B.Sc. SEMESTER – I
PHYSICS COURSE: US01CPHY01
UNIT – 4 SOUND II

Doppler Effect

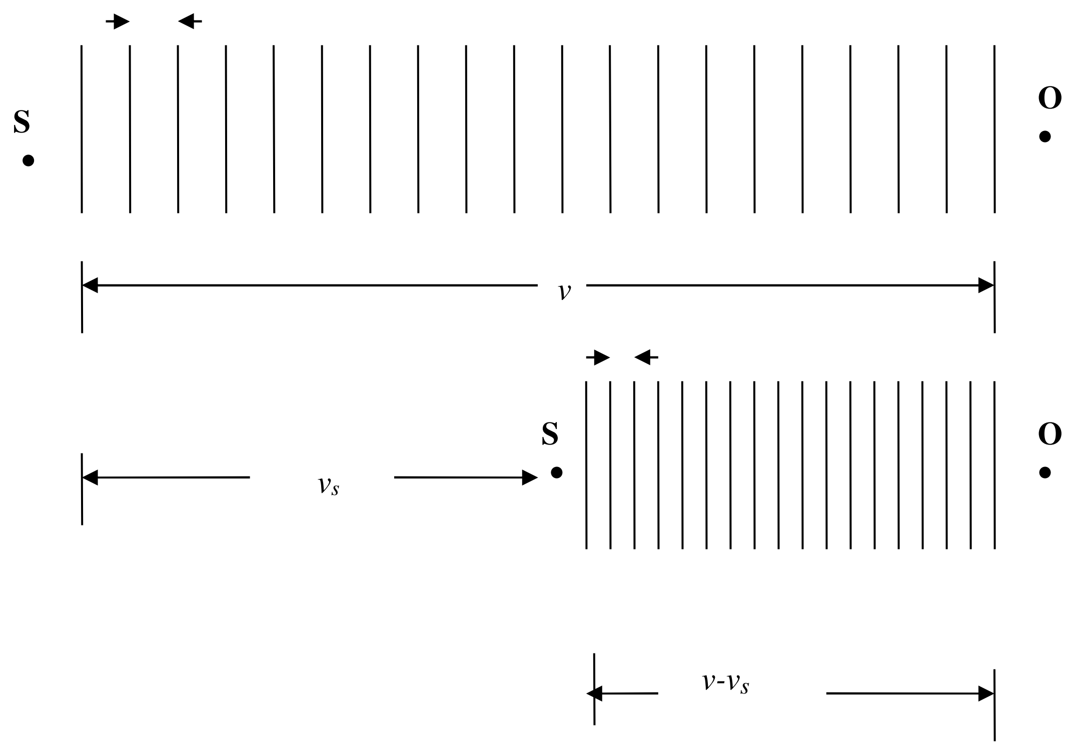
Introduction:
It is our common experience that when there is a relative motion between an observer and source of sound, the pitch (frequency) of the sound appears to change (e.g., an observer standing on the platform observes that the pitch of note of a whistling engine approaching him is higher than its true pitch while lowered when the engine recedes away from him).The apparent change in pitch, when there is relative motion between source and observer, was first investigated by C. Doppler in 1842 and is known as Doppler's principle after his name.

Doppler Effect: It is the apparent change in the pitch of a note due to relative motion between observer and source of sound.

Consider the following cases:

(1) Source in motion and observer at rest:

Let S and O are the relative positions of sound and observer in the beginning as shown in the figure.



Let,

ν = velocity of sound

n = true frequency of source
v_1 =velocity of the source

When the source is stationary, then the number of waves received by the observer per sec. is n. As v is the velocity of sound wave, the actual wavelength λ is

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

When the source moves towards observer, the first vibration is emitted at its first position which has reached a distance v in one second while the n^{th} vibration is emitted at a distance v_s, because in one second, the observer has also moved a distance v_s. in this way all the n^{th} vibrations are now confined in a distance $v-v_s$ as shown in the figure.
The apparent wavelength is given by

$$\lambda_1 = \frac{v - v_s}{n}$$

The apparent frequency is given by,

$$n_1 = \frac{v}{\lambda_1} = \frac{v}{(v - v_s)/n}$$

$$= \frac{vn}{v - v_s} \qquad (1)$$

Since the denominator is less than the numerator, the new frequency n_1 is greater than the original frequency n.

If the source is moving away from the observer, the apparent wavelength λ'_1 is given by

$$\lambda'_1 = \frac{v + v_s}{n}$$

The apparent frequency is given by,

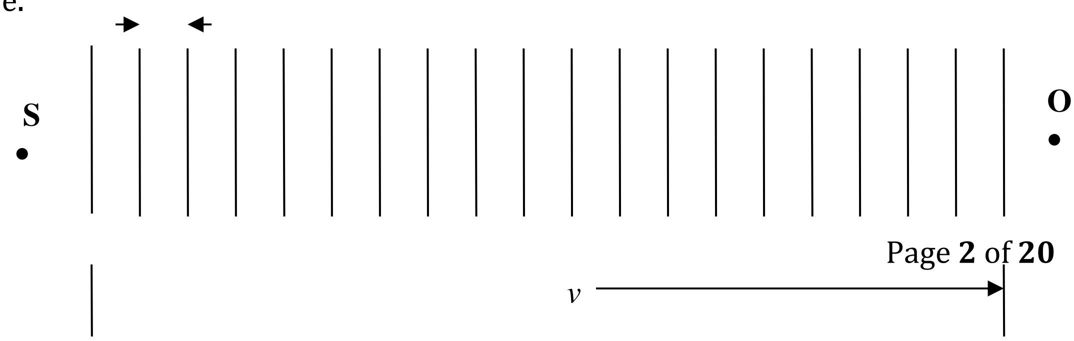
$$n_1 = \frac{v}{\lambda_1} = \frac{v}{(v + v_s)/n}$$

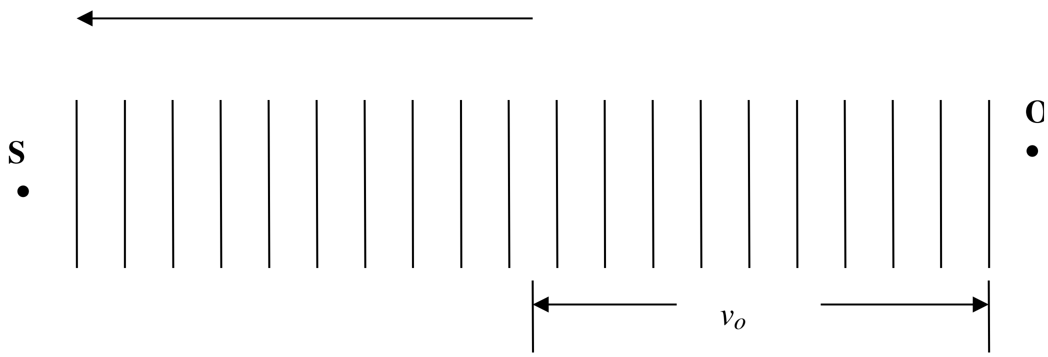
$$= \frac{vn}{v + v_s} \qquad (2)$$

This equation shows that $n_1 < n$ i.e. the apparent frequency is decreased.

(2) Observer in motion, source at rest:

Let S and O are the relative positions of sound and observer in the beginning as shown in the figure.





Let,
v = velocity of sound
n = true frequency of source
v_o= velocity of the observer

As v is the velocity of sound wave hence the actual wavelength λ is

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

When the observer starts moving towards the source, he covers distance v_o in one second.
Hence the number of vibrations received by him = n+(number of vibrations confined in a distance v_o).

$\therefore$ The number of vibrations confined in distance v_o is given by $\frac{v_o}{\lambda} = \frac{v_o}{v/n} = \frac{v_o n}{v}$

$\therefore$ Number of additional waves = $\frac{v_o n}{v}$

$\therefore$ Total number of vibrations received = $n + \frac{v_o n}{v}$

Hence the apparent frequency n_2 is given by

$$n_2 = n + \frac{v_o n}{v}$$

From above equation it clear that n_2 is greater than n i.e. **the apparent frequency is increased.**

If the observer moves away from the stationary source, the apparent frequency n_2' is given by

$$n_2' = n - \frac{v_o n}{v} = \frac{(v - v_o)n}{v}$$

i.e. n_2' is less than n i.e. **the apparent frequency is decreased.**

(3) Source and observer both in motion:

When observer is at rest and source is moving towards observer, the apparent frequency n_1 is given by

$$n_1 = \frac{v\,n}{v - v_s} \qquad (1)$$

Where, v = velocity of sound

v_s = the velocity of source and

n = the actual frequency of sound.

When the observer is also moving away from the source with velocity v_o, then apparent frequency is given by

$$n_3 = n_1 \frac{(v - v_o)}{v} \qquad (2)$$

Substituting the value of n_1 we have

$$n_3 = \frac{v\,n}{v - v_s}\, x \,\frac{(v - v_o)}{v}$$

$$n_3 = \frac{(v - v_o)\,n}{v - v_s} \qquad (3)$$

If the observer is moving towards the source

$$n_3' = n_1 \frac{(v + v_o)}{v}$$

Substituting the value of n_1 we have

$$n_3' = \frac{v\,n}{v - v_s}\, x \,\frac{(v + v_o)}{v}$$

$$n_3' = \frac{(v+v_o)\,n}{v-v_s} \qquad (4)$$

The above equation shows that the **apparent frequency will increase.**

Effect of wind:

If the wind blows with velocity w in the direction of sound, then the sound wave covers a distance (v+w) instead of v in one second. If wind blows in the opposite direction of sound then the sound wave covers a distance (v-w) instead of v in one second.

Using equations of the apparent frequency when source and observer both are moving the effect of wind can be estimated. Consider,

(1) When observer is moving away form the source and wind blows in the direction of sound

$$n_4 = \frac{(v+\mathrm{w}-v_o)\,n}{(v+\mathrm{w}-v_s)}$$

(2) When observer is moving away from the source and wind blows in the opposite direction of sound

$$n_4' = \frac{(v-\mathrm{w}-v_o)\,n}{(v-\mathrm{w}-v_s)}$$

(3) When observer is moving towards the source and wind blows in the direction of sound

$$n_5 = \frac{(v+\mathrm{w}+v_o)\,n}{(v+\mathrm{w}-v_s)}$$

(4) When observer is moving towards the source and wind blows in the opposite direction of sound

$$n_5' = \frac{(v-\mathrm{w}-v_o)\,n}{(v-\mathrm{w}-v_s)}$$

Applications of Doppler's principle:

(1) In estimating the speed of distant stars and planets:

Doppler's effect is very much important in determining the velocity of heavenly bodies (e.g. planets and stars) which are moving away or moving towards the earth.

We know that when a source of light moves towards the observer, the frequency of light increases (i.e. wavelength decreases) and vice versa. When the star moves towards the earth, the spectral lines seen by spectrometer are shifted towards the shorter wavelength i.e. blue end of the spectrum. On the other hand, when the stars move away from the earth, the lines are shifted towards the red end.

By measuring the shift the velocity can be calculated as shown below.

Let, a star is moving away with a velocity ν with respect to the earth.

Now, from the Doppler's principle, the altered frequency n' is given by

$$n' = \frac{c\,n}{c - v_s}$$

Where c= velocity of light and *n* = true frequency of light waves.

If λ and λ' are true and altered wavelengths respectively

$$n = \frac{c}{\lambda} \text{ and } n' = \frac{c}{\lambda'}$$

$$\frac{c}{\lambda'} = \frac{c}{(c+v)} x \frac{c}{\lambda}$$ (. . when source is in motion $n' = \frac{v\,n}{v + v_s}$)

$$\frac{\lambda'}{\lambda} = \frac{c}{(c+v)} = 1 + \frac{v}{c}$$

$$\frac{\lambda' - \lambda}{\lambda} = \frac{d\lambda}{\lambda} = \frac{v}{c}$$

The change in wavelength

$$d\lambda = \lambda \frac{v}{c}$$

Thus knowing the change in wavelength ν can be calculated.

(1) To estimate the velocities of moving aeroplane and submarine:

When the radar waves are sent towards a moving aeroplane they are reflected back and are received by the radar. If the wavelength of the reflected waves is decreased, it means that the aeroplane is moving towards the radar. If the wavelength of the reflected wave is increased, it indicates that the aeroplane is moving away from the radar.

The above method can also be applied to submarines moving under the water.

Thus by noting the change in wavelength, the velocities of aeroplanes and submarines can be calculated.

Musical Sound & Noise: Sounds roughly classified as musical sounds or noises.

Musical Sounds (Def^n): Sounds producing pleasant effects on ears are called musical sounds.

Noises (Def^n): Sounds producing unpleasant effects (or jarring) on ears are called noises.

Differences between musical sounds and noises:

	Musical Sound	Noises
1	They produce pleasant effects on ears.	They produce unpleasant (or jarring) effects on ears.
2	They have regularity in their waves.	They have irregularity in their waves.
3	They have definite periodicity in their waves.	They have not definite periodicity in their waves.
4	In musical sounds there are no sudden changes in their amplitude of waves.	In noises there are sudden changes in their amplitude of waves.

Characteristics of Musical Sound: Musical sounds are characterized by the following factors;
(i) Pitch or frequency,
(ii) Loudness,
(iii) Quality.

(i) **Pitch or Frequency**: Pitch is a physiological quantity. It is a sensation conveyed to our brain by the sound waves falling on the ears. It is a characteristic of sound which differentiates between shrill sound and grave sound. It directly depends upon frequency.
Higher the frequency higher is the pitch.
-Frequency of a note is a physical quantity which can be measured accurately while pitch is merely a mental sensation feeling by an observer.

(ii) **Loudness** (Def$^{n.}$): It is degree of sensation produced on the ears.
-It is expressed in terms of intensity of sound through Weber and Fachner relation;

$$\mathbf{L = K\log I}$$

Where,

L = loudness, K = constant, I = intensity of sound.

- Here intensity of sound is the amount of energy of sound wave crossing per unit time a unit crossection area which is perpendicular to the direction of propagation of sound waves.

(iii) **Quality** (Def^n): This characteristic of sound enables one to distinguish between the same notes produced by different musical instruments or voices even though they have the same pitch and loudness.

- e.g. If a same note is produced by a violin and a piano by two musician, one will definitely feel some difference between them due to difference in their quality.
- Quality of sound produced by any two instruments producing the same note is different due to associated harmonics with fundamental frequency. These associated harmonics are the characteristics of a musical instrument.

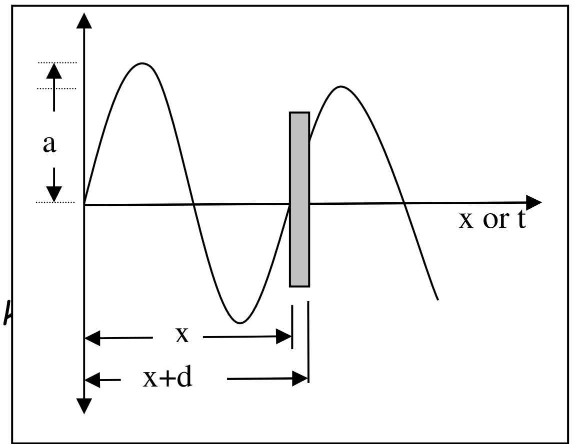
<u>Intensity of Sound</u> (Def^n): It is an average rate of acoustic (sound) energy crossing unit area which is perpendicular to the direction of propagation of the sound waves.

- It is purely a physical quantity and can be measured accurately.
- Intensity of sound is directly proportional to;

(i) Square of amplitude of sound wave,
(ii) Square of frequency,
(iii) Density of the medium,
(iv) Velocity of sound wave in medium,
(v) Size of vibrating body.

It is inversely proportional to the square of the distance of the sound origin.

Derivation of Intensity of Sound:



Let us consider a plane progressive sound wave traveling along x-axis with a velocity v. A simple harmonic wave can be represented by an equation,

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

Where,

y = displacement at time t

a = amplitude

x = position

$\omega = 2\pi n = \frac{\quad}{T}$; (Where, n = frequency, T = time period)

t = time;

$(kx - \omega t)$ = phase

Now we can write,

$$y = -a\sin(\omega t - kx) \qquad (\because \sin(-\theta) = -\sin\theta)$$

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

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

We have,

$v = n\lambda$ (Where v = velocity)

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

$$\therefore \frac{1}{T} = \frac{v}{\lambda}$$

Substituting this value in equation (2)

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

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

Particle velocity is obtained by differentiating above equation w. r. t. time.

$$\therefore \frac{dy}{dt} = -a \cos\left[\frac{2\pi}{\lambda}(tv - x) \right]\left(\frac{2\pi v}{\lambda} \right)$$

Now consider a unit area perpendicular to the direction of propagation having thickness dx and a distance x from the origin. If ρ is the density of the medium then the mass in this unit area is;

$$m = \rho dx$$

The change in kinetic energy;

$$dK = \frac{1}{2} m v^2 = \frac{1}{2} \rho \, dx \, v^2$$

$$dK = \frac{1}{2} \rho \, dx \left(\frac{dy}{dt} \right)^2$$

$$dK = \frac{1}{2} \rho \, dx \left[-a \cos\left[\frac{2\pi}{\lambda}(tv - x) \right]\left(\frac{2\pi v}{\lambda} \right) \right]^2$$

$$dK = \frac{1}{2} \rho a^2 4\pi^2 \left(\frac{v}{\lambda} \right)^2 \cos^2\left(\frac{2\pi}{\lambda}(tv - x) \right) dx$$

But $v/\lambda = n$ = frequency

$$dK = 2\pi^2 \rho a^2 n^2 \cos^2\left(\frac{2\pi}{\lambda}(tv - x) \right) dx$$

Now the total energy

E = K + V

The change in total energy;

dE = dK + dV

But the change in potential energy is zero i.e. dV = 0

dE = maximum change in the kinetic energy

dE = $(dK)_{maximum}$

dK is maximum when cosine function in the expression of dK is equal to 1

$$dE = 2\pi^2 \rho a^2 n^2 dx$$

Total energy for the length from x = 0 to x = x

$$E = \int dE = \int_0^x \left(2\pi^2 a^2 n^2 \rho dx\right)$$

$$E = 2\pi^2 a^2 n^2 \rho \int_0^x dx$$

$$E = 2\pi^2 a^2 n^2 \rho [x]_0^x = 2\pi^2 a^2 n^2 \rho x$$

But $$I = \frac{E}{At} = \frac{E}{t}$$

$$I = \frac{E}{t} = 2\pi^2 a^2 n^2 \rho \frac{x}{t} \qquad (\because A = 1)$$

$$I = 2\pi^2 a^2 n^2 \rho\, v$$

The above relation shows that the intensity is directly proportional to

(1) square of the frequency of the sound wave
(2) square of the amplitude of the sound wave
(3) density of the medium
(4) velocity of sound in that medium.

 # Measurement of intensity of sound:

Decibel:

The absolute intensity of sound wave is measured in terms of watt/m^2. Instead of measuring absolute intensity, it is the relative intensity which has more practical significance

The ratio of the intensity of sound wave to the standard intensity is defined as intensity level of sound.

Thus,

Intensity level of sound = Intensity (I)/Standard Intensity (I_0)

Where, $I_0 = 10^{-12}$ watt/m^2 and is called as threshold of audibility or threshold Intensity for sound wave of frequency 1000 Hz

The relation between loudness L and Intensity I is expressed as

$$L = k\log I$$

Let L_1 be the loudness of the sound Intensity I and L_2 the standard or zero loudness corresponding to standard or zero Intensity I_0 , then

$$L_1 = k \log I$$
$$L_2 = k \log I_0$$

Now, Intensity level L is the difference in loudness given by

$$L = L_1 - L_2 = k\log_{10} I - K\log_{10} I_0$$

$$= k\log_{10}(I/Io)$$

This relation is true for all frequencies. The loudness is measured in bel

if $k = 1$ and $I/I_0 = 10$ Then

$L = 1 * \log_{10} [10] = 1$bel

if $k = 10$ and $I/I_0 = 10$, then

$L = 10 \log_{10}(10) = 10$ decibel(dB)

1 bel = 10 Decibel = 10 dB

In practice, bel is too large unit and hence decibel is generally used. **Decibel is (1/10) of a bel.**

When the Intensity of sound wave is equal to I_0 or 10^{-12} watt/m^2, then its Intensity level is regarded as zero level. **The maximum Intensity which the ear can tolerate without sensation of pain is about 120dB. This is the upper limit of hearing. This is called as threshold of feeling or pain threshold.**

Phon :

For the measurement of sound wave in decibel , it was assumed that zero Intensity level I_0 is same for sounds of all frequencies But it is not the actual case i.e. The sound of same Intensity but having different frequencies may differ in loudness . Hence, scientists have adopted standard sources of frequency 1000Hz with which all sounds are compared. This gives another unit for measuring loudness and is called as phon. The measure of loudness in Phon of any sound is equal to the loudness is decibel of any equally loud pure tone of frequency 1000 Hz.

Ultrasonic waves

The human ear can hear the sound waves between **20Hz to 20KHz**. This range is known as **audible range**. The sound waves which have frequencies less than 20Hz are called **infrasonic waves**.

The sound waves which have frequencies above the **20KHz** are called **Ultrasonic waves or supersonic waves.** Because of higher frequencies, wavelengths of ultrasonic waves are very small compared to audible sound. Due to the smaller wavelengths there are many applications of the ultrasonic waves.

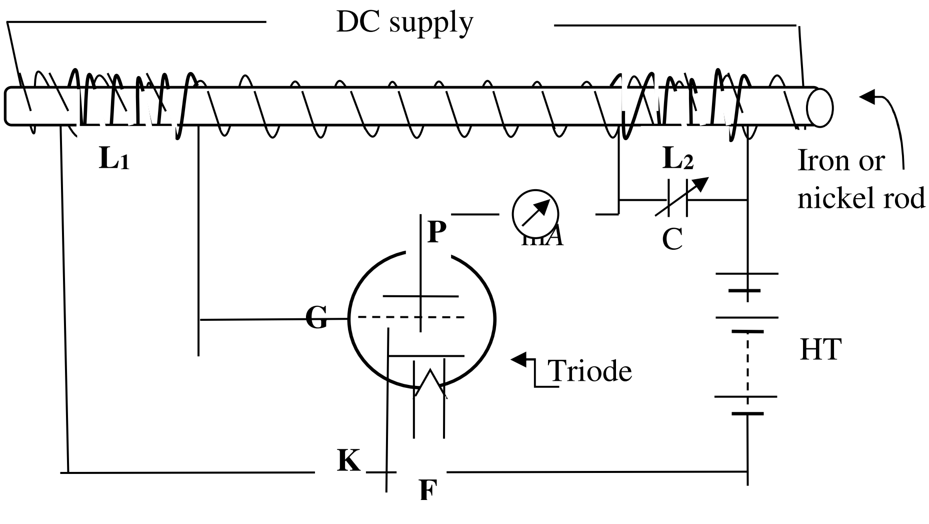
Production of ultrasonic waves:

The ultrasonic waves have very high frequencies hence it cannot be produced using loudspeaker because at higher frequencies the inductance of the loudspeaker's coil has very high reactance ($X_L = 2\pi fL$). So practically no current flows through the coil. Also diagraph of a speaker cannot vibrate at these higher frequencies. Hence other methods are used for the production of ultrasonic waves.

There are mainly two methods (i) Magnetostriction and (ii) Piezo electric method used for the production of ultrasonic waves. **Magnetostriction method is useful when frequencies up to 100 KHz are required. Piezo-electric method is useful when frequencies are higher than 100 KHz.**

(i) Magnetostriction method:

Principle: When a rod of **ferromagnetic material** (e.g. Nickel or Iron) is placed in the magnetic field parallel to its length a small extension or contraction occurs in its length. This change of length is independent of the sign of the field and depends on the magnitude of the field and nature of material.



Construction:

- A rod of ferromagnetic material (iron or nickel) is taken.
- This rod is clamped at the centre.
- A copper coil is wound (wrapped) on the rod through which dc current is passed. Due to this the rod gets permanently magnetized.
- Two other coils L_1 and L_2 are also wrapped on two opposite ends of the rod.

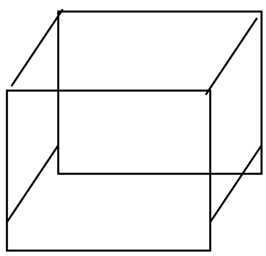
- The coil L_1 is connected in the grid circuit of the triode and the coil L_2 is connected to the plate circuit of the triode.
- A tank (resonant) circuit is formed by connecting a variable capacitor C parallel to the coil L_2.

Working:

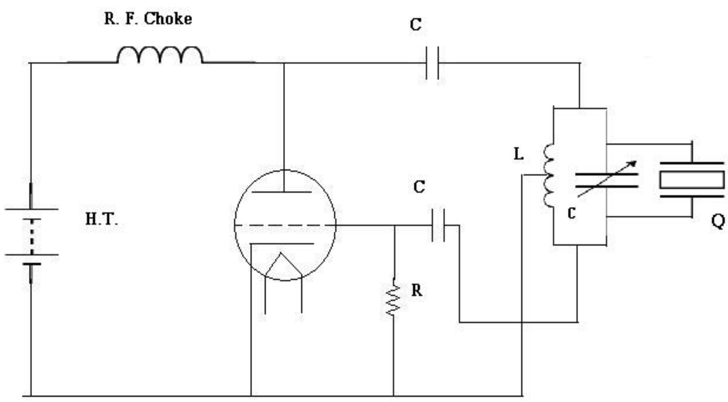
- When the circuit gets on, a current is passing through the coil L_2 due to which magnetization of the rod get changed (the rod is permanently magnetized by dc current). Hence there is variation of the length of the rod.
- Variation in the length of the rod causes the change in the magnetic flux linkage of the coil L_2. This induces e.m.f. in the coil L_1. This induced e.m.f. is applied to the grid which amplifies the plate current passing through the coil L_2. Thus the oscillations are maintained.
- Now the value of capacitor C' is adjusted such that the frequency $N = \frac{1}{2\pi\sqrt{L_2 C}}$ of the tank circuit becomes equal to the natural frequency "n" of the rod i. e. $n = N = \frac{1}{2\pi\sqrt{L_2 C}}$. Hence resonance occurs which is indicated by the maximum plate current read through milliammeter.
- By adjusting the length of the rod and value of capacitance C, high frequency oscillations of different frequencies are obtained.

Piezo-electric method:

Principle: when certain crystals like **quartz, Rochelle salt, tourmaline** etc. are stretched or compressed along certain axis (known as mechanical axis), an electric potential difference is produced along a perpendicular axis (known as electrical axis). The converse of this effect is also true i.e. when an alternating potential difference is applied along electric axis; the crystal is set into elastic vibration along mechanical axis. This effect is known as Piezo-electric effect.



Construction:



- Above figure shows experimental arrangement of piezo-electric oscillator.
- It consists of Hartley oscillator circuit.
- The tank circuit in the above oscillator circuit consists of parallel combination of centrally tapped inductor L_1 and variable capacitor C_1.
- A quartz crystal Q is connected in parallel to the variable capacitor C_1.
- One end of the tank circuit is connected to the grid circuit of the triode through grid capacitor C_g.
- Other end of the tank circuit is connected to the plate circuit of the triode through the blocking capacitor C_b.
- The positive terminal of high tension (H. T.) supply is connected to the plate P through RF(radio frequency) choke while the negative terminal of H. T. is connected to the cathode K.

Working:

- Grid resistor C_g and R_g provides proper biasing to the grid circuit.
- H. T. dc voltage is applied to the plate P through the RF choke which prevents high frequency current to reach the H. T. battery.
- The blocking capacitor C_b is used to block dc current and to pass only high frequency current.
- the frequency of the Hartley oscillator is set to the natural frequency of the quartz crystal Q with help of the variable capacitor C_1.
- Hence resonance is achieved and crystal is set into mechanical vibration with the maximum amplitude.
- **The Ultrasonic wave upto 500 KHz can be produced with moderate size quartz crystal using the above arrangement.**

- The Ultrasonic wave upto 150 MHz (15 x 10^7 Hz) can be produced with tourmaline crystal.

Derivation of expression for frequency:

When resonance is set up the velocity of quartz crystal along x-direction is given by

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

For material of quartz Y = 7.9 x 10^{10} N/m^2 and ρ= 2650 kg/m^3

$$v = \sqrt{\frac{7.9x10^{10}}{2650}}$$

= 5450 m/s.

If t is the thickness of quartz slab in meters, then

$$v = n\lambda = n(2t) \qquad \text{(Because } t = \lambda/2\text{)}$$

Where n is the frequency.

$$n = \frac{v}{2t} = \frac{5450}{2t} = \frac{2725}{t} Hz$$

If t is expressed in mm then

$$n = \frac{v}{2t} = \frac{5450}{2t} = \frac{2725000}{t} Hz \qquad \text{(Because 1m =1000mm)}$$

Or

$$n = \frac{v}{2t} = \frac{5450}{2t} = \frac{2725}{t} KHz$$

(If t= 1mm, n = 2725 KHz =2.725 MHz)

At the time of resonance the frequency of tank circuit is same as the frequency of natural frequency of vibration of quartz crystal. Thus

$$n = \frac{1}{2\pi\sqrt{L_1C_1}}$$ = frequency of quartz crystal = frequency of tank circuit

(Resonance can be established by adjusting variable capacitor C of the tank circuit).

Detection of Ultrasonic waves:
Ultrasonic sound can be detected by some animals like bat but human ear cannot detect it. So, alternate methods are used to detect ultrasonic sound.

(1) Piezo-electric detector: The quartz crystal can also be used for the detection of ultrasonic sound. One pair of faces of quartz crystal is subjected to ultrasonic sound. On the other perpendicular faces electric charges are produced and hence we get current. These current is amplified and then frequency of the current is determined which may be of the range of ultrasonic waves.

(2) Kundt's tube method: A Kundt's tube is used for the measurement of the velocity of audible sound. In a same way it can be used for the measurement of velocities of ultrasonic waves having longer wavelength. The ultrasonic sound passed through the tube, lycopodium powder collects in the form of heaps at the nodal points and displaced from the antinodes. So from the distance between the successive nodal points the velocity of ultrasound can be calculated.

(3) Sensitive flame method: When a sensitive flame is moved in a medium where ultrasonic waves are present, the flame remains stationary at anti nodes and flickers at nodes.

(4) Thermal detector method: When ultrasonic waves pass through the medium, the temperature of the medium changes due to alternate compression and rarefactions. The temperature remains constant at antinodes and it changes at the nodal points. When a fine platinum wire is moved in this medium, the resistance of the platinum wire with respect to time can be detected by using a sensitive bridge method. The bridge remains in the balanced condition when the platinum wire is at antinodes.

Properties of Ultrasonic Waves:

The properties of ultrasonic waves are listed as under,

(1) Because of higher frequency they are highly energetic ($E = hf$).

(2) The speed of propagation of ultrasonic waves is given by $v=\lambda f$. so it increases with increase in frequency.

(3) Because of higher frequency they have shorter wavelength. So they are not so much diffracted. Hence they can be transmitted up to long distance with negligible loss of energy.

(4) Intense ultrasonic radiation has a disruptive effect in liquids by causing bubbles to be formed.

(5) When ultrasonic waves are propagated in liquid bath, stationary wave pattern is formed. The density of the liquid thus varies from layer to layer along the direction of propagation. In this way a plane diffraction grating is formed which can diffract light.

Outline of the Applications of Ultrasonic waves:

(1) Detection of flaws (imperfections) in metals: Ultrasonic waves can be used to detect flaws in metal. When ultrasonic waves pass through a metal having a hole or crack or some imperfections inside it, an appreciable reflection occurs. The reflections also take place from back surface of the metal. When we see these reflected waves on the C. R. O., it is possible to locate the position of flaws.

(2) Sonar (Detection of submarines, Iceberg and other objects in Ocean): It is possible to determine the presence of the submarine under the water or an enemy air craft by a system known as Sonar. Sonar is a device which stands for Sound Navigation and Ranging. In this system a sharp ultrasonic beam is directed in various directions into the sea. When there is some object in sea these beams are reflected. The time interval between generation of ultrasonic beam and reflected beam gives the idea of the distance of the object. The change in the frequency of the echo signal due to Doppler Effect helps to determine the velocity of the object and its direction.

(3) Depth of sea: To find out the depth of the sea, the time interval between sending the wave and the reflected wave from the sea is recorded. As the velocity of the wave is known, hence the depth of the sea can be estimated.

$\therefore$ Depth of the sea = $v\,t/2$

(4) Cleaning and clearing: ultrasonic waves can be used for cleaning utensils, washing cloths, removing dust and soot from the chimney.

(5) Directional signaling: the Ultrasonic waves can be concentrated into a sharp beam due to smaller wavelength and hence can be used for signaling in a particular direction.

(6) Soldering and metal cutting: Ultrasonic waves can be used for drilling and cutting processes in metals. These waves can also be used for soldering. e.g. aluminum can not be soldered by normal methods. To solder aluminum ultrasonic wave along with electrical soldering iron is used. Also, ultrasonic welding can be done at room temperature.

(7) Formation of alloys: The constituents of alloys having widely different densities can be mixed uniformly by a beam of ultrasonic. Thus it possible to have alloy of uniform composition.

(8) Ultrasonic mixing: A colloidal solution or emulsion of two non-miscible liquids like oil and water can be formed by simultaneously subjecting to ultrasonic radiations. Now-a-days most of the emulsions like polishes, paints, food products and pharmaceutical preparations are prepared by using ultrasonic mixing.

(9) Coagulation and crystallization: The particles of suspended liquids can be brought quite close to each other by ultrasonic so that coagulation may take place. The crystallization rate is also affected by ultrasonic. When molten metal is put to crystallization, the size of crystals can be made smaller and more uniform by the use of ultrasonic.

(10) Ultrasonics in metallurgy: Ultrasonic waves are used to irradiate molten metals which are in the process of cooling. This is required to refine grain size and to prevent the formation of cores and to release trapped gases.

(11) Destruction of lower life: The animals like rats, frogs, fishes etc. can be killed or injured by high intensity ultrasonic.

(12) Treatment of neuralgic pain: The body parts affected due to neuralgic or rheumatic pains get great relief from pain when they are exposed to ultrasonic.

(13) Detection of abnormal growth: Abnormal growth in the brain, certain tumours which cannot be detected by X-ray can be detected by ultrasonic waves.

Question Bank

MULTIPLE CHOICE QUESTIONS:

1. Ultrasonic waves are
(a) Longitudinal waves (b) Progressive wave
(c) Transverse waves (d) Inverse waves

2. Ultrasonic waves are
(a) Mechanical waves (b) Progressive wave
(c) Transverse waves (d) Non-mechanical waves

3. Ultrasonic waves can have frequency
(a) < 20 Hz (b) **> 20 KHz** (c) < 20 KHz (d) none of these

4. Ultrasonic waves move faster than the sound waves. The sentence is
(a) True (b) False (c) Irrelevant (d) none of these

5. Ultrasonic waves move with the same velocity as the sound waves. The statement is

(a) True **(b) False** (c) Irrelevant (d) none of these

6. Ultrasonic waves are also called
(a) Super Position Waves (b) SONAR waves
(c) Super Sonic Waves (d) none of these

7. In the phenomenon of Magnetostriction the length of the ferromagnetic rod
(a) increases (b) decreases **(c) changes** (d) none of these

8. Which one of the following materials is not a Piezo-electric material?
(a) Quartz (b) Tourmaline (c) Rochelle Salt **(d) Aluminum**

9. The speed of ultrasonic waves in a solid medium depends upon
(a) length (b) height (c) volume **(d) density**

10. Ultrasonic waves can be transmitted over long distances without any appreciable loss of energy because of their
(a) variable wavelength **(b) small wavelength**
(c) medium wavelength (d) large wavelength

11. In a liquid bath, ultrasonic waves make a
(a) plane diffraction prism (b) plane reflection prism
(c) plane diffraction grating (d) plane reflection grating

12. Ultrasonic waves produce
(a) interference in liquids (b) diffraction in liquids
(c) non-destructive effects in liquids
(d) disruptive effects in liquids

13. The sound which creates a pleasing effect on the ear is called
(a) noisy sound (b) noisy voice
(c) musical sound (d) musical voice

14. Which of the following is **not** a characteristic property of a musical sound
(a) pitch (b) loudness **(c) amplification** (d) quality

15. Pitch of sound is a
(a) psychological quantity (b) illogical quantity
(c) phenomenal quantity **(d) physiological quantity**

16. The relation between the loudness and the intensity is expressed as
(a) $L = k / \log I$ **(b) $L = k \log I$**
(c) $L = k + \log I$ (d) $L = k - \log I$

17. The intensity of sound is given by the expression
(a) $I = 2\pi^3 a^2 n^2 \rho v$ **(b) $I = 2\pi^2 a^2 n^2 \rho v$**
(c) $I = 2\pi^2 a^3 n^2 \rho v$ (d) $I = 2\pi^2 a^2 n^3 \rho v$

18. The threshold of audibility I_0 has the value

(a) 10^{+12} watt/m^2 (b) 10^{-12} watt/m
(c) 10^{-12} watt/m^2 (d) 10^{-12} watt^2/m^2

19. 1 bel is equal to
(a) 10 decibel (b) 1 decibel (c) 100 decibel (d) 1000 decibel

20. Phon is the unit of measurement of
(a) loudness of sound (b) amplitude of sound
(c) intensity of sound (d) phase of sound

21. In case of a sound source moving away from a stationary observer, the apparent frequency is
(a) increased (b)halved (c) doubled **(d) decreased**

22. In case of a sound source moving towards a stationary observer, the apparent frequency is
(a) increased (b)halved
(c) doubled (d) decreased

23. The relation between velocity, frequency and wavelength of a wave v is
(a) λ/f (b) f/λ **(c) λf** (d) $\lambda + f$

24. The velocity of sound in air at 0 ^{o}C temperature is
(a) 330 m/s (b) 331.6 m/s (c) 280 m/s **(d) 332 m/s**

SHORT QUESTIONS:

(1) Explain the phenomenon of Magnetostriction.
(2) Explain the phenomenon of piezo-electric effect.
(3) Enlist any four properties of ultrasonic waves.
(4) Enlist any four applications of ultrasonic waves.
(5) Enlist the various methods of detection of ultrasonic waves.
(6) Explain the musical sound and noise.
(7) Write a short note on the Pitch of musical sound.
(8) Write a short note on the Loudness of musical sound.
(9) Write a short note on the Quality of musical sound.
(10) Write a short note on Phon.

LONG QUESTIONS:

(1) With the help of necessary figures, explain the phenomenon of megnetostriction and discuss the megnetostriction method of production of ultrasonic waves in detail.
(2) Explain piezo-electric effect. Discuss the piezo-electric method of production of ultrasonic waves with the help of necessary figures and equations.
(3) Write a note on detection of ultrasonic waves in detail.
(4) Give a detailed account of properties of ultrasonic waves.
(5) Discuss the various applications of ultrasonic waves in detail.
(6) Write a detailed note on the characteristics of musical sound.
(7) Derive the expression for the intensity of sound waves at a point in a medium.
(8) What is Doppler's effect? Derive the formula for the apparent pitch of a note when the source is moving and the observer is at rest.

(9) What is Doppler's effect? Derive the formula for the apparent pitch of a note when the observer is moving and the source is at rest.
(10) What is Doppler's effect? Derive the formula for the apparent pitch of a note when the source and the observer both are moving.
(11) State and explain Doppler's effect. Deduce an expression for the change in frequency of a note due to the relative motion of the source and observer.