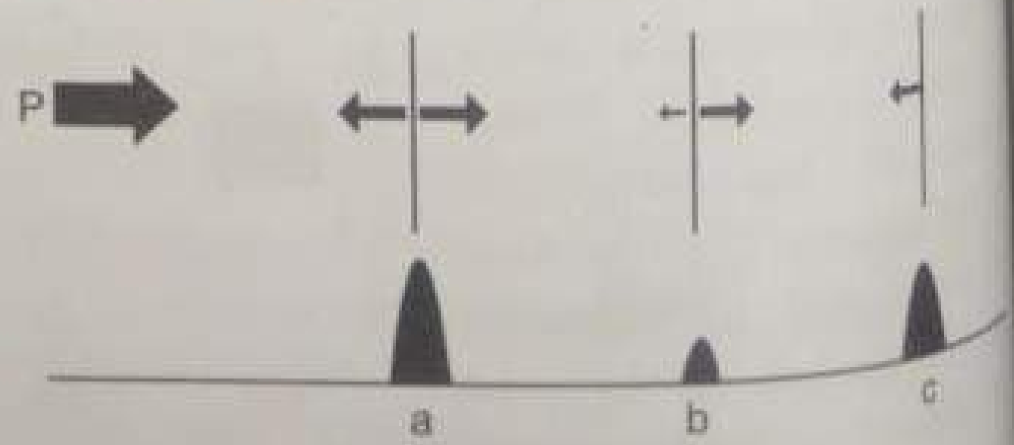


Fig. 12.15

12.16.2 Doppler Ultrasound Imaging

Doppler ultrasound imaging is based upon the Doppler effect. When the object reflecting the ultrasound waves is moving, it changes the frequency of the echoes, creating a higher frequency if it is moving toward the probe and a lower frequency if it is moving away from the probe. The change in frequency depends upon how fast the object is moving. Doppler mode enables to measure the change in frequency of the echoes to calculate how fast an object is moving. Doppler ultrasound has been used mostly to measure the rate of blood flow through the heart and major arteries.

Fig. 12.20. *A primary use of ultrasound is to monitor the progress of a pregnancy. The above sonogram shows the 27 weeks stage.*

Advantages

- Most ultrasound scanning is noninvasive (no needles or injections) and is usually painless.
- Ultrasound is widely available, easy-to-use and less expensive than other imaging methods.
- Ultrasound imaging uses no ionizing radiation.
- Ultrasound scanning gives a clear picture of soft tissues that do not show up well on x-ray images.
- Ultrasound causes no health problems and may be repeated as often as is necessary.
- Ultrasound is the preferred imaging modality for the diagnosis and monitoring of pregnant women and their unborn babies.

Limitations

- Ultrasound waves are disrupted by air or gas; therefore ultrasound is not an ideal imaging technique for the bowel or organs obscured by the bowel.
- Ultrasound waves do not pass through air; therefore an evaluation of the stomach, small intestine and large intestine may be limited. Intestinal gas may also prevent visualization of deeper structures such as the pancreas and aorta.
- Ultrasound has difficulty penetrating bone and therefore can only see the outer surface of bony structures and not what lies within.

OTHER MEDICAL APPLICATIONS

Ultrasonic therapy is used in treatment of rheumatic pains. Ultrasonic waves produ massaging action and relieves pain.

The waves are useful for dental cutting and they make the cutting painless.

Ultrasonic waves destroy bacteria and therefore they are used in sterilization water and milk.

Ultrasonics
Problems :-

1) Calculate the natural frequency of 40 mm length of a pure iron rod. Given the density of pure iron is 7.25×10^3 kg/m³ and its Young's modulus is 115×10^9 N/m². Can you use it in magnetostriction oscillator to produce ultrasonic waves?

Soln:-

$$f = \frac{n}{2L}\sqrt{\frac{Y}{\rho}}$$

$$\left[\begin{array}{l} n = 1 \\ L = 40\times10^{-3}\ m \\ \rho = 7.25\times10^{3}\ kg/m^3 \\ Y = 115\times10^{9}\ N/m^2 \end{array}\right]$$

$$\therefore f = \frac{1}{2L}\sqrt{\frac{Y}{\rho}}$$

$$= \frac{1}{2\times40\times10^{-3}}\sqrt{\frac{115\times10^{9}}{7.25\times10^{3}}}$$

$$= 12.5\times 3982.72$$

$$f = 49784\ Hz$$

$$\boxed{f = 49.784\ kHz}$$

Since, this $f < 100$ kHz, this can be used in magnetostriction oscillator to produce ultrasonic waves.

Prob. 2) Calculate the length of an iron rod which can be used to produce ultrasonic waves of 20kHz. Given that.

Young's modulus of iron $= 11.6 \times 10^{10}\ N/m^2$
Density of iron $= 7.23 \times 10^3\ kg/m^3$

Soln →

$Y = 11.6 \times 10^{10}\ N/m^2$

$\rho = 7.23 \times 10^3\ kg/m^3$

$f = 20kHz$

$L = ?$

assume $n = 1$

$$f = \frac{n}{2L}\sqrt{\frac{Y}{\rho}}$$

$$L = \frac{1}{2f}\sqrt{\frac{Y}{\rho}}$$

$$= \frac{1}{2 \times 20 \times 10^3}\sqrt{\frac{11.6 \times 10^{10}}{7.23 \times 10^3}}$$

$$= 2.5 \times 10^{-5} \times 4005.52$$

$$L = 0.1\ m$$

Date
Page

Prob. 3) Calculate the natural frequency of ultrasonic waves using the following data.

Thickness of quartz plate $(t) = 5.5 \times 10^{-3}$ m

Young's modulus of quartz $(Y) = 8 \times 10^{10}$ N/m^2

Density $(\rho) = 2.65 \times 10^{3}$ kg/m^3

Soln →

$$f = \frac{n}{2t}\sqrt{\frac{Y}{\rho}}$$

$$= \frac{1}{2 \times 5.5 \times 10^{-3}}\sqrt{\frac{8 \times 10^{10}}{2.65 \times 10^{3}}}$$

$$= 90.9091 \times 5494.42$$

$$= 499492.77 \text{ Hz}$$

$$\boxed{f = 499.49 \text{ kHz}}$$

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Date

Page

Prob.4) The wavelength of light transmitted through a liquid is 6000 A°. The first order angle of diffraction is 0.046°. Calculate the velocity of ultrasonic waves (v) in the liquid. The frequency of the ultrasonic waves produced by the transducer is 2 MHz.

Soln → Given :- $\lambda = 6000\,A^\circ = 6000 \times 10^{-10}\,m$

$\theta = 0.046^\circ$

$n = 1$, $f = 2\,MHz = 2 \times 10^6\,Hz$

$v = ?$

$$v = f \cdot \lambda_u$$

$$= f \times \frac{2n\lambda}{\sin\theta}$$

$$= 2 \times 10^6 \times \frac{2 \times 1 \times 6000 \times 10^{-10}}{\sin 0.046^\circ}$$

$$= \frac{2.4}{0.0285 \times 10^{-4}}$$

$$\boxed{v = 2989.34\ m/s}$$

Date
Page

Prob. 5) An ultrasonic source of 0.07 MHz sends down a pulse towards the seabed, which returns after 0.65 s. The velocity of sound in seawater is 1700 m/s. Calculate the depth of sea and wavelength of pulse.

Soln:- $v = 1700\ m/s$, $f = 0.07\ MHz$
$= 0.07 \times 10^6\ Hz$
$t = 0.65\ s$
$l = ?$ $\lambda = ?$

i) Depth of sea $l = \frac{vt}{2}$

$$= \frac{1700 \times 0.65}{2}$$

$$\boxed{l = 552.5\ m}$$

ii) Wavelength of the pulse λ

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

$$= \frac{1700}{0.07 \times 10^6}$$

$$\lambda = 0.024\ m$$

$$\boxed{\lambda = 24\ mm}$$