UNIT-I

SYLLABUS

Superposition of Two Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses. Waves Motion- General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity.

SIMPLE HARMONIC MOTION:

Simple harmonic motion is a type of vibratory motion in which the acceleration is proportional to the displacement and is always directed toward the position of equilibrium. For such a motion to take place the force acting on the body should be directed towards the fixed point and should also be proportional to the displacement i.e, the displacement from the fixed point. The function of the force is to bring the body back to its equilibrium position and hence this force is often termed as restoring force.

The backward and forward swing of a pendulum, the up and down motion of a weight hanging on a spring, and the twisting and untwisting motion of a body suspended by a wire are the examples of motions which are nearly simple harmonic.

Suppose a particle of mass m is executing simple harmonic motion. If y represents the displacement of the particle from equilibrium position at any instant t, the restoring force F acting on the particle would be given by

or $$F = -Sy \qquad \text{---------------- (1)}$$

Where S denotes the force constant of proportionality or stiffness. In Equation (1) the negative sign is used to reveal that the direction of the force is opposite to the direction of increasing displacement.

If $\frac{d2y}{dt2}$ represents the acceleration of the particle at time then equation (1) becomes as follows:

$$m \frac{d^2y}{dt^2} = -Sy$$

or $$\frac{d^2y}{dt^2} + \frac{S}{m} y = 0$$

But $$\frac{S}{m} = \omega^2$$

$$\therefore \frac{d^2y}{dt^2} + \omega^2 y = 0 \qquad \text{----------- (2)}$$

Equation (2) is the general differential equation of motion of a simple harmonic oscillator.

In order to find a solution of this equation, Equation (2) is multiplied by $2\frac{dy}{dt}$ and we get

$$2\frac{dy}{dt}\cdot\frac{d2y}{dt2} ++ \omega^2 2y\frac{dy}{dt} = 0 \qquad \text{------------ (3)}$$

On integrating equation (3), we get

$$(\frac{dy}{dt})^2 = -\omega^2 y^2 + C \qquad \text{------------(4)}$$

Where C is the constant of integration whose value can be calculated by using the initial conditions.

If the displacement is maximum i.e, at y=a where a refers to the amplitude of the oscillating particle, then

$$\frac{dy}{dt} = 0$$

i.e, the particle is momentarily at rest and starts its journey in the backward direction.

On substituting y = a and $\frac{dy}{dt} = 0$ in equation (4), we get

$$C = a^2\omega^2$$

On substituting this value of C in equation (4), we get

$$(\frac{dy}{dt})^2 = \omega^2(a^2 - y^2)$$

Or

$$\frac{dy}{dt} = \omega\sqrt{a^2 - y^2} \qquad \text{--------------- (5)}$$

Equation (5) gives the velocity of the particle if it is executing simple harmonic motion at a time t, when the displacement = y

$$\frac{dy}{\sqrt{a^2-y^2}} = \omega\, dt \qquad \text{---------------- (6)}$$

On integrating equation (6), we get

$$\sin^{-1}\frac{y}{a} = \omega t + \phi$$

Or

$$y = a\sin(\omega t + \phi) \qquad \text{----------------- (7)}$$

Where φ denotes another constant of integration.

In equation (7) the term $(\omega t + \phi)$ represents the total phase of the particle at time t and ϕ is termed as the initial phase or phase constant. I f the time has been recorded from the instant then y = 0 and increasing then ϕ + o.

THE RESULTANT OF TWO SIMPLE HARMONIC MOTION VIBRATIONS OF THE SAME FREQUENCY ACTING ALONG THE SAME LINE BUT DIFFERING IN PHASE :

Suppose the two simple harmonic vibrations of angular velocity ω acting along X- axis and having initial phases ϕ_1 and ϕ_2 are given as follows:

$$x_1 = a_1\sin(\omega t + \phi_1) \qquad \text{------------- (1)}$$
$$x_2 = a_2\sin(\omega t + \phi_2) \qquad \text{------------- (2)}$$

As the two vibrations are assumed to be of the same frequency, it means that ω is the same for both. The resultant can be calculated as well as geometrically.

The resultant displacement due to the two simple harmonic vibrations may be given as follows.

$$x = x_1 + x_2 = a_1\sin(\omega t + \phi_1) + a_2\sin(\omega t + \phi_2)$$

$= \sin \omega t\, (a_1 \cos \phi_1 + a_2 \cos \phi_2) + \cos \omega t\, (a_1 \sin \phi_1 + a_2 \sin \phi_2)$ -------------(3)

As the amplitudes a_1 and a_2 and angles ϕ_1 and ϕ_2 are constant, the coefficients of sin ωt and cos ωt in equation (3) can be substituted by R cos θ and R sin θ i.e,

$a_1 \cos \phi_1 + a_2 \cos \phi_2 = R \cos \theta$ ---------- (4)

$a_1 \sin \phi_1 + a_2 \sin \phi_2 = R \sin \theta$ ---------- (5)

Where $x = R \sin \omega t \cos \theta + R \cos \omega t \sin \theta = R \sin (\omega t + \theta)$ ----------- (6)

Equation (5) gives the equation of the resultant simple harmonic vibration of amplitude R and initial phase θ. The value of R is obtained by squaring equations (4) and (5) and then adding to yield.

$R^2 = R^2 \cos^2 \theta + R^2 \sin^2 \theta = a_1^2 + a_2^2 + 2a_1a_2 (\sin \phi_1 \sin \phi_2 + \cos \phi_1 \cos \phi_2)$

$= a_1^2 + a_2^2 + 2a_1a_2 \cos (\phi_2 - \phi_1)$

$= a_1^2 + a_2^2 + 2a_1a_2 \cos \phi$ ----------- (7)

And $\tan \theta = \frac{R \sin \theta}{R \cos \theta} = \frac{a_1 \sin \phi 1 + a_2 \sin \phi 2}{a_1 \cos \phi 1 + a_2 \cos \phi 2}$

LISSAJOUS FIGURES :

If a particle is acted upon simultaneously by two simple harmonic motions at right angles of each other, the resultant motion of particle traces a curve. This is called Lissajous figure. The nature or shape of curve traced out is depend upon:

(i) Time periods (or frequencies)
(ii) Amplitudes, and
(iii) Phase difference between two constituent vibrations.

Lissajous figures are useful for determining the ratio of the time periods of two vibrations and are also useful for comparing the frequencies of two turning forks.

THE RESULTANT OF TWO SIMPLE HARMONIC MOTIONS OF EQUAL PERIOD ACTING AT RIGHT ANGLES TO ONE ANOTHER :

If x is the displacement of the vibrating particle at any instant t, a the amplitude of vibration, ω the angular velocity and ϕ the initial phase, then the equation of a simple harmonic motion may be given as follows:

$$x = a \sin (\omega t + \phi)$$

Suppose the two simple harmonic vibrations having the same period are taking place along the X-axis and Y vibrations respectively and are represented by Or

$x = a \sin (\omega t + \phi_1)$ ----------- (1)

$y = b \sin (\omega t + \phi_2)$ ----------- (2)

Where b denotes the amplitude of the vibration along the Y-axis, ϕ_1 and ϕ_2 denote the initial phases of X and Y vibrations respectively. The phase difference between the two vibrations would be denotes as

$$\phi = \phi_2 - \phi_1$$

From equation (1), we get

$\frac{x}{a} = \sin \omega t \cos \phi_1 + \cos \omega t \sin \phi_1$ ------------ (3)

From equation (2), we get

$$\frac{y}{b} = \sin \omega t \cos \phi_2 + \cos \omega t \sin \phi_2 \qquad ------------ (4)$$

On multiplying equation (3) by sin ϕ_2 and equation (4) by sin ϕ_1 and subtracting, we get

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1) = \sin \omega t(\cos \phi_1 \sin \phi_2 - \cos \phi_2 \sin \phi_1)$$

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1) = \sin \omega t \sin (\phi_2 - \phi_1) \qquad ------------- (5)$$

Similarly on multiplying equation (4) by cos ϕ_1 and equation (3) by cos ϕ_2 and subtracting, we get

$$(\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2) = \cos \omega t (\sin \phi_2 \cos \phi_1 - \cos \phi_2 \sin \phi_1)$$

$$(\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2) = \cos \omega t \sin (\phi_2 - \phi_1) \qquad ------------- (6)$$

On squaring equations (5) and (6) and then adding, we get

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1)^2 + (\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2)^2 = \sin^2 (\phi_2 - \phi_1) [\sin^2 \omega t + \cos^2 \omega t]$$

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1)^2 + (\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2)^2 = \sin^2 (\phi_2 - \phi_1)$$

Or $$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} (\sin \phi_2 \sin \phi_1 + \cos \phi_2 \cos \phi_1) = \sin^2 (\phi_2 - \phi_1)$$

Or $$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} \cos (\phi_2 - \phi_1) = \sin^2 (\phi_2 - \phi_1)$$

On substituting $\phi_2 - \phi_1 = \phi$ in the above equation, we get

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} \cos \phi = \sin^2 \qquad ------------- (7)$$

Equation (7) represents the equation of an ellipse whose major and minor axes get inclined to the co-ordinate axes. This ellipse can be inscribed in a rectangle whose sides are taken as 2a and 2b.

Important cases:

(i) If ϕ = 0, cos ϕ = 1 and sin ϕ = 0.

Then equation (7) becomes as follows:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} = 0$$

Or $$(\frac{x}{a} - \frac{y}{b})^2 = 0$$

This represents the equation of a pair of coincident straight lines which are lying in the first and third quadrant as shown in figure.

The straight line gets inclined to the X-axis at angle θ which is given by

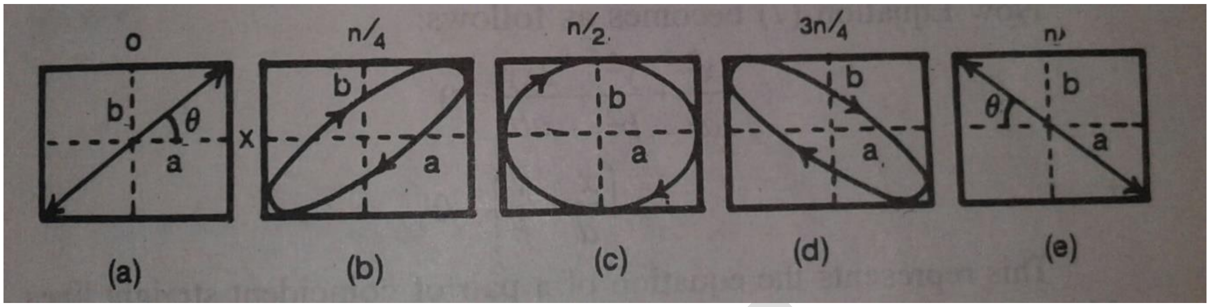
$$\theta = \tan^{-1} (\frac{b}{a})$$

(ii) If $\phi = \frac{\pi}{4}$, then $\cos \frac{\pi}{4} = \frac{1}{\sqrt{2}}$ and $\sin \frac{\pi}{4} = \frac{1}{\sqrt{2}}$

Now equation (7) becomes as follows:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{\sqrt{2xy}}{ab} = \frac{1}{2}$$

This represents the equation of an oblique ellipse as shown in figure.



THE RESULTANT OF TWO RECTANGULAR SIMPLE HARMONIC MOTIONS HAVING AMPLITUDES AND PERIODS IN THE RATION 1:2 AND THE PHASE DIFFERENCE 90 ^{0} :

Suppose a particle is subjected to two simple harmonic motions of periods as well as amplitudes in ratio 1 : 2, and acting along the axes of x and y respectively. If the x-motion leads over the y-motion by 90^o i.e. $\pi/2$ radian in phase, then the equations of these motions would be

$$x = a \sin (1\,\omega t + \frac{\pi}{2}) \qquad \text{-------------- (1)}$$

and

$$y = 2a \sin \omega t \qquad \text{-------------- (2)}$$

Where a and 2a denote the amplitudes, and $2\pi/2\omega$ and $2\pi/\omega$ the periods respectively.

It is possible to get the equation of the resultant path of the particle by eliminating t between equations (1) and (2). From equation (1), we get

$$\frac{x}{a} = \sin (2\,\omega t + \frac{\pi}{2})$$

$$= \cos 2\,\omega t = 1 - 2 \sin^2 \omega t$$

But from equation (2), $\sin \omega t = y/2a$

$$\therefore \quad \frac{x}{a} = 1 - \frac{y^2}{2a^2}$$

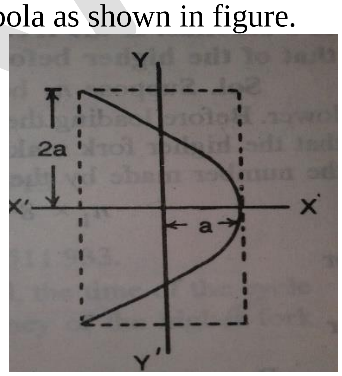
Or

$$\frac{y^2}{2a^2} = 1 - \frac{x}{a}$$

Or

$$y^2 = 2a (a-x)$$

This has been the equation of a parabola as shown in figure.



We will now consider the case when the y-motion leads over the x-motion by $\pi/2$. Now the equations of motions will be

$$x = a \sin 2\omega t \quad \text{----------- (3)}$$

and $$y = 2a \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{----------- (4)}$$

From equation (3), we get

$$\frac{x}{a} = 2 \sin \omega t \cos \omega t$$

$$= \sqrt{(1 - \cos^2 \omega t)} \cos \omega t$$

But from equation (4), $\frac{y}{2a} = \sin\left(\omega t + \frac{\pi}{2}\right) = \cos \omega t$

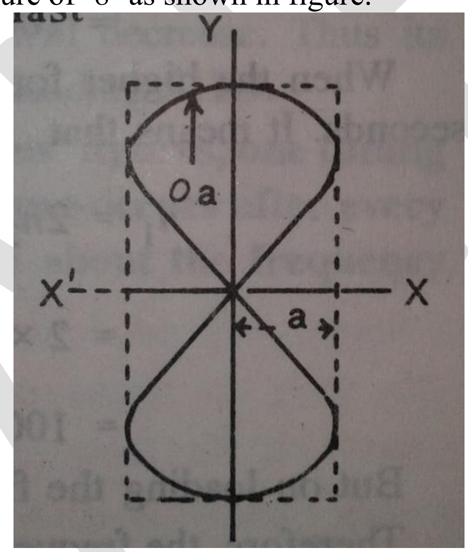
On substituting for cos ωt in the last equation we obtain

$$\frac{x}{a} = 2\sqrt{\left(1 - \frac{y}{4a^2}\right)}\frac{y}{2a}$$

Or $$\frac{x^2}{a^2} = \frac{y^2}{a^2}\left(1 - \frac{y^2}{4a^2}\right)$$

Or $$x^2 + y^2\left(\frac{y^2}{4a^2} - 1\right) = 0$$

This has been the equation of the figure of ‘8’ as shown in figure.



OSCILLATIONS HAVING DIFFERENT FREQUENCIES (BEATS) :

Consider two wave trains of frequencies n_1 and n_2 where $(n_1 - n_2)$ is small. Let a and b the amplitudes of the waves respectively. For the sake of simplicity, it is assumed that two waves are in phase at any point in the medium at t=0. The displacement y_1 and $y_2$due to each wave are given by

$$y_1 = a \sin \omega_1 t$$
$$y_2 = b \sin \omega_2 t$$

Here $$\omega_1 = 2\pi n_1$$
$$\omega_2 = 2\pi n_2$$

$\therefore$ $$y_1 = a \sin 2\pi n_1 t \quad \text{--------- (1)}$$

And $$y_2 = b \sin 2\pi n_2 t \quad \text{---------- (2)}$$

The resultant displacement is given by

$$y = y_1 + y_2$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi n_2 t$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi [n_1 - (n_1 - n_2)] t$$
$$y = a \sin 2\pi n_1 t + b [\sin 2\pi n_1 t \cos 2\pi (n_1 - n_2) t - \cos 2\pi n_1 t \sin 2\pi (n_1 - n_2) t]$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi n_1 t \cos 2\pi (n_1 - n_2) t - b \cos 2\pi n_1 t \sin 2\pi (n_1 - n_2) t]$$
$$y = \sin 2\pi n_1 t [a + b \cos 2\pi (n_1 - n_2) t] - \cos (2\pi n_1 t) [b \sin 2\pi (n_1 - n_2) t]$$

Take $a + b \cos 2\pi (n_1 - n_2) t = A \cos \theta$

And $b \sin 2\pi (n_1 - n_2) t = A \sin \theta$

$$\therefore \quad y = A \sin (2\pi n_1 t - \theta) \qquad \text{----------} (3)$$

Here $$\tan \theta = \frac{b \sin 2\pi (n_1 - n_2) t}{a + b \cos 2\pi (n_1 - n_2) t} \qquad \text{-----------} (4)$$

And $$A = \sqrt{a^2 + b^2 + 2ab \cos 2\pi (n_1 - n_2) t} \qquad \text{-----------} (5)$$

From equation (4), it is evident that the phase angle θ changes with respect to time. Similarly from equation (5) the amplitude of the resultant vibration also charges with time.

LINEARITY AND SUPERPOSITION PRINCIPLE:

From a general simple harmonic oscillation wave equation,

$$\frac{d^2y}{dt^2} = -\omega^2 y$$

We may add some constants,

$$\frac{d^2y}{dt^2} = -\omega^2 y + Ay^2 + By^2 + Cy^2 \ldots \qquad \text{------------} (1)$$

If A=B=C=0, then the equation (1) becomes,

$$\frac{d^2y}{dt^2} = -\omega^2 y \qquad \text{-----------} (2)$$

The above equation is known as linear homogeneous equation.

Let us consider, y_1 is the first solution of equation (2) at time t_1 and y_2 is the second solution of equation (2) at time t_2

$$\frac{d^2y}{dt^2} = -\omega^2 y_1 + Ay_1^2 + By_1^3 + Cy_1^4 \ldots\ldots \qquad \text{------------} (3)$$

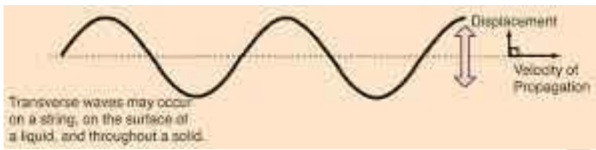
$$\frac{d^2y}{dt^2} = -\omega^2 y_2 + Ay_2^2 + By_2^3 + Cy_2^4 \qquad \text{------------} (4)$$

The equation for the resultant displacement

$$\frac{d^2y}{dt^2} = \frac{d^2}{dt^2}(y_1 + y_2)$$

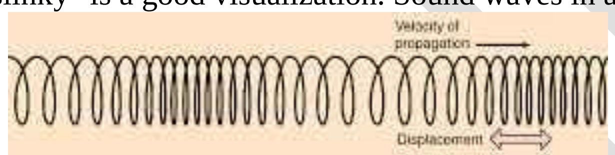
$$\frac{d^2y}{dt^2} = \frac{d^2}{dt^2}(y_1 + y_2) = -\omega^2 (y_1 + y_2) + A (y_1 + y_2)^2 + B (y_1 + y_2)^3 + C (y_1 + y_2)^2 \ldots\ldots \qquad \text{----------} (5)$$

TRANSVERSE WAVES:
For transverse waves the displacement of the medium is perpendicular to the direction of propagation of the wave. A ripple on a pond and a wave on a string are easily visualized transverse waves.

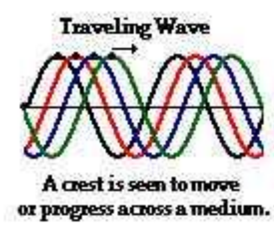


Transverse waves cannot propagate in a gas or a liquid because there is no mechanism for driving motion perpendicular to the propagation of the wave.

LONGITUDINAL WAVES:
In longitudinal waves the displacement of the medium is parallel to the propagation of the wave. A wave in a "slinky" is a good visualization. Sound waves in air are longitudinal waves.



TRAVELLING WAVES :
A mechanical wave is a disturbance that is created by a vibrating object and subsequently travels through a medium from one location to another, transporting energy as it moves. The mechanism by which a mechanical wave propagates itself through a medium involves particle interaction; one

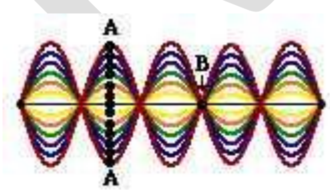


particle applies a push or pull on its adjacent neighbour, causing a displacement of that neighbour from the equilibrium or rest position. As a wave is observed traveling through a medium, a crest is seen moving along from particle to particle. This crest is followed by a trough that is in turn followed by the next crest. In fact, one would observe a distinct wave pattern (in the form of a sine wave) traveling through the medium. This sine wave pattern continues to move in uninterrupted fashion until it encounters another wave along the medium or until it encounters a boundary with another medium. This type of wave pattern that is seen traveling through a medium is sometimes referred to as a traveling wave.
Traveling waves are observed when a wave is not confined to a given space along the medium. The most commonly observed traveling wave is an ocean wave. If a wave is introduced into an elastic cord with its ends held 3 meters apart, it becomes confined in a small region. Such a wave

has only 3 meters along which to travel. The wave will quickly reach the end of the cord, reflect and travel back in the opposite direction. Any reflected portion of the wave will then interfere with the portion of the wave incident towards the fixed end. This interference produces a new shape in the medium that seldom resembles the shape of a sine wave. Subsequently, a traveling wave (a repeating pattern that is observed to move through a medium in uninterrupted fashion) is not observed in the cord. Indeed there are traveling waves in the cord; it is just that they are not easily detectable because of their interference with each other. In such instances, rather than observing the pure shape of a sine wave pattern, a rather irregular and non-repeating pattern is produced in the cord that tends to change appearance over time. This irregular looking shape is the result of the interference of an incident sine wave pattern with a reflected sine wave pattern in a rather non-sequenced and untimely manner. Both the incident and reflected wave patterns continue their motion through the medium, meeting up with one another at different locations in different ways. For example, the middle of the cord might experience a crest meeting a half crest; then moments later, a crest meeting a quarter trough; then moments later, a three-quarters crest meeting a one-fifth trough, etc. This interference leads to a very irregular and non-repeating motion of the medium. The appearance of an actual wave pattern is difficult to detect amidst the irregular motions of the individual particles.

STANDING WAVES:

It is however possible to have a wave confined to a given space in a medium and still produce a regular wave pattern that is readily discernible amidst the motion of the medium. For instance, if an elastic rope is held end-to-end and vibrated at just the right frequency, a wave pattern would be produced that assumes the shape of a sine wave and is seen to change over time. The wave pattern is only produced when one end of the rope is vibrated at just the right frequency. When the proper frequency is used, the interference of the incident wave and the reflected wave occur in such a manner that there are specific points along the medium that appear to be standing still. Because the observed wave pattern is characterized by points that appear to be standing still, the pattern is often called a standing wave pattern. There are other points along the medium whose displacement changes over time, but in a regular manner. These points vibrate back and forth from a positive displacement to a negative displacement; the vibrations occur at regular time intervals such that the motion of the medium is regular and repeating. A pattern is readily observable.



The diagram at the right depicts a standing wave pattern in a medium. A snapshot of the medium over time is depicted using various colors. Note that point A on the medium moves from a maximum positive to a maximum negative displacement over time. The diagram only shows one-half cycle of the motion of the standing wave pattern. The motion would continue and persist, with point A returning to the same maximum positive displacement and then continuing its back-and-forth vibration between the up to the down position. Note that point B on the medium is a point that never moves. Point B is a point of no displacement. Such points are known as nodes and will be discussed in more detail later in this lesson. The standing wave pattern that is shown at the right is just one of many different patterns that could be produced within the rope.

PLANE WAVES:

In a plane wave disturbances travel in single direction.

Plane waves examples :

For example when a string is fixed at both ends and the string is plucked at one end ,then transverse waves are generated in the string in which particles of the medium vibrate in one direction.So the transverse waves are plane waves. It is not possible in practice to have a true plane wave.

A finite part of large spherical wave coming from the sun is considered a plane wave.

SPHERICAL WAVES:

A wave in which the disturbance a propagated outward in all directions from the source of wave is called a spherical wave.

Spherical waves examples:

The light waves are the example of spherical waves.

The light waves produced by a single light source ,are spherical waves.During the propagation of light waves ,the spherical wave fronts spread out in all directions.

PHASE VELOCITY:

Phase velocity is a concept discussed in propagation of waves. The phase velocity of a wave is the velocity of a “phase” which propagates. For clarification, assume a crest of a wave, which is travelling in the x direction of the axis. The phase velocity is the x component of the velocity of the selected point at the crest. This also can be obtained by dividing the wavelength by the time taken for a single wavelength to pass a selected point. This time is equal to the period of the oscillation, which is causing the wave. Now consider a standard sine wave A sin (wt – kx), where w is the angular velocity of the source, t is the time, k is the wave number (number of complete wavelengths per length of 2π), and x is the position on the x-axis. At the crest, wt – kx is equal to zero. Therefore, the phase velocity (x/t) is equal to w / k. mathematically, the value p=wt – kx is the phase of the wave.

GROUP VELOCITY:

Group velocity is discussed under superposition of waves. To understand group velocity one must first understand the concept of superposition. When two waves intercept each other in space, the resultant oscillation is somewhat complex than the sine behaviour. Particle at a point oscillates with varying amplitudes. The maximum amplitude is the unison of the two amplitudes of the original waves. The minimum amplitude is the minimum difference between the two original amplitudes. If the two amplitudes are equal, the maximum is twice the amplitude and the minimum is zero. For the sake of clarity, let us assume that the two modulated waves are of the same amplitude and different frequencies. This causes the wave with the higher frequency to be enveloped in the wave with the lower frequency. This causes a group of waves packed in an envelope. The velocity of this envelope is the group velocity of the wave. It must be noted that, for a standing wave, the group velocity is zero. For the group velocity to be zero both of the waves have to be of the same frequency and they must have opposite directions of travel.

WAVE INTENSITY :

In general, an Intensity is a ratio. For example, pressure is the intensity of force as it is force/area.
Also, density (symbol ρ) is the intensity of mass as it is mass/volume.
The Intensity of waves (called Irradiance in Optics) is defined as the power delivered per unit area.
The unit of Intensity will be W.m-2.
definition of intensity

$$\text{Intensity} = \frac{\text{power}}{\text{area}} \quad \text{in W.m}^{-2}$$
$$= \frac{\text{energy}}{\text{time} \times \text{area}}$$
$$= \frac{\text{energy} \times \text{length}}{\text{time} \times \text{volume}}$$
$$\text{Intensity} = \left(\frac{\text{energy}}{\text{volume}}\right) \times (\text{wave speed})$$

POSSIBLE QUESTIONS
PART B

1. Define Simple Harmonic Motion
2. Define frequency.
3. What is Lissajous Figures?
4. What is beats?
5. Define transverse wave.
6. Define longitudinal wave.
7. What is standing wave?
8. Define group velocity.
9. Define wave velocity.
10. Explain plain waves.
11. Explain spherical waves
12. Define wave intensity.
13. What are the conditions for SHM?

PART C

1. Explain in detail about the simple harmonic oscillations have same frequency.
2. Explain about the oscillations having different frequencies.
3. Discuss about the superposition of two perpendicular harmonic oscillations with Lissajous Figures of ratio 1:1
4. Discuss about the superposition of two perpendicular harmonic oscillations with Lissajous Figures of ratio 1:2
5. Write a note on (i) Transverse wave (ii) Longitudinal waves (iii) standing waves
6. Write a note on (i) Group velocity (ii) Phase velocity (iii) Wave intensity.
7. Derive the expression for group velocity and phase velocity.
8. Obtain the relation between V_g (group velocity) and V_p(phase velocity).

Suggested Books for Reading:

1. Singh, Devraj (2015), Fundamentals of Optics, 2nd Edition,PHI Learning Pvt. Ltd.
2. McGraw-Hill Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
3. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
4. George Arfken (2012), University Physics. Academic Press.

AGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

II B.SC PHYSICS BATCH: 2017-2020

WAVES AND OPTICS (17PHU401)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3
UNIT I			
Maximum displacement from equilibrium position is	frequency	amplitude	wavelength
Displacement-time graph depicting an oscillatory motion is	cos curve	sine curve	tangent curv
In s.h.m, velocity at equilibrium position is	minimum	constant	maximum
Natural frequency of a guitar string can be changed by changing it's	area	diameter	length
A particle is executing SHM of amplitude a with a time-period T sec. The time taken by it to move from positive extreme position to half of the amplitude is	T/12 sec	2T/12 sec	3T/12 sec
For s.h.m, maximum speed is proportional to	wavelength	acceleration	time
A force that acts to return mass to it's equilibrium position is called	frictional f	restoring fo	normal forc
As amplitude of resonant vibrations decreases, degree of damping	increases	remains sar	decreases
Oscillations become damped due to	normal for	friction	tangential f
Angular frequency of s.h.m is equal to	2π	2πf	2f
For a resonating system it should oscillate	bound	only for sor	freely
Velocity at equilibrium position is	constant	minimum	maximum
Time period of simple pendulum 1 m long at a location where g=10ms-1 will be	2.5 s	1.5 s	3 s
If 100 waves pass through a medium in 20seconds and their wavelength is 6cm then velocity is	0.5ms-1	0.3ms-1	1ms-1
Velocity of simple harmonic motion at mean position is always	maximum	minimum	zero
If spring is stiff, then value of k is	small	moderate	large
Motion of a ball placed in a bowl is	simple harmonic motion	compressional motion	damped motion

Velocity of bob in SHM becomes zero at	mean position	in air	extreme position
Kinetic energy of mass attached to spring at extreme position is	minimum	Maximum	moderate
Time period of simple pendulum is independent of it's	length	friction	gravity
Mechanical waves in which particles of medium vibrate about their mean position along direction of propagation of waves are called	transverse waves	longitudin al waves	mechanical waves
In a simple pendulum, force acting along string is	zero	mg sinθ	mg cosθ
Relationship between speed (v), frequency (f) and wavelength (λ) is	vf = λ	fλ = v	v&lambda =
if potential energies and kinetic energies are equal then displacement of an object in SHM is	4	0	2
If time period of simple pendulum is 2 s then it's length is	1.02m	1.2m	1.4m
Oscillations are damped due to presence of	linear moti	restoring fo	frictional fo
Categories of waves are	3	4	2
Maximum displacement from mean position of a body performing simple harmonic mean is called	time perioc	amplitude	frequency
Restoring force pushes or pulls oscillatory object	Towards m	Away from	at central pc
To produce both transverse and longitudinal waves, we can use	a string	a helical sp	a ripple tanl
As compare to longitudinal waves, transverse waves move through solids at a speed of	less than ha	less than or	half
If speed is 180 ms-1 and frequency is 200 Hz, wavelength should l	0.9 m	0.5 m	1.2 m
Force that pulls mass towards mean position is called	Gravitatior	Frictional f	Torque
If a simple pendulum is 1.0 m long and force of gravity acting on it is 10.0 ms-2, then it's period and frequency are	1.99s and (	2s and 60H	5s and 40H:
Potential energy of mass attached to spring at extreme position is	maximum	minimum	zero
A human ear can oscillate back and fourth up to	18,000 tim	200 times p	20,000 time
A device to produce water waves and to study their characteristics	screw gaug	ripple tank	measuring c
When friction reduces mechanical energy of system as time passes, motion is said to be	simple	damped	random
From one place to another, through waves we can transfer	heat	energy	sound
Velocity of simple harmonic motion at extreme position is always	maximum	minimum	zero
Time taken by a body to complete on vibration is	amplitude	frequency	time period
A pendulum of length 0.65 m is taken to moon. Time period is 5.2 s. value of gon surface of moon is	1.5 ms-2	0.948 ms-2	0.35 ms-2
Speed of a wave in water depends on the	depth of ta	temperature	depth of wa
If mass of bob is increased 3 times then it's time period	increases	decreases 2	remains san
Characteristic of wave independent of others is	frequency	speed	wavelength
If 160 waves pass through a point of a medium in 40 seconds. Its frequency is	4 Hz	2 Hz	5 Hz

Time period T of simple harmonic motion of a mass m attached to a spring is given by	T = 2π √(k	T = 2π √(m	T = π √(k/m
Speed (v) of wave is equal to product of frequency and	vibration	amplitude	wavelength
Oscillations of a system in presence of some resistive force are	linear oscil	simple harm	damped osc
A transverse wave produced on a spring has a frequency of 200 Hz and travels along length of a spring of 80 m in 0.5 seconds. speed of wave will be	122 ms-1	140 ms-1	133 ms-1
Water waves are	electromag	longitudina	mechanical
Christian Huygens invented pendulum clock in	1657	1670	1682
Motion of particles about their mean position in regular intervals of time is called	wave	frequency	gravity
If spring is stretched or compressed through a small displacement x from its mean position, then on mass it exerts a	strain	stress	energy
A force that is always pushed or pulls object performing oscillatory motion towards mean position is called	restoring fo	net force	negative for
Motion of ceiling fan	is SHM	isn't SHM	Linear
Expression for Hooke's law is	F = ma	F = -kx	F = vl

Prepared By N.Geetha, Assistant Professor,Department of Physics, KAHE,coimbatore-21.

opt4	opt5	opt6	Answer
period			amplitude
straight line			sine curve
zero			maximum
stiffness			length
6T/12 sec			2T/12 sec
frequency			frequency
contact force			restoring force
varies			decreases
parallel force			friction
1/T			$2\pi f$
for infinite time			freely
zero			maximum
1.99 s			1.99 s
2.5ms-1			0.3ms-1
negative			maximum
approx. zero			large
none of the above			simple harmonic motion

middle	
of mean	
and	
extreme	extreme
position	position
zero	zero
mass and amplitude	mass and amplitude
electrom	
agnetic	longitudinal
waves	waves
1	zero
$v = \lambda/f$	$f\lambda = v$
6	0
1.5m	1.02m
mechanical force	frictional force
5	2
wave length	amplitude
extreme point	Towards mean position
a tuning fork	a helical spring
less than quarter	less than half
2 m	0.9 m
Restoring force	Restoring force
4s and 60Hz	1.99s and 0.50Hz
moderate	maximum
100 times per second	20,000 times per second
wave container	ripple tank
linear	damped
gas	energy
negative	zero
vibration	time period
2.35 ms-2	0.948 ms-2
none of the above	depth of water
increases 4 times	remains same
amplitude	amplitude
3 Hz	4 Hz

$T = 2\pi \sqrt{(m+k)}$	$T = 2\pi \sqrt{(m/k)}$
time period	wavelength
random oscillations	damped oscillations
150 ms-1	133 ms-1
chemical	mechanical
1656	1656
resistance	wave
force	force
zero force	restoring force
quadratic	isn't SHM
F = m1m2	F = -kx

UNIT-II

SYLLABUS

Sound: Sound waves, production and properties. Intensity and loudness of sound. Decibels. Intensity levels. musical notes. musical scale. Acoustics of buildings (General idea). Wave Optics: Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle.

SOUND WAVES :

A sound wave is the pattern of disturbance caused by the movement of energy traveling through a medium (such as air, water, or any other liquid or solid matter) as it propagates away from the source of the sound. The source is some object that causes a vibration, such as a ringing telephone, or a person's vocal chords. The vibration disturbs the particles in the surrounding medium; those particles disturb those next to them, and so on. The pattern of the disturbance creates outward movement in a wave pattern, like waves of seawater on the ocean. The wave carries the sound energy through the medium, usually in all directions and less intensely as it moves farther from the source.

PRODUCTION OF SOUND WAVES:

Sound is a sensation or feeling that we hear. We produce sounds by doing something. The motion of materials or objects causes vibrations. A sound originates in the vibration of an object, which makes the air or another substance around the object vibrate. The vibration of the air moves outward in all directions in the form of a wave. The following are examples of how certain sounds are produced.

<u>Human Voice:</u>

The human voice is produced in the larynx, which is a part of the throat. There are two small pieces of tissue that stretch across the larynx with a small opening between them, these tissues are our vocal cords. As we speak, muscles in our larynx tighten the vocal cords making this small opening become narrower. When air from our lungs passes through the tightened cords a vibration is produced. This vibration produces vocal sounds. The tighter the vocal cords, the more rapidly the vocal cords vibrate and the higher the sounds that are produced. This is what causes the human voices to have different pitches.

<u>Animal Sounds:</u>

Animals also produce sounds. Almost all mammals, birds, and frogs have vocal cords or similar structures, which allow them to produce sounds in a similar way to humans. However, many other animals produce distinctly different sounds. For example, bees buzz as they fly because of the rapid movement of their wings. Their wings make the air vibrate producing a buzzing sound. A cricket produces a singing type sound as it scrapes parts of its front wings together. Some types of shellfish produce clicks by tapping their claws together.

Musical Sounds:

Musical instruments produce many different sounds in various ways. There are three categories of musical instruments, percussion, string, and wind. Some instruments need to be struck by an object in order to produce a sound, these are called percussion instruments. For example when the membrane of a drum is hit the membrane vibrates, producing a sound, or when a bar of a xylophone is struck, a sound is produced. Each bar of a xylophone produces a different note when struck. String instruments, such as a harp or violin, produce sounds when one or more of their strings are plucked, causing them to vibrate. This vibration causes parts of the body of the instrument to vibrate, creating sound waves in the air. The pitch of a stringed instrument depends upon the string's thickness, its length, the distance stretched, and the number of times it vibrates. Wind instruments, such as a flute or trumpet produce sound when a column of air inside the instrument vibrate. For example, with a trumpet it is the vibrating lips of the player which makes the air column vibrate.8 Sounds produced by musical instruments are usually pleasing for us to hear. "A musical sound is a regular vibration."

Noise:

Humans, animals, and instruments are not the only sounds we hear, many of us come across various other sounds or noise every day. For example thunder is caused when lightning heats the air, causing the air to vibrate. A car makes a rather loud noise, which is produced when the engine vibrates, causing the other parts of the car to vibrate. These types of noises are produced by irregular vibrations occurring at irregular intervals. This is what makes noise a rather unpleasant sound.

PROPERTIES OF SOUND:

Six Basic Properties of Sound are,

(i) Frequency/Pitch:

Frequency refers to how often something happens -- or in our case, the number of periodic, compression-rarefaction cycles that occur each second as a sound wave moves through a medium -- and is measured in Hertz (Hz) or cycles/second. The term pitch is used to describe our perception of frequencies within the range of human hearing.

(ii) Amplitude/Loudness:

Amplitude/Loudness refer to how loud or soft the sound.

(iii) Spectrum/Timbre:

Timbre (pronounced TAM-burr) refers to the characteristic sound or tone colour of an instrument. A violin has a different timbre than a piano.

(iv)Duration:

Duration refers to how long a sound lasts.

(v) Envelope:

Envelope refers to the shape or contour of the sound as it evolves over time. A simple envelope consists of three parts: attack, sustain, and decay. An acoustic guitar has a sharp attack, little sustain and a rapid decay. A piano has a sharp attack, medium sustain, and medium decay.

Voice, wind, and string instruments can shape the individual attack, sustain, and decay portions of the sound.

(vi) Location:

Location describes the sound placement relative to our listening position. Sound is perceived in three dimensional space based on the time difference it reaches our left and right eardrums.

SOUND INTENSITY:

Sound intensity is defined as the sound power per unit area. The usual context is the measurement of sound intensity in the air at a listener's location. The basic units are watts/m ^{2} or watts/cm ^{2}. Many sound intensity measurements are made relative to a standard threshold of hearing intensity I_0 :

$$I_0 = 10^{-12} \text{ watts/m}^2 = 10^{-16} \text{ watts/cm}^2$$

The most common approach to sound intensity measurement is to use the decibel scale:

$$I(dB) = 10 \log_{10} [\frac{I_0}{I}] \qquad \text{(intensity in decibles)}$$

Decibels measure the ratio of a given intensity I to the threshold of hearing intensity , so that this threshold takes the value 0 decibels (0 dB). To assess sound loudness, as distinct from an objective intensity measurement, the sensitivity of the ear must be factored in.

LOUDNESS OF SOUND:

Loudness of sound depends upon the intensity of sound. It is found that.

$$L \propto \text{Log } I$$

i.e. greater the amplitude, greater will be the intensity ($I \propto A2$) and so louder will be the sound. The Unit of loudness is decibels (dB) and-

$$L = 10 \text{ Log10}(I/Io) \text{ in dB}$$

Here Io is constant i.e. minimum intensity ($=10^{-12}$ W/m2) just audible at intermediate frequencies.

The loudness of normal talks is about 60 dB.

DECIBEL:

Decibel (dB), unit for expressing the ratio between two physical quantities, usually amounts of acoustic or electric power, or for measuring the relative loudness of sounds. One decibel (0.1 bel) equals 10 times the common logarithm of the power ratio. Expressed as a formula, the intensity of a sound in decibels is 10 log10 (S1/S2), where S1 and S2 are the intensity of the two sounds; i.e., doubling the intensity of a sound means an increase of a little more than 3 dB. In ordinary usage, specification of the intensity of a sound implies a comparison of the intensity of the sound with that of a sound just perceptible to the human ear. For example, a 60-dB, or 6-bel, sound, such as normal speech, is six powers of 10 (i.e., 106, or 1,000,000) times more intense than a barely detectable sound, such as a faint whisper, of 1 dB. Decibels are also used more generally to express the logarithmic ratio of two magnitudes of any unit, such as

two electric voltages or currents (or analogous acoustic quantities). In cases where the ratio is of a squared quantity, 1 dB equals 20 times the common logarithm of the ratio.
The term bel is derived from the name of Alexander Graham Bell, inventor of the telephone. The unit decibel is used because a one-decibel difference in loudness between two sounds is the smallest difference detectable by human hearing.

INTENSITY LEVELS:

Another quality described by a decibel level is sound intensity, which is the rate of energy flow across a unit area. The reference for measuring sound intensity level is Io = 10^{-12} Watt/m2, and the sound intensity level (IL or Li,) is defined as:

$$L_i = 10 \log_{10} [\frac{I_O}{I}]$$

For a free progressive wave in air (e.g., a plane wave travelling down a tube or a spherical wave travelling outward from a source), sound pressure level and sound intensity level are nearly equal (L_P - L_i) This is not true in general, however, because sound waves from many directions contribute to sound pressure at a point. When we speak of simply sound level, we nearly always mean sound pressure level, L_P, since that is what is indicated by our sound-measuring instruments.

MUSICAL SCALE:

In music theory, a scale is any set of musical notes ordered by fundamental frequency or pitch. A scale ordered by increasing pitch is an ascending scale, and a scale ordered by decreasing pitch is a descending scale.

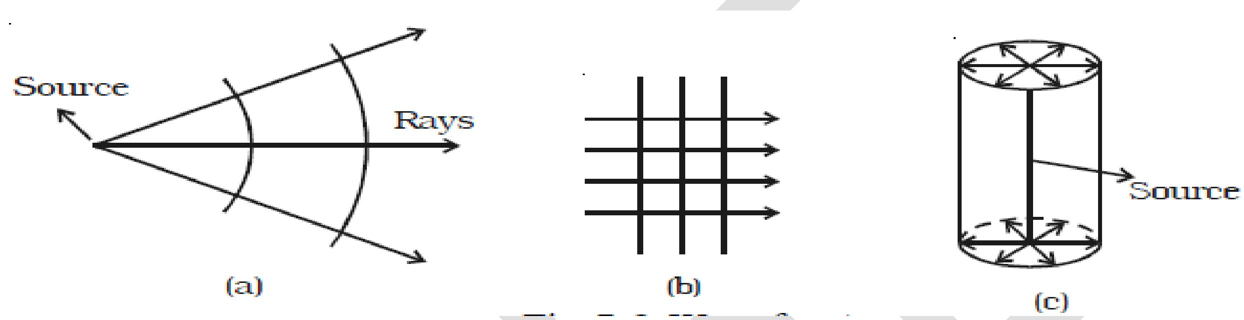
MUSICAL NOTE:

In music, a note is the pitch and duration of a sound, and also its representation in musical notation
(♪, ♩). A note can also represent a pitch class.

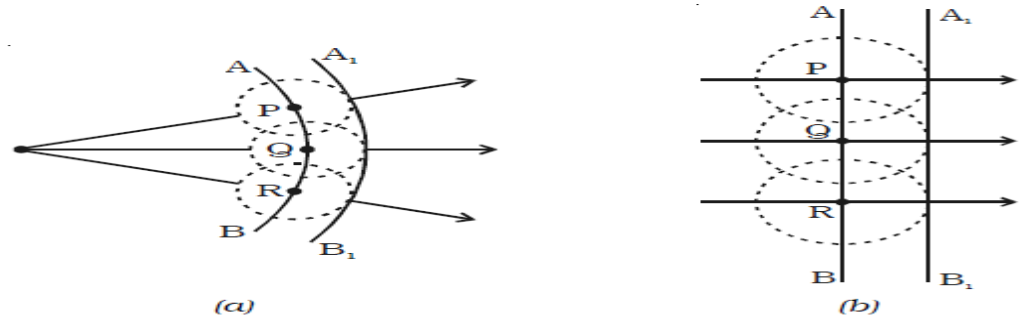
WAVE FRONT:

When a stone is dropped in a still water, waves spread out along the surface of water in all directions with same velocity. Every particle on the surface vibrates. At any instant, a photograph of the surface of water would show circular rings on which the disturbance is maximum (Fig.1). It is clear that all the particles on such a circle are vibrating in phase, because these particles are

at the same distance from the source. Such a surface which envelopes the particles that are in the same state of vibration is known as a wave front. The wave front at any instant is defined as the locus of all the particles of the medium which are in the same state of vibration.
A point source of light at a finite distance in an isotropic medium emits a spherical wave front (Fig 2a). A point source of light in an isotropic medium at infinite distance will give rise to plane wavefront (Fig 2b). A linear source of light such as a slit illuminated by a lamp, will give rise to cylindrical wavefront (Fig 2c).



HUYGEN'S PRINCIPLE :
Huygen's principle helps us to locate the new position and shape of the wavefront at any instant, knowing its position and shape at any previous instant. In other words, it describes the progress of a wave front in a medium. Huygen's principle states that, (i) every point on a given wave front may be considered as a source of secondary wavelets which spread out with the speed of light in that medium and (ii) the new wavefront is the forward envelope of the secondary wavelets at that instant. Huygen's construction for a spherical and plane wavefront is shown in Fig.3a. Let AB represent a given wavefront at a time $t = 0$. According to Huygen's principle, every point on AB acts as a source of secondary wavelets which travel with the speed of light c. To find the position of the wave front after a time t, circles are drawn with points P, Q, R ... etc as centres on AB and radii equal to ct. These are the traces of secondary wavelets. The arc A1B1 drawn as a forward envelope of the small circles is the new wavefront at that instant. If the source of light is at a large distance, we obtain a plane wave front A1 B1 as shown in Fig.3b.



POSSIBLE QUESTIONS
PART B

1. What is sound wave?
2. Define sound intensity.
3. Define decibels.
4. Write a note on musical note.
5. What is musical scale?
6. Define wave font.
7. Define frequency.
8. Write any two properties of waves.

PART C

1. Discuss about the sound waves, production and properties.
2. Explain about the electromagnetic nature of the light.
3. Explain about the Huygen's principle.
4. Write a note on (i) decibels (ii) loudness of sound (iii) musical note.
5. Write a note on (i) musical scale (ii) acoustics of building.
6. Write the decibel value and power density(intensity) for various sources in
   (i) Threshold of pain (ii) Whisper (iii) Threshold of hearing (iv) Conversation (v) Busy traffic
7. What is the distance travelled by sound in air when a tuning fork of frequency 256 Hz complete 25 vibrations? The speed of sound in air is $343ms^{-1}$.

Suggested Books for Reading:

1. Singh, Devraj (2015), Fundamentals of Optics, 2nd Edition,PHI Learning Pvt. Ltd.
2. McGraw-Hill Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
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II B.SC PHYSICS **BATCH: 2017-2020**

WAVES AND OPTICS (17PHU401)

MULTIPLE CHOICE QUESTIONS

Questions UNIT II	opt1	opt2	opt3
Human ear responds to intensities in range	10-12Wm-2 to 1Wm-2	15Wm-2 to 18Wm-2	108Wm-2 to 2Wm-2
Sound is produced due to	friction	circulation	vibration
Sound passes from one place to another in form of	rays	waves	energy
Sound is slowest in	Air	Liquid	Solid
Compressions are formed where air pressure is	higher	lower	normal
Distance between two consecutive compressions and rarefactions i	frequency	amplitude	wavelength
A good example of sound waves is	Rope	Slinky sprir	Elastic banc
Sound is a	form of po'	form of ene	form of tran
If temperature increases, speed of sound	also increa:	decreases	remains san
Sound waves are produced by	linear moti	circular mo	vibrating bc
Loudness of sound varies directly with vibrating body's	intensity	amplitude	pitch
Sensation of sound persists in our brain for about	0.001s	0.2s	0.1s
Sound energy passing per second through a unit area held perpendicular is called	intensity	frequency	amplitude
Sounds of frequency higher than 20,000 Hz which are inaudible to normal human ear are called	noise	frequency	ultrasonics
Loudness and amplitude of sound varies	directly	inversely	Not related
Speed of sound varies with	humidity	temperature	both humidi
Scale to measure intensity level of sound is called	vector scal	measuring	bel scale
Echoes maybe heard more than once due to	multiple re	single time	refraction
SONAR is abbreviation of	small navig	sky navigat	sun nuclear
Old people can not hear sounds even above	5,000 Hz	15,000 Hz	10,000 Hz
Sound waves are	Longitudin	Transverse	Electromag
Intensity level of rustling of leaves is	25 dB	0 dB	10 dB
To communicate with each other, Elephants use	low freque:	low frequer	high freque
Technique or method to absorb undesirable sounds by soft and porous surface is called	acoustic pr	unacoustic	audible prot
A normal human ear can hear a sound only if its frequency lies bet	30 Hz to 3(	50 Hz to 50	20 Hz to 20

Speed of sound in air is	343ms-1	343ms-2	341ms-1
Speed of sound can be found by relation	v = cλ	v = ma	v = fλ
Pitch of sound depends upon	frequency	distance of	amplitude
Main sources of noise pollution are	Transporta	Musical ins	Heavy macl
Loudness of sound is directly proportional to	intensity	area	pitch
Area and loudness are	inversely r	directly rela	not related a
A ship sends ultrasound that returns from seabed and is detected after 3.42 s. If speed of ultrasound through seawater is 1300 ms-1, then distance of seabed from ship would be	3000 m	2600 m	2200 m
Speed of sound in solids is	10 times th	20 times th	5 times that
Humans can hear sound up to highest frequency of 20,000 Hz. If wavelength of sound in air at this frequency at temperature of 20° would be	5.7×10-2	3.7×10-2	1.7×10-2
Speed of sound in air depends on the	chemical c	Physical co	pitch
Sound waves can be transmitted by any	medium	vacuum	both mediu
When sound is incident on surface of a medium it bounces back into first medium. phenomenon is called	refraction c	deflection c	defraction o
When sound is incident on surface of a medium it bounces back into first medium. phenomenon is called	refraction c	deflection c	defraction o
1 bel is equal to	100 dB	50dB	10dB
Characteristic of sound by which we can distinguish between a shrill and a grave sound is known as	quality	intensity	loudness
Sounds which are pleasant to our ears are called	noise	musical sou	frequency
Loudness of sound is related most closely to its	frequency	period	amplitude
SI unit of intensity of sound is	W m-2	W m-1	m-2
Cats can hear frequencies up to	30,000 Hz	25,000 Hz	40,000 Hz
Frequency of tuning fork depends on	mass of its	area of its p	stiffness of
Sound which has Jarring effect on ears is	Noise	Music	pleasant sou
If speed of sound in air is 330 ms-1 and wavelength is 10 cm. frequency of sound should be	3.9×103 H	4.7×103 Hz	3.3×103 Hz
Sound produced by a large drum is louder than a small drum because of its	distance fro	small vibra	large vibrati
Characteristic of sound by which loud and faint sounds can be distinguished is known as	loudness	pitch	quality

Prepared By N.Geetha, Assistant Professor,Department of Physics, KAHE,coimbatore-21.

opt4	opt5	opt6	Answer
10-3Wm-1 to 10-6Wm-1			10-12Wm-2 to 1Wm-2
refraction			vibration
light			waves
Vacuum			Air
zero			higher
wave point			wavelength
Elastic rod			Slinky spring
form of latitudinal waves			form of energy
may increase or decrease			also increases
transitional motion			vibrating bodies
quality			amplitude
10s			0.1s
quality			intensity
amplitude			ultrasonics
proportionally			directly
none of the above			both humidity and temperature
decibel scale			decibel scale
diffraction of waves			multiple reflections
sound navigation and rangin			sound navigation and ranging
8,000 Hz			15,000 Hz
Only magnetic			Longitudinal
100 dB			10 dB
low frequency heat waves			low frequency sound waves
decibel protection			acoustic protection
10 Hz to 10,000 Hz			20 Hz to 20,000 Hz

250ms-1	343ms-1
f=1/T	v = fλ
temperature	frequency
A and C both	A and C both
log of intensity	log of intensity
inversly proportional	directly related
2800 m	2600 m
15 times that in gas	15 times that in gas
2.7×10-2	1.7×10-2
Area	Physical conditions
none of the above	medium
reflection of sound	reflection of sound
reflection of sound	reflection of sound
20dB	10dB
pitch	pitch
amplitude	musical sounds
wavelength	amplitude
W -1	W m-2
50,000 Hz	25,000 Hz
density of its prongs	mass of its prongs
soul music	Noise
5.3×103 Hz	3.3×103 Hz
none of the above	large vibrating area
intensity	loudness

UNIT-III

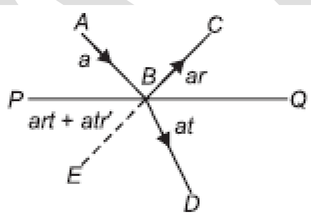
SYLLABUS

Interference: Interference: Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror & Fresnel's Biprism.Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: measurement of wavelength and refractive index. Michelson's Interferometer: Construction and working. Idea of form of fringes (no theory needed), Determination of wavelength, Wavelength difference, Refractive index, and Visibility of fringes.

PHASE CHANGE ON REFLECTION STOKE'S TREATMENT:

When a ray of light is reflected at the surface of a medium which is optically denser than the medium through which the ray is travelling, a change of phase equal to π or *a* path difference $\frac{\lambda}{2}$ is introduced.

When reflection takes place at the surface of a rarer medium, no change in phase or path-difference takes place.



Let *PQ* be the surface separating the denser medium below it from the rarer medium above it as shown in Fig. A ray of light *AB* of amplitude *a* incident on this surface is partly reflected along *BC* and partly refracted into the denser medium along *BD*. If *r* is the coefficient of reflection at the surface of a denser medium, i.e., the fraction of the incident light which is reflected, then

Amplitude of the ray $BC = ar$

If '*t*' is the coefficient of transmission from the rarer into the denser medium i.e., the fraction of the incident light transmitted, then

Amplitude of the refracted ray $BD = at$ if there is no absorption of light, then

$$ar + at = a$$

or

$$r + t = 1$$

If the reflected and the refracted rays are reversed the resultant should have the same amplitude '*a*' as that of the incident ray. When *CB* is reversed it is partly reflected along *BA* and partly refracted along *BE*.

The amplitude of the refracted ray along *BE* = *art* Similarly when the ray *DB* is reversed it is partly refracted along *BA* and partly reflected along *BE*. IF *r*' is the coefficient of reflection at the surface of a rarer medium, then Amplitude of the reflected ray along *BE* = *atr*'
The two amplitudes along *BA* will combine together to produce the original amplitude, only if the total amplitude along *BE* is zero.

$$art + ar't = 0$$

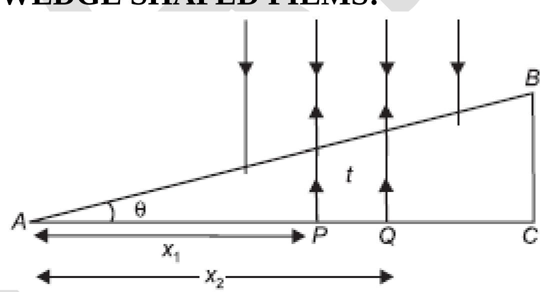
OR

$$r = -r'$$

The negative sign shows that when one ray has a positive displacement the other has a negative displacement. Hence the two rays, one reflected on reaching a denser medium and the other reflected on reaching a rarer medium, differ in phase by π from each other. This explains the presence of a central dark spot in Newton's rings and is also responsible for the reversal of the condition of darkness and brightness produced in the reflected and transmitted systems in colours of thin films and in the fringes produced by Lloyd's single mirror.

INTERFERENCE IN THIN FILMS:
Newton and Hooke observed and developed the interference phenomenon due to multiple reflections from the surface of thin transparent materials. Everyone is familiar with the beautiful colours produced by a thin film of oil on the surface of water and also by the thin film of a soap bubble. Hooke observed such colours in thin films of mica and similar thin transparent plates. Newton was able to show the interference rings when a convex lens was placed on a plane glass-plate. Young's was able to explain the phenomenon on the basis of interference between light reflected from the top and the bottom surface of a thin film. It has been observed that interference in the case of thin films takes place due to (1) reflected light and (2) transmitted light.

FRINGES PRODUCED BY WEDGE SHAPED FILMS:



Let *ABC* be a wedge-shaped film of refractive index μ, having a very small angle at *A*, as shown in Fig. If a parallel beam of monochromatic light is allowed to fall on the upper surface and the surface is viewed by reflected light, then alternate dark and bright fringes become visible. Consider a point *P* at a distance *x*1 from *A* where the thickness of the film is *t*. When light is incident normally the total path-difference between the light reflected at *R* from the upper face *AB* and that reflected at *P* from the lower face *AC* is 2μt + $\frac{\lambda}{2}$ as an additional path-difference of $\frac{\lambda}{2}$ is produced in the beam reflected from the upper face *AB* at *R* where reflection takes place at the surface of a denser medium. The point *P* will appear dark and a dark band will be observed across the wedge, if

$$2\mu t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2} \quad \text{or} \quad 2\mu t = n\lambda$$

The point *P* will appear bright and a bright band will be observed across the wedge, if

$$2\mu t + \frac{\lambda}{2} = n\lambda \quad \text{or} \quad 2\mu t = (2n-1)\frac{\lambda}{2}$$

If the *n*th dark fringe is formed at *P*, then

$$2\mu t = n\lambda$$

But

$$\frac{t}{x_1} = \theta$$

Or $$t = x_1\theta$$

Similarly for the (*n* + 1) the dark band, which is formed at *Q* at a distance *x*2 from *A*, we have

$$2\mu\theta x_2 = (n+1)\lambda$$

Subtracting (*i*) from (*ii*), we have

$$2\mu\theta(x_2 - x_1) = \lambda$$

$$\beta = x_2 - x_1 = \frac{\lambda}{2\mu\theta}$$

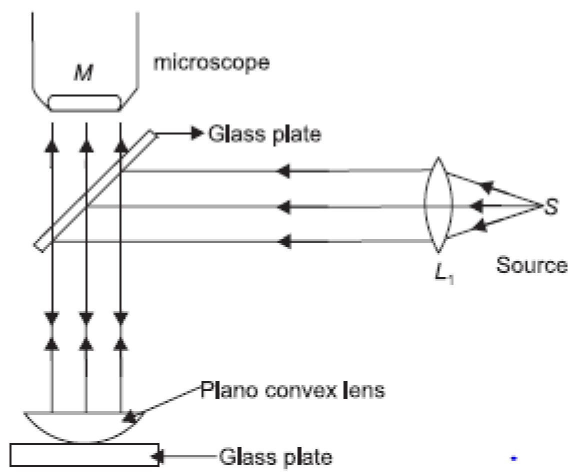
or Fringe-width

Similarly if we consider two consecutive bright fringes the fringe width β will be the same. A wedge-shaped air film can be obtained by inserting a thin piece of paper or hair between two plane parallel plates.

For air film $\mu = 1$, and $\theta = t/x$

Where *t* is the thickness of the hair and *x* its distance from the edge where the two plates touch each other.

NEWTON'S RING:



Circular interference fringes can be produced by enclosing a very thin film of air or any other transparent medium of varying thickness between a plane glass plate and a convex lens of a large radius of curvature. Such fringes were first obtained by Newton and are known as Newton's rings. When a plane-convex lens of long focal length 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. The thickness of the air film is very small at the point of contact and gradually increases from the centre outwards. The fringes produced with monochromatic light are circular. The fringes are concentric circles, uniform in thickness and with the point of contact as the centre. When viewed with white light, the fringes are coloured. With monochromatic light, bright and dark circular fringes are produced in the air film. *S* is a source of monochromatic light as shown in Fig. A horizontal beam of light falls on the glass plate *B* at 45^o. The glass plate *B* reflects a part of the incident light towards the air film enclosed by the lens *L* and the plane glass plate *G*. The reflected beam from the air film is viewed with a microscope, Interference takes place and dark and bright circular fringes are produced. This is due to the interference between the light reflected from the lower surface of the lens and the upper surface of the glass plate G.

MEASUREMENT OF WAVELENGTH:

The arrangement used is shown earlier. In Figure *S* is a source of sodium light. A parallel beam of light from the lens *L*1 is reflected by the glass plate *B* inclined at an angle of 45° to the horizontal. *L* is a plano-convex lens of large focal length. Newton's rings are viewed through *B* by the travelling microscope *M* focussed on the air film. Circular bright and dark rings are seen with the centre dark. With the help of a travelling microscope, measure the diameter of the *n*th dark ring.

Suppose, the diameter of the nth ring = *D*n

$$r_n^2 = n\lambda R$$

$$\text{But } r_n = \frac{D_n}{2}$$

$$\frac{(D_n)^2}{4} = n\lambda R$$

$$D_n^2 = 4n\lambda R \qquad \text{---------------- (1)}$$

Measure the diameter of the (*n* + *m*)th dark ring

Let it be

$$\frac{(D_{n+m})^2}{4} = (n+m)\,\lambda R$$

$$(D_{n+m})^2 = 4\,(n+m)\,\lambda R \qquad \text{---------------(2)}$$

Subtracting (1) from (2)

$$(D_{n+m})^2 - (D_n)^2 = 4m\lambda R$$

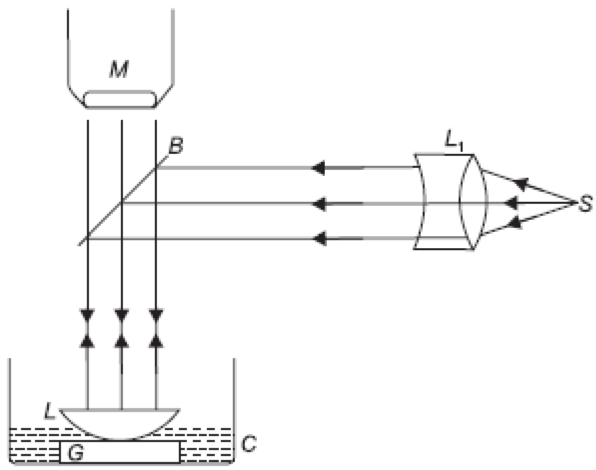
$$\lambda = \frac{(D_{n+m})^2 - (D_n)^2}{4mR}$$

Hence, λ can be calculated. Suppose the diameters of the 5th ring and the 15th ring are determined. Then $m = 15 – 5 = 10$.

$$\lambda = \frac{(D_{15})^2 - (D_5)^2}{4 \times 10 R}$$

The radius of curvature of the lower surface of the lens is determined with the help of a spherometer but more accurately it is determined by Boy's method. Hence the wavelength of a given monochromatic source of light can be determined.

MEASUREMENT OF REFRACTIVE INDEX:



The experiment is performed when there is an air film between the plano-convex lens and the optically plane glass plate. These are kept in a metal container *C*. The diameter of the nth and the (*n*+*m*)th dark rings are determined with the help of a travelling microscope. For air,

$$(D_{n+m})^2 = 4\,(n + m)\,\lambda R, \quad D_n^{\,2} = 4n\lambda R$$

$$D^2_{n+m} - D_n^{\,2} = 4\,m\lambda R \qquad \text{------------ (1)}$$

The liquid is poured in the container *C* without disturbing the arrangement. The air film between the lower surface of the lens and the upper surface of the plate is replaced by the liquid. The diameters of the *n*th ring and the (*n*+*m*)th ring are determined.

$$2\mu t = n\lambda, \text{ But } t = \frac{r^2}{2R}$$

$$\frac{2\mu r^2}{2R} = n\lambda$$

$$r^2 = \frac{n\lambda R}{\mu} \quad \text{But } r = \frac{D}{2};$$

$$D^2 = \frac{4n\lambda R}{\mu}$$

For the liquid, $2\mu t \cos\theta = n\lambda$ for dark rings
If D'_n is the diameter of the nth ring and D'_{n+m} is the diameter of the $(n + m)$th ring then

$$(D'_{n+m})^2 = \frac{4(n+m)\lambda R}{\mu}; \quad (D'_n)^2 = \frac{4n\lambda R}{\mu} \qquad \text{---------------- (1)}$$

$$(D'_{n+m})^2 - (D'_n)^2 = \frac{4m\lambda R}{\mu} \qquad \text{------------ (2)}$$

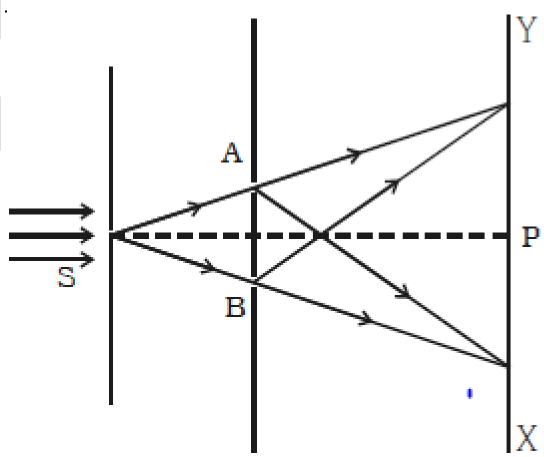
Or

$$\mu = \frac{4m\lambda R}{(D^1_{n+m}) - (D^1_n)^2} \qquad \text{----------- (3)}$$

If m, λ , R, D'_{n+m} and D'_n are known μ can be calculated.
If λ is not known t hen divide (3) by (2) we get,

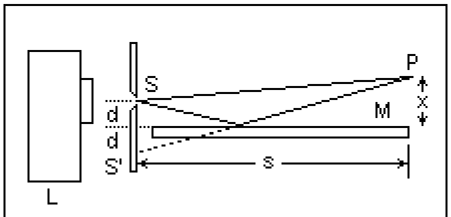
$$\mu = \frac{(D_{n+m})^2 - (D_n)^2}{(D'_{n+m})^2 - (D'_n)^2}$$

YOUNG'S DOUBLE SLIT EXPERIMENT:



The phenomenon of interference was first observed and demonstrated by Thomas Young in 1801. The experimental set up is shown in Fig. Light from a narrow slit S, illuminated by a monochromatic source, is allowed to fall on two narrow slits A and B placed very close to each other. The width of each slit is about 0.03 mm and they are about 0.3 mm apart. Since A and B are equidistant from S, light waves from S reach A and B in phase. So A and B act as coherent sources. According to Huygen's principle, wavelets from A and B spread out and overlapping takes place to the right side of AB. When a screen XY is placed at a distance of about 1 metre from the slits, equally spaced alternate bright and dark fringes appear on the screen. These are called interference fringes or bands. Using an eyepiece the fringes can be seen directly. At P on the screen, waves from A and B travel equal distances and arrive in phase. These two waves constructively interfere and bright fringe is observed at P. This is called central bright fringe. When one of the slits is covered, the fringes disappear and there is uniform illumination on the screen. This shows clearly that the bands are due to interference.

LOYD'S SINGLE MIRROR:



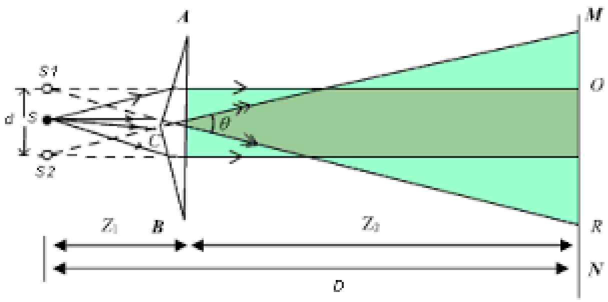
Lloyd's Mirror

This experiment for the production of interference fringes was performed by Lloyd in 1834. He used a plan mirror about 30 cm in length and 6 to 8 cm in breath. The mirror *M* is either a flat polished metal or a piece of black glass so that no reflection takes place from the back of the mirror. *S* is a source of monochromatic light and *B* is the image of *S* formed by reflection. *S* corresponds to one of the coherent source (*viz A*). Hence *S* and *B* are very close and the rays from *S* are reflected almost at grazing incidence. Interference fringes are produced on the screen placed at a distance *D* from *S* in the shaded portion *EF*.

For complete theory refer to article 8.6. But there is one difference in the case. The central fringe, instead of being bright is dark. If the screen is brought at the end *R* of the mirror *M*, such that the point *C* of the screen touches the end of the mirror, *C* comes at the centre of the dark Fringe. *C* is equidistant from *A* and *B.* according to the theory it should lie at the center of a bright fringe. Here, one of the two beams, producing interference fringes, has undergone a phase change of π. Due to this reason, the central fringe instead of being white is dark in this case. This experiment proves that a light beam after reflection form an optically denser medium undergoes a phase change of π.

One objection can be raised here, as to why the central fringe in the case of Frensnel's double mirror is bright and not dark. In the case undergo a phase change of π. Therefore, the path difference is not altered as in the case of Lloyd's single mirror.

FRESNEL'S BIPRISM:

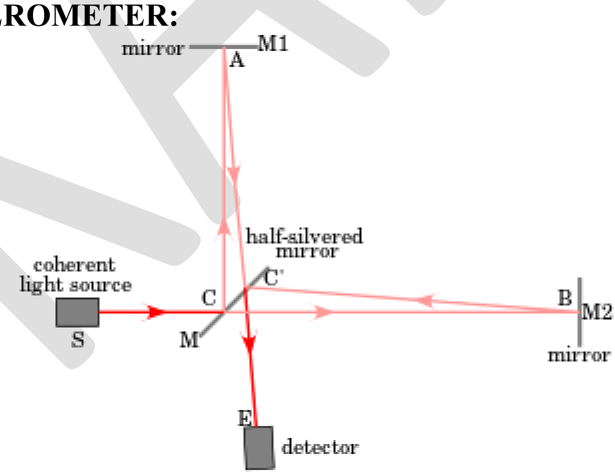


A Fresnel Biprism is a thin double prism placed base to base and have very small refracting angle (0.5o). This is equivalent to a single prism with one of its angle nearly 179° and other two of 0.5o each.

The interference is observed by the division of wave front. Monochromatic light through a narrow slit S falls on biprism , which divides it into two components. One of these component is refracted from upper portion of biprism and appears to come from S1 where the other one refracted through lower portion and appears to come from S2. Thus S1 and S2 act as two virtual coherent sources formed from the original source. Light waves arising from S1and S2 interfere in the shaded region and interference fringes are formed which can be observed on the screen .

Applications of Fresnel's Biprism:
Fresnel biprism can be used to determine the wavelength of a light source (monochromatic), thickness of a thin transparent sheet/ thin film, refractive index of medium etc.

MICHELSON'S INTERFEROMETER:



It is excellent device which is used to get interferometer fringes of various shapes which find a number of applications in optics.

Construction:
Its main optical part have been two plane mirrors M_1 and M_2 and two similar optically plane, parallel glass plates P_1 and P_2. The plane mirror M_1 and M_2 have been silvered on their front surfaces and get mounted vertically on two arms which are at right angles to each other.
It is possible to tilt their planes slightly about vertical and horizontal axes by adjusting screws at their backs. The mirror M_1 is mounted on a carriage provided with a very accurate and fine of a very uniform pitch and can be moved in the direction of the arrows.
The plates P_1 and P_2 are mounted vertically, exactly parallel to each other and inclined at 45^o to M_1 and M_2. The surface of P_1 towards P_2 are mounted has been partially silvered.
Working:
Light from an extended monochromatic source S, which is rendered nearly parallel by a lens L, falls on P_1. A ray of light incident on the partially-silvered surface of P_1 gets partly reflected and partly transmitted.
The reflected ray1, and the transmitted ray, travels to M_1 and M_2 respectively. After reflection at M_1 and M_2, the two ray re-combine at the partially-silvered surface and enter a short-focus telescope T. As the ray entering the telescope have been from derived from the same incident ray, they have been coherent and hence in apposition to interfere. The interference fringes can be seen in the telescope.
Function of the Plate P_2:
After partial reflection and transmission at O, the ray 1 would travel through the glass plate P_1 twice, whereas ray 2 does not do so even once. Thus in the absence of P_2, the path of rays 1 and 2 in glass would not be equal. To equalize these paths a glass plate P_2, which is having the same thickness as P_1, is kept parallel to P_1. P_2 is termed as the 'compensating plate'.
Form of Fringes:
The form of the fringes has been found to depend on the inclination of M_1 and M_2 .Suppose M_2 is the image of M_2 formed by refection at the semi-silvered surface of P_1 is that $OM_2 = OM_2$.
The interference fringe may be considered to be formed by light reflected from the surfaces of M_1 and M_2 . Hence the arrangement would be equivalent to an air-film which is enclosed between the reflecting surfaces M_1 and M_2 .

DETERMINATION OF WAVELENGHT OF MONOCHROMATIC LIGHT:
First of all the interferometer is set for circular fringes and the position of the mirror M_1 is adjust to get a bright spot at the position of the mirror M_1 is adjust to get a bright spot at the centre of the field of view. If *d* denotes the thickness of the film and *n* the order of the spot obtained, we get

$$2d \cos r = n\,\lambda.$$

But at the centre r = 0, so that cos r = 1. Therefore, we get 2d = n λ.
If now the mirror M_1 is moved away from M_2 by a $\lambda/2$ then 2d increases by λ.
Therfore n + 1 would replace n in equation (1). Thus (n + 1)st bright spot now appears at the centre. Hence each time M_1 moves through a distance $\lambda/2$, next bright spot appears at the centre. Suppose during the movement of M1 through a distance x, N new fringes would appear at the center of the field. Then, we get

$$X = N\frac{\lambda}{2}$$

Or $$\lambda = \frac{2x}{N}$$

Hence, measuring the distance x on the micrometer screw and counting the number N, the value of λ would be obtained.

The determination of λ by this method this much accurate, as x can be measured to an accuracy of 10^{-4} mm, and the circular fringes can be obtained upto large path differences.

Determination of difference in Wavelengths:

If the source of light is having two wavelengths very close to each other (like sodium D-lines), each wavelength would produce its own system of rings.

If the movable mirror of the interferometer is made to move in one direction, the thickness of the air-film would increase and the rings would become alternately distinct and indistinct. This phenomenon can be used for determining the difference in the two wavelengths.

Suppose $\lambda 1$ and $\lambda 2$ denote the two wavelengths an dsuppose $\lambda 1 > \lambda 2$. If the thickness of the film is small, the rings due to $\lambda 1$ and $\lambda 2$ would almost coincides because $\lambda 1$ and $\lambda 2$ are nearly equal. The mirror M1 is moved away. Then, due different spacing between the rings $\lambda 1$ and $\lambda 2$, the rings of $\lambda 1$ would be slowly separated from those $\lambda 2$.

If the thickness of the air-film become such that a dark ring of $\lambda 1$ coincides with a bright ring of $\lambda 2$ (due to closeness of $\lambda 1$ and $\lambda 2$, he dark ring due to $\lambda 1$ would alomost coincide with bright rings due to $\lambda 2$ in the entire field of view), the rings are having maximum indistinctness.

The mirror 1 is moved further away through a distance x (say0 until the rings, after becoming most distinct, would once again become most indistinct.

Clearly, during this movement, n fringes of $\lambda 1$ and (n+1) fringes of $\lambda 2$ have appeared at the centre (because then the dark ring of $\lambda 1$ will again coincide with the bright ring of $\lambda 2$.) Now, as the movement of the mirror M1 by $\lambda/2$ gives rise the appearance of one new fringes at the centre, we get

$$X = n\frac{\lambda 1}{2} = (n+1)\frac{\lambda 2}{2}$$

Or $$N = \frac{2x}{\lambda 1} \text{ and } (n+1) = \frac{2x}{\lambda 2}$$

$$\therefore \frac{2x}{\lambda 2} - \frac{2x}{\lambda 1} = 1$$

Or $$2x\frac{\lambda 1 - \lambda 2}{\lambda 1 \lambda 2} = 1$$

Or $$\lambda 1 - \lambda 2 = \frac{\lambda 1 \lambda 2}{2x}$$

As $\lambda 1$ and $\lambda 2$ are close together, $\lambda 1 \lambda 2$ could be replace by $\lambda 2$ where $\lambda$is the mean of the mean of $\lambda 1$ and $\lambda 2$. Thus

$$\lambda - \lambda 2 = \frac{\lambda 2}{2x}$$

Thus if one is able to measure the distance moved by 1 between two consecutive position of maximum indistinctness, and the mean wavelength is known one can determine the difference $(\lambda 1 - \lambda 2)$.

Determination of refractive index of a thin plate:

This interferometer can be adjusted for producing straight white-light fringes and the cross wire is made to set on the achromatic fringe which is perfectly straight.

The given plate is now inserted in the path of one of the beam by $(\mu - 1)$ t would be introduced between the two interfering beams. The fringes are therefore shifted. The movable mirror M1 gets moved till the fringes are bought back to their initial position so that the achromatic fringes again gets coincide with the cross-wire. If the displacement of M1 is x, then we have

$$2x = 2(\mu - 1)\ t$$

Or

$$x = (\mu - 1)t.$$

Thus, by measuring x, t can be calculated if μ is known, or μ can be calculated if t is known.

POSSIBLE QUESTIONS

PART B

1. Define interference.
3. Define amplitude.
4. What is wavelength difference?
5. Define refractive index.
6. Write a note on visibility of fringes.
7. What is meant by Fizeau fringes?
8. Define reflection.
9. Write the applications of Michelson interferometer.

PART C

1. Explain in detail about the Young's Double slit experiment.
2. Write a note on Fringes of equal thickness.
3. Discuss in detail about the determination of the wavelength of monochromatic source.
4. Determine the refractive index of the material by Newton's ring with neat diagram.
5. Explain in detail about the Michelson interferometer experiment and explain the determination of wavelength with neat diagram.
6. Explain in detail about the Michelson interferometer experiment and explain the determination of difference in wavelength with neat diagram.
7. Explain in detail about the Michelson interferometer experiment and explain the determination of refractive index of a thin plate with neat diagram.
8. Describe about the Fresnel's Biprism with neat diagram.
9. Explain Lloyd's single mirror.

Suggested Books for Reading:

1. Singh, Devraj (2015), Fundamentals of Optics, 2nd Edition,PHI Learning Pvt. Ltd.
2. McGraw-Hill Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
3. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
4. George Arfken (2012), University Physics. Academic Press.

AGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

II B.SC PHYSICS **BATCH: 2017-2020**

WAVES AND OPTICS (17PHU401)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3
UNIT III			
If two waves (y1) and (y2) traverse in a medium, then the resultant displacement at a point in the medium is given by	y1 - y2	y1 + y2	y1 * y2
The condition for constructive interference is path difference should be equal to	odd integral multiple of wavelength	Integral multiple of wavelength	odd integral multiple of half wavelength
The condition for destructive interference is path difference should be equal to	odd integral multiple of wavelength	Integral multiple of wavelength	odd integral multiple of half wavelength
The ratio of intensities of two waves that produce interference pattern is 16:1 then the ratio of maximum and minimum intensities in the pattern is	25:09:00	09:25	01:04
Correlation between the field at a point and the field at the same point at later time is known as	Temporal coherence	Spatial coherence	coherence
A phase difference π between two interfering beams is equivalent to the path difference	λ	λ/2	λ/3
The penetration of waves into the regions of the geometrical shadow is	Dispersion	polarizatior	diffraction
Interference occurs due to of light	Wave natu	particle nat	both a and b
Superposition of crest and trough results in	Destructive	Constructiv	Diffraction
Two waves having their intensities in the ratio 9:1 produce interference. In the interference pattern the ratio of maximum to minimum intensity is equal to	02:01	09:01	03:01

Two interfering beams have their amplitudes ratio 2:1 then the intensity ratio of bright and dark fringes is	02:01	01:02	09:01
If the two coherent waves intensity ratio is 9:4 then the ratio of maximum to minimum intensity of the fringe is	25:09:00	09:25	01:04
If a1 and a2 are the amplitudes of light coming from two slits in Young's double slit experiment, then the maximum intensity of interference fringe is	(a1 + a2)	2(a1 + a2)	(a1 + a2)2
The fringe width (β) of the interference pattern in the Young's double slit experiment increases	with increa	With decre	independen
The fringe width (β) of the interference pattern in the Young's double slit experiment decreases distance between the two slits.	with increa	With decre	independen
The fringe width (β) of the interference pattern in the Young's double slit experiment increases distance between the slits and the screen.	with increa	With decre	independen
If the thickness of the parallel film increases, the path difference	increases	Decreases	remains san
When a light wave is reflected at the surface of an optically denser	π/4	π / 2	π
Interference due to reflected light is also called law	sine law	cosine law	Tangent law
In case of the thin film, the condition for constructive interference	odd integra	Integral mu	odd integral
Usually,vapour lamp is used as source of light to demonstrate Newton's rings experiment.	mercury	sodium	neon
The lens used in Newton's rings experiment in addition to the glas	concave	plano conv	plano conca
In Newton's rings experiment, the diameter of bright rings is prop	Odd natura	Natural nur	Even natura
In Newton' rings experiment, the diameter of dark rings is proport	Odd natura	Natural nur	Even natura
In Newton's rings experiment, rings are formed when the light by	reflected	refracted	both
Newton's rings can be viewed through a	microscop	telescope	gyroscope
Which of the following can be used as monochromator in addition	thin film	thin glass p	diffraction
If in a given source the charges all oscillate in phase, the source is	incoherent	orthogonall	coherent
The basic concept of spatial coherence is in	Michelson	Michelson'	Turryman-C
The function __________ is called the mutual coherence function	$G_{21}(t)$	$G_{12}(t)$	$G_{11}(t)$
For a circular source, the transverse coherence width (l_t) is	1.22 l/q_s	1.44 l/q_s	0.22 l/q_s
One of the largest stars measured, Betelgeuse, was found to have a	0.47 arc se	0.0047 arc	0.00047 arc
A useful convention for the resolution of multiple-beam interferen	Fabry-Pero	Taylor crite	Michelson
A Fabry-Perot interferometer consists of __________ optically fla	4	3	2
The coherence time of the laser sources will be equal to	10^{-6} s	10^{-5} s	10^{-4} s
A normalized correlation function is also called as the	degree of c	degree of p	degree of c
According to Fourier analysis the frequency bandwidth is given by	1/Df	1/Dt	Df
The interferometer devised by C. Fabry and A. Perot in the year __	1869	1879	1889
____________ was the first to determine stellar diameters by inter	Michelson	Hanbury-B	Fabry and P
The Fourier transform pair are	F(t) and G(	f(t) and g(w	F(T) and G(
The angular diameter of stars are of the order of ____________ of	tenths	thousandth	ten thousan
The spectral width of a white light source is about	1300 Å	1400 Å	1500 Å
The material used for coating lenses is	magnesiun	magnesium	magnesium

The light from a sodium lamp has coherence length of the order of	1 cm	10 cm	1 mm
The maximum spectral sensitivity of a human eye is about ______	4000 Å	4500 Å	5000 Å
Light produced by _______________ is highly coherent	mercury la	sodium lam	laser
Spatial coherence of waves ____________ with the increasing size	increases	decreases	remains con
Transverse coherence width (l_t) is given by	l¤q_s	l¤2q_s	2l¤q_s
If a high quality camera lens has six components, then the number	2	3	6
The spectral width of the transmission band depends on the ______	transmittan	reflectance	both (a) and
Multilayer dielectric films are superior to the metal films because (	higher refl(	lower reflec	higher refle(
Resolving power of a Fabry-Perot instrument is given by	Np(ÖR/Ö1	Np (R/1-R)	Np(ÖR/1-R
Coherence length (l_c) is given by	c/t_0	c+t_0	c-t_0
-______________ of waves decreases with the increasing size of th	Partial coh	Spatial coh	Both a & b
______________ are superior to the metal films because of higher r	Multilayer	High reflec	Antireflecti
The basic concept of ______________ is in Turryman-Green interf	Partial coh	Spatial coh	Both a & b
The ____________ of any spectroscopic instrument is given by l¤½	Reflection	Transmissi	Resolving p
A useful convection for resolution in the case of ______________ i	Multiple b	Constructiv	Destructive
The coherence time of ____________ will be equal to 10^{-3} s.	Maser sour	Laser sourc	Both a & b
--______________, a largest star was found to have an angular dian	Betelgeuse	Crab Nebul	Proxima Ce
According to ____________analysis, the frequency bandwidth is gi	Laplace	Hartley	Mellin
The light from a ____________ lamp has a coherence length of the	Mercury	Sodium	UV
In use, the interferometer is usually mounted between ___________	Collimatin	In front of t	In front of t
When the index of refraction $n_o<n_E$, the crystal is said to be	positive	negative	cubic
Choose the one that falls under optically isotropic crystal category	Ice	Diamond	Calcite
Example for uni-axial positive crystals	Fluorite	Beryl	Topaz
Which of the following is uni-axial negative crystal	Sodium ch	Zircon	Tourmaline
Choose the one corresponds to Bi-axial crystals	Diamond	Quartz	Calcite
The magnitude of ray velocity and phase velocity are related by	u=cosq/v	u=v/cosq	u=v.cosq
Fused quartz is	optically ac	optically is	optically an
The amount of optical activity of quartz varies with	wavelengtl	polarisation	thickness
A dielectric becomes optically active in the presence of	electric fiel	magnetic fi	both
High Verdet constant value is observed in	Fluorite	Diamond	Crown Glas
Verdet constant, magnetic induction and rotation angle of polarise	q=VBl	V=qBl	B=qVl

Prepared By N.Geetha, Assistant Professor,Department of Physics, KAHE,coimbatore-21.

opt4	opt5	opt6	Answer
y1 / y2			y1 + y2
Integral multiple of half wavelength			Integral multiple of wavelength
Integral multiple of half wavelength			odd integral multiple of half wavelength
04:01			25:09:00
none			Temporal coherence
λ/4			λ/2
interference			diffraction
none of these			Wave nature
Polarization			Destructive interference
04:01			04:01

04:01	09:01
25:01:00	25:01:00
(a1 – a2)2	(a1 + a2)2
none of these	with increase in wavelength
none of these	with increase in wavelength
none of these	with increase in wavelength
None of these	increases
2π	π
cotangent law	Tangent law
Integral multiple of half wav	Integral multiple of wavelength
nitrogen	sodium
none	plano convex
Square root of odd natural nu	Square root of odd natural numbers
Square root of natural numbe	Square root of natural numbers
none	reflected
any of the three	telescope
none	diffraction grating
partial coherence	coherent
Hanburry-Brown Twiss inter	Turryman-Green interferometer
$G_{22}(t)$	$G_{12}(t)$
0.44 l/q_s	1.22 l/q_s
0.047 arc second	0.047 arc second
Young criterion	Taylor criterion
1	2
10^{-3} s	10^{-3} s
degree of partial incoherence	degree of partial coherence
Dt	1/Dt
1899	1889
Young	Michelson
$F_{(t)}$ and $G_{(w)}$	f(t) and g(w)
hundredths	hundredths
1600 Å	1500 Å
magnesium chloride	magnesium fluoride

10 mm	1 mm
5500 Å	5500 Å
ordinary bulb	laser
none of the above	decreases
lq_s	l¤q_s
12	12
none of the above	reflectance
lower reflectance and lower	higher reflectance and lower absorption
Np(Ö1-R/R)	Np(ÖR/1-R)
ct_0	ct_0
None of the above	Spatial coherence
None of the above	Multilayer dielectric films
None of the above	Spatial coherence
None of the above	Resolving power
None of the above	Multiple beam interference
None of the above	Laser source
None of the above	Betelgeuse
Fourier	Fourier
None of the above	Sodium
None of the above	Collimating lens and a focusing lens
triclinic	positive
Mica	Diamond
Quartz	Quartz
Feldspar	Tourmaline
Gypsum	Gypsum
u=1/v.cosq	u=v/cosq
none of the above	optically isotropic
number of atoms	wavelength
light	magnetic field
Flint Glass	Flint Glass
V=q/Bl	q=VBl

UNIT-IV

SYLLABUS

Diffraction: Fraunhofer diffraction: Single slit; Double Slit. Multiple slits & Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.

FRAUNHOFER DIFFRACTION – SINGLE SLIT:

To obtain a Fraunhofer diffraction pattern, the incident wavefront must be plane and the diffracted light is collected on the screen with the help of lens. Thus, the source of light should either be at a large distance from the slit or a collimating lens must be used.

In figure, S is a narrow slit perpendicular to the plane of the paper and illuminated by monochromatic light. L1 is the collimating lens and AB is a slit of width a. XY is the incident spherical wavefront. The light passing through the slit AB is incident on the lens L2 and the final refracted beam is observed on the screen MN. the screen is perpendicular to the plane of the paper. The line SP is perpendicular to the screen. L1 and L2 are achromatic lenses.

A plane wavefront is incident on the slit AB and each point on this wavefront is a source of secondary disturbance. The secondary wave travelling in the direction parallel to OP viz. AQ and BV come to focus at P and a bright central image is observed. The secondary wave from points equidistant from O and situated in the upper and lower halves OA and OB of the wavefront travel the same distance is reaching P and hence the path difference is zero. The secondary waves reinforce one another and P will be a point of maximum intensity.

Now, consider the secondary waves travelling in the direction AR, inclined at an angel θ to the direction OP. All the secondary wave travelling in this direction reach the point P' on the screen. The point p' will be of maximum or minimum intensity depending on the path difference between the secondary waves originating from the corresponding points of the wavefront. Draw OC and BL perpendicular to AR.

Then, in the Δ ABL

$$\sin\theta = \frac{AL}{AB} = \frac{AL}{\alpha}$$

$$\text{or } AL = a \sin\theta$$

Where a is the width of the slit and AL is the path difference between the secondary waves originating from A and B. If this path difference is equal to λ the wavelength of light used, then P' will be a point of minimum intensity. The whole wavefront can be considered to be of two halves OA and OB and if the path difference between the secondary waves from A and B is λ, then the path difference between the secondary waves from A and O will be $\frac{\lambda}{2}$. Similarly for every point in the upper half OA, there is a corresponding point in the lower half OB, and the path difference between the secondary waves from these points is be $\frac{\lambda}{2}$. Thus, destructive interference takes place and point P' will be of minimum intensity. If the direction of the secondary waves is such that AL = 2λ , then also the point they meet the screen will be minimum intensity. This is so because the secondary waves from the corresponding points of the lower half, differ in path by $\frac{\lambda}{2}$ and this again gives the position of minimum intensity. In general

$$a \sin \theta_n = n\lambda$$

$$\sin \theta_n = \frac{n\lambda}{a}$$

Where θn gives the direction of the n th minimum. Here n is an integer. If, however, the path difference is odd multiplies of $\frac{\lambda}{2}$, the directions of the secondary maxima can be obtained. In the case,

$$a \sin \theta_n = (2n+1)\frac{\lambda}{2}$$

$$\text{or } \sin \theta_n = \frac{(2n+1)\lambda}{2a}$$

Where n = 1,2,3 etc.

Thus, the diffraction pattern due to a single slit consists of a central bright maximum at P followed by secondary maxima and minima on both the sides. The intensity distribution on the screen is given in figure. P corresponds to the position of the central bright maximum and the points on the screen for which the path difference between the points A and B is λ, 2λ etc, correspond to the positions of secondary minima. The secondary maxima are of much less intensity. The intensity falls off rapidly from the point P outwards.

If the lens L2 is very near the slit or the screen is far away from the lens L2 , then

$$\sin \theta = \frac{x}{f} \text{----------(1)}$$

Where f is the focal length of the lens L2,

But
$$\sin \theta = \frac{\lambda}{a} \quad \text{-----------(2)}$$

$$\frac{x}{f} = \frac{\lambda}{a}$$

or
$$x = \frac{f\lambda}{a}$$

Where x is the distance of the secondary minimum from the point P. Thus, the width of the central maximum = 2x.

Or
$$2x = \frac{2f\lambda}{a} \qquad \text{-----------(3)}$$

The width of the central maximum is proportional to λ , the wave-length of light. With red light (longer wavelength), the width of the central maximum is more than with violet light (shorter wavelength). With a narrow slit, the width of the central maximum is more. The diffraction pattern consists of alternate bright and dark bands with monochromatic light. With white light, the central maximum is white and the rest of the diffraction bands are coloured. From equation (2), if the width a of the slit is large, sin θ is small and hence θ is small. The maxima and minima are very close to the central maximum at P. But with a narrow slit, a is small and hence θ is large. This results a distinct diffraction maxima and minima on both sides of P.

FRAUNHOFER DIFFRACTION – DOUBLE SLIT:

In figure AB and CD are two rectangular slits parallel to one another and perpendicular to the plane of the paper. The width of each slit is a and the width of the opaque portion is b. L is a collecting lens and MN is a screen perpendicular to the plane of the paper. P is a point on the screen such that OP is perpendicular to the screen. Let a plane wavefront be incident on the surface of XY. All the secondary waves travelling a direction parallel to OP come to focus at P. Therefore, P corresponds to the position of the central bright maximum.

In the case, the diffraction pattern has to be considered in to a parts: (i) the interference phenomenon due to the secondary waves emanating from the corresponding points of the two slits and (ii) the diffraction pattern due to the secondary waves from the two slits individually. For calculating the positions of interference maxima and minima, the diffracting angle is denoted as θ and for the diffraction maxima and minima it is denoted as φ. Both the angles θ and φ refer to the angle between the direction of the secondary waves and the initial direction of the incident light.

(i)Interference maxima and minima:

Consider the secondary waves travelling in a direction inclined at an angle θ with the initial direction.

In the ΔACN (Figure)

$$\sin\theta = \frac{CN}{AC} = \frac{CN}{a+b}$$

or $$c = (a+b)\sin\theta$$

If this path difference is equal to odd multiples of $\frac{\lambda}{2}$, θ gives the direction of minima due to interference of the secondary waves from the two slits .

$$CN=(a+b)\sin\theta n =(2n+1)\,\frac{\lambda}{2}\ ....(i)$$

putting n=1,2,3,...etc , the values of θ1θ2θ3 ,etc. corresponding to the directions of minima can be obtained

from equation (**i**)

$$\sin\theta n = \frac{(2n+1)\,\lambda}{2(a+b)}\ ....(ii)$$

On the other hand, if the secondary waves travel in a direction θ' such that the path difference is even multiple of $\frac{\lambda}{2}$, then θ' gives the direction of the maxima due to interference of light waves emanating from the two slits.

$$CN = (a+b)\sin\theta' n = 2n.\frac{\lambda}{2}$$

$$\text{or } \sin\theta' n =\frac{n\lambda}{a+b}\ \text{-------------(iii)}$$

Putting n= 1,2,3 etc, the values of θ'1, θ'2, θ'3 ,etc. corresponding to the directions of minima can be obtained.

From equation (ii)

$$\sin\theta 1 = \frac{3\lambda}{2(a+b)}$$

$$\text{and } \sin\theta 2 = \frac{5\lambda}{2(a+b)}$$

sin θ1 - sin θ2 = $\frac{\lambda}{a+b}$ ------------(iv)

Thus, the angular separation between any two consecutive minima (or maxima) is equal to $\frac{\lambda}{a+b}$. The angular seperation is inversely proportional to (a+b), the distance between the two slits.

(ii)Diffraction maxima and minima:

Consider the secondary waves travelling in a direction inclined at an angle φ with the initial direction of the incident light.

If the path difference BM is equal to λ the wavelength of light used, then φ will give the direction of diffraction minimum (figure). That is, the path difference between the secondary waves emanating from the extremities of a slit (i.e. points A and B) is equal to λ Considering the wavefront on AB to be made up of two halves, the path difference between the corresponding points of the upper and the lower halves is equal to $\frac{\lambda}{2}$. The effect at P' due to the wavefront incident on AB is zero. Similarly for the same direction of the secondary waves, the effect at P' due to the wavefront incident on th slit CD is also zero. In general,

a sin φn = nλ ------------(v)

Putting n=1,2,3,etc, the values of θ1θ2θ3 ,etc. corresponding to the directions of diffraction minima can be obtained.

FRAUNHOFER DIFFRACTION – MULTIPLE SLIT:

Fraunhofer diffraction at two slits consists of diffraction maxima and minima governed by

$$\frac{sin^2}{\alpha^2}\alpha$$

and sharp interference maxima and minima, in each diffraction maximum governed by the $\cos^2 \beta$ term.

To derive an expression for the intensity distribution due to diffraction at N slits, the expression for by has to be integrated for N slits.

For a single slit,

$$dy = k\int_{\frac{-a}{2}}^{\frac{+a}{2}} \sin[2\pi\,(\frac{t}{T}-\frac{r}{\lambda}+\frac{z\,sin\theta}{\lambda})]dz$$

Let $\sin[2\pi\,(\frac{t}{T}-\frac{r}{\lambda}+\frac{z\,sin\theta}{\lambda})]dz$ be equal to φ (z) (i.e. function of z)

For N slits

$$dy = \int_{\frac{-a}{2}}^{\frac{+a}{2}} \phi(z)dz + \int_{d\frac{-a}{2}}^{d\frac{+a}{2}} \phi(z)dz + \int_{2d\frac{-a}{2}}^{2d\frac{+a}{2}} \phi(z)dz + \;\ldots\ldots \int_{(N-1)d\frac{-a}{2}}^{(N+1)d\frac{+a}{2}} \phi(z)dz$$

On simplification

$$y = ka\,\frac{\sin\alpha}{\alpha}\sin[2\pi\,(\frac{t}{T}-\frac{r}{\lambda}) + \sin[2\pi\,(\frac{t}{T}-\frac{r}{\lambda}+\frac{d\,sin\theta}{\lambda}) + \sin 2\pi\,(\frac{t}{T}-\frac{r}{\lambda}+\frac{2d\,sin\theta}{\lambda}) + \ldots\ldots\ldots\sin 2\pi\,(\frac{t}{T}-\frac{r}{\lambda}+\frac{(N-1)d\,sin\theta}{\lambda})$$

Here $\alpha = \frac{\pi a\,sin\theta}{\lambda}$

For a general trigonometric summation

$$\sum_{p=0}^{p=n} \sin(x+pm) = \frac{\sin\left(x+\frac{nm}{2}\right)\sin[\left(\frac{n+1}{2}\right)m]}{\sin\frac{m}{2}}$$

Here x = $2\pi\ (\frac{t}{T}-\frac{r}{\lambda})$

And m = $\frac{2\pi d\ \sin\theta}{\lambda}$

= $2[\frac{\pi d\ \sin\theta}{\lambda}] = 2\beta$

n = (N-1)

Then y = ka $\frac{\sin\alpha}{\alpha}\frac{\sin N\beta}{\beta}\sin 2\pi\ (\frac{t}{T}-\frac{r}{\lambda}+\frac{(N-1)d\ \sin\theta}{\lambda})$

The intensity at point P'

$$I = k^2a^2\ (\frac{\sin^2\alpha}{\alpha^2})\frac{\sin^2 N\beta}{\sin^2\beta} \quad \text{-----------(2)}$$

The maximum intensity, when α = k^2a^2

$$I = I_0(\frac{\sin^2\alpha}{\alpha^2})\frac{\sin^2 N\beta}{\sin^2\beta} \quad \text{-----------(3)}$$

Since the expression $(\frac{\sin^2\alpha}{\alpha^2})$ represents the diffraction pattern due to a single slit. The additional factor $\frac{\sin^2 N\beta}{\sin^2\beta}$represents the interference effects due to the secondary waves from the N slits.

The numerator will be zero when

Nβ = 0,π,2π,3π......etc. = kπ'

The denominator is also zero when

β= 0,π,2π,3π......etc

Since the quotient 0/0 is indeterminate, therefore N β = kπ gives the condition for minimum intensity for all values of k other than

k = 0,N,2N,3N etc.

The directions of principal maxima correspond to the values of k=0,N,2N etc.

$$N\beta = \frac{N\pi d\ \sin\theta}{\lambda}$$

OR

$$k\pi = \frac{N\pi d\ \sin\theta}{\lambda}$$

For the directions of principal maxima.

k = 0,1N,2N,3N etc. = nN

When n = 0,1,2,3,....etc.

$$n\pi N = \frac{N\pi d\ \sin\theta}{\lambda}$$

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

Here n = 0,1,2,3 etc.

If the width of the slit is a and the width of the opaque spacing is b.

$$d = (a+b)$$

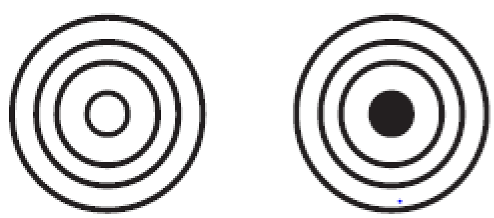
$$(a+b)\sin\theta = n\lambda$$

Putting n = 1,2,3 etc., the directions of principal maxima θ1θ2θ3......etc can be determined.

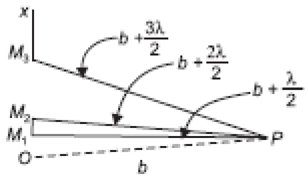
For values of k in between 0 and N, between N and 2N etc, there arew (N-1) secondary minima and (N-2) secondary maxima.
The intensity distribution due to diffraction and N slits is shown in figure.

DIFFRACTION GRATING:
A diffraction grating is an extremely useful device and in one of it's forms it consists of a very large number of narrow slits are separated by opaque spaces. When a wavefront is incident on a grating surface, light is transmitted through the slits and obstructed by the opaque portions. Such a grating is called a transmission grating. The secondary waves from the positions of the slits interfere with one another, similar to the interference of waves in Young's experiment. Joseph Fraunhofer used the first gratings which considered of a large number of parallel fine wires stretched on a frame. Now, gratings are prepared by ruling equidistant parallel lines on a glass surface. The lines are drawn with a fine diamond point. The space in between any two lines is transparent to light and the lined portion is opaque to light. Such surfaces act as transmission gratings. If on the other hand the lines are drawn on a silvered surface (plain or concave) then light is reflected from the positions of the mirror in between any two lines and such surfaces act as reflections gratings.
If the spacing between the lines is of the order of the wavelength of light, then the appreciable deviation of the light is produced. Gratings used for the study of the visible region of the spectrum contain 10,000 lines per centimetre. Gratings, width originally ruled surfaces are only few. For practical purposes, replicas of the original grating is prepared. On
the original grating surface a thin layer of collodion solution is poured and the solution is allowed to harden. Then, the film of collodion is removed from the grating surface and then fixed between two glass plates. This serves as a plane transmission grating. A large number of replicas are prepared in this way from a single original ruled surface.

ZONE PLATE:
A zone plate is a specially constructed screen such that light is obstructed from every alternate zone. It can be designed so as to cut off light due to the even numbered zones or that due to the odd numbered zones. The correctness of Fresnel's method is dividing a wavefront into half period zones can be verified with its help.



To Construct a zone plate, concentric circles are drawn on white paper such that the radii are proportional to the square roots of the natural numbers. The odd numbered zones (i.e., 1st, 3rd, 5th etc) are covered with black ink and a reduced photograph is taken. The drawing appears as shown in Fig. The negative of the photograph will be as shown in Fig . In the developed negative, the odd zones are transparent to incident light and the even zones will cut off light.



If such a plate is held perpendicular to an incident beam of light and a screen is moved on the other side to get the image, it will be observed that maximum brightness is possible at some position of the screen say *b* cm from the zone plate. *XO* is the upper half of the incident plane wavefront. *P* is the point at which the light intensity is to be considered. The distance of the point *P* from the wavefront is *b*. *OM*1 (= *r*1), *OM*2 (= *r*2) etc. are the radii of the zones,

$$r_1 = \sqrt{b\lambda} \text{ and } r_2 = \sqrt{2b\lambda}$$

Where λ is the wavelength of light

$$r_n = \sqrt{n\,b\lambda} \text{ or } b = \frac{r_n^2}{n\lambda}$$

The source is at a large distance from the zone plate, a bright spot will be obtained at *P*. As the distance of the source is large, the incident wavefront can be taken as a plane one with respect to the small area of the zone plate. The even numbered zones cut off the light and hence the resultant amplitude at *P* = *A* = *m*1 + *m*3 + … etc. In this case the focal length of the zone plate *f*n is given by

$$f_n = b = \frac{r_n^2}{n\lambda} \qquad \because r_n^2 = bn\lambda$$

Thus, a zone plate has different foci for different wavelengths, the radius of the *n*th zone increases with increasing value of λ. It is very interesting to note that as the even numbered zones are opaque, the intensity at *P* is much greater than that when the whole wavefront is exposed to the point *P*.
In the first case the resultant amplitude is given by

$A = m1 + m3 + m5 + \_mn$ (*n* is odd)

When the whole wavefront is unobstructed the amplitude is given by

Thus, a zone plate has different foci for different wavelengths, the radius of the *n*th zone increases with increasing value of λ. It is very interesting to note that as the even numbered zones are opaque, the intensity at *P* is much greater than that when the whole wavefront is exposed to the point *P*. In the first case the resultant amplitude is given by

$A = m1 + m3 + m5 + \ldots..m_n$ (*n* is odd)

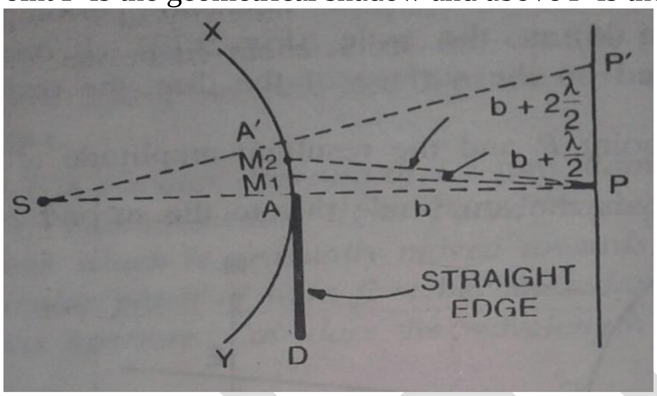
When the whole wavefront is unobstructed the amplitude is given by

$$A = m1 - m2 + m3 - m4 + \ldots.. + m_n$$
$$= \frac{M_1}{2} \text{ (if n is very large and odd)}$$

If a parallel beam of white light is incident on the zone plate, different colours came to focus at different points along the line *OP*. Thus, the function of a zone plate is similar to that of a convex (converging) lens and a formula connecting the distance of the object and image paints can be obtained for a zone plate also.

DIFFRACTION PATTERN DUE TO A STRAIGHT EDGE:

Let *S* be narrow slit illuminated by a source of monochromatic light of wavelength λ. The length of the slit is perpendicular to the plane of the paper. *AD* is the straight edge and the length of the edge is parallel to the length of the slit *XY* is the incident cylindrical wavefront. *P* is a point on the screen and *SAP* is perpendicular to the screen. The screen is perpendicular to the plane of the paper. Below the point *P* is the geometrical shadow and above *P* is the illuminated portion.

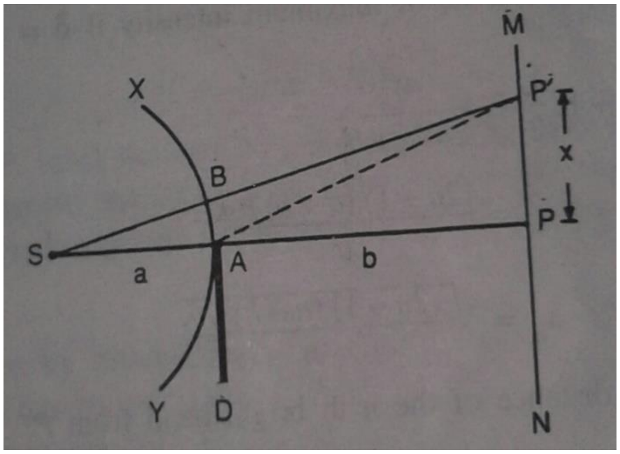


Let the distance *AP* be *b*. with reference to the Point *P*. the wavefront can be divided into a number of half period strips as shown above. *XY* is the wavefront, *A* is the pole of the wavefront and *AM*,*M M*,*M M* etc. Measure the thickness of the 1st, 2nd,3rd etc. Half period strips. With the increase in the order of the strip, the are of the strip decreases.

In figure AP = b, $PM_1 = b + \frac{\lambda}{2}$

$PM_2 = b + \frac{2\lambda}{2}$ etc.

Let *P'* be a point on the screen in the illuminated portion. To calculate the resultant effect at *P'* due to the wavefront *XY*, join *S* to *P'*. this line meet the wavefront at *B*. *B* is the pole of the wavefront with reference to the point *P'* and the intensity at *P'* will depend mainly on the number of half period strips enclosed between the point *A* and *B*.



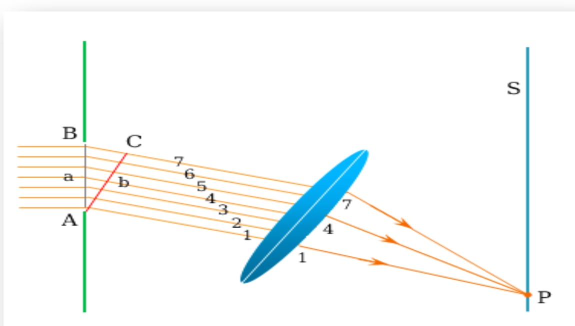
The effect at *P'* due to the wavefront above *B* is the same at all points on the screen whereas it is different at different point due to the wavefront between *B* and *A*. the point *P'* will be of maximum intensity, if the number of half period strips enclosed between *B* and *A* is odd and the intensity at *P'* will be minimum if the number of half period strips enclosed between *B* and *A* is even.

DIFFRACTION PATTERN DUE TO A SLIT:

As light bends around an obstacle this phenomena can also be observe by passing light through a narrow slit which proves that light ray deviates from its straight path while passing from sharp edge.

Explanation:

The figure below, shows the experimental arrangement for studying the diffraction of light due to a narrow slit.



The slit AB width d is illuminated by a parallel beam of monochromatic light of wavelength λ. The screen s is placed parallel to the slit for observing the effects of the diffraction of light. A small portion of the incident wavefront passes through the narrow slit. Each point of this section of the wavefront sends out secondary wavelets to the screen. These wavelets then interfere to produce the diffraction pattern. It becomes simple to deal with rays instead of wavefronts as shown in the figure. In the above figure, only seven rays have been drawn whereas actually there are a large number of them. Let us consider rays 1 and 4 which are in phase when in the wavefront AB. After these reach the wavefront AC, ray 4 would have path difference ab say equal to λ/2. Thus, when these two rays reach point P on the screen they will interfere destructively. Similarly, each pair 2 and 6, 3 and 7 differ in path by λ/2 and will do the same. But the path difference ab = d/2 sinθ.

The equation for the first minimum is, then

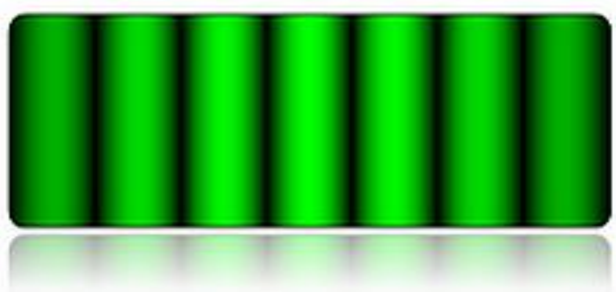
$$\frac{d}{2}\sin\theta = \frac{\lambda}{2}$$

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

In general, the condition for different orders of minima (dark regions) on either side of center are given by,

$$d \sin\theta = m\lambda \qquad \text{where } m = 1,2,3,...$$

The region between any two consecutive minima both above and below O will be bright. A narrow slit, therefore, produces a series of bright and dark regions with the first bright region at the center of the pattern. Such a diffraction pattern is shown in figures given below:



Diffraction due to monochromatic light

Diffraction due to white light

POSSIBLE QUESTIONS
PART B

1. Define diffraction.
2. What is zone plate?
3. Write a short notes about half period zone.
4. Define wavefront.
5. Define constructive fringe.
6. Define destructive fringe.
7. Write any two difference between interference and diffraction.

PART C

1. Write a note on Fraunhofer double slit experiment.
2. Write an expression of intensity distribution for multiple slit experiment.
3. Write a note on diffraction grating.
4. Write a note on (i) Half-period Zone (ii) Zone Plate.
5. Obtain the expression for Fraunhofer single slit.
6. Derive the expression for Fraunhofer multi slit.

Suggested Books for Reading:

1. Singh, Devraj (2015), Fundamentals of Optics, 2nd Edition,PHI Learning Pvt. Ltd.
2. McGraw-Hill Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
3. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
4. George Arfken (2012), University Physics. Academic Press.

AGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

II B.SC PHYSICS BATCH: 2017-2020

WAVES AND OPTICS (17PHU401)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3
UNIT IV			
Splitting of white light in to constituent colors is called	diffraction	refraction	reflection
Grating element is equal to	$n\lambda/\sin\theta$	$n\lambda$	$\sin\theta$
With diffraction grating, angles are	small	greater	zero
Fringes are referred to as	minima	maxima	nodes
Wavelength of an incident light when it is incident normally on a diffraction grating having 3000 lines per centimeter angular separation is 10° is	500 nm	650 nm	580 nm
The diffraction is divided into two different categories	Fresnel	Fraunhofer	Fresnel and
In Fraunhofer diffraction, the diffracted wave front is	**Plane**	Spherical	Cylindrical
In Fresnel diffraction, the diffracted wave front is	Plane	Spherical	**Either spheri**
For first minimum, the order of spectrum is	**One**	Two	Three
The bending property of light at the sharpedge of the obstacle is	Interferenc	Dispersion	**Diffraction p**
In Fraunhofer diffraction at circularaperature, the radius of central disc is	Independent on diameter of aperture	Large as the diameter of aperture is large	**Small as the diameter of aperture is large**
Slit to screen distance is finite in ------diffraction	**Fresnel**	Fraunhofer	Young's
Slit to screen distance is infinite in ____diffraction	Fresnel	**Fraunhofer**	Young's
Source to slit distance is finite in _____diffraction.	**Fresnel**	Fraunhofer	Young's
Source to slit distance is Infinite in ____diffraction	Fresnel	**Fraunhofer**	Young's
In Fresnel diffraction, the wave front incident on slit is_____	Spherical	Cylindrical	**Spherical or**
In Fraunhofer diffraction, the wave front incident on slit is_____	Spherical	Cylindrical	Spherical an
Light enters the geometrical shadow of slit in ______	Fresnel	Fraunhofer	**Fresnel and**
Diffraction of light manifest its _____nature	Particle	**Wave**	Dual nature
There is path difference between the rayscoming from a source before entering the slit in _____	**Fresnel**	Young's	Lloyd's
There is no path difference between the rayscoming from a source before entering the slit in ______	**Fraunhofer**	Young's	Lloyd's
To observe the diffraction pattern lenses are required in	**Fraunhofer**	Young's	Lloyd's
A line on diffraction grating is	An opaque	A slit	**An opaque s**

In Fraunhofer diffraction at a single slit, as slitwidth decreased , the ad jacent minima	Come closer	**Move apart**	Remains at fi
Which of the following depends on the total number of lines on the grating	**Intensity of principal maxima**	Intensity of minima	Position of principle of minima
Which orders of maxima cannot be absentin the diffraction pattern of any grating	0	1	2
Which of the following depends on grating element	Position of p	Position of n	Maximum or
Scattering of light by very small particles canbe considered to be a spe cial case of	Reflection	Refraction	Interference
Diffraction appears if the size of obstacle inpath of rays is the order of	1 mm	**10-4 mm**	0.1 mm
In a single slit experiments, if the slit width is reduced	Fringes becomes bright	**Fringes become narrower**	Fringes become wider
In diffraction, the intensity of central maxima is	Minimum	**Maximum**	No intensity
In Fresnel's Biprism experiment the central fringe is	**Bright**	Dark	First dark the
Zone plate behaves like a _____	**Convex lens**	Concave lens	Diffraction le
The radii of circles are ______ to the square roots of natural numbers.	Inversely proportional	**Proportional**	Directly proportional
______ has a number of focii.	Convex lens	Concave lens	Diffraction le
The area of each zone will be ____	**Same**	Not same	Double
if the central half-period of the zone plate is clear it is called as	Negative zo	**Positive zon**	Glass plate
In diffraction pattern, the fringes are not equally spaced have	**Different w**	Same width	Average widt
When light traveling in air gets reflected from water surface, there is -----	No phase ch	Phase chang	Phase chang
When light traveling in air gets transmitted in water, there is -----	**No phase ch**	Phase chang	Phase chang
An excessively thin film appears in reflected light	White	**Black**	Red
Two sources are said to be coherent	Same wavel	Same amplit	Constant pha
To observe colour in thin films, film must exposed to	**Broad sourc**	Point source	Either A or B
Width of fringes for wedge shape filmchanges with the increase of wed	Increases	**Decreases**	Remains the
For bright or dark fringes of any particularorder, the path difference m ust be	**Constant**	Increases	Decreases

Prepared By N.Geetha, Assistant Professor,Department of Physics, KAHE,coimbatore-21.

opt4	opt5	opt6	Answer
dispersion			dispersion
$\cos\theta$			$n\lambda/\sin\theta$
close to zero			greater
normal points			maxima
600 nm			580 nm
None of these			Fresnel and Fraunhofer
Triangle			
Triangle			
Five			
polarization			
Equal as the diameter of aperture is large			
Lloyd’s			
Lloyd’s			
Lloyd’s			
Lloyd’s			
plane			
plane			
Young’s			
All the above			
Fraunhofer			
Fresnel			
Fresnel			
None of these			

Increases and decreases

Position
of minima

0 and 1
All the above

diffraction
1 cm

Colour of
fringes
change
Same
First bright then dark
Interference lens

Same
Zone plate
Dark
Concave plate
None of these

Phase change of π
Phase change of π
yellow
All the above
None of the above
Difficult to say

Equal

UNIT-I

SYLLABUS

Superposition of Two Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses. Waves Motion- General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity.

SIMPLE HARMONIC MOTION:

Simple harmonic motion is a type of vibratory motion in which the acceleration is proportional to the displacement and is always directed toward the position of equilibrium. For such a motion to take place the force acting on the body should be directed towards the fixed point and should also be proportional to the displacement i.e, the displacement from the fixed point. The function of the force is to bring the body back to its equilibrium position and hence this force is often termed as restoring force.

The backward and forward swing of a pendulum, the up and down motion of a weight hanging on a spring, and the twisting and untwisting motion of a body suspended by a wire are the examples of motions which are nearly simple harmonic.

Suppose a particle of mass m is executing simple harmonic motion. If y represents the displacement of the particle from equilibrium position at any instant t, the restoring force F acting on the particle would be given by

or $$F = -Sy \qquad \text{---------------- (1)}$$

Where S denotes the force constant of proportionality or stiffness. In Equation (1) the negative sign is used to reveal that the direction of the force is opposite to the direction of increasing displacement.

If $\frac{d2y}{dt2}$ represents the acceleration of the particle at time then equation (1) becomes as follows:

$$m \frac{d^2y}{dt^2} = -Sy$$

or $$\frac{d^2y}{dt^2} + \frac{S}{m} y = 0$$

But $$\frac{S}{m} = \omega^2$$

$$\therefore \frac{d^2y}{dt^2} + \omega^2 y = 0 \qquad \text{----------- (2)}$$

Equation (2) is the general differential equation of motion of a simple harmonic oscillator.

In order to find a solution of this equation, Equation (2) is multiplied by $2\frac{dy}{dt}$ and we get

$$2\frac{dy}{dt}\cdot\frac{d2y}{dt2} ++ \omega^2 2y\frac{dy}{dt} = 0 \qquad \text{------------ (3)}$$

On integrating equation (3), we get

$$(\frac{dy}{dt})^2 = -\omega^2 y^2 + C \qquad \text{------------(4)}$$

Where C is the constant of integration whose value can be calculated by using the initial conditions.
If the displacement is maximum i.e, at y=a where a refers to the amplitude of the oscillating particle, then

$$\frac{dy}{dt} = 0$$

i.e, the particle is momentarily at rest and starts its journey in the backward direction.
On substituting y = a and $\frac{dy}{dt} = 0$ in equation (4), we get

$$C = a^2 \omega^2$$

On substituting this value of C in equation (4), we get

$$(\frac{dy}{dt})^2 = \omega^2(a^2 - y^2)$$

Or
$$\frac{dy}{dt} = \omega\sqrt{a^2 - y^2} \qquad \text{--------------- (5)}$$

Equation (5) gives the velocity of the particle if it is executing simple harmonic motion at a time t, when the displacement = y

$$\frac{dy}{\sqrt{a^2-y^2}} = \omega\, dt \qquad \text{---------------- (6)}$$

On integrating equation (6), we get

$$\mathrm{Sin}^{-1}\frac{y}{a} = \omega t + \phi$$

Or
$$y = a\sin(\omega t + \phi) \qquad \text{----------------- (7)}$$

Where φ denotes another constant of integration.
In equation (7) the term $(\omega t + \phi)$ represents the total phase of the particle at time t and ϕ is termed as the initial phase or phase constant. I f the time has been recorded from the instant then y = 0 and increasing then ϕ + o.

THE RESULTANT OF TWO SIMPLE HARMONIC MOTION VIBRATIONS OF THE SAME FREQUENCY ACTING ALONG THE SAME LINE BUT DIFFERING IN PHASE :

Suppose the two simple harmonic vibrations of angular velocity ω acting along X- axis and having initial phases ϕ_1 and ϕ_2 are given as follows:

$$x_1 = a_1 \sin(\omega t + \phi_1) \qquad \text{------------- (1)}$$
$$x_2 = a_2 \sin(\omega t + \phi_2) \qquad \text{------------- (2)}$$

As the two vibrations are assumed to be of the same frequency, it means that ω is the same for both. The resultant can be calculated as well as geometrically.
The resultant displacement due to the two simple harmonic vibrations may be given as follows.

$$x = x_1 + x_2 = a_1\sin(\omega t + \phi_1) + a_2\sin(\omega t + \phi_2)$$

$= \sin \omega t\,(a_1 \cos \phi_1 + a_2 \cos \phi_2) + \cos \omega t\,(a_1 \sin \phi_1 + a_2 \sin \phi_2)$ -------------(3)

As the amplitudes a_1 and a_2 and angles ϕ_1 and ϕ_2 are constant, the coefficients of sin ωt and cos ωt in equation (3) can be substituted by R cos θ and R sin θ i.e,

$a_1 \cos \phi_1 + a_2 \cos \phi_2 = R \cos \theta$ ---------- (4)

$a_1 \sin \phi_1 + a_2 \sin \phi_2 = R \sin \theta$ ---------- (5)

Where $x = R \sin \omega t \cos \theta + R \cos \omega t \sin \theta = R \sin(\omega t + \theta)$ ----------- (6)

Equation (5) gives the equation of the resultant simple harmonic vibration of amplitude R and initial phase θ. The value of R is obtained by squaring equations (4) and (5) and then adding to yield.

$R^2 = R^2 \cos^2 \theta + R^2 \sin^2 \theta = a_1^2 + a_2^2 + 2a_1a_2 (\sin \phi_1 \sin \phi_2 + \cos \phi_1 \cos \phi_2)$

$= a_1^2 + a_2^2 + 2a_1a_2 \cos(\phi_2 - \phi_1)$

$= a_1^2 + a_2^2 + 2a_1a_2 \cos \phi$ ----------- (7)

And $\tan \theta = \frac{R \sin \theta}{R \cos \theta} = \frac{a_1 \sin \phi 1 + a_2 \sin \phi 2}{a_1 \cos \phi 1 + a_2 \cos \phi 2}$

LISSAJOUS FIGURES :

If a particle is acted upon simultaneously by two simple harmonic motions at right angles of each other, the resultant motion of particle traces a curve. This is called Lissajous figure. The nature or shape of curve traced out is depend upon:

(i) Time periods (or frequencies)
(ii) Amplitudes, and
(iii) Phase difference between two constituent vibrations.

Lissajous figures are useful for determining the ratio of the time periods of two vibrations and are also useful for comparing the frequencies of two turning forks.

THE RESULTANT OF TWO SIMPLE HARMONIC MOTIONS OF EQUAL PERIOD ACTING AT RIGHT ANGLES TO ONE ANOTHER :

If x is the displacement of the vibrating particle at any instant t, a the amplitude of vibration, ω the angular velocity and ϕ the initial phase, then the equation of a simple harmonic motion may be given as follows:

$$x = a \sin(\omega t + \phi)$$

Suppose the two simple harmonic vibrations having the same period are taking place along the X-axis and Y vibrations respectively and are represented by Or

$x = a \sin(\omega t + \phi_1)$ ----------- (1)

$y = b \sin(\omega t + \phi_2)$ ----------- (2)

Where b denotes the amplitude of the vibration along the Y-axis, ϕ_1 and ϕ_2 denote the initial phases of X and Y vibrations respectively. The phase difference between the two vibrations would be denotes as

$$\phi = \phi_2 - \phi_1$$

From equation (1), we get

$\frac{x}{a} = \sin \omega t \cos \phi_1 + \cos \omega t \sin \phi_1$ ------------ (3)

From equation (2), we get

$$\frac{y}{b} = \sin \omega t \cos \phi_2 + \cos \omega t \sin \phi_2 \qquad \text{------------ (4)}$$

On multiplying equation (3) by sin ϕ_2 and equation (4) by sin ϕ_1 and subtracting, we get

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1) = \sin \omega t(\cos \phi_1 \sin \phi_2 - \cos \phi_2 \sin \phi_1)$$

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1) = \sin \omega t \sin (\phi_2 - \phi_1) \qquad \text{------------- (5)}$$

Similarly on multiplying equation (4) by cos ϕ_1 and equation (3) by cos ϕ_2 and subtracting, we get

$$(\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2) = \cos \omega t (\sin \phi_2 \cos \phi_1 - \cos \phi_2 \sin \phi_1)$$

$$(\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2) = \cos \omega t \sin (\phi_2 - \phi_1) \qquad \text{------------- (6)}$$

On squaring equations (5) and (6) and then adding, we get

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1)^2 + (\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2)^2 = \sin^2 (\phi_2 - \phi_1) [\sin^2 \omega t + \cos^2 \omega t]$$

$$(\frac{x}{a} \sin \phi_2 - \frac{y}{b}\sin \phi_1)^2 + (\frac{y}{b} \cos \phi_1 - \frac{x}{a}\cos \phi_2)^2 = \sin^2 (\phi_2 - \phi_1)$$

Or $\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} (\sin \phi_2 \sin \phi_1 + \cos \phi_2 \cos \phi_1) = \sin^2 (\phi_2 - \phi_1)$

Or $\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} \cos (\phi_2 - \phi_1) = \sin^2 (\phi_2 - \phi_1)$

On substituting $\phi_2 - \phi_1 = \phi$ in the above equation, we get

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} \cos \phi = \sin^2 \qquad \text{------------- (7)}$$

Equation (7) represents the equation of an ellipse whose major and minor axes get inclined to the co-ordinate axes. This ellipse can be inscribed in a rectangle whose sides are taken as 2a and 2b.

Important cases:

(i) If $\phi = 0$, cos $\phi = 1$ and sin $\phi = 0$.

Then equation (7) becomes as follows:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2xy}{ab} = 0$$

Or $(\frac{x}{a} - \frac{y}{b})^2 = 0$

This represents the equation of a pair of coincident straight lines which are lying in the first and third quadrant as shown in figure.

The straight line gets inclined to the X-axis at angle θ which is given by

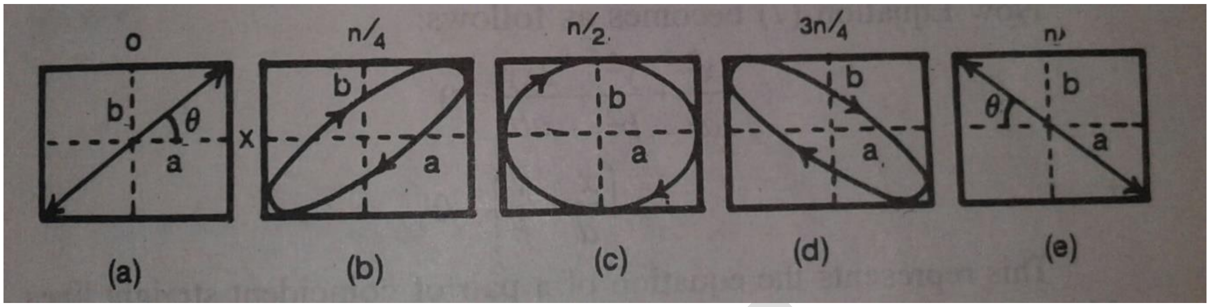
$$\theta = \tan^{-1} (\frac{b}{a})$$

(ii) If $\phi = \frac{\pi}{4}$, then $\cos \frac{\pi}{4} = \frac{1}{\sqrt{2}}$ and $\sin \frac{\pi}{4} = \frac{1}{\sqrt{2}}$

Now equation (7) becomes as follows:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{\sqrt{2xy}}{ab} = \frac{1}{2}$$

This represents the equation of an oblique ellipse as shown in figure.



THE RESULTANT OF TWO RECTANGULAR SIMPLE HARMONIC MOTIONS HAVING AMPLITUDES AND PERIODS IN THE RATION 1:2 AND THE PHASE DIFFERENCE 90 ^{0} :

Suppose a particle is subjected to two simple harmonic motions of periods as well as amplitudes in ratio 1 : 2, and acting along the axes of x and y respectively. If the x-motion leads over the y-motion by 90^{o} i.e. π/2 radian in phase, then the equations of these motions would be

$$x = a \sin (1\, \omega t + \frac{\pi}{2}) \qquad \text{-------------- (1)}$$

and

$$y = 2a \sin \omega t \qquad \text{-------------- (2)}$$

Where a and 2a denote the amplitudes, and 2π/2ω and 2π/ω the periods respectively.

It is possible to get the equation of the resultant path of the particle by eliminating t between equations (1) and (2). From equation (1), we get

$$\frac{x}{a} = \sin (2\, \omega t + \frac{\pi}{2})$$

$$= \cos 2\, \omega t = 1 - 2 \sin^2 \omega t$$

But from equation (2), sin ωt = y/2a

$$\therefore \quad \frac{x}{a} = 1 - \frac{y^2}{2a^2}$$

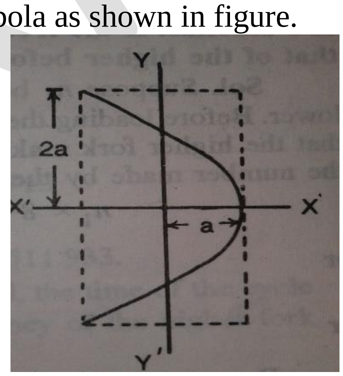
Or

$$\frac{y^2}{2a^2} = 1 - \frac{x}{a}$$

Or

$$y^2 = 2a\,(a-x)$$

This has been the equation of a parabola as shown in figure.



We will now consider the case when the y-motion leads over the x-motion by π/2. Now the equations of motions will be

$$x = a \sin 2\omega t \quad \text{----------- (3)}$$

and $$y = 2a \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{----------- (4)}$$

From equation (3), we get

$$\frac{x}{a} = 2 \sin \omega t \cos \omega t$$

$$= \sqrt{(1 - cos^2\,\omega t)} \cos \omega t$$

But from equation (4), $$\frac{y}{2a} = \sin\left(\omega t + \frac{\pi}{2}\right) = \cos \omega t$$

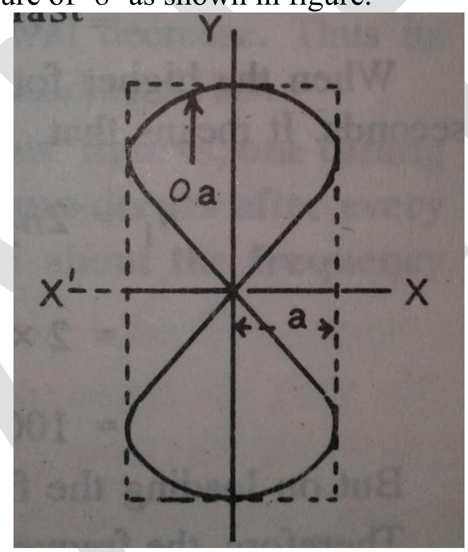
On substituting for cos ωt in the last equation we obtain

$$\frac{x}{a} = 2\sqrt{\left(1 - \frac{y}{4a^2}\right)}\,\frac{y}{2a}$$

Or $$\frac{x^2}{a^2} = \frac{y^2}{a^2}\left(1 - \frac{y^2}{4a^2}\right)$$

Or $$x^2 + y^2\left(\frac{y^2}{4a^2} - 1\right) = 0$$

This has been the equation of the figure of ‘8’ as shown in figure.



OSCILLATIONS HAVING DIFFERENT FREQUENCIES (BEATS) :

Consider two wave trains of frequencies n_1 and n_2 where $(n_1 - n_2)$ is small. Let a and b the amplitudes of the waves respectively. For the sake of simplicity, it is assumed that two waves are in phase at any point in the medium at t=0. The displacement y_1 and $y_2$due to each wave are given by

$$y_1 = a \sin \omega_1 t$$

$$y_2 = b \sin \omega_2 t$$

Here $$\omega_1 = 2\pi n_1$$

$$\omega_2 = 2\pi n_2$$

$\therefore$ $$y_1 = a \sin 2\pi n_1 t \quad \text{--------- (1)}$$

And $$y_2 = b \sin 2\pi n_2 t \quad \text{---------- (2)}$$

The resultant displacement is given by

$$y = y_1 + y_2$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi n_2 t$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi [n_1 - (n_1 - n_2)] t$$
$$y = a \sin 2\pi n_1 t + b [\sin 2\pi n_1 t \cos 2\pi (n_1 - n_2) t - \cos 2\pi n_1 t \sin 2\pi (n_1 - n_2) t]$$
$$y = a \sin 2\pi n_1 t + b \sin 2\pi n_1 t \cos 2\pi (n_1 - n_2) t - b \cos 2\pi n_1 t \sin 2\pi (n_1 - n_2) t]$$
$$y = \sin 2\pi n_1 t [a + b \cos 2\pi (n_1 - n_2) t] - \cos (2\pi n_1 t) [b \sin 2\pi (n_1 - n_2) t]$$

Take $a + b \cos 2\pi (n_1 - n_2) t = A \cos\theta$

And $b \sin 2\pi (n_1 - n_2) t = A \sin\theta$

$$\therefore \quad y = A \sin (2\pi n_1 t - \theta) \qquad \text{---------- (3)}$$

Here $$\tan\theta = \frac{b \sin 2\pi (n_1 - n_2) t}{a + b \cos 2\pi (n_1 - n_2) t} \qquad \text{----------- (4)}$$

And $$A = \sqrt{a^2 + b^2 + 2ab \cos 2\pi (n_1 - n_2) t} \qquad \text{----------- (5)}$$

From equation (4), it is evident that the phase angle θ changes with respect to time. Similarly from equation (5) the amplitude of the resultant vibration also charges with time.

LINEARITY AND SUPERPOSITION PRINCIPLE:

From a general simple harmonic oscillation wave equation,

$$\frac{d^2y}{dt^2} = -\omega^2 y$$

We may add some constants,

$$\frac{d^2y}{dt^2} = -\omega^2 y + Ay^2 + By^2 + Cy^2 \ldots \qquad \text{------------ (1)}$$

If A=B=C=0, then the equation (1) becomes,

$$\frac{d^2y}{dt^2} = -\omega^2 y \qquad \text{----------- (2)}$$

The above equation is known as linear homogeneous equation.

Let us consider, y_1 is the first solution of equation (2) at time t_1 and y_2 is the second solution of equation (2) at time t_2

$$\frac{d^2y}{dt^2} = -\omega^2 y_1 + Ay_1^2 + By_1^3 + Cy_1^4 \ldots\ldots \qquad \text{------------ (3)}$$

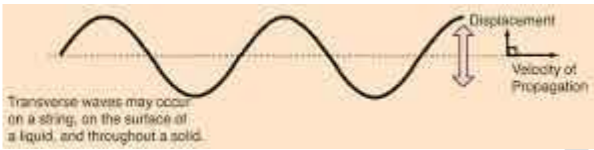
$$\frac{d^2y}{dt^2} = -\omega^2 y_2 + Ay_2^2 + By_2^3 + Cy_2^4 \qquad \text{------------ (4)}$$

The equation for the resultant displacement

$$\frac{d^2y}{dt^2} = \frac{d^2}{dt^2}(y_1 + y_2)$$

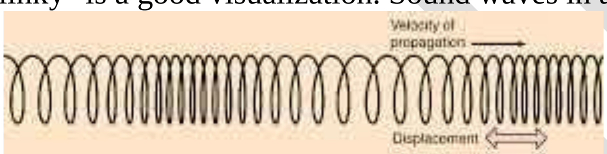
$$\frac{d^2y}{dt^2} = \frac{d^2}{dt^2}(y_1 + y_2) = -\omega^2 (y_1 + y_2) + A (y_1 + y_2)^2 + B (y_1 + y_2)^3 + C (y_1 + y_2)^2 \ldots.. \qquad \text{---------- (5)}$$

TRANSVERSE WAVES:
For transverse waves the displacement of the medium is perpendicular to the direction of propagation of the wave. A ripple on a pond and a wave on a string are easily visualized transverse waves.

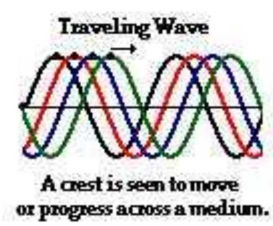


Transverse waves cannot propagate in a gas or a liquid because there is no mechanism for driving motion perpendicular to the propagation of the wave.

LONGITUDINAL WAVES:
In longitudinal waves the displacement of the medium is parallel to the propagation of the wave. A wave in a "slinky" is a good visualization. Sound waves in air are longitudinal waves.



TRAVELLING WAVES :
A mechanical wave is a disturbance that is created by a vibrating object and subsequently travels through a medium from one location to another, transporting energy as it moves. The mechanism by which a mechanical wave propagates itself through a medium involves particle interaction; one

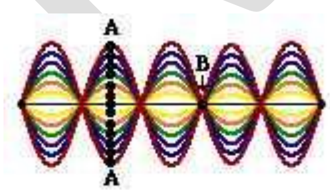


particle applies a push or pull on its adjacent neighbour, causing a displacement of that neighbour from the equilibrium or rest position. As a wave is observed traveling through a medium, a crest is seen moving along from particle to particle. This crest is followed by a trough that is in turn followed by the next crest. In fact, one would observe a distinct wave pattern (in the form of a sine wave) traveling through the medium. This sine wave pattern continues to move in uninterrupted fashion until it encounters another wave along the medium or until it encounters a boundary with another medium. This type of wave pattern that is seen traveling through a medium is sometimes referred to as a traveling wave.
Traveling waves are observed when a wave is not confined to a given space along the medium. The most commonly observed traveling wave is an ocean wave. If a wave is introduced into an elastic cord with its ends held 3 meters apart, it becomes confined in a small region. Such a wave

has only 3 meters along which to travel. The wave will quickly reach the end of the cord, reflect and travel back in the opposite direction. Any reflected portion of the wave will then interfere with the portion of the wave incident towards the fixed end. This interference produces a new shape in the medium that seldom resembles the shape of a sine wave. Subsequently, a traveling wave (a repeating pattern that is observed to move through a medium in uninterrupted fashion) is not observed in the cord. Indeed there are traveling waves in the cord; it is just that they are not easily detectable because of their interference with each other. In such instances, rather than observing the pure shape of a sine wave pattern, a rather irregular and non-repeating pattern is produced in the cord that tends to change appearance over time. This irregular looking shape is the result of the interference of an incident sine wave pattern with a reflected sine wave pattern in a rather non-sequenced and untimely manner. Both the incident and reflected wave patterns continue their motion through the medium, meeting up with one another at different locations in different ways. For example, the middle of the cord might experience a crest meeting a half crest; then moments later, a crest meeting a quarter trough; then moments later, a three-quarters crest meeting a one-fifth trough, etc. This interference leads to a very irregular and non-repeating motion of the medium. The appearance of an actual wave pattern is difficult to detect amidst the irregular motions of the individual particles.

STANDING WAVES:

It is however possible to have a wave confined to a given space in a medium and still produce a regular wave pattern that is readily discernible amidst the motion of the medium. For instance, if an elastic rope is held end-to-end and vibrated at just the right frequency, a wave pattern would be produced that assumes the shape of a sine wave and is seen to change over time. The wave pattern is only produced when one end of the rope is vibrated at just the right frequency. When the proper frequency is used, the interference of the incident wave and the reflected wave occur in such a manner that there are specific points along the medium that appear to be standing still. Because the observed wave pattern is characterized by points that appear to be standing still, the pattern is often called a standing wave pattern. There are other points along the medium whose displacement changes over time, but in a regular manner. These points vibrate back and forth from a positive displacement to a negative displacement; the vibrations occur at regular time intervals such that the motion of the medium is regular and repeating. A pattern is readily observable.



The diagram at the right depicts a standing wave pattern in a medium. A snapshot of the medium over time is depicted using various colors. Note that point A on the medium moves from a maximum positive to a maximum negative displacement over time. The diagram only shows one-half cycle of the motion of the standing wave pattern. The motion would continue and persist, with point A returning to the same maximum positive displacement and then continuing its back-and-forth vibration between the up to the down position. Note that point B on the medium is a point that never moves. Point B is a point of no displacement. Such points are known as nodes and will be discussed in more detail later in this lesson. The standing wave pattern that is shown at the right is just one of many different patterns that could be produced within the rope.

PLANE WAVES:
In a plane wave disturbances travel in single direction.
Plane waves examples :
For example when a string is fixed at both ends and the string is plucked at one end ,then transverse waves are generated in the string in which particles of the medium vibrate in one direction.So the transverse waves are plane waves. It is not possible in practice to have a true plane wave.
A finite part of large spherical wave coming from the sun is considered a plane wave.

SPHERICAL WAVES:
A wave in which the disturbance a propagated outward in all directions from the source of wave is called a spherical wave.
Spherical waves examples:
The light waves are the example of spherical waves.
The light waves produced by a single light source ,are spherical waves.During the propagation of light waves ,the spherical wave fronts spread out in all directions.

PHASE VELOCITY:
Phase velocity is a concept discussed in propagation of waves. The phase velocity of a wave is the velocity of a "phase" which propagates. For clarification, assume a crest of a wave, which is travelling in the x direction of the axis. The phase velocity is the x component of the velocity of the selected point at the crest. This also can be obtained by dividing the wavelength by the time taken for a single wavelength to pass a selected point. This time is equal to the period of the oscillation, which is causing the wave. Now consider a standard sine wave A sin (wt – kx), where w is the angular velocity of the source, t is the time, k is the wave number (number of complete wavelengths per length of 2π), and x is the position on the x-axis. At the crest, wt – kx is equal to zero. Therefore, the phase velocity (x/t) is equal to w / k. mathematically, the value p=wt – kx is the phase of the wave.

GROUP VELOCITY:
Group velocity is discussed under superposition of waves. To understand group velocity one must first understand the concept of superposition. When two waves intercept each other in space, the resultant oscillation is somewhat complex than the sine behaviour. Particle at a point oscillates with varying amplitudes. The maximum amplitude is the unison of the two amplitudes of the original waves. The minimum amplitude is the minimum difference between the two original amplitudes. If the two amplitudes are equal, the maximum is twice the amplitude and the

minimum is zero. For the sake of clarity, let us assume that the two modulated waves are of the same amplitude and different frequencies. This causes the wave with the higher frequency to be enveloped in the wave with the lower frequency. This causes a group of waves packed in an envelope. The velocity of this envelope is the group velocity of the wave. It must be noted that, for a standing wave, the group velocity is zero. For the group velocity to be zero both of the waves have to be of the same frequency and they must have opposite directions of travel.

WAVE INTENSITY :
In general, an Intensity is a ratio. For example, pressure is the intensity of force as it is force/area.
Also, density (symbol ρ) is the intensity of mass as it is mass/volume.
The Intensity of waves (called Irradiance in Optics) is defined as the power delivered per unit area.
The unit of Intensity will be W.m-2.
definition of intensity

$$\text{Intensity} = \frac{\text{power}}{\text{area}} \quad \text{in W.m}^{-2}$$
$$= \frac{\text{energy}}{\text{time} \times \text{area}}$$
$$= \frac{\text{energy} \times \text{length}}{\text{time} \times \text{volume}}$$
$$\text{Intensity} = \left(\frac{\text{energy}}{\text{volume}}\right) \times \left(\text{wave speed}\right)$$

POSSIBLE QUESTIONS
PART B

1. Define Simple Harmonic Motion
2. Define frequency.
3. What is Lissajous Figures?
4. What is beats?
5. Define transverse wave.
6. Define longitudinal wave.
7. What is standing wave?
8. Define group velocity.
9. Define wave velocity.
10. Explain plain waves.
11. Explain spherical waves
12. Define wave intensity.
13. What are the conditions for SHM?

PART C

1. Explain in detail about the simple harmonic oscillations have same frequency.
2. Explain about the oscillations having different frequencies.
3. Discuss about the superposition of two perpendicular harmonic oscillations with Lissajous Figures of ratio 1:1
4. Discuss about the superposition of two perpendicular harmonic oscillations with Lissajous Figures of ratio 1:2
5. Write a note on (i) Transverse wave (ii) Longitudinal waves (iii) standing waves
6. Write a note on (i) Group velocity (ii) Phase velocity (iii) Wave intensity.
7. Derive the expression for group velocity and phase velocity.
8. Obtain the relation between V_g (group velocity) and V_p(phase velocity).

Suggested Books for Reading:

1. Singh, Devraj (2015), Fundamentals of Optics, 2nd Edition,PHI Learning Pvt. Ltd.
2. McGraw-Hill Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
3. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
4. George Arfken (2012), University Physics. Academic Press.

AGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

II B.SC PHYSICS BATCH: 2017-2020

WAVES AND OPTICS (17PHU401)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3
UNIT V			
The experiments on interference and diffraction have shown that li	transverse	particle mo	light waves
The light waves are __________________	circular	longitudina	ellipitical
The light is not propagated as ___________	circular	longitudina	ellipitical
After paasinf through a crystal light waves vibrate in __________	all	only in one	perpendicul
Light coming from a crystal is known as __________	polarized	non polariz	refraction
Its experimentally proved that light waves are ______ in nature	circular	longitudina	ellipitical
When light is passed through a ______________ crystal, the light	quartz	diamond	ruby
The plane of polarization is that plane in which no ___________ o	disturbance	attenuation	polarization
The plane of vibration occurs at __________ angle	acute	optuse	straight
Polarization of light by _____________ from the surface of glass	reflection	refraction	polaraizatio
Polarized light is obtained when ordinary light is reflected by a pla	glass	tourmaline	mica
Brewster performed no of experiments to study the polarization of	reflection	refraction	polaraizatio
Reflection from a transparent medium at a particular angle is know	angle of po	angle of vib	diffraction
Snells law ________	sin i/sin r	sin r/sin i	tan i
Brewster law ______	sin i/sin r	sin r/sin i	tan i
The refractive index of glass is __________	1.52	0	1.98
________________ window type of window is used in laser	Brewster	snells	langivian
The pile of plates consists of _________ plates	glass	cearamic	FTO
A beam of _____________ light is allowed to fall on the pile of pl	sodium	mercury	dichromatic
Who discovered the double refarction phenomenon ?	Malus	Brewster	Snell
calcite is also known as __________	ice	iceland	calcium
The phenomenon of double refraction is absent when _________ i	light	sound	wave
The stationary image is known as __________	ordinary in	extraordina	imaginary in
The image which rotates with the roataion of the crystal is known	ordinary in	extraordina	imaginary in
The velocity of light for the ordinary ray inside the crystal will be	less	high	zero
The ordinary and the extradinary rays are ____________ polarized	plane	elliptically	cirucularly
________________ is a device used for producing and analysing pl	prism	gratting	lens
William nicol is expert in cutting and polishing gems and ______	prism	quatrz	crystal
In calcite crystal the ordinary ray has its vibrtion __________ to its	all	only in one	perpendicul
In calcite crystal the extraordinary ray has its vibrtion __________	all	only in one	perpendicul
____________ can be used in the detection of plane polarizer light	nicol prism	brewster law	Snells law

Nicol prism are coated with _______ paint to absorb ordianr ray	blue	red	green
Canada balsam acts as _________ medium for ordinary ray	rarer	denser	thinner
Canada balsam acts as _________medium for extraordinary ray	denser	thinner	rarer
Huygens explained the phenomenon of double refraction with the l	primary	secondary	tetra
The velocities of ordinary and extraordinary rays are same along th	wave axis	particle axi	optic axis
The _________ is the wave surface for ordinary ray	sphere	ellipsoid	triangle
The _________ is the wave surface for extraordinary ray	sphere	ellipsoid	triangle
The ordinary wave surface lies with in the extraordinary wave surf	negative	positive	quartz
_________ crystal are known as positive crystal	quartz	calcite	tourmaline
The direction of the line joining the two points is the __________	wave axis	particle axi	optic axis
The __________ of the extraordinary ray through a uniaxial crysta	velocity	time	speed
The refractive index of extraordinary ray is known as principle of _	refractive i	angle of vib	angle of refi
The plane of vibration inclined at an angle of ______to the optic a:	45˚	90˚	75˚
The ordinary and extraordinary rays have a path difference of ___	λ/2	λ/4	λ
A half wave plate rotates the azimuth of a beam of plane polarizec	45˚	90˚	75˚
The ordinary and extraordinary rays travel with different velocitie	crystal	media	glass
Polaroids are widely used as polarizing ________	windows	sun glasses	gems

Prepared By N.Geetha, Assistant Professor,Department of Physics, KAHE,coimbatore-21.

opt4	opt5	opt6	Answer
wave motion			wave motion
transverse			transverse
transverse			longitudinal
parallel			only in one
transverse waves			polarized
transverse			transverse
tourmaline			tourmaline
vibration			vibration
right			right
diffraction			reflection
quartz			glass
diffraction			reflection
vibration			angle of polarization
tan r			sin i/sin r
tan r			tan i
2			1.52
Malus			Brewster
Si			glass
monochromatic			monochromatic
Erasmus Bartholinus			Erasmus Bartholinus
iceland spar			iceland spar
particle			light
standing image			ordinary image
standing image			extraordinary image
one			less
optically			plane
nicol prism			nicol prism
glass			crystal
parallel			perpendicular
parallel			parallel
calcite crystal			nicol prism

black	black
thicker	rarer
thicker	denser
zero	secondary
sound axis	optic axis
circular	sphere
circular	ellipsoid
calcite	negative
calcium	quartz
sound axis	optic axis
distance	velocity
refractive media	refractive index
180˚	45˚
0	$\lambda/2$
180˚	90˚
compensator	compensator
crystal	sunglasses