**XI PHY SET 2**

**CHAPTER # 8**

**“WAVE & SOUND”**

**VIBRATORT MOTION: -**

When a body repeats its motion about its mean position then its motion is vibrators motion or vibrational motion.

**EXAMPLE: -**

* Motion of a swing
* Motion of a pendulum
* Atoms in solid
* Sitar’s string when plucked

**PERIODIC MOTION: -**

Any motion that repeats itself in equal intervals of time is called periodic motion.

**COMMON TERMS**

**DISPLACEMENT: -**

The distance of the vibrating body from its equilibrium position at any instant is known as displacement.

It is denoted by ‘x’

**AMPLITUDE: -**

The maximum distance of a vibrating body from its equilibrium position is known as Amplitude.

It is denoted by

Following figure illustrates the idea.

**TIME PERIOD: -**

The time required to complete one vibration or one round is called time period and it is denoted by ‘T’.

**FREQUENCY: -**

It is the no of vibration or round completed in one sec. it is denoted by .

**SIMPLE HARMONIC MOTION: -**

Simple harmonic motion is the particular type of periodic motion in which acceleration of the vibrating body is always directed towards its mean position (or equilibrium position) and is directly proportional to its displacement from the mean position.

**MATHEMATICAL EXPRESSION: -**

**MASS ATTRACHED TO THE SPRING PERFORMING S.H.M: -**

Consider a block of mass ‘m’ attached to one and of the horizontal spring and placed on a smooth horizontal surface when a block is given a small displacement to the right applied force is given as

Where,

The above expression is the mathematical expression of the Hook’s law which states that

“Extension of an elastic solid is directly proportional to the applied force provided that the force remains below the elastic limit”.

**ELASTICITY: -**

A characteristic of solid due to which they return or tends to return to their original shape or position.

Due to elasticity spring opposes this applied force. Spring exerts an elastic restoring force to bring the mass back to its mean position.

**RESTORING FORCE: -**

Restoring force is defined as the internal force of the system which returns or tends to return the system to its original shape or mean position.

Restoring force is always equal and opposite to that of applied force.

Force exerted by the spring on block is given by

(Diagrammatical Representation of mass attached to spring performing S.M.H)

When the block is released at position ‘A’ it moves towards the left under the influence of restoring force . Due to inertia it does not stop at mean position and continue to move towards the left now the spring compresses and exert restoring force towards the right. Hence the block perform vibratory motion under the influence of elastic restoring force.

We note that two conditions are necessary for a system to execute vibratory motion.

* They must have inertia.
* There must be a restoring force in the system.

Restoring force acting m the block is given by,

Applying Newton’s Second Law of motion force acting m the block is given by,

This shows that the acceleration of the block is directly proportional to its displacement and is always directed towards its mean position.

Hence by the definition the motion of the block is S.H.M

**UNIFORM CIRCULAR MOTION: -**

When a body moves along a circular path with constant speed. The motion of the body is said to be uniform circular motion.

**ANGULAR DISPLACEMENT: -**

When a body moves along a circular path it subtends an angle at the center of the circle known as angular displacement.

**EXPLANATION: -**

Suppose an object is moving along a circle of radius ‘r’ having a centre at ‘O’. It moves from point to point along and arc of length ‘s’. Following figure illustrates the idea.

**SIMPLE PENDULUM: -**

“An ideal simple pendulum consist of a spherical bob suspended by a weightless, flexible and inextensible string tied to a rigid, fixed and frictionless support”.

**MOTION OF A SIMPLE PENDULUM IS SIMPLE HARMONIC: -**

Consider a simple pendulum consisting of a spherical bob of mass ‘m’ suspended by an inelastic string of length ‘l’ as shown in the figure.

When it is displaced from its mean position. It starts oscillation about the mean position ‘O’. we consider position ‘B’ where the string makes an angle with the vertical. There are two forces acting on the bob . Assuming air friction to negligible.

1. Gravitational force (i.e. weight of the bob acting vertically downward)

i.e.

1. Tension in the string as indicated Net force acting on the pendulum is given by.

Force is resolved into two rectangular components as shown,

This is the component of the force which is parallel to the string.

This the component of the force which is perpendicular to the string.

As there is no motion along the string therefore is balance by Tension ‘T’.

Therefore the net force acting on the pendulum is given by

or

This is the force which is responsible for the vibration of pendulum. i.e. to say that it is the restoring force acting on the pendulum. Since it brings the pendulum to its mean position. Therefore we introduced a negative sign to its expressions.

If ‘a’ denotes the instantaneous acceleration of the pendulum then according to the Newton’s Second Law of motion. The net force acting on the bob is given as

Equaling equation (1) and (2)

If is so small (less than 261 radian or ) then

∴ The above expression becomes.

If ‘x’ denotes the displacement of the pendulum along the arc then we have

Here we have

So the equation becomes

∴ eq. (3) may be written as

The above expression shows that the motion of the pendulum is S.H.M

**TIME PERIOD**

Instantaneous acceleration of the pendulum is given by:

We also know that

Instantaneous acceleration of the body executing S.H.M is given by:

Comparing equation (i) and (ii)

As we know that

Time period of an object executing, S.H.M is given by

∴ The time period of the simple pendulum is given by

**CONCLUSION: -**

The above expression that:

1. The time period of the simple pendulum is independent of the mass of the bob and it is directly proportional to

**“WAVES”**

A single isolated disturbance travelling through a medium is called a wave or wave pulse.

**WAVE MOTION: -**

The mechanism of energy transfer by the wave is known as wave motion.

**TRANSVERSE WAVES:**

**DEF: -**

There are the waves in which particles of the medium vibrate in a direction perpendicular to the direction of the propagation of the waves.

**DIAGRAMATICAL ILLUSTRATION: -**

**EXAMPLE:**

**WATER WAVES**

When a stone is dropped on the surface of the water in a pound a depression is produced where the stone falls by virtue of elasticity. These particles try is regain their original position but in this attempt they over shoot their mean position (original position) due to inertia, due to cohesion this disturbance is communicated to the adjoining molecules and hence the wave travels towards the shore.

Since the molecules of water vibrate up and down at right angle to the direction of propagation of wave therefore water waves are transverse waves.

**GRAPHICAL REPRESENTATION: -**

**COMMON TERMS: -**

1. The distance b/w two consecutive crest or trough is called wave length denoted by Greek letter
2. The position of the wave in which the particles of the medium are higher than their normal position is called crest.
3. The position of the wave in which the particles of the medium are lower than their normal position is called trough.

**LONGITUDINAL WAVES: -**

These are the waves in which the particles of the medium vibrate along the direction of the propagation of waves.

**DIAGRAMATICAL ILLUSTRATION: -**

**GRAPHICAL ILLUSTRATION: -**

These waves are represented in the same graphical fashion as the Transverse waves.

**EXAMPLE: -**

Sound waves are the most common example of longitudinal waves.

Generation of sound waves is explained as,

Consider the diaphragm of the loud speaker moving initially to the right. It compresses the air in front of it seating a region of increased air pressure called compression. This compression travel outs through the air and at instant later the diaphragm is moving towards the left leaving behind a region of decreased air pressure called rarefaction. This disturbance travel outs through the air. Therefore sound waves producing by a vibrating body consist of alternate low and high air pressure region.

Following figures illustrates the idea.

We see that the air particle vibrate in the direction parallel to the direction of the propagation of the wave therefore sound waves are termed as longitudinal waves.

**WAVE FUNCTION: -**

A mathematical expression which shows the relation b/w displacement of the particle during vibration, location of the wave and time is called the wave function.

The wave function of the wave also give the shape, of the wave.

**For example.**

Wave function of a travelling harmonic wave is given by,

Where,

**PROVE**

**RELATION B/W VELOCITY, FREQUENCY AND WAVE LENGTH**

Let the velocity of the wave be and the wave length be and frequency of the wave be .

* The time required to complete one vibration is called time period and it is represented by .
* The number of vibration completed by a particle in one second is known as frequency of the wave.

Since the wave travel a distance which is equal to the wavelength during the time period . Therefore its velocity is given as,

Here,

Using equation of motion,

**THIRD EXAMPLE OF S.H.M**

Consider a particle moving in a circle of radius with the constant angular velocity . As the particle describes circular motion its projection executes vibratory motion along diameter AB

**DERIVATION FOR ACCELERATION: -**

Suppose that is the linear velocity of particle and is the displacement of the projection at any instant.

Since, particle revolving with constant angular velocity, therefore its tangential acceleration is zero and it has only one acceleration directed towards the centre of the circle. Following figure illustrates the idea.

As we know that,

Here,

Instantaneous acceleration of projection is the x-component of the centripetal acceleration of the particle

where,

negative sign introduce due to the following reasons.

When is to the right of its acceleration is towards the negative x-axis.

When is to the left of is negative

Put the value of in eq. (ii)

where,

a is the instantaneous acceleration of the projection .

The above expression shows that the motion of the projection of the particle is simple harmonic.

**VELOCITY: -**

The instantaneous velocity of the projection is the x-component of the velocity of the particle . Following figure illustrates the idea:

As we know that;

Put the value of in eq. (ii)

eq. (iv) and (v) represents the instantaneous value of the velocity of projection , the velocity of the projection is maximum at its mean position. And at mean position,

The velocity of the projection is minimum at its extreme position and at extreme position,

The acceleration of the mass attached to the spring performing simple harmonic motion is given as: -

where,

k is the spring constant.

The general expression for the acceleration of a body performing simple harmonic motion is given as: -

Equating eq. (vi) and (vii)

In order to find the velocity of the mass attached to the spring at any instant. Put the value of in eq. (iv) and (v)

If the displacement is zero then the velocity of the body is maximum.

The relation between maximum velocity and instantaneous velocity is given as: -

The velocity of the mass attached to the horizontal spring is zero at its extreme position Mathematically, it can be proved as: -

The instantaneous velocity of the mass attached to the horizontal spring performing simple harmonic motion is given as: -

At extreme position

**TIME PERIOD**

Consider a particle moving in a circle of radius with constant angular velocity . the angle which makes with x-axis at , is called as PHASE ANGLE OR PHASE CONSTANT. In time particle advanced by an angle . The angle which makes at any instant with x-axis is called as PHASE OF MOTION OR PHASE.

Following figure illustrates the idea.

Here,

Phase angle is and Phase of Motion or Phase is which is given as: -

When completes one revolution around the circle its projection complete one vibration along the diameter . Therefore and have the same time period. When one cycle is completed increases by time period and the PHASE increase by which shown as: -

Acceleration of the mass attached to the horizontal spring performing simple harmonic motion is given as: -

Where,

is the spring constant.

The general expression of the acceleration of a body executing simple harmonic motion is given as: -

By equating eq. (ii) and (iii)

**FREQUENCY: -**

**DISPLACEMENT: -**

Displacement of projection of particle when initial phase angle is is given as: -

When the phase angle is

**ENERGY IN MASS ATTACHED TO SPRING:**

1. **POTENTIAL ENERGY:**

Consider an object of mass ‘m’ attached to a spring of spring constant ‘k’ performing simple harmonic motion on a smooth and frictionless horizontal surface.

The restoring force on the block is given as,

When displacement is zero the force is zero, and at displacement ‘x’ from the mean position it is kx.

The work done on the block can be given as,

This work done on the block appears as the potential energy of the block.

i.e.

It shows that at equilibrium position the potential energy of the block is zero.

At extreme position the P.E is maximum.

i.e.

1. **KINETIC ENERGY:**

At any instant the kinetic energy of the block is given as:

Here,

This expression shows that at extreme position , the K.E is zero.

At equilibrium position, K.E is maximum.

1. **TOTAL ENERGY:**

At any instant the total energy of the block is given as:

**STATIONARY WAVES: -**

“These are the waves under the influence of which particles of the medium vibrate in such a manner so that the motion of the wave is not visible through the medium”

Stationary waves are set up in a medium as a result of super position of two exactly similar waves of same frequency, amplitude and wavelength travelling along the same line but in opposite direction.

**EXPLANATION: -**

Consider a string which is kept stretched by clamping its two ends, when the string is plucked at its middle two transverse waves originate from this point. One wave travel towards the right and other one travel towards the left end of the string. After reflection from the clamps end and then super position stationary waves are formed.

**ANTI NODES: - (A)**

The points where the particle vibrates with the greatest amplitude are known as “Anti nodes” denoted by “A”.

**NODES: - (N)**

The point where the particles do not vibrate (having zero amplitude) are known as Nodes denoted by “N”.

**ONE LOOP VIBRATION: -**

Consider a string of mass ‘m’ and length ‘L’ which is held under the tension ‘T’ between two fixed ends. When a string is plucked at its middle point, two transverse waves originate from this point, one wave travel towards the right and the other wave travel towards left end of the string. After reflection from the clamp end and then super position. Stationary waves are formed. Under the influence of these waves string is seemed to vibrate in one loop. As show in the figure.

Suppose be the wavelength and be the frequency, in the mode of vibration.

As we know that the distance between the two nearest node is equal to the half of wavelength.

If be the velocity of the wave, then we know that:

As we know that:

This expression shows that velocity of the wave depends upon the tension ‘T’, mass ‘m’ and length ‘L’ of the string. It is independent of mode of vibration, therefore remains constant.

Substituting the values of ‘v’ in eq. (i) we get,

**TWO LOOP VIBRATION: -**

When the string is plucked at one-fourth of its length, it vibrates in two loops as shown,

Let be the wavelength and be the frequency in this mode of vibration.

As we know that:

**THREE LOOP VIBRATION: -**

When the string is plucked at of its length it vibrates in 3 Loops as shown:

Let be the wave length and be the frequency in this mode of vibration.

As we know that:

**“n” LOOP VIBRATION: -**

In general, when the string vibrates in ‘n’ loops, the general equation of the wavelength and frequency is given as:

where,

and

**CONCLUSION: -**

This shows that in a medium, stationary waves of all the frequencies cannot be setup only those stationary wave are possible whose frequencies are integral multiple of .

**FUNDAMENTAL FREQUENCY OR 1ST HARMONIC: -**

The lowest frequency of vibration is called fundamental frequency or first harmonic. It is denoted by .

**OVERTONES: -**

Higher frequency which are the integral multiple of are know as the overtones.

|  |  |  |
| --- | --- | --- |
| Frequency | Harmonics | Overtones |
|  | First Harmonic  Second Harmonic  Third Harmonic  Fourth Harmonic  So on (n) | ×  1st overtone  2nd overtone  3rd overtone  So on (n-1) |

**“SONOMETER”**

**DEFINITION:**

It is an arrangement which is used to verify the laws of vibrating string and to determine the unknown frequency of a vibrating body like tunning fork.

**PRINCIPLE: -**

Its function based on the fact that stationary waves are set up in a stretched string whenever it is plucked by a certain frequency.

**CONSTRUCTION: -**

It consists of a metallic wire stretched across two bridges A and B, on the top of a hollow, wooden sounding box about one metre long. One end of the wire is fixed to the sounding box by a screw and the other end of string is passed over a frictionless pulley fixed at the other and of the box. A pass is attached to it for carrying weights. Hence the tension in string can be altered by changing the weights in the pan.

**WORKING: -**

Bridges A, B and C always from nodes at their position. When there is no bridge C b/w A and B string vibrates in one loop with fundamental frequency .

Where,

‘L’ is the length of vibrating portion b/w A and B and ‘V’ is the velocity of the wave given by:

Where ‘T’ is the tension in the string and is mass per unit length of string i.e.

→ This equation is used to determine the unknown frequency of a vibrating body provided that L, T and are known.

When bridge C is placed exactly b/w bridge A and B, string vibrates in two loop with frequency .

When string vibrates in n loop the corresponding frequency is given by

Where ‘n’ is a +ve integer.

Above expressions can be used to verify the law of vibrating string by Sonometer.

1. Frequency of vibration of stretched string of given material subjected to given tension is inversely proportional to length of vibrating portion of string.
2. Frequency of vibration of stretched string of given material and given length of vibrating portion of string is directly proportional to the square root of the tension in string.
3. At fixed tension in the string, frequency of vibration of stretched string of given length of vibrating portion is inversely proportional to the square root of mass per unit length of string.

**SPEED OF SOUND WAVES**

**NEWTON’S FORMULA FOR THE SPEED OF SOUND WAVES**

Sound waves produced in a medium travel in all directions.

The velocity of sound ‘v’ depends upon the following two factors.

1. The density of the medium.

i.e.

1. The elasticity of the medium.

i.e.

Newton deduced a formula for the speed of sound from above basic principles which is

When the formula is used for liquids or gases, the elasticity is measured in Bulk modulus (B). therefore the above formula when the medium is liquid or gases is written as,

Where,

is the mass density of the medium.

**BULK MODULUS: -**

Bulk modulus of a material is defined as The ratio of change in pressure to the resulting fractional change in volume of the material mathematically it is written as,

Where,

The ratio is always negative because pressure and volume are inversely proportional to each other when pressure increases volume decreases i.e. when is and vice versa. Therefore B is always positive.

**SPEED OF SOUND IN SOLID: -**

The speed of sound in solid rod is calculated as,

Where is the Young’s Modulus and can be written as,

Where,

Equation (i) and (ii) can be expressed in a general form as

**NEWTON’S ASSUMPTION: -**

While deriving the formula Newton assumed that the temperature of the medium (air) remains constant when the sound waves pass through it. According to his assumption sound travels through air and other gas under isothermal process.

A process in which the temperature of the system remains constant is known as isothermal process. By using Boyle’s law he found that the bulk modulus of air at constant temperature is equal to its pressure.

i.e. B = P

∴ eq. (i) may be written as

The speed of sound at STP in air calculated by this formula is . The experimental value of speed of sound in air is . This large difference between theoretical and experimental values of speed sound in air shows that there is some error in Newton’s formula. A French scientist Laplace corrected Newton’s formula.

**LAPLACE’S CORRECTION: -**

Newton’s idea regarding the bulk modulus (B) of a gas in which sound waves were travelling was a mistaken one.

Laplace pointed out the error in his assumption. He said that the temperature of a layer of air rises when a compression passes through it whereas cooling effect is produced when a rarefaction passes through it. Since air is a very poor conductor of heat no during a compression air cannot lose heat and during a rarefaction it cannot gain heat. Therefore the temperature throughout the medium does not remain constant it decreases in case of rarefaction and increases in case of compress on. As the temperature of the air does not remain constant. Therefore Boyle’s law is not applicable.

According to Laplace the process is Adiabatic and an adiabatic process is one in which no heat is allowed to leave or enter the system.

According to Newton the speed of sound in a gaseous medium is

Where,

But according to Laplace it can be shown that under adiabatic condition.

Bulk modulus of a gas is equal to times the pressure of a gas. i.e.

∴ The speed of sound in gaseous medium with Laplace correction is given as:

Where,

is a constant for gas and it is defined by the equation.

Since density is defined as mass per unit volume

i.e.

∴ equation no (i) may be written as

Using general gas equation

Where,

No. of moles can be found by using following formula.

Therefore the above general gas equation is written as,

The above equation can be used to determine the speed of sound in air at .

**SPEED OF SOUND AT**

In order to calculate the speed of sound in air at first we shall calculate for air. We know that air contains Nitrogen and Oxygen by mass therefore for air molecular mass is calculated as:

Put these values in the expression of velocity of sound.

**SPEED OF SOUND AT ANY OTHER TEMPERATURE: -**

At any other temperature ‘T’ the speed of sound in air can be obtained by multiplying i.e.

Where:

and

**FACTORS EFFECTING: -**

1. **EFFECT OF TEMPERATURE ON VELOCITY OF SOUND:**
2. The speed of sound is directly proportional to the square root of the absolute temperature of air or gas which is shown as:

Speed of sound in gaseous medium is given as:

For a particular medium are constant where as is the general gas constant

It has been found that speed of sound in air increases by for rise of temperature.

The speed of sound in air may also be calculated as

Where,

is the speed of sound in air at is the absolute temperature.

1. **EFFECT OF PRESSURE ON VELOCITY OF SOUND:**

Speed of sound in a medium of Bulk modulus and mass density is given as

or

Where is a constant for a particular gas with the increase or decrease of pressure the density of the air also increase or decrease therefore the ratio remains constant in above equation for a particular gas.

Hence we conclude that the velocity of sound in a particular gas is independent of the pressure of a gas.

**IMPORTANT POINT TO REMEMBER**

**b/c**

**DOPPLER’S EFFECT: -**

“When a source of sound or a listener or both are in motion relative to one another, the frequency and pitch of the sound as heard by the listener is differ from the frequency and pitch when both are at rest. This phenomenon is known as Doppler’s effect”.

**OR**

The observed change in the pitch and frequency due to relative motion b/w the source and the listener is called as Doppler’s effect.

**EXPLANATION: -**

When a source of sound and a listener or both are in motion, no. of waves striking a listener’s ear per second changes and this causing a change in frequency and pitch as heard by the listener.

There are the general possibilities to discuss the Doppler effect.

**POSSIBILITY # 1**

1. **When the listener is moving and source is at rest**

**CASE # 1: WHEN A LISTNER MOVES MOVES TOWARDS A STATIONARY SOURCE OF SOUND:**

Suppose that a listener is moving towards a stationary source of sound with a velocity and the frequency of sound emitted by the source is and the wave length of the sound waves be .

When both source and listener are at rest, frequency heard by the listener is . i.e.

Since the listener is approaching the source of sound with velocity , velocity of sound appears to him is (relative to listener).

Therefore apparent frequency as heard by the listener is

**CONCLUSION: -**

From the above expression it is clear that.

i.e. the frequency and pitch heard by a listener moving towards a stationary source of sound are greater than the frequency and pitch when both are at rest. In this case change in pitch is given by:

**CASE # 2: WHEN A LISTENER MOVES AWAY FROM A STATIONARY SOURCE OF SOUND:**

Suppose that a listener is moving away from a stationary source of sound with velocity . Since the listener is moving away from the source of sound ∴ speed of sound appears to him is (relative to listener)

∴ The apparent frequency heard by the moving listener is given by,

**CONCLUSION: -**

The above expression shows that i.e. frequency and pitch heard by a listener moving away from a stationary source of sound are less than the frequency and pitch when both are at rest.

Change in pitch is given by:

**POSSIBILITY # 2**

1. **When the source is moving and the listener is at rest**

**Case # 3: WHEN A SOURCE OF SOUND MOVES TOWARDS A STATIONARY LISTNER:**

Suppose that a source of sound is moving towards a stationary listener with a velocity and the frequency of sound emitted by the source is and the wavelength of sound waves be ,

When both source and listener are at rest, frequency heard by the listener is i.e.

Since the source of sound is moving towards the stationary listener therefore sound waves are now compressed in smaller length thus decreasing the wavelength. Let new wavelength be . Distance towards the stationary listener by the source of sound during one vibration is calculated as follows:

But,

From the above figure it is clear that:

∴ The apparent frequency heard by the listener is given as:

**CONCLUSION: -**

From the above expression we conclude that i.e. when a source of sound moves towards a stationary listener apparent frequency and pitch are greater than the real frequency and pitch.

**CASE # 4: WHEN A SOURCE OF SOUND MOVES AWAY FROM A STATIONARY LISTENER:**

Suppose that a source of sound is moving away from the stationary listener with a velocity and the frequency of the sound emitted by the source is and the wave length of sound waves be .

When both source and listener are at rest then the frequency heard by the listener is given by:

Since the source is moving away from the stationary listener ∴ sound waves are now occupying a greater distance and wavelength increases for the stationary listener.

Let the new wavelength be Distance travelled by the source during one vibration (generation of one wave) is given by:

from the above figure it is clear that,

The apparent frequency heard by the listener is

**CONCLUSION: -**

From the above expression we conclude that i.e. when a source of sound moves away from a stationary listener apparent frequency and pitch are less than the real frequency and pitch.

**POSSIBILITY # 3**

1. **When both the source and the listener are moving**

**CASE # 5: WHEN A SOURCE OF SOUND AND A LISTNER MOVES TOWARDS ONE ANOTHER:**

Suppose that a listener and the source of sound moving towards each other with a velocity respectively. Let be the speed of sound waves. Then the apparent frequency heard by the moving listener is given as:

**CONCLUSION: -**

From the above expression we conclude that i.e. the apparent frequency and pitch are greater than the real frequency and pitch.

**CASE # 6: WHEN A SOURCE OF SOUND AND A LISTENER MOVES AWAY FROM EACH OTHER:**

If the source and observer (listener) are moving away from each other along the line joining the two then the apparent frequency heard by the listener is given as:

**CONCLUSION: -**

From the above expression we conclude that i.e. the apparent frequency and pitch are lesser than the real frequency and pitch.

**MUSICAL SOUND: -**

**DEFINITION:**

A sound which is produced due to periodic and symmetric vibrations causing delightful sensation is termed as musical sounds.

**EXAMPLES:**

1. The sound produced by a tuning fork.
2. Sound produced by plucking the string of a sitar.
3. Sound produced by blowing into an organ pipe.

**FREQUENCY CURVE: -**

Musical sound with a regular symmetric fluctuation, periodic pattern which produces a smooth pleasant sensation is shown as

**WAVE FORM: -**

**CHARACTERISTICS OF A MUSICAL SOUND**

1. **INTENSITY: -**

**DEFINITION:**

The amount of energy transmitted per second through a unit area held perpendicular to the direction of propagation of sound waves is called intensity of sound waves.

1. **MATHEMATICAL EXPRESSION:**

Mathematically intensity of sound is given by:

i.e.

1. **UNIT:**

The unit of intensity is derived as,

As we know that

The S.I unit of power is and that of area is . Therefore the S.I unit of intensity is given as:

1. **EXPLANATION:**

1: Intensity of sound is a purely physical quantity and it can be measured accurately. It is independent of the ear.

2: The loudness of sound and intensity of sound are two different things.

3: The magnitude of auditory sensation produced in ear by sound is called loudness of sound. It is denoted by L.

4: Loudness depends upon the intensity as well as receiver of sound (ear).

1. **WEBER FECHNER LAW:**

**(Relation B/W Intensity And Loudness)**

Intensity of sound and loudness are interrelated by weber Fechner law according to which loudness of sound is directly proportional to the logarithm of intensity. i.e.

or

Where ‘k’ is a constant of proportionality and its value depends upon system of units.

1. **INTENSITY LEVEL:**

**DEFINITION:**

The difference in loudness of two sounds where one sound is faintest audible sound is called intensity level.

1. **EXPRESSION:**

If represent the intensities of two sounds having loudness respectively then intensity level is defined by equation.

Where is the intensity of any given sound and is the intensity of faintest audible sound which is taken as

If intensity level is expressed in Therefore the expression of intensity level in is written as,

1. **UNIT OF INTENSITY LEVEL:**

The unit of intensity level is

1. **BEL:**

If the intensity of sound is , then the intensity level of given sound is “one bel” where is the intensity of fairest audible sound which is equal to .

Put in eq. no (i)

**DECI BEL: -**

1. ‘Bel’ is very large unit. Therefore decibel (a small unit) is used to measure the intensity level

Therefore the expression of intensity level in decibel is written as,

Where is the fairest audible sound which is taken as

1. If

**POWER LAW: -**

Intensity and loudness of sound are also interrelated by power law which is written as:

Here loudness is measured in which is defined as:

Therefore the above formula is written as

∴ equation no (i) becomes

**INTENSITY LEVEL OF FAINEST AUDIBLE SOUND:**

The expression of intensity level in decibel is written as

For intensity level of fairest audible sound we have

**PITCH**

**DEFINITION: -**

The characteristic of musical sound by which a shrill sound can be distinguished from a grave one is known as the pitch of the sound.

**EXPLANATION: -**

1. Pitch of a sound depends upon frequency. The greater the frequency the higher will be the pitch and the lower the frequency the lower will be the pitch.
2. For example sound produced by a tunning fork of high frequency will be the shrill while that by a fork of low frequency will be the grave.
3. Pitch is the sensation which depends on frequency and therefore it is measured in hertz .

**QUALITY**

**DEFINITION: -**

The characteristic of musical sound by which a sound produced by a certain source is well distinguished from the sound of the same pitch and intensity produced by another source of sound is called quality of sound.

**OR**

Quality is the characteristic of musical sound which enables us to distinguish between notes of the same pitch and intensity when played on different instrument a sung by different voices.

**EXPLANATION: -**

1. We can recognize the value of our friend over the telephone by quality.
2. Our exact knowledge of sound quality is due to Helmholtz. According to him the difference in the sound produced by two notes of the same pitch and intensity is due to the difference in their resultant wave forms. The resultant wave form of any sound is obtained by combining the amplitudes of fundamental and over tones of the given sound. In the following figure combination of fundamental and third harmonic (second over tone) is shown.

**SUPER POSITION OF WAVES**

When two or more waves travel through a medium simultaneously along the same line the net displacement of medium at each time is equal to the algebraic sum of displacement caused by the waves individually. This is known as principle of super position of waves.

**REPRESENTATION: -**

When waves travel through the medium simultaneously along the same line, the net displacement of each particle is given by:

Where,

are the individual displacement caused by each of the waves.

**EXPLANATION: -**

Consider two harmonic waves of same amplitude, frequency and wave length travelling simultaneously along the same line. The phase difference b/w the two waves is . So the waves function of these waves are:

When the two waves superpose, resultant wave is given by:

As we know that:

Amplitude of the resultant wave is

**CONSTRUCTIVE INTERFERENCE**

When the phase difference b/w the two waves is zero i.e. waves are in phase.

Then,

i.e.

amplitude of the resultant wave is twice the amplitude of any one of the superposing waves. This type of superposition in which waves support each other is known as constructive interference. In constructive interference crests of one wave fall on the crests of another and so are the trough. This is illustrates in the figure:

**CONDITIONS:**

In general constructive interference take place when,

Where is a positive integer

**DISTRUCTIVE INTERFERENCE: -**

When i.e. when the waves are out of phase then,

i.e. Amplitude is zero at each point of medium. This type of superposition of waves in which they cancel the effects of each other is known as distructive interference.

In distructive interference crests of one wave coincide with the troughs of other wave. This is illustrated in following figure.

**CONDITIONS: -**

In general distructive interference takes place when,

Where is a odd integer

**BEATS**

**DEFINITION: -**

The periodic alternation b/w maximum and minimum sound intensity at a point due to super position of two sound waves of slightly different frequencies are called beats.

**EXPLANATION: -**

Consider two sound waves of same amplitude at slightly different frequencies . These waves are travelling simultaneously along the same line. Wave function of the two waves are given as.

When these two waves are superpose the resultant wave function of these waves is given by.

Let,

∴ Amplitude of resultant wave is

This shows that the amplitude of resultant wave varies with time. Resultant wave form shown in the following figure.

Amplitude of the resultant wave form attains its maximum value twice in a cycle. It means that we have two beats in one cycle.

“No. of beats in one second is known as beat frequency ”

Amplitude of resultant wave completes cycle in one second.

Since no. of beats completed in one second is known as beat frequency

**CONCLUSION:**

The above equation shows that the beat frequency is equal to the difference of frequencies of the two superposing sound waves.

**LIMITATION:**

We cannot hear more than 7 beats per second.

**APPLICATION:**

The phenomenon of beats is used in finding the unknown frequencies and also in tuning the musical sound.

For

A musical instrument is tune by beating it against standard instrument and counting the number of beats per second when the frequencies of two instrument become equal no beats are heard.

**ENERGY IN WAVES**

“Waves are energy carriers i.e. they transport energy from one place to another. It can be easily be verified by placing a weight in the way of a transverse wave set upon a stretched string. The wave displaces the weight showing that it has ability to do work i.e. it possess energy.”

Consider a harmonic wave set up on a stretched string. Under the influence of this force particles of the string execute S.H.M up and down. We consider a segment of mass of string b/w two nearest-crest.

We know that during S.H.M total energy is equal to the maximum kinetic energy.

As we know that

Where:

and mass per unit length of string is given by:

Substituting the value of and in eq. no (1)

we have,

∴ Power transmitted by harmonic wave is given by

This shows that power transmitted by Harmonic wave on a stretched string is proportional to the following:

1. Velocity
2. Square of amplitude
3. Square of angular frequency
4. mass per unit length

**ENERGY OF ELECTRO MAGNETIC WAVES: -**

Energy of electromagnetic waves is proportional to the frequency and given by

Where

**SHOCK WAVES: -**

If the moving source has a speed of equal to the speed of sound then all the wave (rests in front of the source lie upon one another) They together with the source itself all pass a given point at the same time. Therefore all the energy of the sound waves is compressed into a very small region in front of the source. This region of very dense sound energy is known as shock wave.

The exact shape of the shock wave depends upon the speed of the moving object.

When the source is moving nearly equal to the speed of sound the waves pile up and form a plane that extends perpendicular to the direction of motion of the source, following figure illustrates the idea.

When the speed of the source is greater than the speed of sound the resultant shock wave is conical. Following figure illustrates the idea.

**CHAPTER # 9**

**NATURE OF LIGHT**

**INTERFERENCE OF LIGHT**

It is the phenomenon in which light wave support or cancels the effect of each other.

**OR**

When a wave passes through a medium the particles of the medium are displaced from their mean position. When two waves pass through the same region at the same time they both produce disturbance in the particles of the medium. The combined effect of two sets of waves is known as INTERFERENCE.

**CONSTRUCTIVE INTERFERENCE**

If the resultant of the interfering waves is greater than the intensity of the individual wave then this type of interference is known as CONSTRUCTIVE INTERFERENCE.

**OR**

It is the phenomenon in which light waves support each other so that the resultant intensity of the light waves increases.

**DESTRUCTIVE INTERFERENCE**

If the resultant intensity of the interfering waves is zero or less than the intensity of an individual wave then this type of interference is known as DESTRUCTIVE INTERFERENCE.

**OR**

It is the phenomena in which light wave the effect of each other so that the resultant intensity of the light decreases.

**The Conditions for two source of light to produce observable interference:**

The essential condition for interference of light waves is phase coherence which means that light waves must be of equal frequency, wave length and has constant difference of phase.

Source of coherent waves are called coherent source.

Light waves from different light source can never be phase coherent. Only those light waves are phase coherent which come from a single light source.

**Conditions For Constructive Interference**

Constructive interference takes place when the path difference b/w light waves is zero or when the path difference b/w two light waves is the integral multiple of wave length

Where,

**Conditions for Destructive Interference**

Destructive interference takes place when path difference b/w light source is an odd multiple of i.e.

Where,

The above relation may be written as

Where

**YOUNG DOUBLE SLIT EXPERIMENT**

The phenomenon of interference in light waves from two sources was first demonstrated by Thomas Young in 1801. In order to explain Young’s experiment. Consider the light from a single source falls on two slits and separated by a distance . Let be the distance of the slit from the screen and is the central point of the screen as shown in the figure:

Consider the diagram,

Two rays and are reached at a point from the slit and from diagram it is clean that:

Where,

is the path difference which shows that wave travelling from the slit covers a distance move than that covered by the wave from the slit to reach the point . Also from the

**CONSTRUCTIVE INTERFERENCE**

If the path difference is either zero or integral multiple of wavelength of the light used. The two waves are in phase and constructive interference results i.e. a bright fringe is produced therefore, for constructive interference.

**or**

Where,

is also called order of fringe.

**DESTRUCTIVE INTERFERENCE**

On the other hand the point will be on a dark region when the path difference is odd multiple of half wavelength i.e.

**OR**

Where,

Also,

**INTERFERENCE FRINGES**

The bright and dark regions (bend) on the screen are known as interference fringes.

In actual experiment is very small as compare to . Therefore is very small that.

Multiply both sides by we get,

The previous expression gives the distance of any bright or dark fringes from the centre of the screen. The distances of bright fringes from can be obtained by putting

The So, when path difference is equal zero we have:

which shows there is always bright fringe at

Now the distance of first bright fringe from is equal to:

The distance of second bright fringe from is equal to:

The distance of third bright fringe from is equal to:

So the distance of bright fringe from is equal to:

The distance of dark fringes from point can be obtained by putting.

Therefore equation ‘1’ becomes

So we conclude that:

Distance of first dark fringe from

Distance of second dark fringe from

Distance of third dark fringe from

**FRINGE SPACING**

The distance b/w two bright fringes or dark fringes are known as fringe spacing or fringe width or fringe separation.

**FRINGE SPACING FOR BRIGHT FRINGE**

**FRINGE SPACING FOR DARK FRING**

So, fringe spacing for both dark and bright fringes is given as:

**INTERFERENCE IN THIN FILMS**

**DEFINITION: -**

If the thickness of film is comparable with the wavelength of light then it is termed as “Thin film”.

**EXAMPLES: -**

Soap bubbles and oil thin layer floating on the water are the examples of thin film in which coloured fringes are formed due to interference of light waves.

**INTERFERENCE EFFECT IN THIN FILM: -**

1. The different colours which are seen in thin film with ordinary white light are produced due to interference of waves reflected from the opposite surfaces of the film.
2. Consider a thin film of uniform thickness and index of refraction as shown below.
3. When the monochromatic beam of light of wavelength is incident on it part 1 is reflected from the upper surface and remaining portion is refracted into the film. This refracted portion is reflected from the lower face of film and comes out as part 2.
4. As the film is very thin so the path difference between 1 and 2 will be very small also part 1 and 2 are the portions of the same beam so they will have phase coherence and will superpose on each other giving the effect of interference.

Speed of light in a transparent medium whose index of refraction is is given as,

where is a velocity of light in vaccum.

1. The wavelength of light in a given transparent medium whose index of refraction is is given as,

But,

(frequency of light is not changed)

or

where is the wavelength of light in vaccum (or in air).

We find that ray 1 which is reflected from the upper surface , undergoes a phase change of with respect to the incident wave. Ray 2 which is reflected from the lower surface under goes no phase change with respect to the incident wave. Therefore rays 1 and 2 are out of phase. Also ray 2 travels an extra distance equal to before the two waves recombine.

**CONDITIONS FOR CONSTRUCTIVE AND DISTRUCTIVE INTERFERENCE**

Since there is a phase reversal is involve in interfering beams (Ray 1 and 2).therefore conditions of constructive and destructive interference are reversed.

1. The condition for constructive interference can be expressed as,

where,

where is the wavelength of light in free space.

when (for air)

1. For destructive interference:

where,

when

(For air)

**DIFFRACTION OF LIGHT**

**DEFINATION:**

When light passes a sharp edge or hole the size of which is comparable with the wavelength of light it bends around the corners of obstacle and spreads out into its geometrical shadow. This phenomenon is called diffraction of light.

**TYPE OF DIFFRACTION:**

Diffraction effects can be classified in the following two types.

1. **FRESNEL DIFFRACTION:**

When the source of light and the screen, on which diffraction pattern is to be obtained, are at finite distances away from the diffraction object, the diffraction is known as Fresnel’s diffraction.

In this type of diffraction the wave front’s falling on the diffraction object are not plane therefore the corresponding rays are not parallel. Similarly the wave fronts leaving the diffraction object to illuminate the screen are not plane.

1. **FRAUNHOFER DIFFRACTION:**

When the source of light and screen are at infinite distances away from the diffracting object, the diffraction is known as Fraunhofer diffraction.

In this type of diffraction the wave from is falling on the diffraction object are plane therefore the corresponding rays are parallel. Similarly the wave fronts leaving the diffraction object to illuminate the screen are plane.

**DIFFRACTION GRATING:**

It is a glass plate on which a number of parallel and equally spaced opaque lines are ruled most often six thousand lines are ruled in one cm length of grating.

**SIGNIFICANCE:**

It is used to determine the wave length of mono chromatic light (e.g. sodium light)

**DETERMINATION OF WAVE LENGTH OF MONOCHROMATIC LIGHT:**

1. The separations between lines act as slits.
2. Let ‘a’ be the thickness of slit ‘b’ be the separation between two adjacent slit.
3. When a parallel beam of light fall on the grating diffracted waves are sent out from each slit as shown.
4. The diffracted light waves are converged by a convex lens to a single point on screen.
5. Let be the angle between line to screen and diffracted light waves from geometry
6. In right triangle CED

represent the path difference between light waves 1 & 2

1. For point to be in the bright region must be an integral multiple of wave length (condition for constructive interference)

Comparing eq. (1) & (2)

where,

is called the grating elements and denoted by

∴ Eq. (3) ⇒

This is called grating Equation.

Grating element may be found as

**NOTE:**

1. can be measured with the help of a spectrometer.
2. The wave length of the light used can be calculate by using grating equation.

when,

it is called FIRST ORDER IMAGE

it is called SECOND ODER IMAGE

1. Part II after reflection from passes through the compensating plate on its return journey and finally it is incident on the silver surface of the plate from where it is reflected to the observer’s eye.
2. The two parts I and II of the beam in between and the eye superpose on each other and consequently they interfere in this region, as the two parts are derived from a single beam they must have a phase where once and the effect of their interference could be detected by the eye.
3. If two parts of beam enter the eye after covering exactly equal distances, they must interfere constructively and brightness will be seen.
4. If the mirror which is moveable is displaced to right through a distance of the part II will cover a distance more than first one now the two parts will interfere Destructively and Darkness will be seen.
5. If is moved further by the part II will travel a distance more than part I and the two parts reinforce each other so brightness will be seen.
6. Thus as the mirror is moved slowly brightness and darkness will appear alternatively at a point in the field of view.
7. Each time when the mirror is moved through a bright fringe will appear. Thus If ‘n’ no. of bright fringes appearing at a certain point in the field of view as the mirror is moved slowly a distance to the right then.
8. By Counting the no. of fringes and by measuring the distance through which the mirror is moved the wave length of light can be determined.

**NEWTON’S RINGS**

When a plano convex lens is placed on a plane glass plate, a thin film of air is enclosed between the lower surface of the lens and the upper surface of the plate. When this arrangement is illuminated by mono chromatic light, a series of dark and bright concentric rings are produced these circular rings (or circular flings) are called as Newton’s rings.

Following figure illustrates the idea:

**EXPLANATION OF INTERFERENCE EFFECT:**

1. Newton’s rings are the result of interference effect. The interference effect is due to the combination of ray’1’ reflected from the glass plate with ray ‘2’ reflected from the lower part (interface) of the lens.

Ray ‘1’undergoes a phase change of upon reflection whereas ray ‘2’ under goes no phase change. These two rays will interfere constructively or destructively depending upon the conditions of they interfere constructively a bright circular fringe is detained and if they interfere distractively a dark circular fringe (ring) is obtained.

1. For bright Newton’s rings

for air

where

1. For dark Newton’s rings since for air

where

and

is the thickness of air film

**EXPRESSION FOR RADIUS ON BRIGHT RING (FRING):**

**Let,**

Wave length of the light used is

Radius of the curvature of plano-convex lens is Thickness of the air film between the lower surface of the plano convex lens and glass plate at point is .

Radius of the ring there

As shown below,

From figure

and

Since is very very less than so the higher power of may be neglected.

or,

For ring

As we know for constructive interference in this thin air film is given by,

For air

where,

So for first bright ring

For second bright ring

For third bright ring

From ii, iii and iv we conclude that for bright ring

Therefore for bright ring

So equation (i)

or

**POLARIZATION OF LIGHT**

* **PLANE POLARIZED LIGHT:**

The beam of light in which all vibrations are confined to one plane of vibration is called plane polarized light or polarization.

Plane polarized light vibrating in a vertical plane.

* **UNPOLARIZED LIGHT:**

A beam of ordinary light consisting of large numbers of plane of vibration vibrates in all probable directions perpendicular to the direction of propagation. Such a beam of light is called un polarized light.

(Ordinary un polarized light)

**EXPLANATION: -**

1. Maxwell showed that light waves (electromagnetic waves) consist of an oscillating electric field and an oscillating magnetic field. Both fields are mutually perpendicular to each other and also perpendicular to the direction of the propagation of the wave as shown in the diagram.
2. The beam of light in which all vibrations are confined to one plane of vibration is called plane polarized. It is possible to produce polarized light be filtering ordinary light through a polarizer which is a material that transmits only those waves that oscillate in a single plane.
3. Tourmaline crystals are often used to polarize the light and to analyses the polarized light. A tourmaline crystal transmits only those vibrations of light waves which are parallel to the axis of crystal.
4. When un polarized light is incident on two tourmaline crystals placed with their crystallographic axes parallel, the light beam is transmitted. If however one of the crystal is rotated with respect to other the emergent beam becomes dimmer and ultimately light is totally cut off when the axes of the two crystals becomes perpendicular to each other.
5. On further rotation the light reappears and becomes brighter when the axes of crystals again parallel.
6. When a beam of light passes through crystal one component of the vibration is absorbed and the other component is transmitted consequently the emerging beam differs from incident light in the lens that all the vibrations are in one direction. Such a beam is said to be plane polarized. When it falls on a second crystal, vibrations can only pass. If they are parallel to the transmission direction of the crystal.
7. We see that polarization of light is due to the selective absorption by tourmaline crystal.
8. The first crystal is known as polarizer whereas the second crystal is known as analyzer.

**DIFFRACTION OF X-RAYS**

X-Rays is a type of electromagnetic radiation of much shorter wavelength about

In order to observe the effects of diffraction the grating spacing must be of the order of the wavelength of the radiation used. The regular array of atoms in a crystal forms a natural diffraction grating with spacing that is typically . The scattering of X-rays from the atoms in a crystalline lattice gives rise to diffraction effects very similar to those observed with visible light incident ordinary grating.

**BRAGG’S EQUATION: -**

Suppose an X-rays beam is incident at an angle on one of the planes. The beam can be reflected from both the upper and lower planes of atoms. The beam reflected from lower plane travels some extra distance as compared to the beam reflected from the upper plane. Let is the path difference between the two incident rays and is the path difference between two reflected rays.

In we have,

Also in we have,

Total path difference is given as,

The effective path difference between the two reflected beams is .

For constructive interference the path difference should be an integral multiple of the wave length thus,

Where, is called order of reflection.

This is known as Bragg’s equation. Bragg’s equation is used to find out.

1. Wave length of X-Rays
2. The atomic spacing of crystal

**PROPERTIES IF STATIONARY WAVES**

1. They do not transfer energy through the medium.
2. There are nodes and antinodes in stationary waves.
3. Amplitude of the vibrating particles is different.
4. Stationary wave does not travel in any direction.

**ACOUSTICS: -**

The branch of physics which deals with the study of production and properties of sound is called acoustics.

**CONDITIONS FOR GOOD ACOUSTICS: -**

Good acoustics conditions are required for proper listening and recording of sound for this purpose.

1. The room or hall must have some open windows, sound absorbing materials like cloth, cork, asbestos, heavy curtains to avoid reflection.
2. Reverberation should be small but non zero.
3. Echoes should be just sufficient to maintain the continuity of sound.
4. The decay period of each sound should be small.
5. The loudness of each separate syllabic should be sufficiently large.

**Power transmitted by Harmonic waves:**

The power transmitted by the harmonic wave is given as,

This shows that power transmitted by harmonic wave on a stretched string is proportional to the following.

1. Velocity
2. Square of the amplitude
3. Square of the angular velocity
4. Mass per unit length

**Energy of electromagnetic waves:**

Energy of electromagnetic waves is given as.

where, is the frequency and is the plank’s constant.

**Mach No: (Mach Number)**

The ratio is called the Mach number. According to this terminology a source travelling at Mach Number 2 is moving at twice the speed of sound. Where,

Relation b/w Torque and Angular momentum

The angular momentum is given by

**or**

Divided both side by

The above equation shows that rate of change of angular momentum is equal to the applied torque.

**LAW OF CONSERVATION OF ANGULAR MOMENTUM:**

According to the Newton’s 2nd Law of motion. The rate of change of Linear momentum is equal to the force acting on it.

i.e.

But,

and

Of the external torque acting on the body is zero then

The angular momentum of a particle on body is conserved (constant) of the net torque acting on it is zero.

**CENTER OF MASS: -**

The center of mass of a body or a system of many masses is a single point a which the whole mass of the body or system is concentrated.

There will be one point in the body which will have translational motion only. This point is called center of mass.

**THE MICHELSON INTERFEROMETER**

**INTRODUCTION: -**

Michelson Interferometer is an instrument which is used to calculated the precise wavelength of light. It was invented by an American scientist name “Michelson”. In this experiment extended monochromatic source of light is used.

**CONSTRUCTION: -**

Michelson interferometer consists two glass slab & two mirrors. One of the glass is semi polished by silver so that the light can be reflected or refracted, extended monochromatic source of light is used to the glass slab is placed at an angle of with the beam of light. A mirror is placed at right angle with the semi polished silver glass slab. A mirror is placed parallel to the glass slab such that it is perpendicular to the beam of light. The mirror is moveable while the mirror is fixed. The distance of mirror from the beam splitter is and the distance of mirror from the beam splitter is .

**WORKING: -**

Light coming from the extended source is broken into two position by the beam splitter. Some part of light is reflected from the beam splitter that falls on the mirror . After reflection from the mirror, it enters the observer eyes by passing through the beam splitter. Once again the remaining position of the light refracted from the beam splitter falls on the mirror after passing through the compensating plate and it is reflected back from the mirror and follows the same path and enters the observe is eye after reflection from the semi-polished silver surface.

1. If and are equal then the path difference between the rays is zero & constructive interference will occur and a bright fringe is obtained.
2. If the mirror is moved by a distance then the path difference between the rays will be equal to & destructive interference will occur and a dark fringe is obtained.
3. If a moveable mirror is moved by a distance of them the path difference between the rays will be equal to and constructive interference will occur & a bright fringe is obtained.

**DETERMINATION OF WAVELENGHT: -**

If is the distance moved by the mirror then wavelength of light can be found out from the following formula.

Where,

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Distance moved by mirror** | **Path difference b/w 2 rays** | **Interference Patten** | **Order of fringe (Only for C.I)** |
| **1** |  |  | C.I | 0 |
| **2** |  |  | D.I | - |
| **3** |  |  | C.I | 1 |
| **4** |  |  | D.I | - |
| **5** |  |  | C.I | 2 |

1st condition will be applied when while the rest of the conditions will be applied when

**Chapter # 10**

**GEOMETRICAL OPTICS**

**THIN LENS FORMULA FOR CONVEX LENS**

**DEFINITION: -**

The relation between object distance , image distance and focal length is called THIN LENS FORMULA.

**MATHEMATICALLY: -**

**DERIVATION: -**

Suppose an object is placed at a distance from the convex lens whose focal length is , then its real image is formed at a distance from the convex lens as shown in the figure.

In the above figure

is similar to

because:

2. Both are right triangle.
3. (By Reason)

Here,

is similar to

because:

2. Both are right angled triangle.
3. (By Reason)

Here,

Comparing eq. (A) and (B)

By cross multiplication

Dividing whole eq. by

**CONCLUSION:**

From the above expression we conclude that the reciprocal of focal length is equal to the sum of reciprocals of the object distance and image distance.

**THIN LENS FORMULA FOR CONCAVE LENS**

**DERIVATION: -**

Suppose an object is placed at a distance from the concave lens of focal length then its virtual image is formed at a distance from the concave lens as shown.

In the above figure

is similar to

because:

1. (same angle)
2. Both are right angled triangle.
3. (By Reason)

is similar to

because:

1. (same angle)
2. Both are right angled triangle.
3. (By Reason)

Comparing eq. (A) and (B)

Dividing whole eq. by

**LENSES IN CLOSED COMBINATION**

Consider two lenses and whose focal lengths are and respectively. They are so close to each other that their distance of separation may be neglected as compared to their focal lengths. Following figure illustrates the idea.

Let,

point object be placed at a distance from lens whose real image is formed by it at a distance as shown in the figure.

Image now serves as a virtual object for second Lens of focal length . If we neglect the small separation between the lenses, the distance if this virtual object from lens will be the same as its distance from the lens i.e.

Now, If the lens forms an image of this virtual object at a distance then this situation can be shown as:

Applying thin lens formula for lens

Applying thin lens formula for lens

Adding eq. (1) and (2)

**MAGNIFYING GLASS**

**DEFINITION: -**

“A convex lens which is used to see the detail of an object by bringing it close than is known as MAGNIFYING GLASS”

If an object is placed within the focal length of a convex lens the image formed by the lens is erect, virtual and magnified. Following figure illustrates an idea.

**MAGNIFYING POWER: -**

The ratio b/w the visual angle subtended by the image when seen through the magnifying glass i.e. and the visual angle subtended by the object when placed at least distance of distinct vision i.e. is termed as MAGNIFYING POWER. Mathematically it can be expressed as,

**Derivation: -**

Consider an object placed at least distance of distinct vision from an eye. Let this object subtend a visual angle at eye. Suppose the same object is placed in front of convex lens of focal length in such a way that its image is formed at least distance of distinct vision which is erect, virtual and magnified. As shown in figure.

In right angle triangle

If the size of the object is assumed to be very small as compare to its distance from the eye lens the tends to zero.

Therefore, the above ratio becomes,

In right angle triangle

* is common

In similar triangle we have,

By comparing eq. no (iii) & (iv)

Applying thin lens formula,

Multiply both sides by

By comparing eq. no (v) & (vi)

**CONCLUSION: -**

From the above expression we conclude that for higher magnification convex lens of short focal length should be used.

**COMPOUND MICROSCOPE**

**DEFINITION: -**

“Compound microscope is an optical instrument which is used to see the detail of an object with very high magnification.”

**CONSTRUCTION: -**

It consist of two convex lenses,

1. Objective
2. Eye piece
3. **OBJECTIVE:**

“The lens near the object or placed before the object is called OBJECTIVE”’

The focal length of objective is much smaller than the focal length of the eye piece .

1. **EYE PIECE:**

“The lens near the eye is known as EYE PIECE”

The focal length of the eye piece is much greater than the focal length of the objective . It acts like a magnifying glass.

**WORKING: -**

The object is placed very close to the focus of the objective which forms its real, inverted and magnified image in front of the eye piece. The position of the eye piece is adjusted in such a way that this image should fall within its focal length. The eye piece will now looks like a magnifying glass and will form a highly magnified virtual image . The image is formed at least distance of distinct vision.

**RAY DIAGRAM OF COMPOUND MICROSCOPE**

**MAGNIFYING POWER: -**

It is the ratio of the visual angle subtended by the image to the visual angle subtended by the object at eye. When they are at least distance of distinct vision. i.e.

From the fundamental definition,

Since is so small,

Again from the fundamental definition.

Since is very small,

By substituting the values of in eq. no (i)

Multiply and divide by on right hand side,

Where,

Therefore, the above ratio becomes

From the above expression we concluded that the resultant magnifying power of compound microscope is the product of magnifying power of the objective and eye piece.

is similar to

Because,

* Both are right angle triangle
* (vertical angles)
* (By reason)

In similar triangles we have,

and,

Since eye piece is used as the magnifying glass therefore its magnification can be expressed as,

Put the values of in eq. no (iv)

Which is the resultant magnifying power of compound microscope.

**APPROXIMATION: -**

Since object is placed very near to the focus of the objective therefore object distant can approximately be taken as,

Since the image formed by the objective is very close to the eye piece therefore,

Therefore, the expression for the resultant magnifying power of compound microscope is given as,

**TELESCOPE**

**DEFINITION: -**

“Telescope is an optical instrument which is used to see the distant objects clearly.”

**EXPLAINATION: -**

The image of the distant objects formed by the telescope is very small as compare to the actual size of the object but a the image is formed very close to the eye so it appears larger when seen through the telescope.

**ASTRONOMICAL TELESCOPE**

**DEFINITION: -**

“Astronomical telescope is an optical instrument which is used to see the heavenly bodies.”

e.g. sun, moon, planets etc

**CONSTRUCTION: -**

It consists of two convex lenses.

1. Objective
2. Eye piece
3. **OBJECTIVE: -**

“The lens near the object or placed before the object is termed as OBJECTIVE.”

It has large focal length and large aperture so that it should receive maximum light from the object. The focal length of objective is denoted by .

1. **EYE PIECE: -**

“The lens near the eye is known as EYE PIECE.”

The focal length of the eye piece is much smaller than the focal length of the objective . It acts like a magnifying glass.

**RAY DIAGRAM OF ASTRONOMICAL TELESCOPE**

**WHEN THE FINAL IMAGE IS FORMED AT LEAST DISTANCE OF DISTINCT VISION**

**WORKING: -**

The objective form real, inverted and diminished image of the distant object at its focus. The position of the eye piece is adjusted in such a way that this image should fall within its focal length. The eye piece will now work like a magnifying glass and will form a magnified image at least distance of distinct vision as shown above.

**WHEN THE FINAL IMAGE IS FORMED AT INFINITY:**

**WORKING: -**

When the distant object is viewed, the parallel rays from the object are converged by the objective to form a real, inverted and extremely dimished image . The position of the eye piece is adjusted in such a way that the image is at the focal point of the eye piece. The rays after refraction from the eye piece becomes parallel to one another and the final image is formed at infinity. In this way the image formed by the objective is at the focal point of both the objective and eye piece. Under this condition the telescope is said to be focused for infinity.

**MAGNIFYING POWER: -**

Let and are the visual angles of object and image respectively. Consider right angle triangle . In this triangle.

is so small.

The above ratio becomes,

Again consider right angle triangle . in this triangle we have,

is so small.

The above ratio becomes,

According to the definition of magnifying power,

**LENGTH OF THE TELESCOPE: -**

The length of astronomical telescope when the final image is formed at infinity can be given as,

**CONCLUSION: -**

From the above expression we concluded that for higher magnification focal length of the objective must be greater than the focal length of the eye piece.

**TERRESTRIAL TELESCOPE**

**DEFINITION: -**

“Terrestrial telescope is an optical instrument which is used to see the distant objects clearly on earth so that the final image should by erect.”

**CONSTRUCTION: -**

It consist of three convex lenses,

1. Objective
2. Erecting or field lens
3. Eye piece

**OBJECTIVE: -**

“The lens near the object or placed before the object is called OBJECTIVE”

The focal length of the objective is much greater than the focal length of the eye piece. Also it has large aperture so that it should receive maximum light from the object.

**ERECTING LENS: -**

“The lens between the objective and the eye piece is termed as ERECTING LENS.”

The main function of the erecting lens is to erect the image produced by objective without any magnification.

**EYE PIECE: -**

“The lens near the eye is known as EYE PIECE.”

It acts like a magnifying glass. The focal length of the eye piece is much smaller, than the focal length of the objective . For construction and working following figure illustrates an idea.

**WORKING: -**

The objective forms a real, inverted and demolished image of the distant object . The image formed by the objective is at distance of from the erecting lens.

The image formed by the erecting lens is also at and its size is equal to . The erecting or field lens does not magnify the image it only erect it.

The image is within the focal length of the eye piece. The eye piece will now works like a magnifying glass and will form a highly magnified, virtual image .

**RAY DIAGRAM OF TERRESTRIAL TELESCOPE**

**GALILEAN TELESCOPE**

**OR**

**GALILEO’S TELESCOPE**

**DEFINITION: -**

“Galilean Telescope is an optical instrument which is used to see the distant objects on earth so that the final image should be erect.”

**CONSTRUCTION: -**

In this telescope following lenses are used:

1. **OBJECTIVE (CONVEX LENS): -**

“A convex lens near the object or placed before the object is termed as OBJECTIVE.”

It has large focal length & large aperture so that it should receive maximum light from the object.

1. **EYE PIECE (CONCAVE LENS); -**

“A concave lens near the eye is known as EYE PIECE.”

The focal length of the eye piece is much smaller than that of objective .

**RAY DIAGRAM OF GALILEAN TELESCOPE**

**WORKING: -**

In the absence of eye piece objective forms a real, inverted and diminished image of distant object at its focus. The eye piece is introduced b/w objective and image in such a way that lies very close to its focus. Thus erect, virtual and highly magnified image is produced by the eye piece.

**MAGNIFYING POWER: -**

Let and are the visual angles of object and image respectively.

In right angle triangle

Since is so small

The above ratio becomes,

Again consider triangle

In this triangle

Since is so small

Therefore the above ratio becomes,

According to definition of angular magnification.

Put values of and in eq. no (iii)

**LENGTH OF THE TELESCOPE: -**

The length of Galilean telescope can be given as,

**DEFECTS OF LENSES**

When the rays of light parallel to the optical centre of the lens are not focused at a point the Following defects are produced.

1. SPHERICAL ABERRATION
2. CHROMATIC ABERRATION
3. **SPHERICAL ABERRATION: -**

When rays parallel to the optical centre of the lens are passed through the convex lens. The rays near the edges of the lens are focused near the lens and the rays near the optical centre of the lens are focused away from the lens. It means that the rays near the middle of the lens have larger focal length than the rays at the edges. Hence, there is no single focal length of the lens. Therefore, light rays are not focused at a point. So the final image is not cleared. This defect of lens is known as SPHERICAL ABERRATION.

**DIAGRAMATIC ILLUSTRATION:**

**MINIMIZATION: -**

In order to minimize this defect optical instrument using lens are provided with a   
“STOP” which allow only the controlled rays to pass through the lens.

For example, in camera.

Following figure illustrates an idea.

The spherical aberration can also be reduced by taking suitable values of radii of curvature of the spherical surfaces of the lens.

1. **CHROMATIC ABERRATION: -**

Two surfaces of convex lens acts like two prisms placed end to end. When poly-chromatic light is refracted through convex lens it dispersed into its constituent colours. Different colours are refracted it different angles due to different wave lengths. Therefore image produced is not clear and sharp and it has colours rings. This defect which is due to dispersion of light is known as CHROMATIC ABERRATION.

**ILLUSTRATION THROUGH DIAGRAM: -**

The following figure shows how a convex lens acts lie two prisms placed end to end.

**REFRACTION OF RED & VIOLET COLOURS: -**

White-light consists of seven colours but only two colours have been represented for the sake of simplicity.

In the above figure we show the refraction of violet and red colours only when light is made to pass through a convex lens. The different angles of refraction are due to different wave lengths of colours.

**MINIMIZATION: -**

This defect is corrected by combining a convex lens of crown glass with a concave lens of flint glass. These lenses are chosen in such a way that chromatic aberration (dispersion) produced by convex lens is neutralized by concave lens so that the combination is free from chromatic aberration.

**EYE: -**

**CONSTRUCTION: -**

1. **SCLEROTIC: -**

The outer most layers is called Sclerotic. It is thick and opaque.

1. **CORNEA: -**

The front portion of sclerotic is called Cornea. It is transparent.

1. **CHOROID: -**

Inside the Sclerotic there is a black pigmented layer called the Choroid.

1. **IRIS: -**

The front portion of the choroid is called Iris.

1. **PUPIL: -**

In the centre of the iris there is an opening called Pupil.

1. **FUNCTION OF IRIS: -**

The Iris contracts in bright light and dilates in dim light. It is adjusted to control the amount of light entering the eye.

1. **RATINA: -**

A transparent and soft convex lens is held just behind the iris which focuses the light entering the eye thus forming an image on a photo-sensitive layer called Retina.

**CILIARY MUSCLES: -**

The flexible lens of the eye is supported by Ciliary muscles.

**WORKING: -**

When the eye is directed towards a near object, the eye lens bulges out by the action of Ciliary muscles and its focal length decreases in such a way that a clear and distinct image is formed on the retina. When eye is looking at some distant object the cilliary muscles are relaked and the focal length of eye lens is increased and a clear and distinct image is formed on the retina.

**DEFECTS OF EYE**

**NEAR SIGHTEDNESS OR SHORT SIGHTEDNESS OR MYOPIA**

The defect of an eye in which the distant objects cannot be seen clearly is called Near Sightedness or Short Sightedness or Myopia

**CAUSES: -**

The eye lens of such an eye is too converging or the eye ball is too elongated. Following figure illustrates the idea.

**IMPROVEMENT: -**

This defect of an eye can remove by using concave lens of suitable focal length. Following figure illustrates the idea.

**LONG SIGHTEDNESS** **OR** **FARSIGHTEDNESS** **OR** **HYPEROPIA**

The defect of an eye in which the near object cannot be seen clearly is called Long Sightedness or Farsightedness or Hyperopia

**CAUSES: -**

In this defect the eye lens of such an eye is less converging or the eye ball is too short. Following figure illustrates the idea.

**IMPROVEMENT: -**

This defect is removed by using convex lens of suitable focal length, following figure illustrates the idea.