UNIT-II GEOMETRICAL OPTICS AND ACOUSTICS

Course Contents

Cardinal points of coaxial lens system,location and properties of cardinal points,Newton's formula, Geometrical optics,Combination of thin lenses, Magnetostriction and piezoelectric oscillator for production of ultrasonic wave, determination of of wavelength of ultrasonic wave and their applications, Basic requirement for acoustically good hall, Reverberation and Sabine's formula for reverberation time, Absorption coefficient and its measurement , Factors affecting architectural acoustics and their remedy.

System

Coaxial lens system :

An instrument employs a combination of lenses having a common principal axis.

Cardinal Points of a Coaxial Lens system:

To find the position and the size of the final image without studying intermediate images, there should be a method by finding the position of some special points, known as Cardinal Points.

Cardinal Points of a Coaxial Lense System

Types of Cardinal Points

A lens system has six cardinal points:

(a) Two Focal Points
(b) Two Principal Points
(c) Two Nodal Points.

(a) Two Focal Points: The two points on the principal axis of the optical system whose conjugate points lie at infinity.

Cardinal Points of a Coaxial Lense System

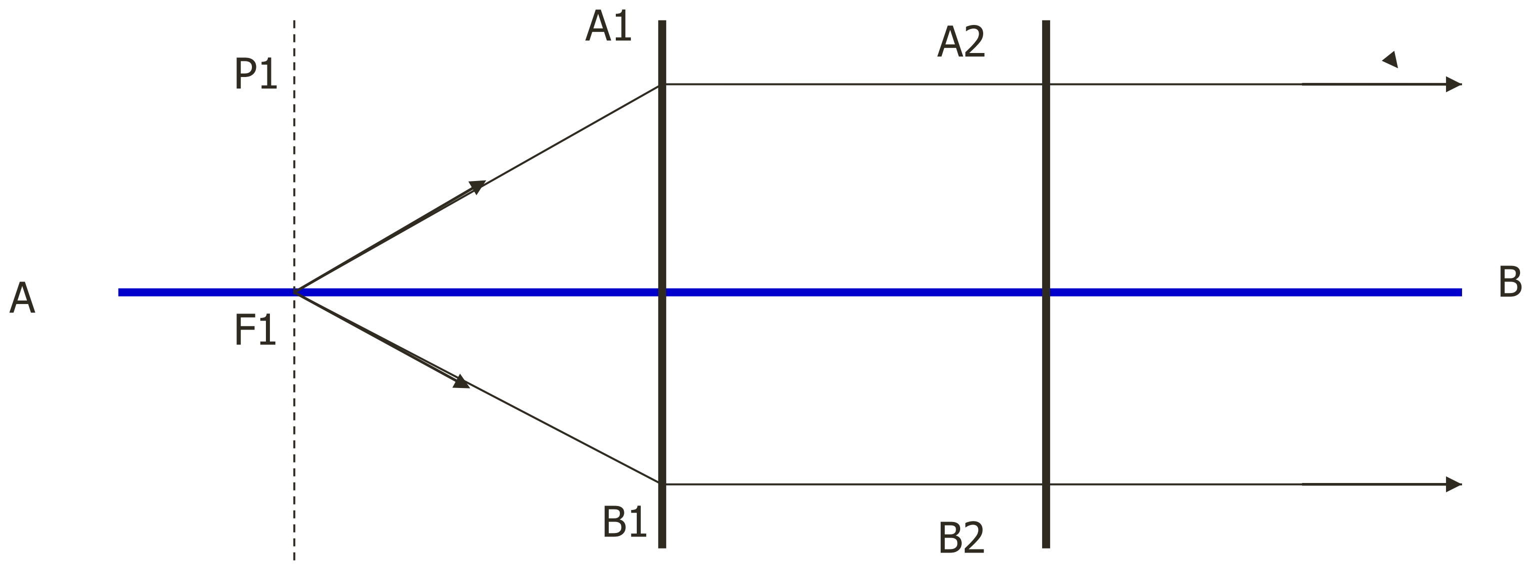
- First Focal Point and First Focal Plane:

  First focal point is that object point on the principal axis of the optical system whose image point is situated at infinity.

  in fig., F1 is the point.

  First Focal Plane: The plane perpendicular to the principal axis and passing through F1 is called first focal point.

Cardinal Points of a Coaxial Lens System

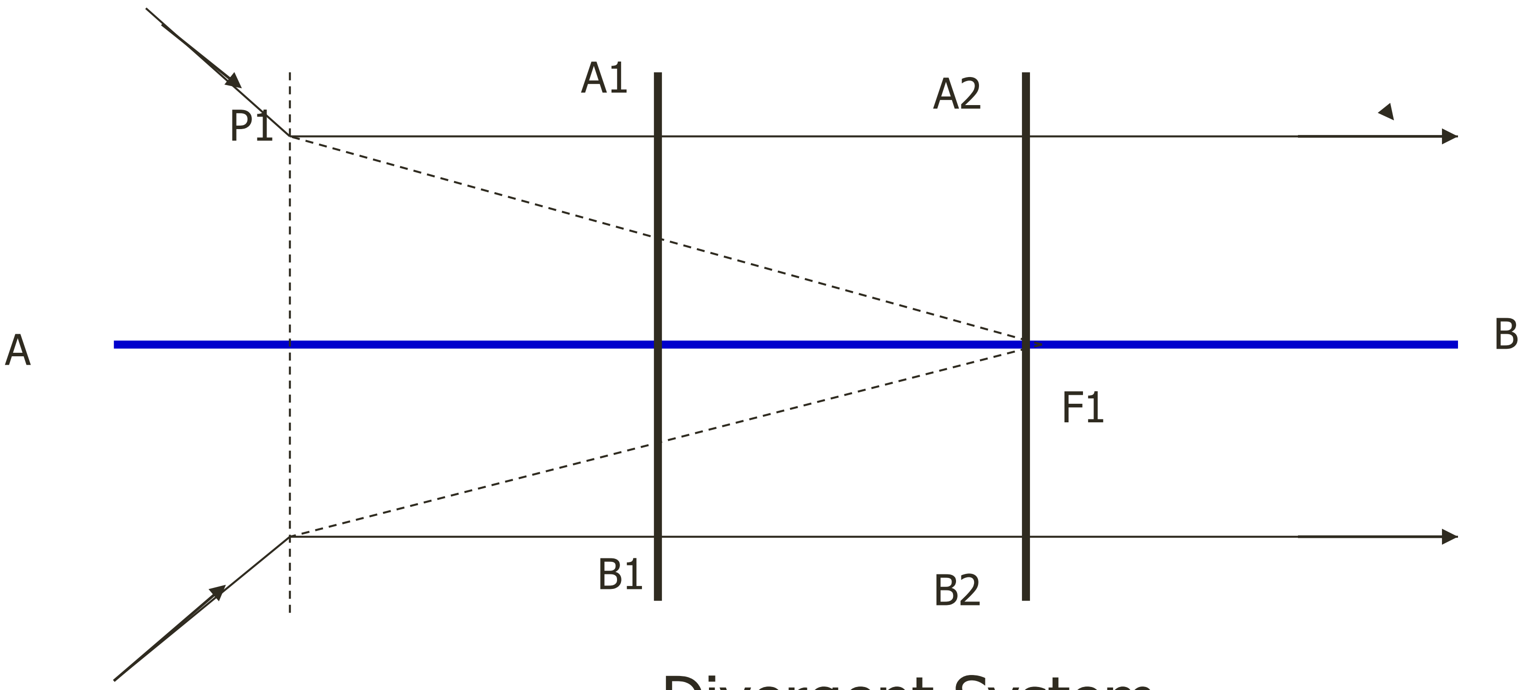


Convergent System

F1: First Focal Point

P1F1: First Focal Plane

Cardinal Points of a Coaxial Lens System



Divergent System

F1: First Focal Point

P1F1: First Focal Plane

Cardinal Points of a Coaxial Lens System

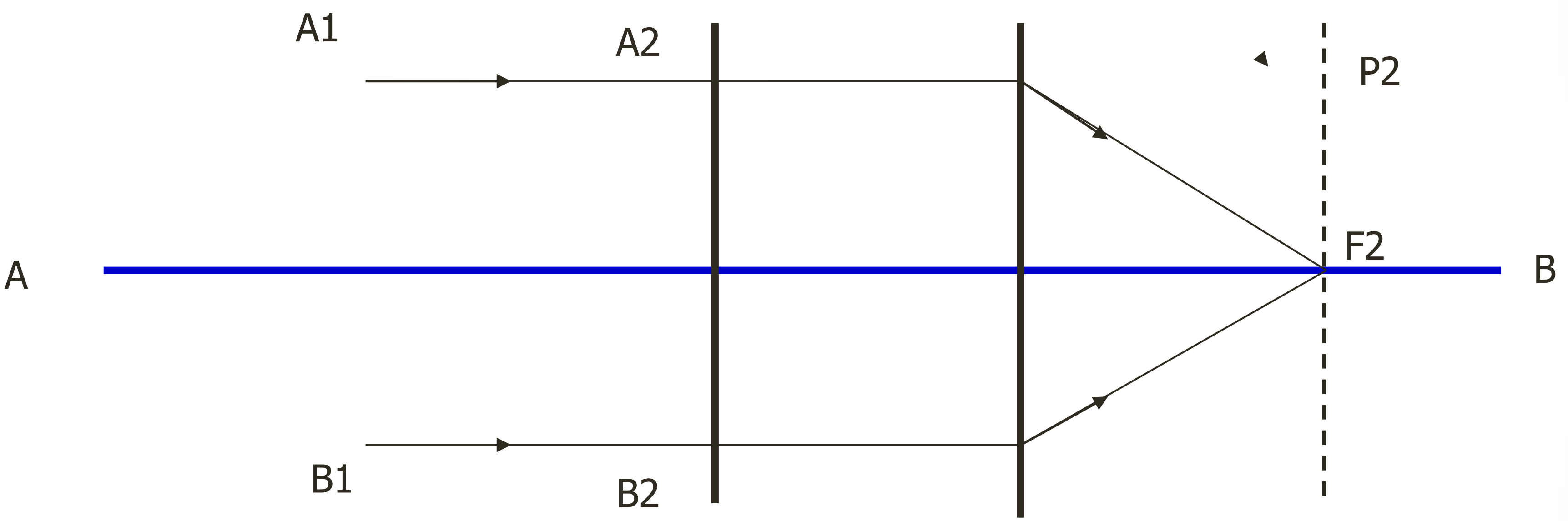
Second Focal Point and First Focal Plane:

Second focal point is that image point on the principal axis of the optical system whose object point is situated at infinity.

in fig., F2 is the point.

Second Focal Plane: The plane perpendicular to the principal axis and passing through F2 is called Second focal Plane.

Cardinal Points of a Coaxial Lens System

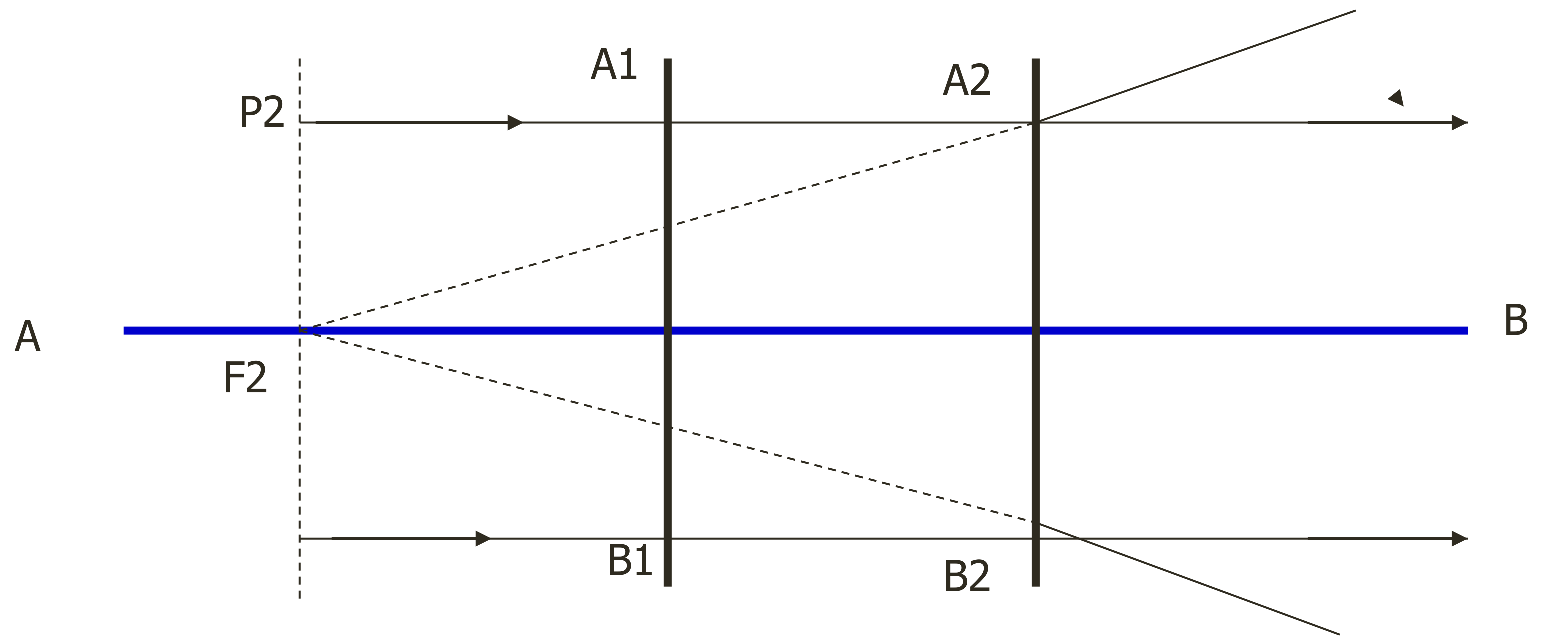


Convergent System

F2: Second Focal Point

P2F2: Second Focal Plane

Cardinal Points of a Coaxial Lens System



Divergent System

F2: Second Focal Point

P2F2: Second Focal Plane

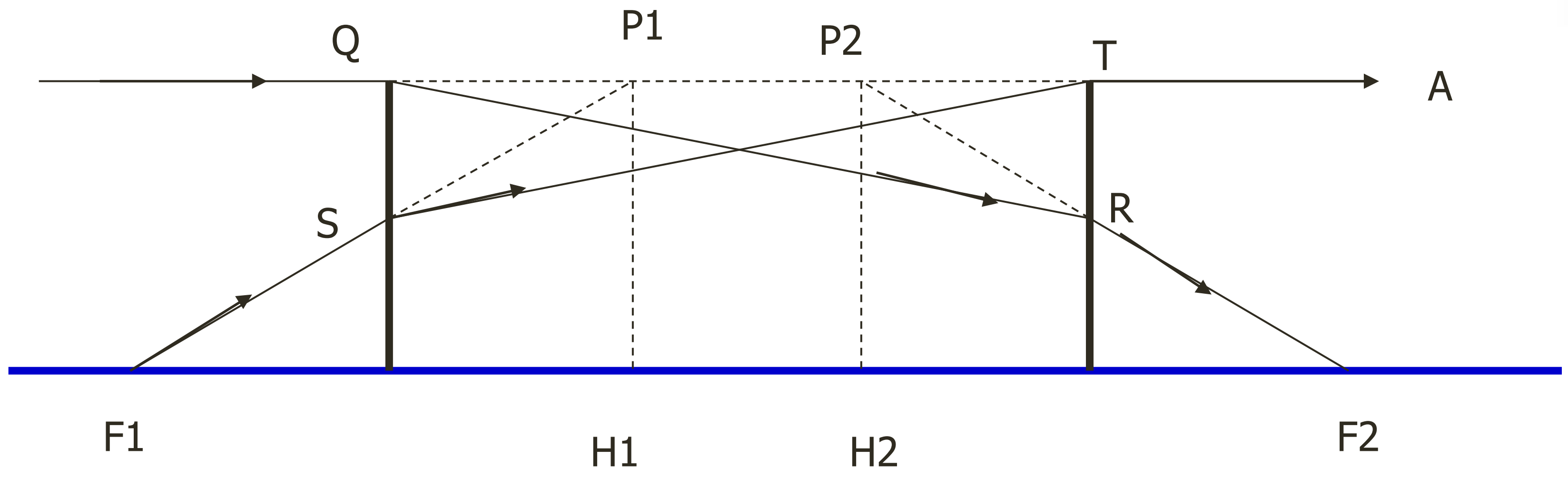
Cardinal Points of a Coaxial Lens System

(b) Two Principal Points :

Two conjugate points on the principal axis of the lens system for whom the linear magnification is +1 .

In fig, H1 and H2 are principal points.

Cardinal Points of a Coaxial Lens System



H1, H2: First and Second principal points

P1H1, P2H2 : First and Second Principal Planes

F1H1, F2H2: First and Second Focal Lengths

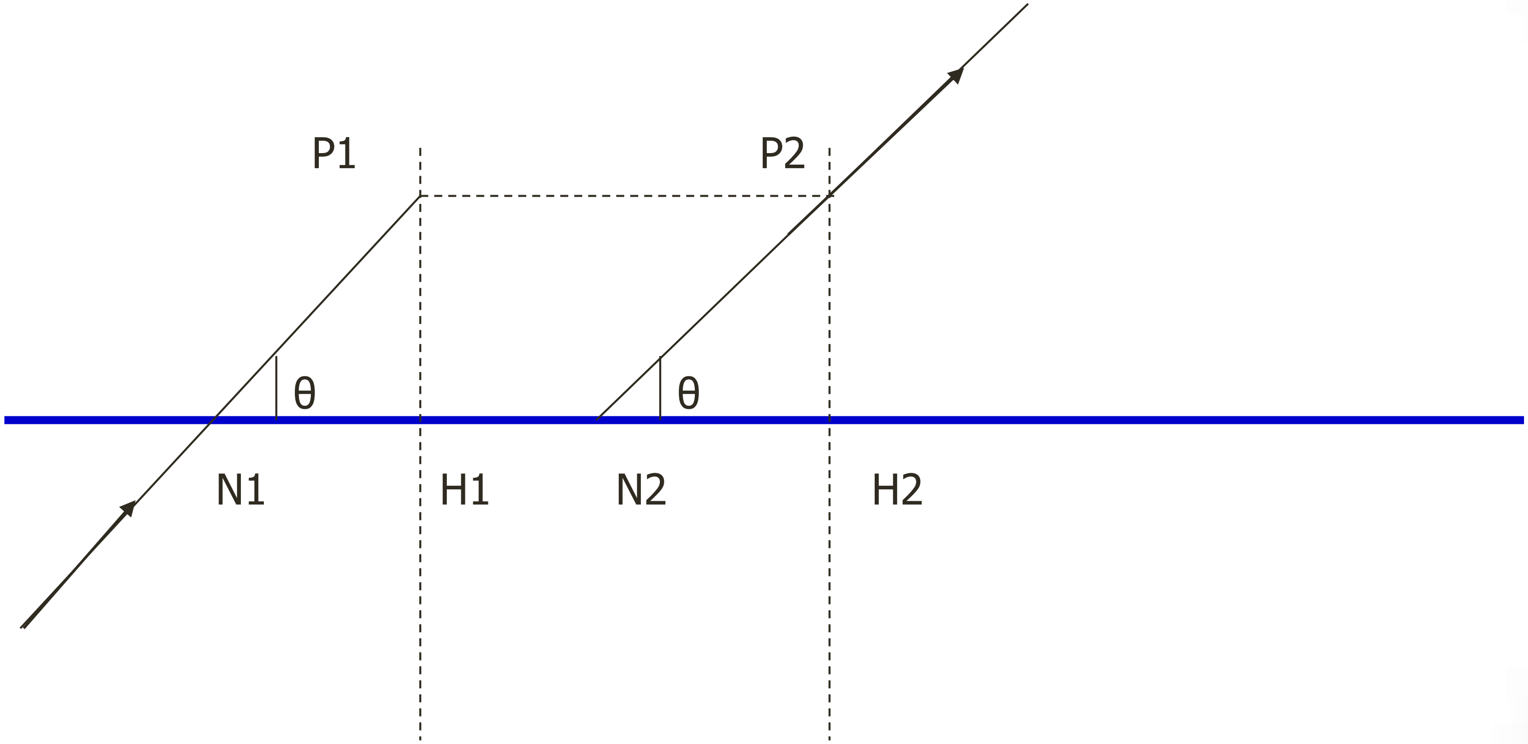
Cardinal Points of a Coaxial Lens System

Two Nodal Points:

The two conjugate points on the principal axis of the coaxial lens system such that the angular magnification is +1 .

In fig, N1 and N2 are Nodal Points.

Cardinal Points of a Coaxial Lens System



N1, N2 : Nodal Points

Image Formation by Cardinal Points

By knowing the position of cardinal points of an optical system, the image of an object can be constructed by the following laws:

(1) Ray of light parallel to principal axis after refraction through lens system passes through the second focus F2.

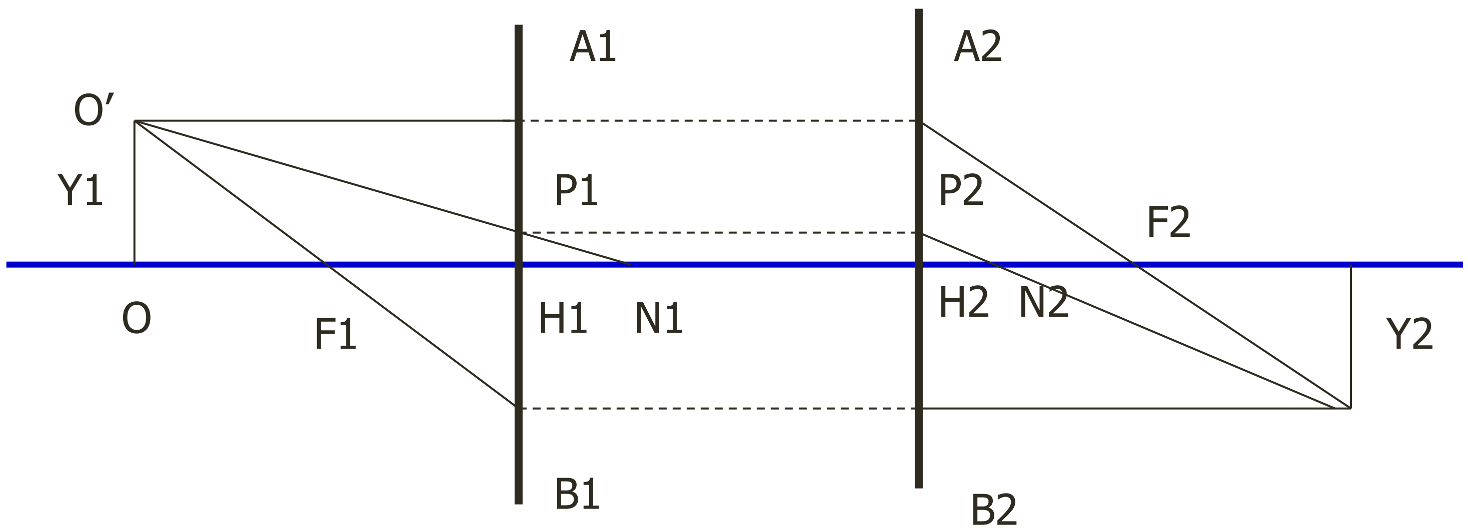
(2) The ray of light coming through first principal focus F1 after refraction from the optical system becomes parallel to the principal axis.

Image Formation by Cardinal Points

(3) An incident ray which cuts the first principal plane at a certain distance from the axis emerge after refraction on the same side of the principal axis at the same distance from it from the second principal plane.

(4) An incident ray which goes through nodal point N1 after refraction emerges parallel to the incident ray through the second nodal point N2.

Image Formation by Cardinal Points

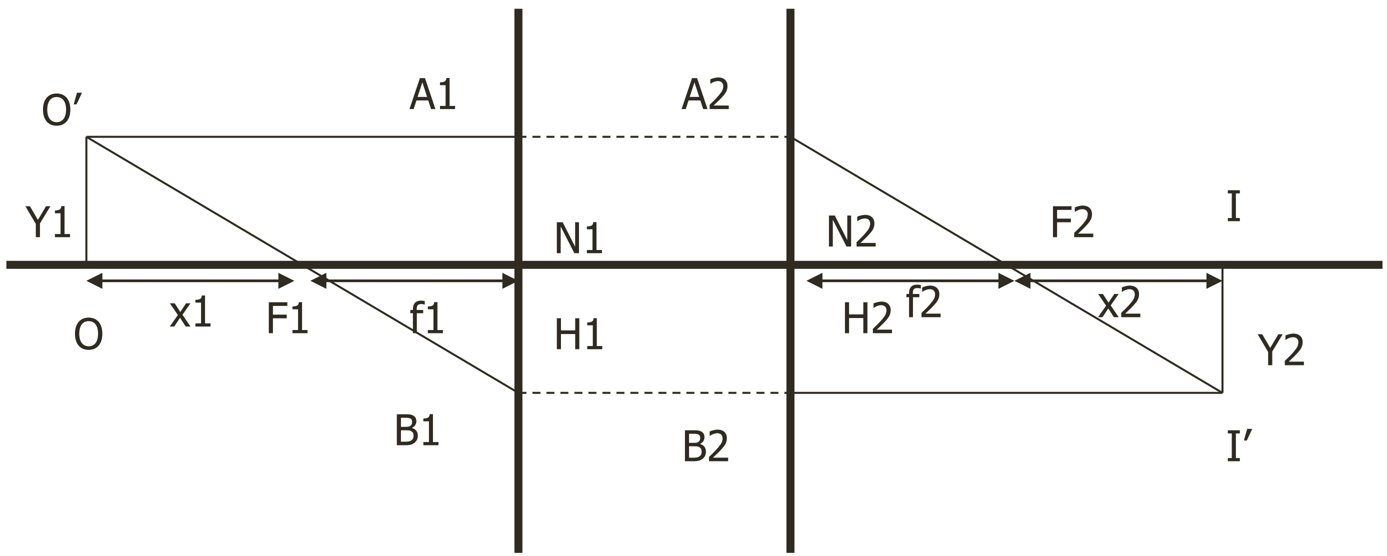


H1,H2: Principal Points

N1,N2: Nodal Points

F1,F2: Focal Points

Newton's Formula



N1, N2 : Nodal Points

H1, H2 : Principal Points

F1, F2 : Focal Points

Newton's Formula

Distance of object from the first focal point F1 be x1

Distance of image from the second focal point F2 be x2

From ΔF1H1B1 and ΔF1OO' , we have

H1B1/OO, = H1F1/F1O OR –Y2/Y1 = -f1/-x1

……………(1)

(According to sign convention f1 and x1 are negative)

Newton's Formula

Similarly, From Δ A2H2F2 and Δ I,IF2, we have

II'/H2A2 = F2I/H2F2 OR –y2/y1 = x2/f2 ……………(2)

(According to sign convention f2 and x2 are positive.

From eq.(1) and eq.(2), we have

$$-f1/-x1 = x2/f2$$

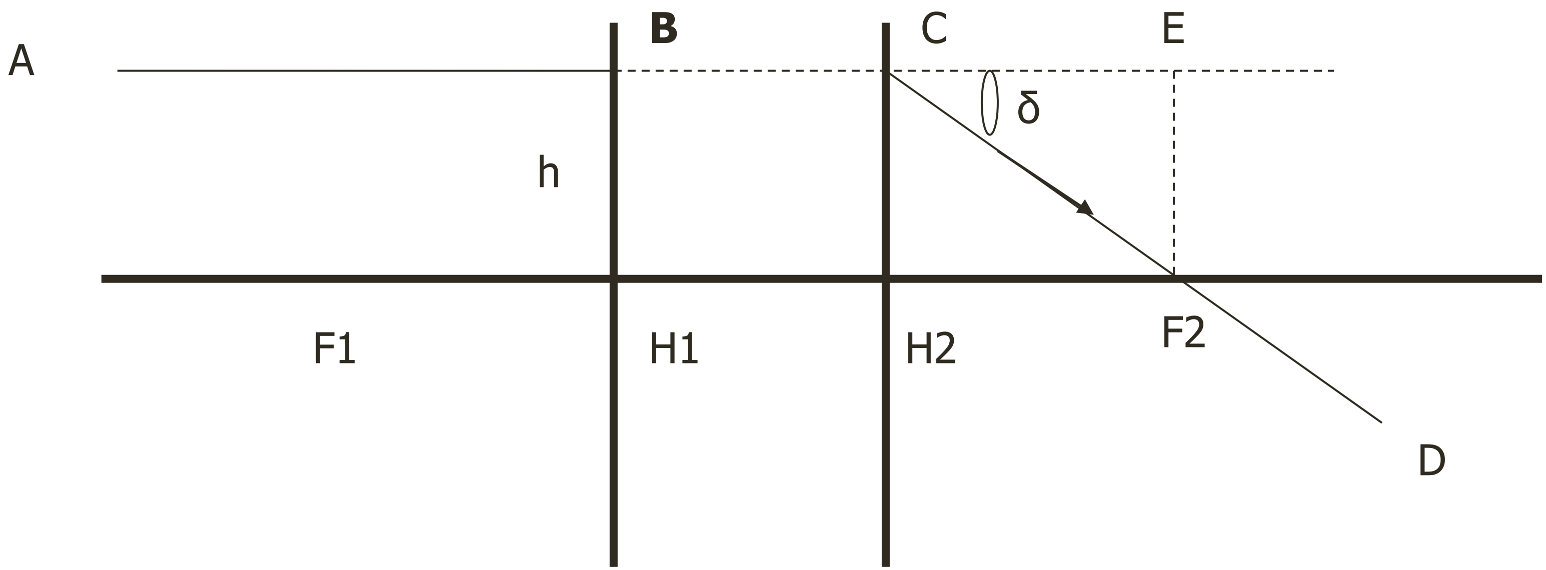
OR

$$x1x2 = f1f2$$

This is NEWTON'S FORMULA.

Deviation produced by an Optical system

- An incident ray parallel to the principal axis



Deviation produced by an Optical system

Angle of Deviation: The angle between incident and refracted ray from any optical system.

From fig. AB=incident ray

CD= Refracted ray

$\Delta ECF2 = \delta$ =angle of deviation

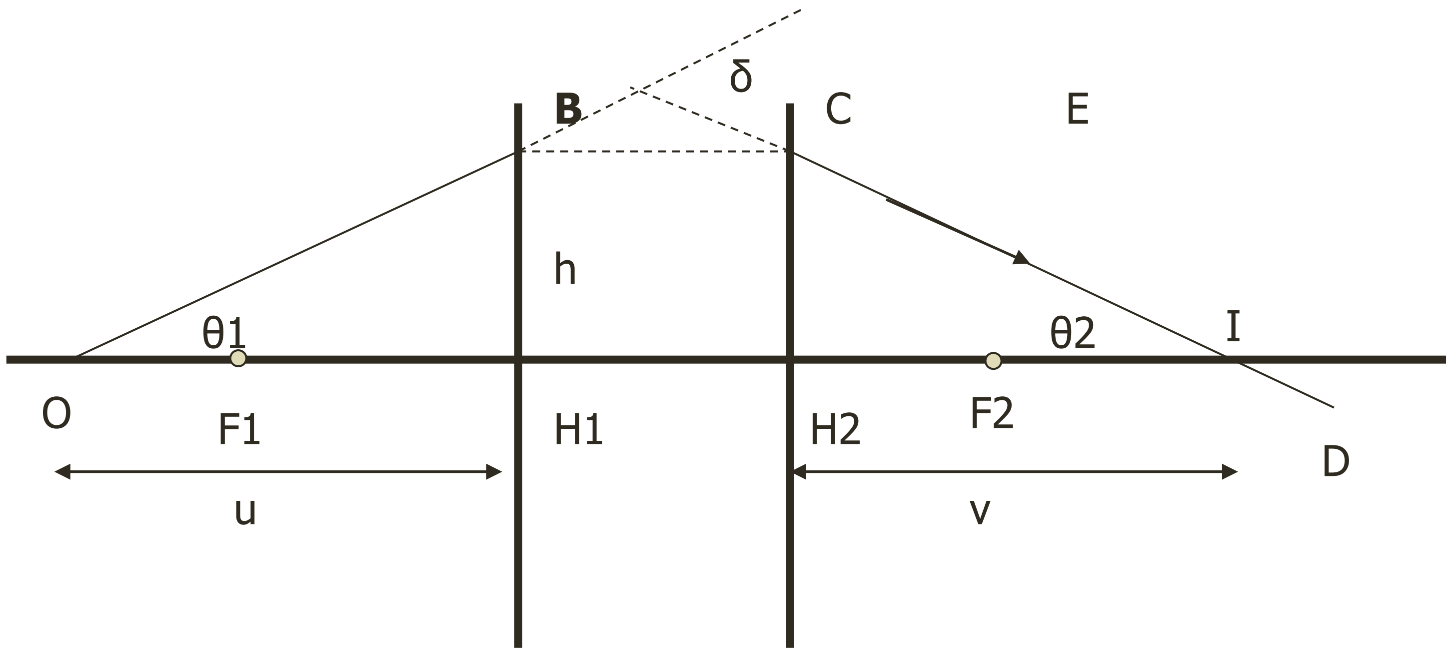
From $\Delta ECF2$,

$$\tan \delta = EF2/CE = BH1/H2F2 = h/f2 = h/f$$

Since δ is very small, therefore

$$\tan \delta = \delta$$

Deviation produced by an Optical system



Deviation produced by an Optical system

From geometry of the fig.

$\delta = \theta 1 + \theta 2$

Where $\theta 1 = \Delta H1OB$,

taken +ve as measured in anticlockwise.

And $\theta 2 = -(\theta 2) = \Delta H1IC$,

taken –ve as measured in clockwise.

Deviation produced by an Optical system

If θ1 and θ2 are small, then by fig.

$\Theta 1 = \tan \theta 1 = BH1/H1O = h/(-u)$

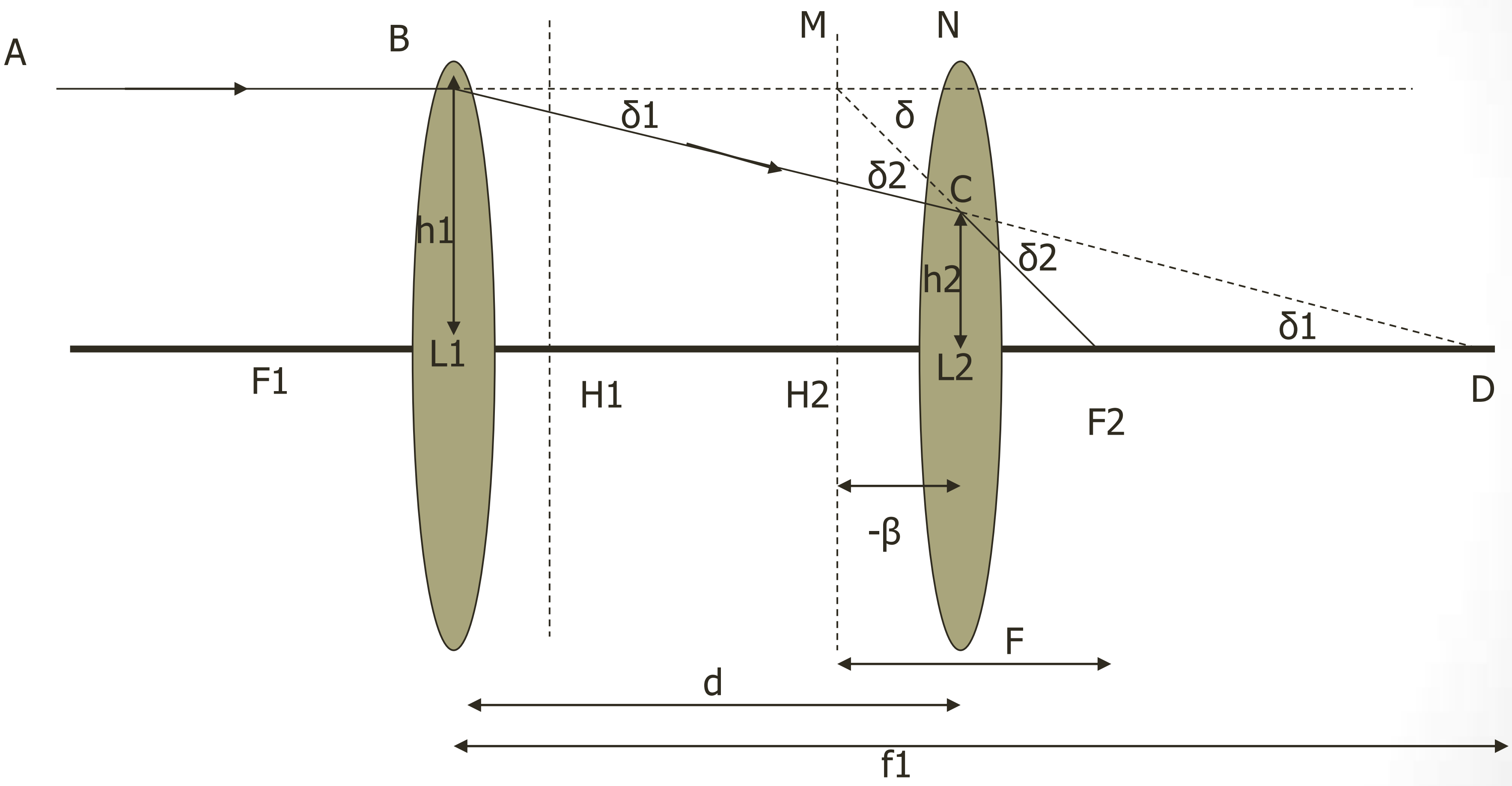
And – $(\theta 2) = \tan(-\theta 2) = CH2/H2I = h/v$

According to sign convention, u=-ve and v=+ve

Therefore $\delta = h/(-u) + h/v = h(1/v - 1/u) = h/f$

$$\delta = h/f$$

Combination of two thin lenses



Combination of two thin lenses

Acoustics of Buildings

The branch of science which deals with the planning of building or a hall with a view to provide best audible sound to the audience is called

"Acoustics of building"

Acoustics of Buildings

Essential feature about good acoustics of hall:

(1) The sound heard must be sufficiently loud in every part of the hall and no echoes should be present.

(2) The total quality of speech and music must be unchanged, i.e. the relative intensities of the several components of a complex sound must be maintained.

(3) The sound syllables spoken must be clear and distinct .

Acoustics of Buildings

Essential feature about good acoustics of hall:

(4) The reverberation should be quite proper, 1 to 2sec. for music and .5sec for speech.

(5) There should be no concentration of sound in any part of the hall.

(6) The boundaries should be sufficiently sound proof.

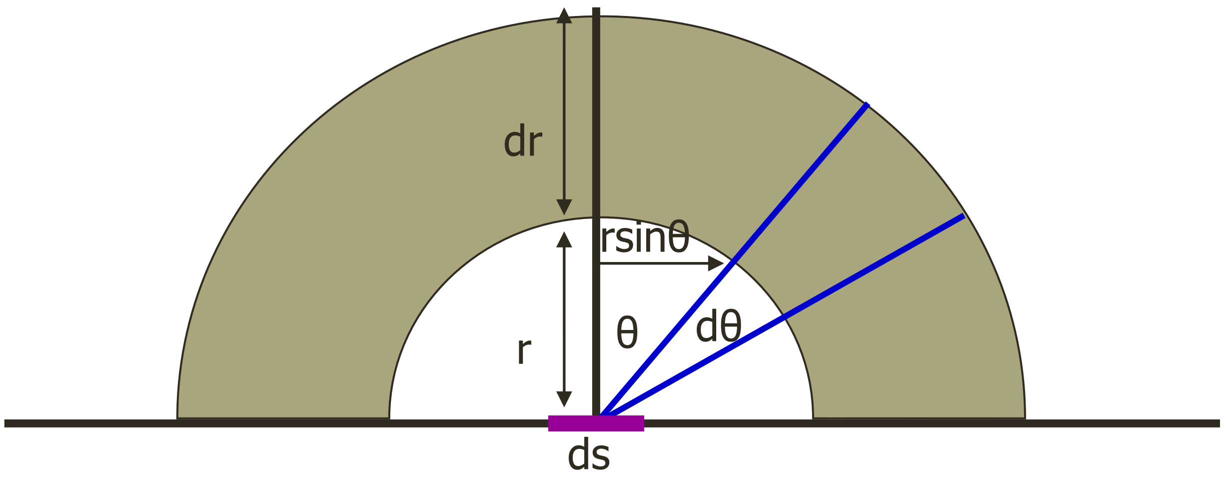
(7) There should be no echelon effect.

(8) There should be no resonance within the building.

Sabine's Formula for Reverberation Time

Persistence of sound after the source has stopped to emit sound is called "REVERBERATION".

The duration for which the sound persist is called "REVERBERATION TIME".



Absorption Coefficient and its measurement

Absorption coefficient of a material:

An Open window behaves as a perfect absorber.

It can also be defined as

Absorption coefficient of a surface is defined as the reciprocal of its area which absorbs the same sound energy as absorbed at a unit area of an open window.

Unit of Absorption Coefficient :

O.W.U. (Open Window Unit)

Absorption Coefficient and its measurement

Measurement of Absorption Coefficient :

It is based on the determination of standard times of reverberation in the room without and with standard large sample of the material inside the chamber.

If the reverberation times are T1 and T2,
then by applying Sabine's Formula, we have

Absorption Coefficient and its measurement

Absorption Coefficient and its measurement

Numerical

Q.1 : A cinema hall has a volume of 7500 m3. It is required to have reverberation time of 1.5 sec. What should be the total absorption in the hall?

Absorption Coefficient and its measurement

Q.2: The volume of a room is 1200 m3. The wall area of the room is 220 m3, the floor area is 120 m3 and the ceiling area is 120 m3. The average sound absorption coefficient (i) for wall is 0.03 , (ii) for the ceiling is .80 and (iii) for the floor is .06. Calculate the average sound absorption coefficient and the reverberation time.

Absorption Coefficient and its measurement

Factors Affecting the Architectural Acoustics and their remedy

Following are the factors affect the architectural acoustics:

(1) Reverberation: When reverberation is large , there is overlapping of successive sound which results in loss of clarity in hearing. If reverberation is very small, the loudness is inadequate.

The standard time of reverberation :

$$T = 0.165V/A$$

It lie between 1 to 1.5 sec. for small hall and 2-3 sec. for large hall.

Factors Affecting the Architectural Acoustics and their remedy

The reverberation cal be controlled by the following factors:

(i) By providing windows and ventilators which can be open or closed to make the value of the time of reverberation optimum.

(ii) Decorating the walls by pictures and maps.

(iii) Using heavy curtains with folds.

(iv) By covering the floor with carpets.

(v) By providing acoustics tiles.

Factors Affecting the Architectural Acoustics and their remedy

(2) Adequate loudness: If the efficiency of sound is weakened then it may go below the level of intelligibility of hearing sufficient loudness in every portion of the hall. The loudness may be increased by following factors:

(i) Using large sounding boards behind the speaker and facing the audience.

(ii) Large polished wooden reflecting surfaces immediately above the speaker are also helpful.

(iii) Low ceilings are also great help in reflecting the sound energy towards the speaker.

(iv) By providing additional sound energy with the help of loudspeaker.

Factors Affecting the Architectural Acoustics and their remedy

(3) Focussing due to walls and ceilings : If there are focussing surfaces(concave, spherical, cylindrical or parabolic) on the walls or ceiling or floor, they produces concentration of sound into that regions which makes non-uniform distribution of sound energy.For uniform distribution of sound energy:

(i) There should be no cured surfaces. If such surfaces are present, they should be covered with absorbent material.

(ii) Ceiling should be low.

Factors Affecting the Architectural Acoustics and their remedy

(4) Absence of echoes: an echo is heard when direct and reflected sound waves coming from the same source reach the listener with the a time interval of about 1/7 second.The reflected sound arriving earlier than this helps raising the loudness while those arriving later produces echoes. It man be avoided by covering the long distance walls and high ceiling with absorbent material.

Factors Affecting the Architectural Acoustics and their remedy

(5) Freedom from resonance: The window pans, sections of wooden portions and walls lacking in rigidity are thrown in vibration and they create other sound. It produces resonance with the sound energy, which makes sound energy entirely different from its original sound.

Enclosed air in the hall also causes resonance. Such resonant vibration should be suitably damped.

Factors Affecting the Architectural Acoustics and their remedy

(6) Echelon Effect: A set of railing or any regular spacing of reflected surfaces may produce a musical note due to the regular succession of echoes of original sound to the listener. This make the sound confused. This type of surfaces should be avoided.

(7) Extraneous noise and sound insulation: In good hall, no noise should reach from outside. They are of three types:

Factors Affecting the Architectural Acoustics and their remedy

(i) Air borne noise: the noise which commonly reaches from outside through open windows, doors and ventilators is known as air borne noise. It can be reduced by :

(a) By allotting proper places for doors and windows.

(b) Double doors and windows with separate frames and having insulating material.

(c) By making arrangement for perfectly shutting doors and windows.

(d) Using heavy glass in doors, windows and ventilators.

Factors Affecting the Architectural Acoustics and their remedy

(ii) Structure borne noise: The noise which are conveyed through the structure of building are known as structural noise. These noise may be caused due to structural vibration due to activity at around, above or below the structure. They are

street traffic, drilling, operating machinery, moving of furniture. It can be avoided by:

(a) Using double walls with air space between them.

(b) By insulating the machinery.

(c) Soft floor finish (carpet, rubber)

Factors Affecting the Architectural Acoustics and their remedy

(iii) Inside noise: The noises which are produces inside the hall in big offices are called inside noises. They are due to machinery, type writer etc. It can be avoided by:

(a) placed machinery on floor with layer of wood.

(b) the floor should be covered with carpet

Ultrasonics

- The audible range of sound waves are between 20Hz to 20,000Hz.
- The sound wave having frequencies above the audible range are known as ULTRASONIC WAVE or SUPERSONICS.

Ultrasonic

Properties of ultrasonic wave:

- They are highly energetic.
- Their speed of propagation depends upon their frequency ,i.e. increases with increase in frequency.
- They show negligible diffraction due to their small wavelength.
- They transmitted over a long distance without any loss of energy.
- Intense ultrasonic radiation has a disruptive effect in liquid by causing bubbles to be formed.

Production of Ultrasonic wave

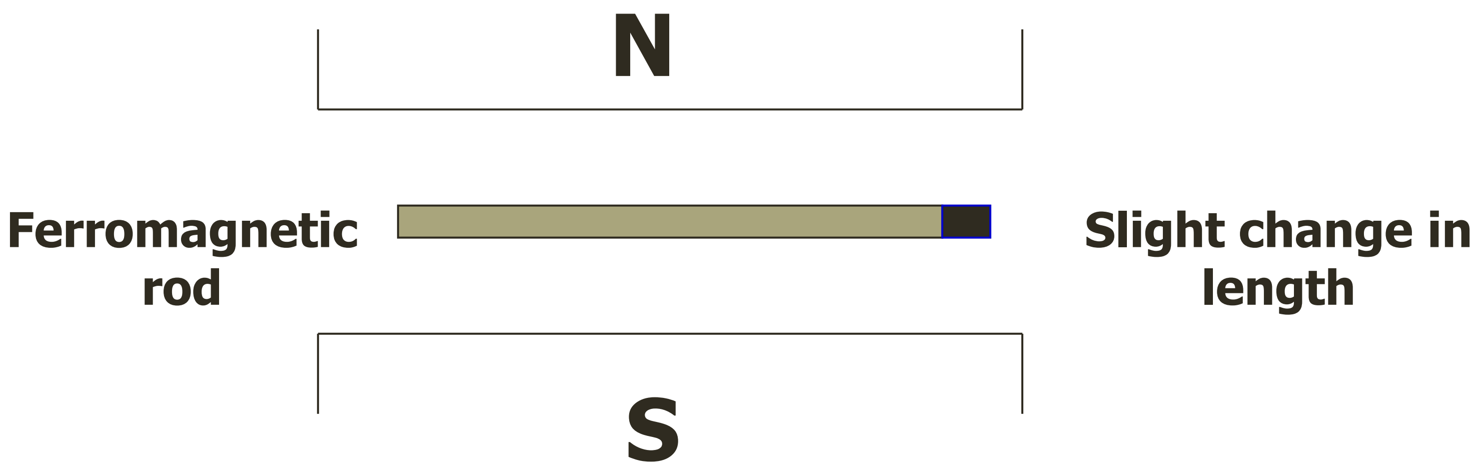
There are two methos used to produce ultrasonic wave:

(1) Magnetostriction Method: In this method, ultrasonic waves produces up to 100kHz.

(2) Piezo-electric Method: In this method , sound waves produces more than 100kHz.

Production of Ultrasonic wave

Magnetostriction Method: When a rod of ferromagnetic material such as iron, nickel is placed in a magnetic field parallel to its length, a small extension or contraction occurs.



Megnetostriction Method

- ❖If the rod is placed inside a coil carrying an alternating current, then it produces vibrations in the rod.
- ❖If frequency of applied alternating current resonance with natural frequency of rod sound waves of frequency 2f are produced.
- ❖If the applied frequency of alternating current is of the order of ultrasonic range, then ultrasonic waves are produces.
- ❖Frequency of ultrasonic waves

$$f = n/2L\sqrt{\gamma/\rho}$$

Megnetostriction Method

Experimental Arrangement:

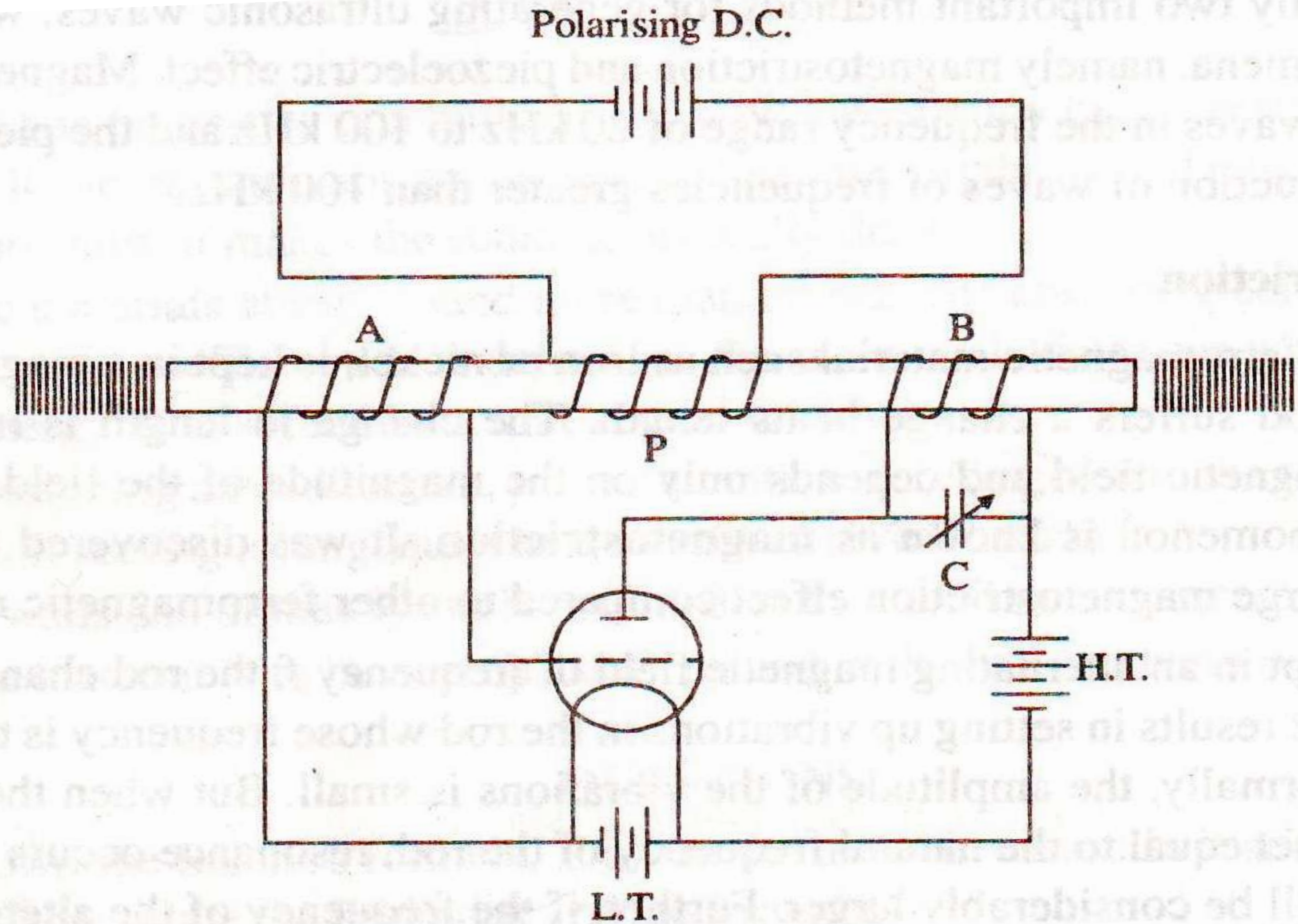


Fig. 12.1 A schemati

Production of Ultrasonic wave

Piezo-electric Method

It is based on Piezo-electric effect.

When certain crystals like Quartz, rochelle salt, Tourmaline etc. are stretched or compressed along certain axis (Mechanical axis) , an electric potential difference is produced along a perpendicular axis (Electrical axis).

Production of Ultrasonic wave

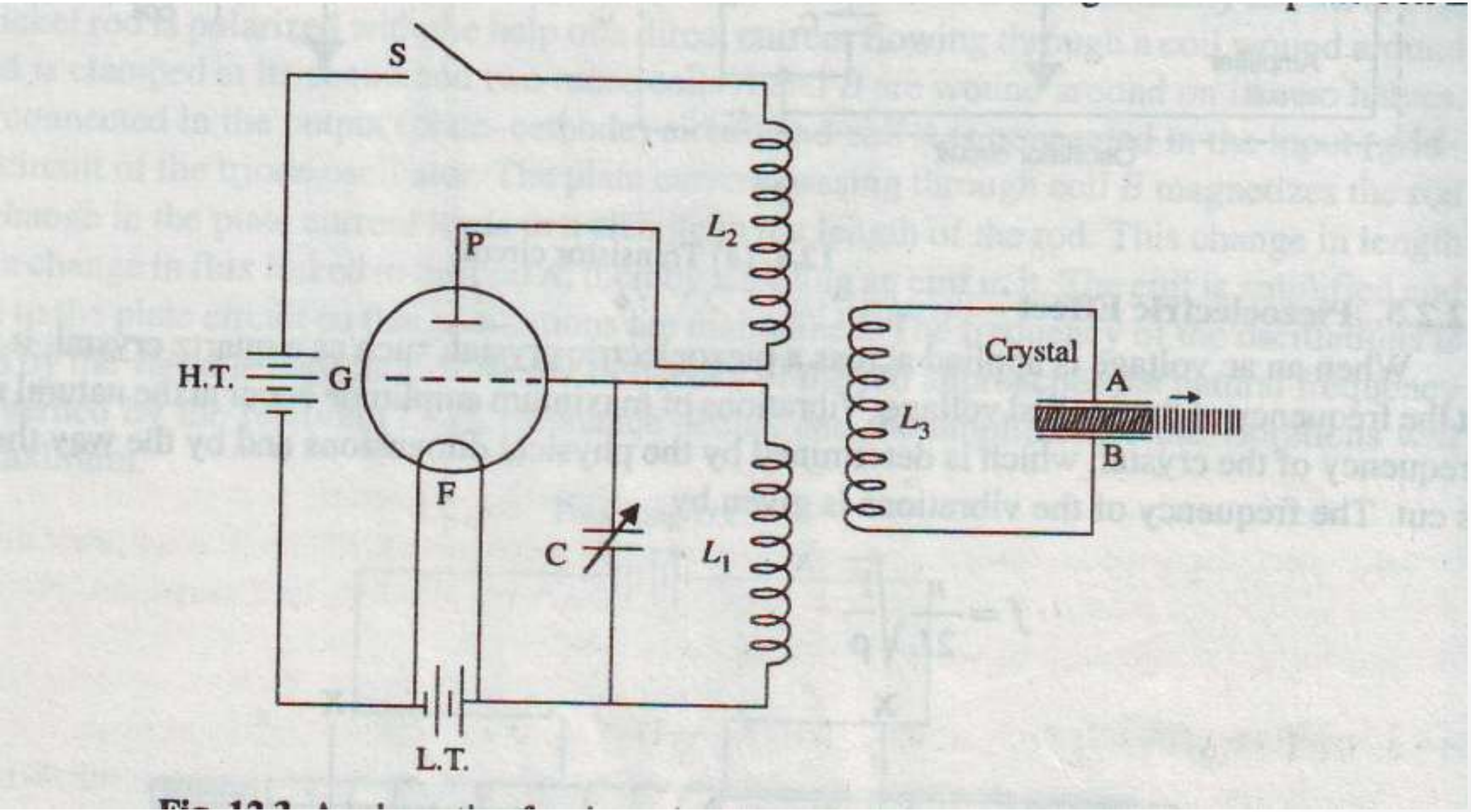
Conversely

When an alternating potential difference is applied along the electrical axis, the crystal is set into elastic vibration along mechanical axis.

If the frequency of electric oscillations coincides with the natural frequency of the crystal, the vibration will be of large amplitude, produces sound waves.

Production of Ultrasonic wave

Experimental Arrangement:



Determination of wavelength of ultrasonic waves

- When ultrasonic waves propagate in a liquid, the alternating compression and rarefaction change the density of the medium.

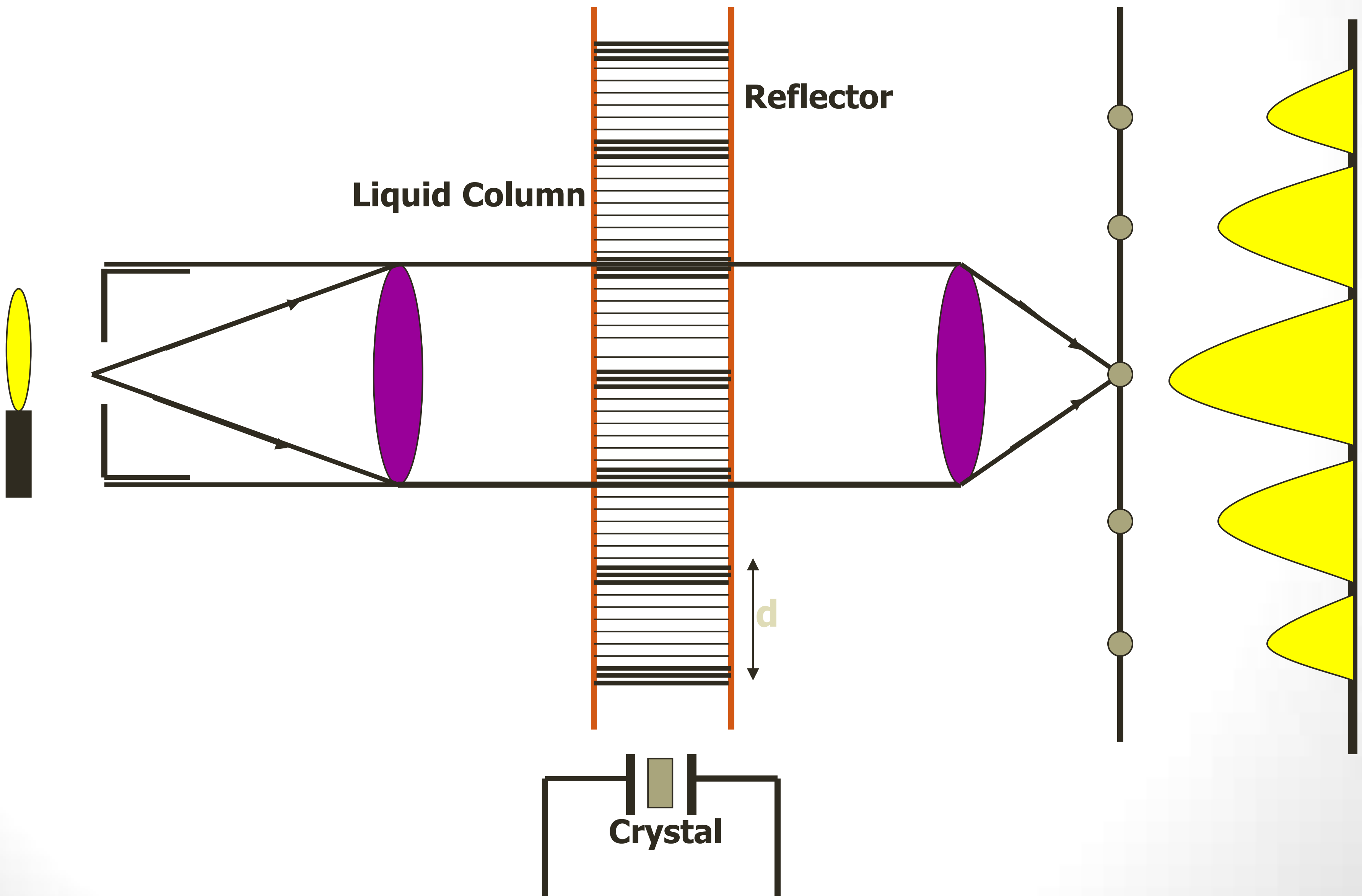
- It produces periodic vibration of refractive index of the liquid.

- Such liquid column subjected to ultrasonic waves constitutes an acoustical grating.

Determination of wavelength of ultrasonic waves

- If the monochromatic light passed through the liquid at right angles to the wave, the liquid causes diffraction of light.
- By diffraction ,wavelength of ultrasonic waves can be calculated.

Determination of wavelength of ultrasonic waves



Determination of wavelength of ultrasonic waves

- When the crystal is at rest, a single image of slit is formed on the screen.
- When the crystal is excited, a diffraction pattern is produced.
- It consists of a central maxima followed by first order, second order maxima and minima.

Determination of wavelength of ultrasonic waves

- Width of grating, $d = \lambda_u/2$ is given by

$$d\sin\theta = n\lambda$$

where

λ_u = wavelength of ultrasonic wave

λ = wavelength of monochromatic light

n = Order of the maxima

- $\lambda_u = 2n\lambda/\sin\theta$, knowing n, λ, θ value of λ_u can be calculated.
- The velocity of wave is given by $v = f\lambda_u$.

Applications of Ultrasonic Waves

Ultrasonics are extensively used in industry, medicine and marine applications.

(1) Echo sounder: Because of undiffracted, long distance traveling nature of ultrasonic waves ,the depth of ocean can be determined using an echo sounder. The ship is equipped at its bottom with a source and a receiver of ultrasonic frequency. The source sends out short pulses of ultrasonic waves and receiver receives reflected pulse. Measuring the time interval between the pulse sent and pulse received, the depth of ocean can be computed by

$l = vt/2$, v= velocity and t= time interval.

Applications of Ultrasonic Waves

(2) SONAR: it stands for sound navigation and ranging. The ultrasonic waves which are highly directional can be used for locating objects and determining their distance in the seas. In the absence of obstacle the ultrasonic pulses do not return to the ship. In the presence of obstacle, pulses are reflected and are picked by the receiver. Knowing the speed of the ultrasound and elasped time, the distance of the object can be determined by $l = vt/2$.

Applications of Ultrasonic Waves

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

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

(5) Soldering and metal cutting: It can be used for drilling and cutting processes in metals. It can also be used for soldering.

Applications of Ultrasonic Waves

(6) Ultrasonic Mixing: A colloid solution or emulsion of two non-miscible liquids like oil and water can be mixed by subjecting to ultrasonic radiations.

Ex.: Polishes, Paints, food products.

(7) Formation of alloys: The constituents of alloys, having widely different densities can be kept mixing uniformly by a beam of ultrasonics. It is easy to get alloy of uniform composition.

Applications of Ultrasonic Waves

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

(9) Detection of abnormal growth: abnormal growth in the brain, certain tumors which cannot be detected by X-rays can be detected by ultrasonic waves.

(10) Treatment of neuralgic pain: The body part affected due to neuralgic pains on being exposed to ultrasonics get great relief from pain.