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RECAP

UNIT – V: Acoustic Applications

Paper Title : Acoustics
Code :17UPH3C5

Date: 28-07-2020
Time : 12.00 noon. – 12.50 p.m.
Mode of Teaching: Online (Microsoft Teams)

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PRODUCTION OF ULTRASONIC WAVES

Paper Title : Acoustics
Code :17UPH3C5

Date: 15-07-2020
Time : 11.45 a.m. - 12.45 p.m.
Mode of Teaching: Online (Microsoft Teams)

UNIT - I Sound and Harmonic Oscillators (12 hours)

Wave motion-- #characteristics of wave motion# – Transverse wave motion – Longitudinal wave motion – Definitions- Relation between frequency and wavelength - Properties of Longitudinal Progressive Waves – Simple harmonic motion – differential equation of SHM – Energy of vibration – Linearity and superposition principle – Simple pendulum – Compound Pendulum- Bar pendulum.

UNIT - II Lissajou's Figures (12 hours)

Lissajou's figures – composition of two SHM in a straight line – composition of two simple harmonic vibrations of equal time periods acting at right angles – composition of two SHM at right angles to each other and having time periods in the ratio 1:2 – Experimental methods for obtaining Lissajou's figures – Uses of Lissajou's figures.

UNIT - III Velocity of Sound (12 hours) Origin of sound - Velocity of longitudinal waves in gases – Newton's formula for velocity of sound in an effect of temperature – experiment - velocity of sound in water – effect of pressure – effect of
density of the medium,humidity,wind – wave velocity and molecular velocity – Doppler effect – observer at rest and source in motion – #Source at rest and observer in motion# – when both the source and the observer are in motion.

UNIT - IV Vibrations in strings and Air Columns (12 hours)

Laws of transverse vibration of strings – verification of laws of transverse vibration of strings Melde's experiment – Vibration of air column- resonance – velocity of sound in Air by Resonance method – Velocity of sound in solids - Kundt's tube – Characteristics of musical sound- Intensity of sound-Decibel and Phone – Bell – musical scale.

UNIT - V Acoustic Applications (12 hours)

Acoustics – Reverberation – Reverberation time - Sabine's reverberation formula -- Factors affecting the acoustics of the buildings- Conditions for good acoustics – Ultrasonics- Properties- Production of ultrasonic waves – magnetostriction oscillator – Piezo electric oscillator – #Applications of ultrasonic waves#.

https://www.jmc.edu/include/department/physics/syllabus/UG2017.pdf

What is a Sound Wave?

*Sound waves are mechanical waves produced by mechanical vibrations. For an example, when your phone rings, it vibrates its surrounding, generating compression and rarefaction in the air. These compression and rarefaction propagate through air. When they reach our eardrum, they cause the eardrum to vibrate; this is what we perceive as a sound. They require a material medium for the propagation as they are mechanical waves. Therefore, sound waves cannot travel through a vacuum.
Sound waves propagate through air, liquids, and plasma as longitudinal waves. In solids, on the other hand, sound waves can propagate as both longitudinal waves and transverse waves. Anyhow the speed of sound depends on the material properties.

*Sound waves are classified into three bands as below.
Infrasound – Frequencies below 20Hz
Audible sound – Frequencies between 20Hz and 20000Hz
Ultrasound – Frequencies above 20000Hz

SOUND WAVES
VERSUS
ELECTROMAGNETIC WAVES

Sound waves are produced by mechanical vibrations.	EM waves are produced by accelerating (or decelerating) charged particles.
Sound waves are created by musical instruments, speakers, tuning forks, etc.	EM waves are created in Current carrying wires, blackbody radiation.
Sound cannot propagate through a vacuum.	EM waves travels with the speed of ms−1 .
Speed of sound in air increases with the temperature.	Speed of EM waves in air is slightly slower than that of in a vacuum.
Longitudinal sound waves aren't polarizable.	EM waves are Polarizable.
Sound waves cannot excite atoms.	EM waves can excite atoms.
Sound waves produce hearing.	EM waves produces seeing.

Pediaa.com

INTRODUCTION

The human ear is sensitive to sound waves in the frequency range from 20 to 20,000 Hz. This range is called audible range. Sound waves of frequency more than 20,000 Hz are called ultrasonics.

These frequencies are beyond the audible limit.

These waves also travel with the speed of sound (330 ms -1).

These waves exhibit the properties of audible sound waves and also show some new phenomena.

Their wavelengths are small.

PROPERTIES OF ULTRASONIC WAVES

1. They have a high energy content.

2. Just like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.

3. They show negligible diffraction due to their small wavelength. Hence they can be transmitted over long distances without any appreciable loss of energy.

4. They produce intense heating effect when passed through a substance.

5. If an arrangement is made to form stationary waves of ultrasounds in a liquid, it serves as a diffraction grating. It is called an acoustic grating.

APPLICATIONS

Investigation of Structure of Matter, Study of Molecular Energies, Elastic Symmetry of Crystals
Industrial Applications, Non-Destrucive Testing, Ultrasonic Soldering, Welding, Drilling and Cutting
Formation of Alloys, Acoustic Holograms etc.,

Sound Navigation and Ranging(SONAR) The method is used for finding the distance and direction of a submarine.

Medical Applications

1.Disease treatment. Ultrasonic therapy can be used to treat diseases like bursites, abscesses, neuralgic and rheumatic pains etc.

2. Surgical use. Kidney stones and brain tumours can be removed without shedding any blood using ultrasonic waves. Also, any tissue in our body can be cut selectively during an operation using ultrasonics.

3. Diagnostic use. Ultrasonics are used for detecting tumours and other defects in human body. State of breast cancer can be identified using ultrasonics in a non-destructive manner.

4. Extraction of broken teeth. Dentists use ultrasonic waves to properly extract broken teeth.

5. Sterilization. Ultrasonic waves can kill bacteria. Therefore, they are used for sterilizing milk.

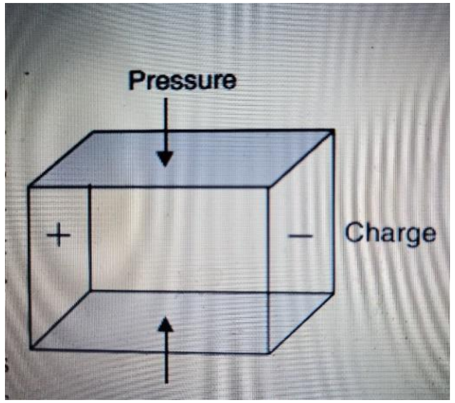
PRODUCTION OF ULTRASONIC WAVES

1. PIEZO-ELECTRIC METHOD
2. MAGNETOSTRICTION METHOD (Principle: When a rod of ferromagnetic material like nickel is magnetized longitudinally, it undergoes a very small change in length. This is called magnetostriction effect.)

PIEZOELECTRIC EFFECT

If one pair of opposite faces of a quartz crystal is subjected to pressure, the other pair of opposite faces develop equal and opposite electric charges on them (Fig.).The electric charge developed is proportional to the amount of pressure or tension. This phenomenon is called Piezoelectric effect.

The effect is reversible i.e., if an electric field is applied across one pair of faces of the crystal, contraction or expansion occurs across the other pair.



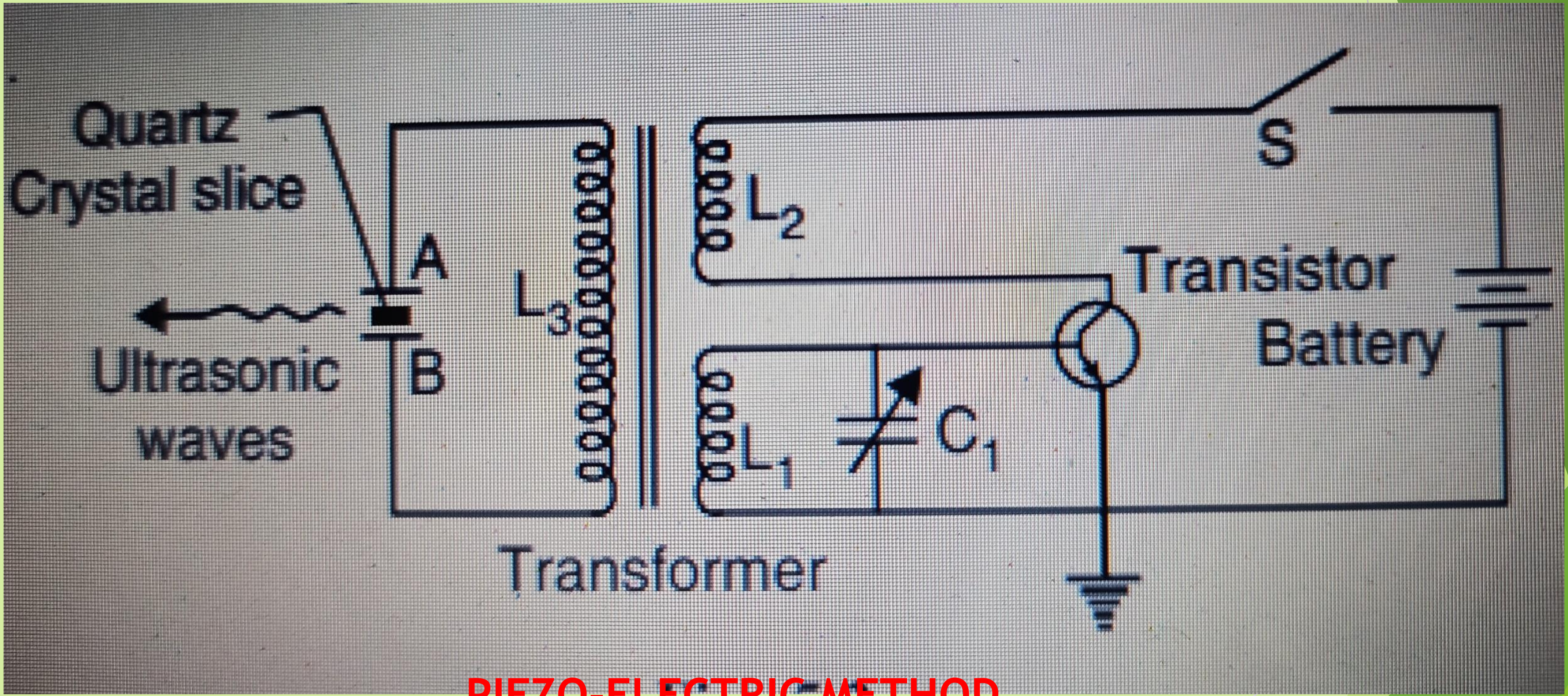
Concept

When the two opposite faces of a quartz crystal, their faces being cut perpendicular to the optic axis, are subjected to alternating voltage, the other pair of opposite faces experiences stresses and strains.

The quartz crystal will continuously contract and expand. Elastic vibrations are set up in the crystal.

When the frequency of the alternating voltage is equal to the natural frequency of vibration of the crystal or its simple higher multiples, the crystal is thrown into resonant vibrations.

PIEZO-ELECTRIC METHOD



PIEZO-ELECTRIC METHOD

Principle

This is based on the inverse piezoelectric effect.

When a quartz crystal is subjected to an alternating potential difference along the electric axis, the crystal is set into elastic vibrations along its mechanical axis.

If the frequency of the electric oscillations coincides with the natural frequency of the crystal, the vibrations will be of large amplitude.

If the frequency of the electric field is in the ultrasonic frequency range, the crystal produces ultrasonic waves.

Construction: The circuit diagram is shown in Fig.

Consider a X-cut crystal plate of thickness t. The fundamental frequency of vibration is given by

$$1/2t \sqrt{E}/\rho$$

E is the Young’s modulus and □ is the density of the material of the crystal plate.

Construction:

The circuit diagram is shown in Fig.

It is a base tuned oscillator circuit. A slice of quartz crystal is placed between the metal plates A and B so as to form a parallel plate capacitor with the crystal as the dielectric. This is coupled to the electronic oscillator through primary coil L3 of the transformer. Coils L2 and L1 of oscillator circuit are taken from the secondary of the transformer. The collector coil L2 is inductively coupled to base coil L1. The coil L1 and variable capacitor C1 form the tank circuit of the oscillator.

Working:

When the battery is switched on, the oscillator produces high frequency oscillations. An oscillatory e.m.f. is induced in the coil L3 due to transformer action. So the crystal is now under high frequency alternating voltage. The capacitance of C1 is varied so that the frequency of oscillations produced is in resonance with the natural frequency of the crystal. Now the crystal vibrates with large amplitude due to resonance. Thus high power ultrasonic waves are produced.

Advantages

1. Ultrasonic frequencies as high as 500 MHz can be generated.

2. The output power is very high. It is not affected by temperature and humidity.

3. It is more efficient than magnetostriction oscillator.

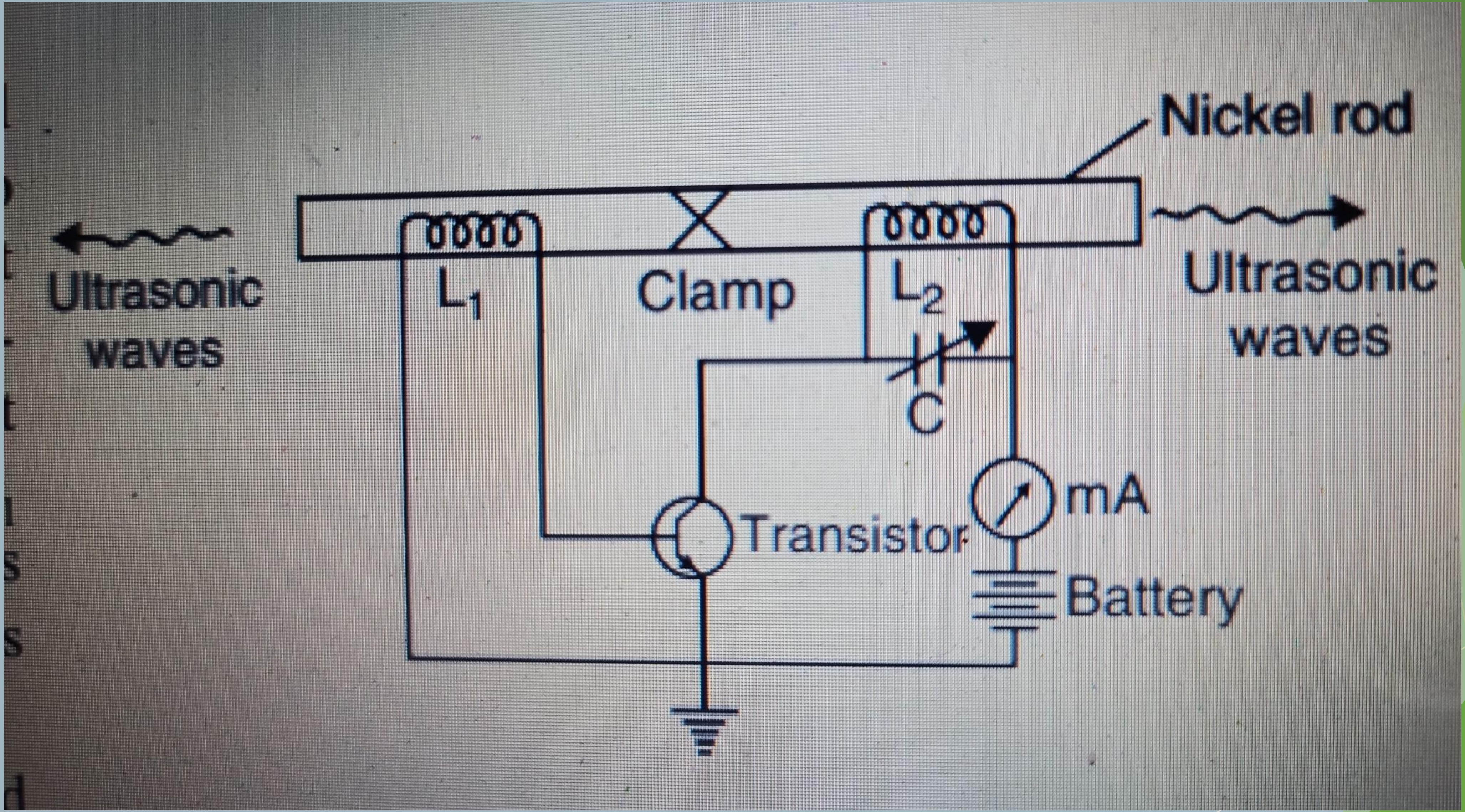
4. The breadth of the resonance curve is very small. So we can get a stable and constant frequency of ultrasonic waves.

Disadvantages

1. The cost of the Qurtz crystal is very high.

2. Cutting and shaping the crystal is very complex.

MAGNETOSTRICTION METHOD



MAGNETOSTRICTION METHOD

The circuit diagram of magnetostriction ultrasonic generator is shown in Fig.

Principle:

When a rod of ferromagnetic material like nickel is magnetised longitudinally, it undergoes a very small change in length. This is called magnetostriction effect.

A nickel rod placed in a rapidly varying magnetic field alternately expands and contracts with twice the frequency of the applied magnetic field. By adjusting the frequency of the alternating magnetic field to be equal to the natural frequency of longitudinal vibration of the rod, resonance is produced. Due to resonance, vibrations of large amplitude are produced in the rod. Ultrasonic waves are emitted from the ends of the rod if the frequency of the alternating magnetic field is more than 20 kHz. The frequency of vibrations of the rod is

$$1/2t\ \sqrt{E}/\rho$$

Here, l = length of the rod, E = Young's modulus of the material of the rod, ρ = density of the material of the rod.

Construction:

The circuit diagram of magnetostriction ultrasonic generator is shown in Fig. A short permanently magnetised nickel rod is clamped in the middle between two knife edges. A coil L2 is wound on the right hand portion of the rod. C is a variable capacitor. L2 and C form the resonant circuit of the collector tuned oscillator. Coil L1 wound on the left hand portion of the rod is connected in the base circuit. The coil L1 is used as a feedback loop.

Working:

When the battery is switched on, the resonant circuit L2C sets up an alternating current of frequency,

$$f = 1/2\pi\sqrt{L2C}$$

This current flowing round the coil L2 produces an alternating magnetic field of frequency f along the length of the nickel rod. The rod starts vibrating due to magnetostrictive effect. The vibrations of the rod create ultrasonic waves. The longitudinal expansion and contraction of the rod produces an e.m.f. in the coil L1. This e.m.f. is applied to the base of the transistor. Hence the amplitude of high frequency oscillations in coil L2 is increased due to positive feedback.

The developed alternating current frequency can be tuned with the natural frequency of the rod by adjusting the capacitor. The resonance condition is indicated by the rise in the collector current shown in the milliammeter.

Advantages

1. Magnetostriction oscillators are mechanically rugged.
2. The construction cost is low.
3. They are capable of producing large acoustical power with fairly good efficiency (e.g., 60%).

Limitations

1. It can produce frequencies upto 3 MHz only.
2. The frequency of oscillations depends greatly on temperature.
3. Breadth of the resonance curve is large. It is due to variations of elastic constants of ferromagnetic material with the degree of magnetisation. So we cannot get a constant single frequency.

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APPLICATIONS OF ULTRASONIC WAVES

Paper Title : Acoustics
Code :17UPH3C5

Date: 17-07-2020
Time : 10.30 a.m. – 11.30 a.m.
Mode of Teaching: Online (Microsoft Teams)

APPLICATIONS OF ULTRASONIC WAVES

Science

Investigation of Structure of Matter We can determine the velocity of ultrasonics in liquids and gases and its variation with frequency and temperature. This study gives information about a number of properties of the medium such as its compressibility, absorption, concentration, specific heat capacity, chemical structure, arrangement of atoms in them etc.

Study of Molecular Energies The frequencies of molecular vibrations are of the same order as the ultrasonic vibrations. So ultrasonic waves are used in the study of molecular energies. They are used in molecular acoustics for investigating structure and properties of substances.

Elastic Symmetries of Crystals When ultrasonic waves are applied to certain crystals, they give rise to diffraction images. The diffraction images reveal the elastic symmetries of crystals.

Industrial Applications

Non-Destructive Testing (NDT)

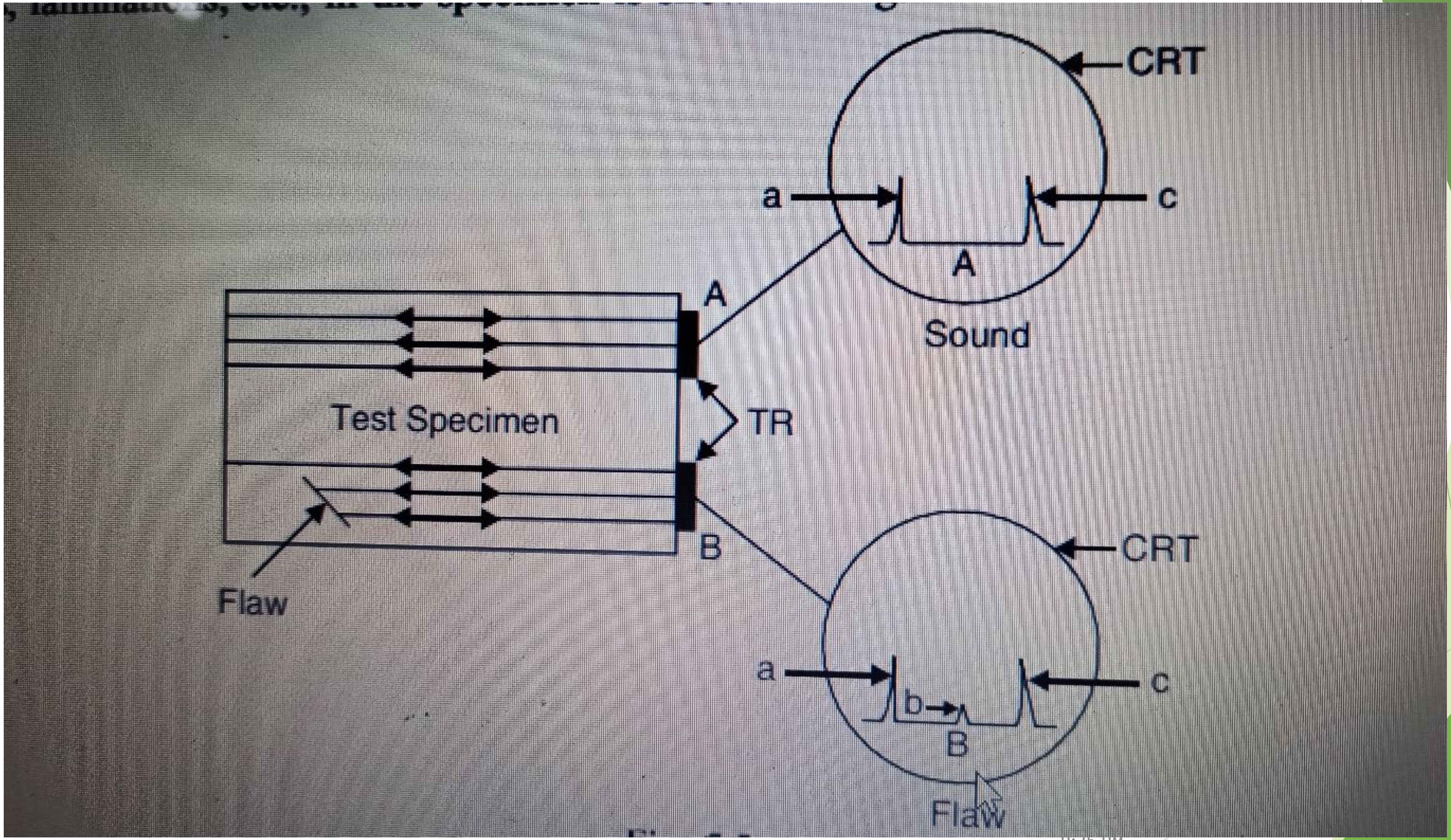
Principle:

Whenever there is a change in medium, the ultrasonic waves will be reflected. Since the flaws can be detected without destroying the materials, it is called non-destructive testing.

Working:

The pulse echo system used to determine the various flaws like cracks, holes, air bubbles, laminations, etc., in the specimen is shown in Fig.

The pulse echo system



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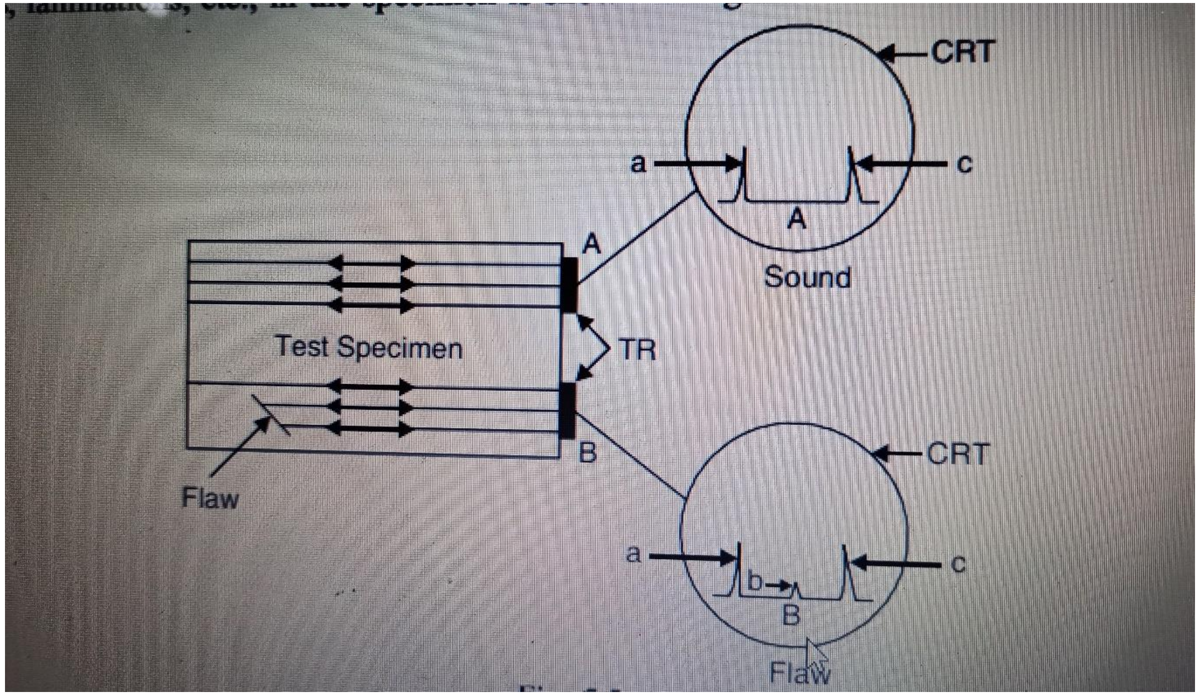
The pulse echo system



a - Incident pulse b - Pulse from flaw
c - Reflected pulse from the boundary of the specimen
TR - Transducer
CRT - Cathode Ray Tube.

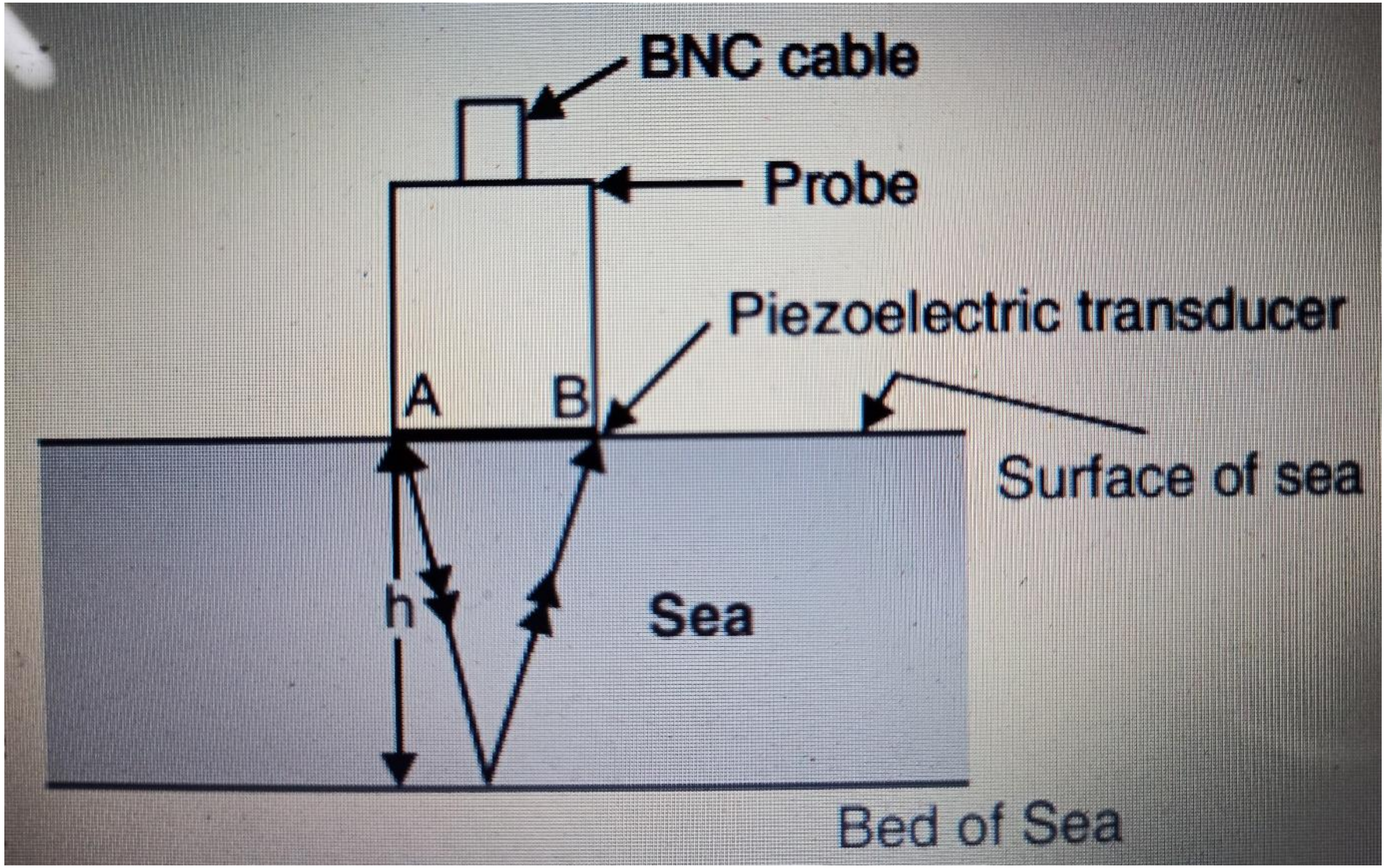
* Here short pulses of ultrasonic waves are transmitted into the material being tested.

* These pulses get reflected from discontinuities on their path or from any boundary of the material on which they strike.

* The received echoes are then displayed on a cathode ray tube screen. The CRT screen furnishes specific data as to the relative size of a discontinuity in terms of signal amplitude.

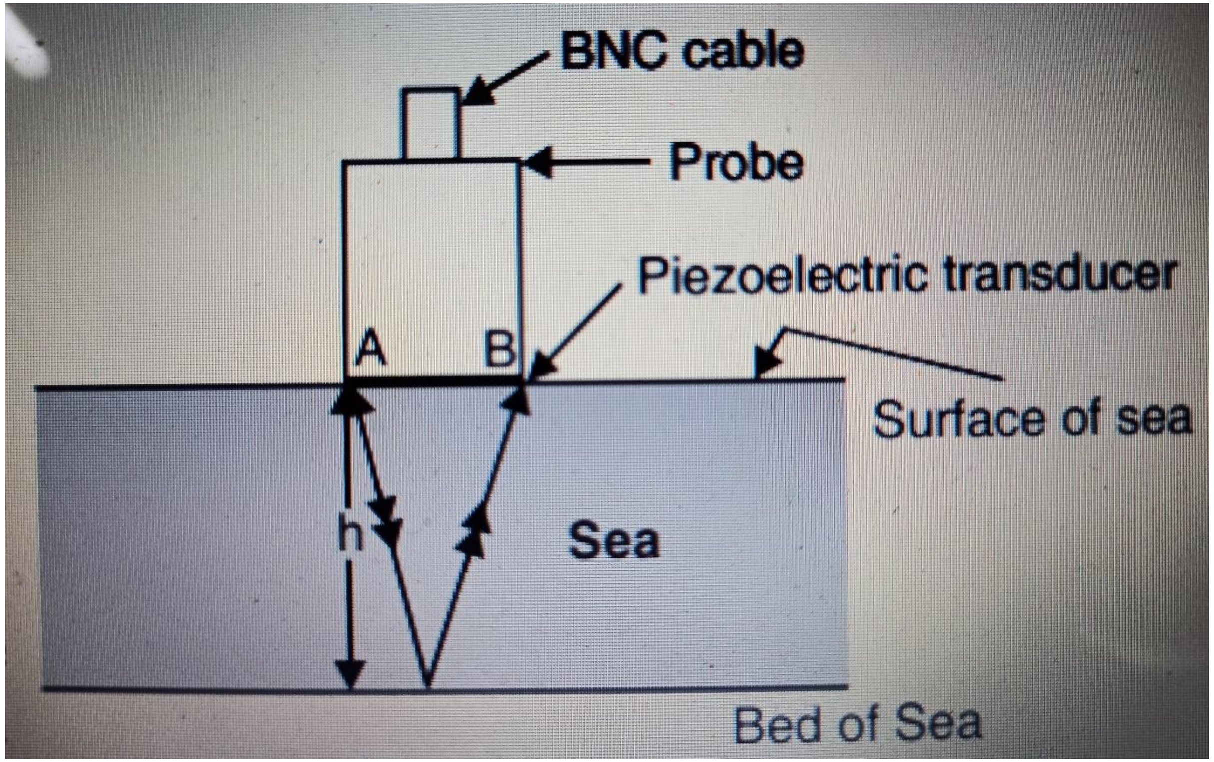
* The location of the discontinuity with respect to the scanning surface can be obtained by proper calibration of the CRT time base scale.

Sound Navigation and Ranging (SONAR)



Sound Navigation and Ranging (SONAR)

Ultrasonic waves sent from a point A travel through sea water and get reflected back from the bottom of the sea (Fig. 5.6). The reflected waves are received at the point B. Using a CRO the time taken t, for the ultrasonic wave to travel to the bottom of the sea and reflected back to the surface is calculated.



Let v = velocity of ultrasonic wave in sea water. Depth of the sea = vt/2.

The same method is used for finding the distance and direction of a submarine. The change in frequency of the echo signal due to Doppler effect helps to determine the velocity of the submarine and its direction. The whole system is called SONAR.

Ultrasonic Soldering

Ultrasonic solders are used for soldering aluminium coil capacitors, aluminium wires and plates without using any fluxes. An ultrasonic soldering iron consists of an ultrasonic generator having a tip fixed at its end. The tip is heated by an electrical heating element. The tip of the soldering iron melts solder on the aluminium. The ultrasonic vibrator removes the aluminium oxide layer. The solder thus gets fastened to the clear metal without any difficulty.

Ultrasonic Welding

The properties of some metals change on heating. Therefore, they cannot be welded by electric or gas welding. In such cases, the metal sheets are welded together at room temperature using ultrasonic waves.

Ultrasonic Drilling and Cutting

Ultrasonics are used for making holes in very hard materials such as glass, diamond, gems and ceramics.

Ultrasonics in Metallurgy

To irradiate molten metals which are in the process of cooling, so as to refine the grain size and to prevent the formation of cores and to release trapped gases, the ultrasonic waves are used.

Formation of Alloys The constituents of alloys, having widely different densities, can be mixed uniformly by a beam of ultrasonics. Thus it is easy to get alloys of uniform composition.

Chemical Applications

Ultrasonic waves are used to form stable emulsions of even immiscible liquids like Water and oil or water and mercury. This finds an application in the preparation of photographic films, face creams etc.

1. They are used to liquefy gels like aluminium hydroxide in the same way as they are liquefied by shaking.
2. They are used to coagulate fine solid or liquid particles in a gas; for example, dust, smoke, mist etc. Ultrasonics thus find use in collecting factory dust and purifying the air.
3. Ultrasonics act like a catalytic agent and accelerate chemical reactions. Ultrasonic waves accelerate crystallisation.

Medical Applications

1. Disease treatment. Ultrasonic therapy can be used to treat diseases like bursites, abscesses, neuralgic and rheumatic pains etc.

2. Surgical use. Kidney stones and brain tumours can be removed without shedding any blood using ultrasonic waves. Also, any tissue in our body can be cut selectively during an operation using ultrasonics.

3. Diagnostic use. Ultrasonics are used for detecting tumours and other defects in human body. State of breast cancer can be identified using ultrasonics in a non-destructive manner. Also, the twins or any defect in the growth of foetus can be identified using ultrasonics before delivery.

4. Extraction of broken teeth. Dentists use ultrasonic waves to properly extract broken teeth.
5. Sterilization. Ultrasonic waves can kill bacteria. Therefore, they are used for sterilising milk.
6. Blood flow meters. Ultrasonic blood flow meters are used to study the blood flow velocities in blood vessels of our body.

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ACOUSTICS OF BUILDINGS

(The requirements of a good auditorium & DERIVATION OF SABINE'S FORMULA FOR REVERBERATION TIME)

Paper Title : Acoustics
Code :17UPH3C5

Date: 20-07-2020
Time : 10.30 a.m. - 11.00 a.m.
Mode of Teaching: Online (Microsoft Teams)

ACOUSTICS OF BUILDINGS

The branch of Physics which deals with the design and construction of buildings with good acoustic properties is called "Acoustics of buildings." It deals basically with (i) reverberation control, (ii) noise insulation and reduction and (iii) sound distribution and absorption.

The following are the requirements of a good auditorium.

1. The sound should be sufficiently loud and intelligible in every part of the hall.
2. Sound of each syllable should soon decay so that the succeeding syllable may be heard distinctly. There must be no confusion due to overlapping of syllables. This means that the auditorium must be free from excessive reverberation.
3. No echoes should be present.
4. There should not be undesirable focussing of sound in any part of hall. There should not be any regions of poor audibility anywhere in the hall.
5. Interference, reflection and resonance effects should be avoided.
6. All extraneous noises must be shut out as far as possible. The boundaries should be sufficiently sound proof to exclude extraneous noise.
7. There should be no Echelon effect.

ACOUSTICS OF BUILDINGS

REVERBERATION

* When a source produces sound waves inside a closed building, the waves are generally reflected repeatedly by walls, ceiling and other materials present in the room. The intensity of the sound wave decreases at every reflection and finally the sound becomes inaudible.

* So the listener receives (i) direct waves and (ii) reflected waves due to multiple reflections, at the various surfaces.

*There is also a time gap between the direct wave received by the listener and the waves received by successive reflection. Due to this, the sound persists for sometime even after the source has stopped. This persistance of sound is called reverberation.

Definition of Reverberation.

* Reverberation is the persistence of sound in an enclosure due to multiple reflections of sound at the walls after the source has ceased to emit sound.

Definition of Reverberation time

* The interval of time taken by sustained or continuous sound to fall in intensity to one millionth of its original value is called reverberation time (T).

ECHELON EFFECT • The process of combination of multiple echoes and forming of a new sound is known as **echelon effect**. A set of railings or rectangular surfaces is said to produce **echelon effect**. This **echelon effect** affects the original quality of sound.

DERIVATION OF SABINE'S FORMULA FOR REVERBERATION TIME

The main assumptions are :

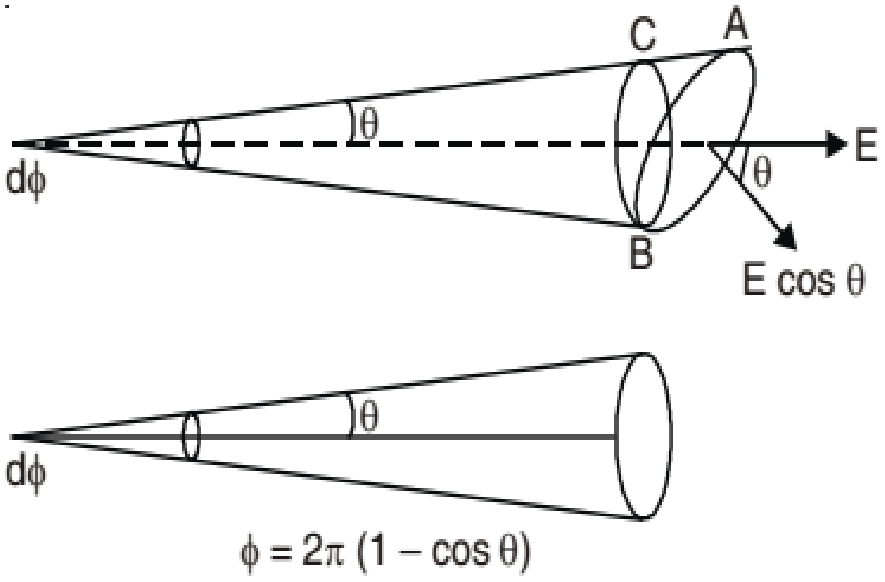
(1) The average energy per unit volume is uniform. It is represented as σ.

(2) The energy is not lost in the auditorium. The energy lost is only due to the absorption of the material of the walls and ceiling and also due to the escape through the windows and ventilators. Both these factors are included in the term **'absorption'** of energy.

Suppose a source is producing sound continuously. This sound energy is propagated in all directions. Let σ be the energy contained in a unit volume, *i.e.*, energy density.

Energy contained in a solid angle $d\phi = \dfrac{\sigma . d\phi}{4\pi}$

Let this energy be incident on a unit surface area of the wall at an angle θ (Fig. 5.7).



Total energy falling per second on a unit surface area of the wall

$$= \left(\frac{\sigma . d\phi}{4\pi}\right)(\cos\theta) . v$$

The total energy falling per second within a hemisphere

$$= \frac{\sigma v}{4\pi} . \int \cos\theta . d\phi \qquad ...(1)$$

But $\phi = 2\pi (1 - \cos\theta)$

or $d\phi = 2\pi \sin\theta . d\theta$

Substituting this value of $d\phi$ in Eq. (1),

The total energy falling per second within a hemisphere

$$= \frac{\sigma v}{4\pi} . \int_0^{\pi/2} 2\pi \sin\theta . \cos\theta . d\theta$$

$$= \frac{\sigma v}{2}\left[-\frac{\cos^2\theta}{2}\right]_0^{\pi/2}$$

$$= \frac{\sigma v}{4}.$$

Let α = absorption coefficient of the walls.

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Continuation of
Derivation of SABINE'S FORMULA FOR REVERBERATION TIME)

Paper Title : Acoustics
Code :17UPH3C5

Date: 22-07-2020
Time : 12.00 noon. – 12.50 p.m.
Mode of Teaching: Online (Microsoft Teams)

The amount of energy absorbed per second per unit area = $\frac{\alpha\sigma v}{4}$.

Let A = area of the walls and the other absorbing materials including ceiling, windows and ventilators etc.

Total amount of energy absorbed per second = $\frac{A\alpha\sigma v}{4}$.

Let V be the volume of the auditorium.

Total sound energy present at any instant = $V\sigma$.

The rate of increase of energy = $\frac{d}{dt}(V\sigma) = V\frac{d\sigma}{dt}$ ...(2)

Suppose, the source supplies energy at the rate of Q units per second.

Rate of increase of energy = $Q - \frac{A\alpha\sigma v}{4}$ ...(3)

Equating (2) and (3), we get

$$V \cdot \frac{d\sigma}{dt} = Q - \frac{A\alpha\sigma v}{4} \quad ...(4)$$

Put $\frac{A\alpha v}{4} = K$, $\frac{K}{V} = \beta$ and $B = \frac{Q}{K} = \frac{4Q}{A\alpha v}$.

Eq. (4) becomes

$$V \cdot \frac{d\sigma}{dt} = Q - K\sigma$$

$$\frac{d\sigma}{dt} = \frac{Q}{V} - \frac{K}{V} \cdot \sigma \quad ...(5)$$

The general solution of this equation is

The general solution of this equation is

$$\sigma = B + be^{-\beta t}$$

When $t = 0, \quad \sigma = 0.$

$$0 = B + b$$

or $b = -B$

$\therefore \quad \sigma = B - Be^{-\beta t}$

$$\sigma = B[1 - e^{-\beta t}]$$

Substituting the values of B and β,

$$\sigma = \frac{4Q}{A\alpha v}\left[1 - e^{-\left(\frac{A\alpha v}{4V}\right)t}\right] \quad ...(6)$$

Eq. (6) represents the rise of average sound energy per unit time from the time the source commences to produce sound.

The maximum value of average energy per unit volume

$$\sigma_{max} = \frac{4Q}{A\alpha v} \quad ...(7)$$

Similarly, after the source ceases to emit sound, the decay of the average energy per unit volume is given by

$$\sigma = \frac{4Q}{A\alpha v} e^{-\left(\frac{A\alpha v}{4V}\right)t} \quad ...(8)$$

$$\sigma = \sigma_{max}\, e^{-\left(\frac{A\alpha v}{4V}\right)t} \quad ...(9)$$

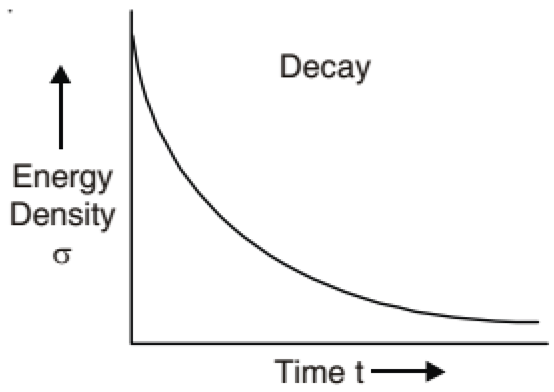

Fig. 5.8

Fig. 5.8 shows the decay of the energy density with time.

Reverberation Time (*T*)

Reverberation time is defined as the time taken for the energy density to fall to one-millionth of its value before the cut off.

Hence, substituting $\sigma = \dfrac{\sigma_{max}}{10^6}$ and $t = T$ in Eq. (9),

$$\frac{\sigma_{max}}{10^6} = \sigma_{max}\ e^{-\left(\frac{A\alpha v}{4V}\right)T}$$

$$10^{-6} = e^{-\left(\frac{A\alpha v}{4V}\right)T}$$

$$e^{\left(\frac{A\alpha v}{4V}\right)T} = 10^6$$

Taking logarithms,

$$\left(\frac{A\alpha v}{4V}\right)T = \log_e 10^6 = 6 \log_e 10 = 6 \times 2.3026$$

Take velocity of sound (v) approximately at room temperature as 350 ms^{-1}.

$$T = \frac{6 \times 2.3026 \times 4V}{A\alpha v} = \frac{6 \times 2.3026 \times 4}{350} \times \left(\frac{V}{A\alpha}\right)$$

$$T = \frac{0.158V}{A\alpha}$$

In general, $$T = \frac{0.158V}{\Sigma A\alpha} \quad \text{...(10)}$$

Here, V and A are in metres.

Eq. (10) represents the Sabine's reverberation time formula.

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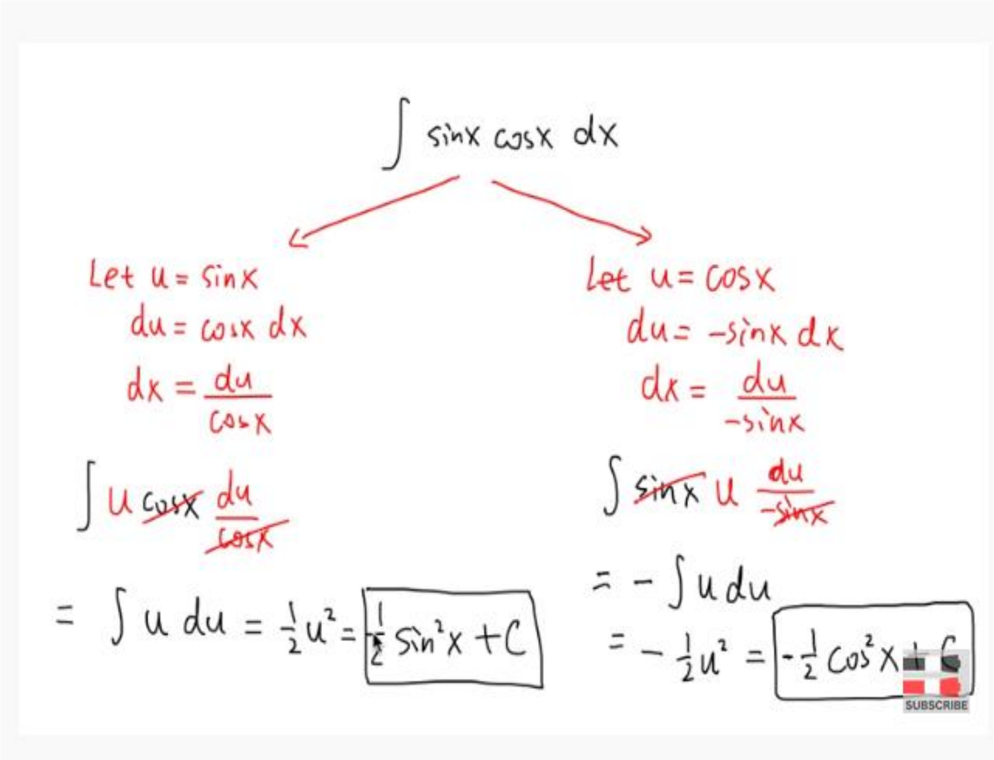
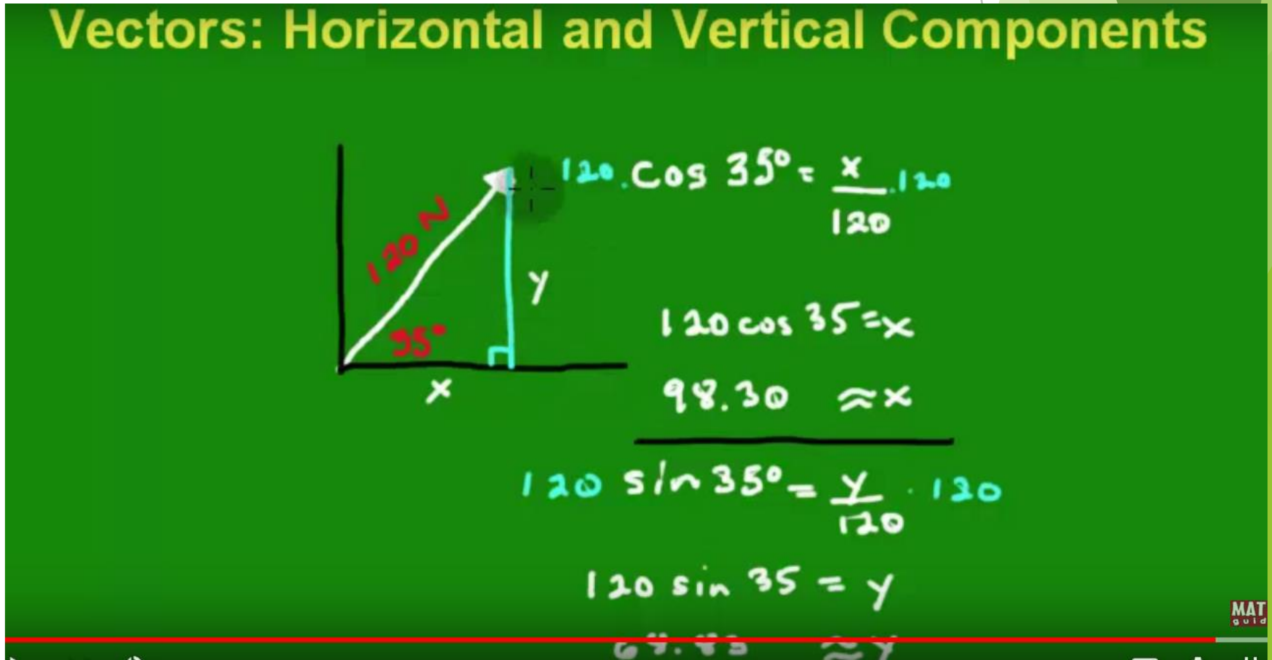


Angles in Radians	0^c	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$
sin	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
cos	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0
tan	0	$\frac{\sqrt{3}}{3}$	1	$\sqrt{3}$	Not defined
csc	Not defined	2	$\sqrt{2}$	$\frac{2\sqrt{3}}{3}$	1
sec	1	$\frac{2\sqrt{3}}{3}$	$\sqrt{2}$	2	Not defined
cot	Not defined	$\sqrt{3}$	1	$\frac{\sqrt{3}}{3}$	0

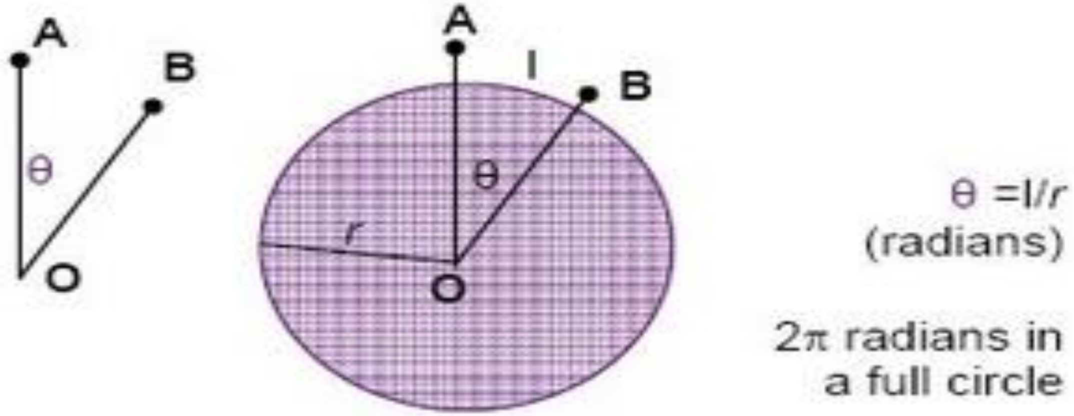
(of a line, arc, or figure) form (an angle) at a particular point when straight lines from its extremities are joined at that point.



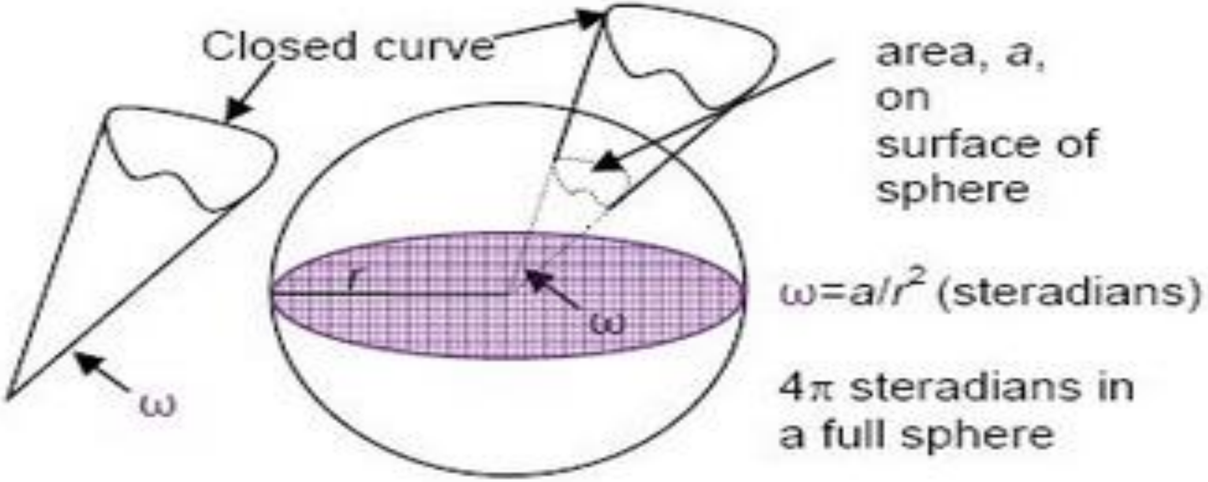
Excerpt from Field Guide to Illumination

The definition of intensity involves the concept of a solid angle. A solid angle is a 3D angular volume that is defined analogously to the definition of a plane angle in two dimensions.

A plane angle, θ, made up of the lines from two points meeting at a vertex, is defined by the arc length of a circle subtended by the lines and by the radius of that circle, as shown below. The dimensionless unit of plane angle is the radian, with 2π radians in a full circle.

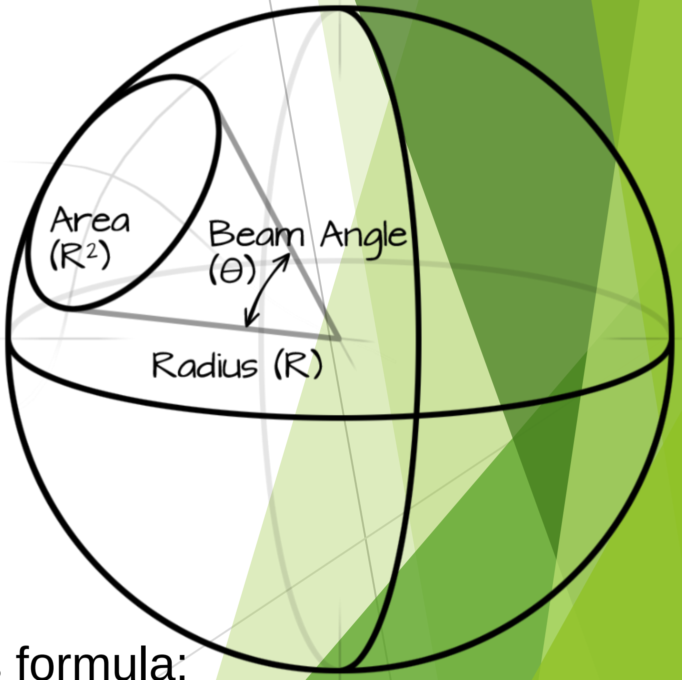


A solid angle, ω, made up of all the lines from a closed curve meeting at a vertex, is defined by the surface area of a sphere subtended by the lines and by the radius of that sphere, as shown below. The dimensionless unit of solid angle is the steradian, with 4π steradians in a full sphere.



This calculator is useful for calculating the luminous flux for LEDS where the angle is known. 1 candela of luminous intensity equals 1 lumen of luminous flux per steradian of solid angle, where a steradian respresents a cone whose surface area at the end equals the length of the cone squared. A steradian is $(180/\pi)^2$ **square degrees** or about 3282.8 **square degrees.**

$$\Phi_v = I_v \times \Omega$$



- where Φ_v is the luminous flux, in measured in Lumens (lm),

- I_v is the luminous intensity, measured in Candela (cd), and
- Ω is the solid angle of the beam is measured in Steradian (sr).

Conversion from beam angle to solid angle (sterians) is done with this formula:

Θ is the beam angle mensured in degrees

$$\Omega = 2\pi\left(1-\cos\left(\frac{\theta\pi}{360}\right)\right)$$

e general solution of dx:dt + 3x = 8

ises 11–22, find the general solution.

Proof. $X^0 = X^{1-1} = X^1 \cdot X^{-1} = \frac{X}{X} = 1.$ ■

$+ 3x = 8.t^0$ 1^{st}- order-linear - NH

eparble Variable

$\frac{x}{t} = 8 - 3x \Rightarrow dx = (8-3x)dt \Leftrightarrow \int \frac{1}{8-3x} dx = \int dt$

$\int \frac{1}{ax+b} dx = \frac{1}{a} \ln|ax+$

$\Rightarrow -\frac{1}{3}\ln|8-3x| + c_1 = t + c_2 \Rightarrow e^{\ln|8-3x|} = e^{(-3t+c_3)}$

$\Rightarrow 8 - 3x = e^{-3t} \cdot e^{c_3} = c_4 e^{-3t} \Rightarrow -3x = c_4 e^{-3t} - 8$

$\Rightarrow x = \frac{8}{3} + c_5 e^{-3t}$

$\therefore x(t) = \frac{8}{3} + C e^{-3t}$

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IMPORTANCE OF SABINE'S FORMULA
&
FACTORS AFFECTING THE ACOUSTICS OF BUILDINGS

Paper Title : Acoustics
Code :17UPH3C5

Date: 24-07-2020
Time : 12.00 noon. – 12.50 p.m.
Mode of Teaching: Online (Microsoft Teams)

Explanation of Sabine's formula

Sabine's formula for reverberation time is

$$T = 0.158V/\Sigma A\alpha$$

According to the equation

The reverberation time is (i) directly proportional to the volume of the auditorium; (ii) inversely proportional to the area of the ceilings, area of the walls etc., and (iii) inversely proportional to the total absorption plus transmission through open surfaces.

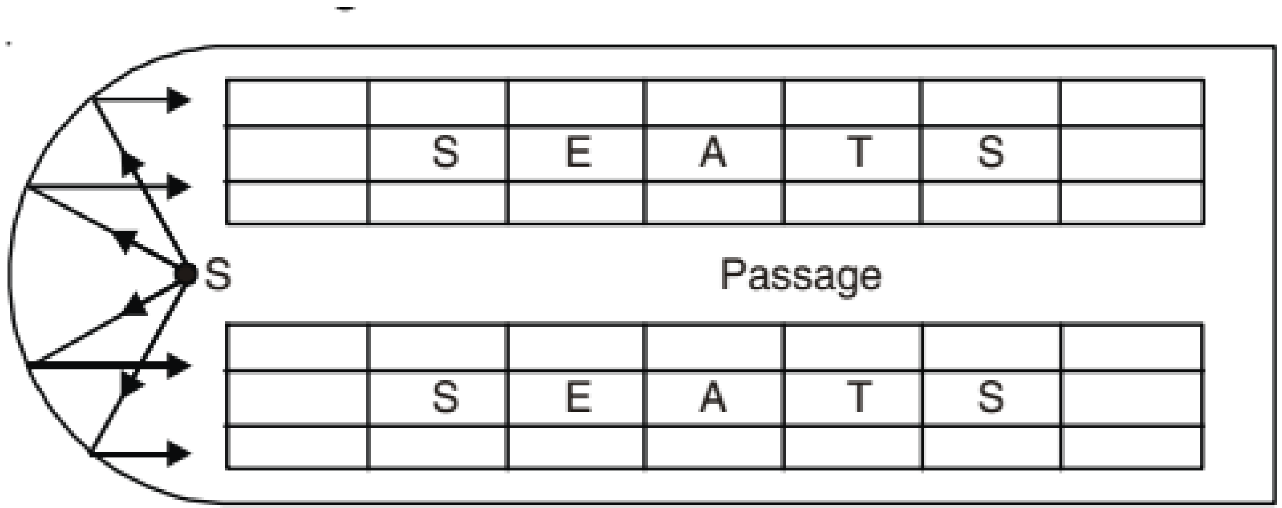
Importance of Sabine's Formula

If the reverberation time is too small, the sound dies away almost instantaneously and gives the hall a 'dead' effect.

If the reverberation time is too long, each syllable continues to be heard even after the next syllable has been uttered. This makes the sound unintelligible.

Therefore, the value of reverberation time is maintained at an optimum value. Rooms of different dimensions were used by Sabine to find the optimum reverberation time. For speech, the reverberation time should be about 1 to 2 seconds. For music, it is between 2 to 2.5 seconds.

Design of Hall



It has a parabolic shape at the speaker’s end S.

As the speaker speaks, sound is reflected from the back almost as a parallel beam.

So there is uniform distribution of sound intensity throughout the hall.

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FACTORS AFFECTING THE ACOUSTICS OF BUILDINGS

(i) Reverberation time

(ii) Presence of echoes

(iii) Adequate loudness

(iv) Focusssing and interference effects

(v) Resonances within the building

(vi) Echelon effect

(vii) Extraneous noises

(viii) Inside noise.