

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

CHAPTER NO. 9 DUAL NATURE OF LIGHT

Introduction: -

Up to 17th century it was said that light consists of a stream of tiny particles and moves in straight line and gives properties of reflection and refraction of light.

In 1676, Huygen says that light travels in the form of waves and said that Law of reflection and refraction can be explained on the basis of wave theory.

Thomas Young made the first clear demonstration that light has wave phenomena in 1773. He demonstrates that under certain condition light gives the interference behavior.

In 1873, Maxwell shows that light waves are electromagnetic waves and can propagate through vacuum.

Up to 1880 scientists accepted the wave nature of light but wave theory can not explain the photoelectric effect.

In 1905, Einstein explains the photoelectric effect by considering that light moves in the form of packets of energy known as photon or quanta. Planks calculated the energy of photon as $E = h\nu$ and confirm that light moves in the form of packets of energy.

Compton in 1921 also confirms the nature of photon and says that it has energy as well as momentum.

From above discussion it is concluded that light has dual nature wave and particle some where it acts as wave and some where it behaves as particle.

Q. Write short note on Wave Front and Huygen's Principle.

Ans. Wave Front and Huygen's Principle: -

Wave Front: -

Whenever a wave passes through a medium, its particles execute S.H.M. The locus of all the points in the medium having same phase of vibration is known as wave front.

Wave fronts are of two types.

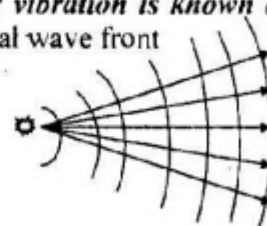
1. Spherical wave front.
2. Plane wave front.

1. Spherical wave front: -

When a point source of light in a homogeneous medium, the wave front will be concentric spheres with center at the source. Such a wave front is known as spherical wave front.

Plane wave front: -

At very large distance from a source, a small portion of a spherical wave front becomes nearly plane, such a portion of wave front is known as Plane wave front.



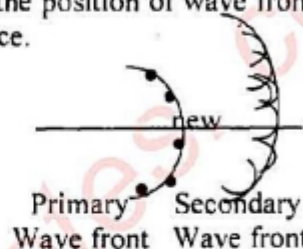
Plane wave front

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Huygen's Principle: -

It consists of two parts.

1. First part state that every point on a wave front can be consider as a source of secondary spherical wavelet as in figure AB represent the position of wave front and there are several points on it behave secondary source.
2. Second part states that drawing a plane tangential to the secondary wave- lets as in figure can form the position of the wave front after time 't'



- Q. What do you mean by interference of light?
 Give the condition for interference of light.

Ans. Interference of light: -

The phenomenon in which two coherent waves of same amplitude and wave length superpose each other such that they support each other at some points cancels the effect of each other at some point is known as interference of light.

Type of Interference: -

There are two types of interference.

1. Constructive Interference.
2. Destructive interference.

1. Constructive Interference: -

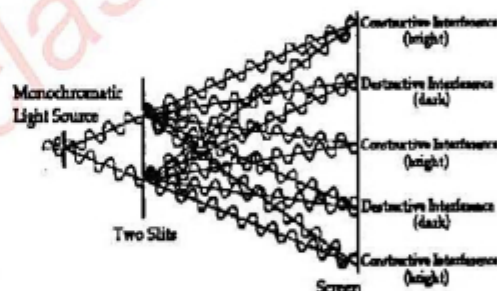
The interference in which two coherent waves of same amplitude and wavelength superpose each other such that they support each other then interference is known as Constructive Interference.

2. Destructive interference: -

The interference in which two coherent waves of same amplitude and wavelength superpose each other such that one cancels the effect of other then interference is known as destructive interference.

Condition for Interference: -

1. There must be two sources, which are very near to each other.
2. The sources must be very sharp and narrow.
3. The two sources of light must have phase coherence i.e. two waves must have it phase.
4. They have same wavelength.
5. The screen is very far as compare to the distance between sources.



A two-point source interference pattern creates an alternating pattern of bright and dark lines when it is projected onto a screen.

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6. The path difference for Constructive Interference must be equal to $m\lambda$. Where $m = 0, 1, 2, 3, \dots$
7. The path difference for destructive Interference must be equal to $(m + 1/2)\lambda$. Where $m = 0, 1, 2, 3, \dots$

Q. Discuss in detail the Young double slit experiment to measure the wavelength of light, Derive expression for fringe spacing.

Ans. Young double Slit Experiment (1801): -

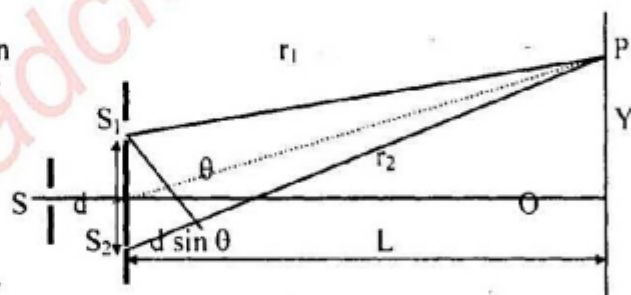
Young was the first who gives clear demonstration of phenomenon of interference. He used one source instead of two and divided the light coming from this source into two parts to get coherent waves of same amplitude and frequency.

Experimental arrangement: -

The two waves are obtained by dividing the wave front coming from single slit S by placing a plate having two narrow slits S_1 and S_2 . The wave front coming from two slits S_1 and S_2 , they behave as two coherent light sources. When light from these source reaches to screen we get bright and dark fringes.

Experiment: -

Let the distance between S_1 and S_2 is 'd' and the distance from slits to screen is L and 'P' is the point of constructive interference then light reaches to point P from slit S_1 covers more distance as compare to S_2 .



The path difference will be $(r_2 - r_1)$ and is equal to $d \sin \theta$.

According to interference condition the path difference for Constructive Interference must be equal to $m\lambda$, therefore for constructive Interference

$$d \sin \theta = m\lambda. \text{ Where } m = 0, 1, 2, 3, \dots$$

The center point X is always bright because path difference is zero.

For destructive interference

$$\text{Path difference} = d \sin \theta = (m + 1/2) \lambda.$$

Where $m = 0, 1, 2, 3, 4, \dots$

Position of bright fringes: -

Let Y is the distance from O to P and Y is very small as compare to L i.e. θ is small there fore

$$\sin \theta = \tan \theta = \frac{Y}{L}$$

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Or $d \sin \theta = d \frac{Y}{L}$ but $d \sin \theta = m\lambda$ therefore

$$d \frac{Y_m}{L} = m\lambda$$

or $Y_m = m \frac{L\lambda}{d}$

For $m = 0$, $Y_m = 0$ i.e. Center point is always bright.

Similarly For $m = 1$, $Y_1 = \frac{L\lambda}{d}$

For $m = 2$, $Y_2 = 2 \frac{L\lambda}{d}$

The other bright points are at $3\lambda L/d$, $4\lambda L/d$, $5\lambda L/d$

Position of dark fringes: -

For dark fringe $d \sin \theta = (m + 1/2) \lambda$. Therefore

$$\left(m + \frac{1}{2}\right) \lambda_d = d \frac{Y_d}{L}$$

$$Y_d = \left(m + \frac{1}{2}\right) \frac{L\lambda}{d}$$

Fringe spacing: -

The distance between two continuous bright or dark fringes is known as fringe spacing.

From above equations

$$\text{fringe spacing} = X = Y_2 - Y_1 = \lambda \frac{L}{d}$$

i.e. The distance between bright and dark fringes is same or they are of equal thickness.

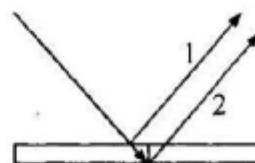
Q. Write short note on Interference from thin film.

Ans. Interference from thin film: -

A soap bubble or thin layer of oil floating on surface of water is said to be a thin film. When light is reflected from that thin film we get different colours because light is consist of seven colours and if one of them is destructively interfere the other become clear.

Working: -

Consider two ultra thin glass plates separated by uniform thin layer of air between them as figure.



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When monochromatic light of wavelength λ falls perpendicularly on it, a part of beam is reflected from upper surface and other part from lower surface of film. The film is thin therefore when the two beams interfere each other and gives interference.

Effect of refractive index: -

The wavelength of light beam, which enters the film, has wavelength λ and n is refractive index of material due to which wavelength is changes and become λ_n

then
$$\lambda_n = \frac{\lambda}{n}$$

Change in Phase: -

The beam reflected from upper surface due to denser medium has changed its phase by 180° . While the refracted beam has no change i.e. the phase difference between two beams become 180° .

Condition of interference: -

If thickness of film is 't' then path difference between two waves will be $2t$ and due to change of phase by 180° the condition of interference are reverse as in Young experiment.

Constructive interference: -

For it Path difference $= 2t = (m + 1/2)\lambda_n$ Where $m = 0, 1, 2, 3, \dots$

Putting $\lambda_n = \lambda/n$ we get

$$2nt = (m + 1/2)\lambda$$

Destructive interference: -

For it path difference $= 2t = m \lambda_n$

Or $2nt = m \lambda$

Light falls with angle θ from normal: -

If light falls with angle θ from normal then path difference become $2nt \cos \theta$
then

For constructive interference

$$2nt \cos \theta = (m + 1/2)\lambda$$

and for destructive interference

$$2nt \cos \theta = m \lambda$$

Where $m = 0, 1, 2, 3, 4, \dots$

Q. What is Newton's ring. They prove an important property of light, what is the property.

(b) Show how Newton's rings can be use to find radius of curvature of lens.

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Ans. **Newton's Rings: -**

Arrangement: -

When a convex lens is placed on a plane glass sheet a thin film of air becomes between the two, whose size is zero at center and increases outward i.e. a wedge type layer is formed.

Definition: -

When a beam of light falls normally on the lens then we get bright and dark rings having concentric circle, known as Newton's rings.

Radius of ring: -

Let the radius of curvature of lens is R and radius of ring is ' r ' where $R \gg r$.

At center point path difference is nearly zero but phase difference 180° therefore it is always be a dark ring.

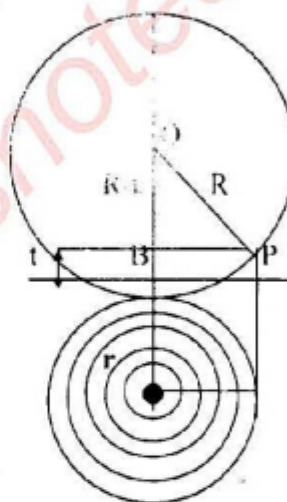
From figure

$$\begin{aligned} OP^2 &= OB^2 + BP^2 \\ R^2 &= (R-t)^2 + r^2 \\ R^2 &= R^2 - 2Rt + t^2 + r^2 \\ r^2 + t^2 &= 2Rt \end{aligned}$$

As $t \ll r$ therefore higher power of t may be neglected i.e.

$$\begin{aligned} r^2 &= 2Rt \\ r &= \sqrt{2Rt} \end{aligned}$$

Where $2t$ is path difference.



Condition of interference: -

Constructive: -

The ring are formed has condition of thin film therefore for constructive interference

$$\text{Path difference} = 2t = (m + \frac{1}{2}) \lambda \quad \text{therefore}$$

$$\text{For Ist. Ring} \quad = 2t_1 = (0 + \frac{1}{2}) \lambda$$

$$\text{For IInd. Ring} \quad = 2t_2 = (1 + \frac{1}{2}) \lambda$$

$$\text{For IIIrd. Ring} \quad = 2t_3 = (2 + \frac{1}{2}) \lambda$$

$$\begin{aligned} \text{For Nth. Ring} \quad &= 2t_N = [(N-1) + \frac{1}{2}] \lambda \\ &= (N - \frac{1}{2}) \lambda \dots \dots \dots (A) \end{aligned}$$

Putting value of $2t_N$ in formula

$$r_N = R \cdot 2t_N \quad \text{we get}$$

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$$r_N = \sqrt{R \left(N - \frac{1}{2} \right) \lambda}$$

Destructive: -

For destructive interference $2t = m \lambda$

Therefore $r_N = \sqrt{N \lambda R}$

Light falls through Gap: -

If light falls making angle θ from normal then path difference become $2t_N \cos \theta$ therefore for

Constructive Interference: -

For constructive interference Path difference $= 2t_N \cos \theta = (m + \frac{1}{2}) \lambda$

From equation (A) $2t_N = \left(N - \frac{1}{2} \right) \frac{\lambda}{\cos \theta}$

Or $r_N = \sqrt{R \left(N - \frac{1}{2} \right) \frac{\lambda}{\cos \theta}}$

Destructive interference:-

For destructive interference

$$2t \cos \theta = m \lambda$$

$$2t = \frac{m \lambda}{\cos \theta}$$

$$r = \frac{m \lambda R}{\cos \theta}$$

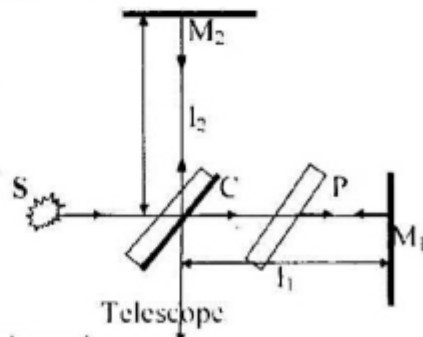
Q. Describe Michelson interferometer, How it is used to determine wavelength of monochromatic light. Explain clearly the condition of phase coherence and equal amplitude for interference take place is satisfactory.

Ans. Michelson Interferometer: -

It is a device use to study the phenomenon of interference and to determine the wavelength of light and was invented by American physicist A.A. Michelson (1852-1931).

Construction: -

It consists of two plane mirror M_1 and M_2 from which M_1 is fixed and M_2 is moveable. A semi-silvered glass plate C At angle 45° from horizontal, a transparent glass plate parallel to plate C and a source of mono-chromatic light source and a telescope. The scheme ray diagram is as figure.



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Working: -

Light from source falls on plate C is splits in two parts, first part is reflected to mirror M_2 and second part is refracted and falls on mirror M_1 after passing from plane glass plate. The both beams are reflected from mirrors M_1 and M_2 come to plate C and after reflection from it comes to telescope.

The interference between two rays depends upon the distance l_1 and l_2 . If $l_1 = l_2$ the path difference will be zero and we get bright fringe. If mirror M_2 is moved by $\lambda/4$ the path difference between two mirrors becomes $\lambda/2$ and we get destructive interference.

If mirror M_2 is moved continuously we get bright and dark fringes and each time when it is moved by $\lambda/2$ we get constructive interference. If the mirror M_2 is moved through distance X due to which we get m fringes then

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

Or
$$\lambda = \frac{2X}{m}$$

With this formula wave length of light can be find out easily.

Q. What is diffraction of light? How is it differing from interference? Differentiate between Fresnel and Fraunhofer.

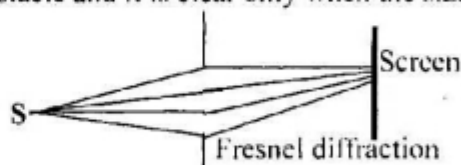
Ans. Diffraction: -

The bending of beam of light around an obstacle is called diffraction. It was discovered by Francesco (1618-1663).

This effect depends upon the size of obstacle and it is clear only when the size of obstacle is equal to wavelength of light.

There are two types of diffraction.

1. Fresnel diffraction.
2. Fraunhofer diffraction.

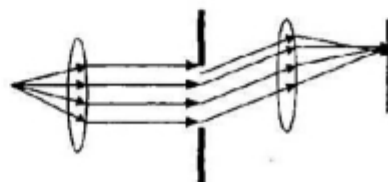


1. Fresnel diffraction: -

When Source of light and screen are at a finite distancing from the obstacle then the spherical wavefront is passes from obstacle and after diffraction we get bright and dark fringes of diffraction on screen.

2. Fraunhofer diffraction: -

When source of light and screen are at infinite distance from the obstacle then parallel wave front is diffracted and we get diffraction pattern at infinity. This situation is called Fraunhofer diffraction.



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To observe it in laboratory we use two converging lens. The source of light is placed at principle focus of first lens, the beam of light become plane wavefront after passing from it, which is diffracted from obstacle. After diffraction we get plane wave front and placing 2nd lens we get diffraction pattern on screen at its principle focus.

Q. Describe diffraction grating. How it can be used to determine the wavelength of monochromatic light.

Ans. Diffraction Grating: -

It is a transparent glass plate on which equally spaced parallel lines are drawn which acts as opaque lines usually several hundred per centimeter.

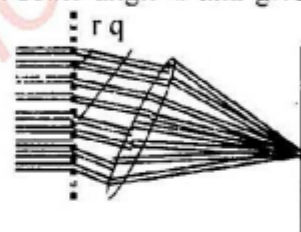
When a parallel beam of light on it is diffracted on some angle θ and gives constructive and destructive at some point.

Grating: -

Let the width of slit is 'b' and distance between two slits is 'a' then $(a + b) = d$ is called grating element.

Theory: -

The diffracted rays are focused on a point with the help of a convex lens which makes angle θ with the normal due to which the waves combination become in phase and we get constructive diffraction at 'P'.



Determination of λ : -

The path difference between two rays must be λ to get constructive interference at 'p' therefore

$$rq = \lambda$$

$$\text{but } rq = (a + b) \sin \theta$$

$$\text{or } (a + b) \sin \theta = \lambda$$

$$\text{or } d \sin \theta = \lambda$$

If path difference is $2\lambda, 3\lambda, 4\lambda, \dots$ then

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

Where $m = 0, \pm 1, \pm 2, \pm 3, \dots, \pm n$

With the help of grating we can find unknown wavelength.

Q. What do you know about X-ray diffraction. How it is obtain through crystal?

Ans. Diffraction of X-rays through crystal: -

X-rays are electromagnetic waves having wavelength of order of 10×10^{-10} m therefore its diffraction can not be seen with the slit. To find its diffraction we use crystal such as rock salt in which the atoms are uniformly spaced in planes and are separated by a distance of the order of $2-5 \text{ \AA}$.

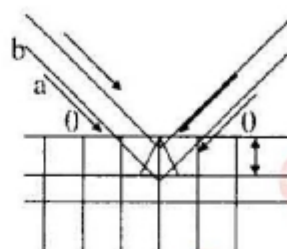
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In figure the rays 'a' and 'b' are reflected from the top layer and the second plane at distance 'd' from it. The reflected rays will reinforced, if path difference is integral multiple of the wavelength i.e.,

$$m\lambda = 2d \sin \theta$$

This relation is known as **Bragg's law**

The distance 'd' of a crystal may be find out from density and atomic weight and hence λ may be calculated.

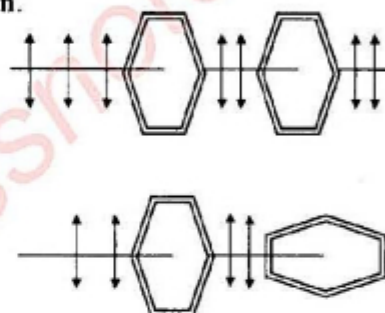


Q. What do you mean by polarization of light explain.

Ans. *The orientation of oscillations in the plane perpendicular to a transverse wave's direction of travel which may include:*

Polarization: -

A ray of light coming from a three dimensional source of light i.e. the component of light moves along X-, Y- and Z- axis.



These three components can be observed separately as under.

The desolation of the components is called polarization of light.

Experiment: -

To understand the polarization effect first considers a stretched string which passes from the slits made in two card board. If transverse waves are produce on sting and slits are parallel to each other then wave will pass from them. If one is rotated through 90° then wave will not pass from it. The same effect is observed by light as under.

When a ray of light falls on two-tourmaline crystals place with their axes parallel to each other the ray is transmitted as figure.

If one of the crystal is rotated at 90° with respect to other the emergent beam becomedimmer and dimmer and at last is disappear when the axis are perpendicular to each other.

When a beam of light passes through a crystal one component of the vibrations absorb and other is transmitted.

The emerging beam is differing from incident light in the sense that all the vibrations are in one direction. Such beam is called plane polarized.

If it falls on a second crystal, the vibration only passes if they are parallel to the transmitted direction of crystal.

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This shows that the light waves are transverse waves.

Polarization may be obtained by reflection from a transparent surface, reflection through a crystal selective absorption in certain crystal or scattering by small particle.

Polarized were invented in 1929 and are of low cost, a polarized is a transparent plastic sheet in which special needle-like crystal of Herapathite have been embedded and oriented. This sheet allowed light to pass through it only if the electric vector is vibrating in a specific direction.

Uses: -

Polarization of light has much technical and scientific application. It is use in the determination of the concentration of optically active substance such as sugar. It is also use in curtain less windows.

In photography it is often desirable to enhance the effect of sky and clouds. Since light from a blue sky is partially polarized and scattering suitable oriented polarization disc in front of the camera lens will serve as a sky filter.

Q. Give some applications of polarization.

Ans. Application of Polarization: -

1. Sunglasses:

Sunlight is reflected from smooth surfaces such as roads and lakes. The reflected light, is linearly polarized in the horizontal plane, and this glare (i.e. reflected light) can be avoided or eliminated by using sunglasses made out of a Polaroid sheet with its optic (or transmission) axis vertical. Thus the horizontally polarized light cannot go through.

2. Optical activity:

When a beam of light is made to pass through certain crystals or liquids, the direction of vibration of the transmitted polarized light is found to be rotated. The phenomenon of the rotation of the plane of polarization is called optical activity. The amount of rotation of the plane of polarization by certain liquids, such as sugar solution, depends upon the density of the molecules in the liquids. The method is used commercially for measuring the amount of sugar present in a given sample; the rotation of the plane of polarization is directly proportional to the concentration of sugar.

3. Stress analysis:

Suppose that a polarizer P and an analyzer A are in a crossed position. No light out of A. If a doubly refracting crystal is placed between them, some light will come out of A. Some substances, such as glass and plastics, under great stress become doubly refracting. Hence, when such an object is placed between P and A, light will come out of A and a pattern of interference fringes will be seen. The pattern of the interference fringes obtained reveals the strong and weak points in the structure.

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SCIENTIFIC REASONS

Q. What is the necessary condition on the path difference between two waves that interference?

(a) Constructively (b) Destructively

Ans. If S be the path difference between the waves, then

i. The waves will interference constructively if $S = 0, \lambda, 2\lambda, 3\lambda$
Or $S = m\lambda$ Where, $m = 0, 1, 2, 3, \dots$

ii. The waves will interference destructively if $S = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$
Or $S = (m + \frac{1}{2})\lambda$ Where $m = 0, 1, 2, 3, 4, \dots$

Q. Explain why two distant flash lights will not produce an interference pattern.

Ans. The two distant flashing lights will not produce interference pattern because the light beams are coming from two non-coherent sources.

Explanation:

The light beams coming from two distant sources are not coherent. However, the light emitted by the atoms in one source may have the same wavelength as that emitted by the atoms in the other, but the atoms in one act independently of those in the other and so the waves sent out by the atoms have random phase. In order words, the crests of one have no fixed relation to the crests of the other. Moreover, the waves emitted by a source in the combination of the multitude of waves limited by its atoms. The shape of the two waves from the two sources are very complex and quite unlike each other. We say that waves such as these are non-coherent. They cannot give rise to the steady interference effects.

Q. If a soap film on a wire loop is held in air, it appears black in the thinnest regions when observed by reflected light and shows a variety of colours in thicker regions. Explain.

Ans. The thinnest region is black due to destructive interference.

The thicker regions show different colours due to constructive interference.

This happens when the thickness of the film is not uniform.

Q. Observe the shadow of your book when it is held a few centimeters above a table with a lamp several meters above the book. Why is the shadow of the book some-what fuzzy at the edges.

Ans. The shadow of the book is somewhat fuzzy due to the bending of light around the edges of the book. This phenomenon is known as diffraction.

Q. Although we can hear around corners, we cannot see around corners. How can you explain this in view of the fact that sound and light are both waves?

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Ans. No doubt both sound and light are waves. But the sound waves, due to large wavelengths, can diffract around corners where the light waves, due to very short wavelengths, cannot diffract around corners so we cannot see around corners.

Q. As a soap bubble evaporates, just before it break its surface, appears black when viewed by reflected light. Explain in detail why it is dark and not bright?

Ans. As a soap bubble evaporates, just before it breaks its thickness becomes negligible. At this instant it appears black, due to destructive interference, when viewed by a reflected light.

Q. What aspect of the nature of light is proved by the phenomenon of polarization?

Ans. The wave nature of light is proved by the phenomenon of polarization.

Q. Describe the use of a Polaroid as an analyzer and as a polarizer.

Ans. Polaroid is an artificially made polarizing material that only transmit light with a single plane of polarization.

When two polarizing sheets (Polaroid) are placed parallel to each other, then the unpolarized light is polarized by the first polarizing sheet and is called the polarizer if the second polarized sheet and the first polarized sheet are crossed then the beam is completely stopped. The second polarized is called as analyzer.

In liquid crystal, used in watches and calculators etc, Polaroid is used as a polarizer and analyzer.

Q. Explain whether a path difference of $\lambda/4$ is associated with a constructive interference or destructive interference or neither of them?

Ans. We know that for constructive interference path difference is $0, \lambda, 2\lambda, 3\lambda, m\lambda$ and for destructive interference path difference is

$$\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \dots \dots \dots = (m + \frac{1}{2})\lambda$$

Thus a path difference of $\lambda/4$ is neither associated with constructive interference nor with destructive interference.

Q. Describe and account for the interference phenomenon which can be seen when a convex lens is pressed against a glass plate?

Ans. When a convex lens is pressed against a glass plate then an air film of variable thickness is enclosed between the glass plate and the lens. When a non-monochromatic light is allowed to fall normally on the lens. Interference takes place and alternate dark and bright rings are formed.

Q. Under what conditions can interference of light take place? Describe some simple method based on interference for measurement of wavelength of light.

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Ans. **Conditions for interference:**

1. There should be two sources giving out continuous waves of the same wavelength
2. Two sources should be coherent i.e. derived from the same sources.
3. Distance between the two sources should be small.
4. The sources should be sharp and narrow.
5. Screen should be at a large distance as compared to distance between the sources.

Wave length of a light can be measured using Michelson Interferometer which is based on the principle of interference. (For details see article 9.6.)

Q. **What are the main facts which support the following statements:**

- (a) **The light is wave-motion and not corpuscular.**
- (b) **The light travels in the form of transverse waves.**
- (c) **Light waves are much shorter than sound waves.**

Ans. (a) The phenomena of interference and diffraction support that light consists of wave motion and is not a flow of particles.
(b) The phenomena of polarization supports that light waves are transverse in nature.
(c) The phenomenon of diffraction supports that the wavelength of light waves is much shorter than those of sound because sound can diffract about large obstacle whereas light cannot.

Q. **Two spectral lines of different colours are observed by means of a grating and it is found that the third order image of one line coincides with the fourth order image of second line. What is the ratio of the wavelength of the two colours?**

Ans. The grating equation is given by $d \sin \theta = n \lambda$

For the third order image of one line

$$d \sin \theta = 3 \lambda_1 \quad \dots\dots (1)$$

For fourth order image of the second line

$$d \sin \theta = 4 \lambda_2 \quad \dots\dots (2)$$

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

$$3 \lambda_1 = 4 \lambda_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{4}{3} = 1.33$$

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Chapter 9 (MCQ's)

1. The characteristic property of light which does not change with the medium is
(a) **frequency** (b) wave length (c) velocity
2. Which of the following phenomenon can not be explained by the wave theory
(a) interference (b) diffraction (c) **photoelectric effect**
3. In Young's double slit experiment, the fringe spacing is:
(a) $\frac{d\lambda}{L}$ (b) $\frac{\lambda L}{d}$ (c) $\frac{d}{\lambda L}$
4. The condition for the interference in a thin film is reversed because of:
(a) small thickness (b) **phase reversal** (c) refraction
5. The appearance of colors in soap bubbles is due to:
(a) Polarization (b) Diffraction (c) Reflection (d) **Interference**
6. In thin film interference the positions of constructive interference and destructive interference are interchanged due to:
(a) Phase coherence (b) **Phase reversal**
(c) Diffraction (d) Interference
7. The bending of light around the sharp corners of an obstacle is called:
(a) Interference (b) Polarization (c) **Diffraction** (d) Refraction
8. In the complete electromagnetic spectrum which of the following has the least frequency:
(a) X-rays (b) **Infrared light** (c) Ultraviolet light (d) γ -rays
9. The phenomenon of interference of light was first demonstrated by
(a) Newton (b) **Thomas Young** (c) Einstein (d) Michelson
10. Two monochromatic waves of the same wavelength are travelling through a medium. They can interfere destructively, provide their path difference is;
(a) λ (b) $3\lambda/2$ (c) 2λ (d) 5λ
11. Light has
(a) Wave Nature (b) Particle Nature (c) **Dual Nature**
12. The mathematical condition for constructive interference is
(a) Path difference = $(m + \frac{1}{2}) \lambda$
(b) **Path difference = $m \lambda$**
(c) Path difference = $1/2 m \lambda$
(d) Path difference = $(m - \frac{1}{2}) \lambda$
13. Points at which waves interfere constructively
(a) **Crest of one wave overlaps trough of the other.**

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- (b) Crest of one wave overlaps crest of the other.
 - (c) Trough of one wave overlaps trough of the other.
 - (d) (a) & (b)
 - (e) (b) & (c)
14. Newton's rings are formed due to
 (a) Interference (b) Diffraction (c) Polarization (d) Reflection
15. Center of Newton's rings are always
 (a) Dark (b) Bright (c) gray

Important Formulas of Chapter

1. Young Experiment $Y_m = m \frac{L\lambda}{d}$ (Bright fringe)
2. Young Experiment $Y_d = \left(m + \frac{1}{2}\right) \frac{L\lambda}{d}$ (Dark fringe)
3. fringe spacing = $X = \lambda \frac{L}{d}$
4. Newton's Ring $r_N = \sqrt{R \left(N - \frac{1}{2}\right) \lambda}$ (Constructive Ring)
5. Newton's Ring $r_N = \sqrt{N\lambda R}$ (Dark ring)
6. Newton's Ring (Light falls at angle) $r_N = \sqrt{R \left(N - \frac{1}{2}\right) \frac{\lambda}{\cos \theta}}$ (Constructive Ring)
7. Newton's Ring (Light falls at angle) $r = \frac{m\lambda R}{\cos \theta}$ (Dark ring)
8. Michelson Interferometer $\lambda = \frac{2X}{m}$
9. Diffraction Grating $d \sin \theta = m\lambda$
10. Bragg's law (X-ray Diffraction) $m\lambda = 2d \sin \theta$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

PROBLEMS

- 9.1** How many fringes will pass a reference point if the moveable mirror of a Michelson's interferometer is moved by 0.08mm. The wave length of light used is 5800 Å.

Data: -

$$m = ?$$

$$d = 0.08\text{mm} = 8 \times 10^{-5} \text{ m}$$

$$\lambda = 5800 \text{ Å} = 5800 \times 10^{-10} \text{ m}$$

Solution: -

$$d = m \frac{\lambda}{2}$$

$$m = \frac{2d}{\lambda}$$

$$m = \frac{2 \times 8 \times 10^{-5}}{5800 \times 10^{-10}} = 275.86 = 275 \quad \text{Ans}$$

- 9.2** In a double slit experiment the separation of slits is 1.9mm and the fringe spacing is 0.31mm at a distance of one meter from slits. Find the wavelength of light?

Data: -

$$d = 1.9\text{mm} = 1.9 \times 10^{-3} \text{ m}$$

$$\Delta X = 0.31\text{mm} = 3.1 \times 10^{-4} \text{ m}$$

$$L = 1 \text{ m}$$

$$\lambda = ?$$

Solution: -

$$\Delta X = L \frac{\lambda}{d}$$

$$\lambda = \frac{d \Delta X}{L}$$

$$\lambda = \frac{1.9 \times 10^{-3} \times 3.1 \times 10^{-4}}{1}$$

$$\lambda = 5.89 \times 10^{-7} \text{ m} = 5890 \text{ Å} \quad \text{Ans.}$$

- 9.3** Interference fringes were produced by two slits 0.25mm apart on a screen 150mm from the slits. If eight fringes occupy 2.62mm. What is the wavelength of the light producing the fringes?

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Data: -

$$\begin{aligned} d &= 0.25 \text{ mm} = 2.5 \times 10^{-4} \text{ m} \\ L &= 150 \text{ mm} = 0.15 \text{ m} \\ m &= 8 \\ Y &= 2.62 \text{ mm} = 2.62 \times 10^{-3} \text{ m} \\ \lambda &= ? \end{aligned}$$

Solution: -

$$\begin{aligned} Y &= m\lambda L/d \\ \lambda &= \frac{Yd}{mL} \\ \lambda &= \frac{2.62 \times 10^{-3} \times 2.5 \times 10^{-4}}{8 \times 0.15} = 5.46 \times 10^{-7} \text{ m} \end{aligned}$$

9.4 Green light of wave length 5400 Å is diffracted by grating having 2000 lines/cm.

- (a) Compute the angular deviation of the third order image.
 (b) Is a 10th. Order image possible?

Data: -

$$\begin{aligned} \lambda &= 5400 \text{ Å} = 5400 \times 10^{-10} \text{ m} \\ \text{No. of lines /cm} &= 2000 \\ \theta &= ? \end{aligned}$$

- (a) $m = 3$
 (b) $m = 10$

Solution: -

$$d = \frac{1}{\text{No. Of lines}} = \frac{1}{2000} = 5 \times 10^{-4} \text{ cm} = 5 \times 10^{-6} \text{ m}$$

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

$$\theta = \sin^{-1} \frac{m\lambda}{d}$$

$$\theta = \sin^{-1} \frac{3 \times 5400 \times 10^{-10}}{5 \times 10^{-6}} = \sin^{-1} 0.324 = 18.4^\circ \quad \text{Ans.}$$

$$\theta = \sin^{-1} \frac{m\lambda}{d}$$

$$\theta = \sin^{-1} \frac{10 \times 5400 \times 10^{-10}}{5 \times 10^{-6}} = \sin^{-1} 1.08 = \text{Impossible} \quad \text{Ans.}$$

9.5 Light of wavelength $6 \times 10^{-10} \text{ m}$ falls normally on a diffraction grating with 400 lines per mm. At what angle to the normal are 1st, 2nd, and 3rd. Order spectra produce?

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

Data: -

$$\lambda = 6 \times 10^{-7} \text{ m}$$

$$\text{No. of lines} = 400 / \text{mm}$$

(a) $n = 1 \quad \theta_1 = ?$

(b) $n = 2 \quad \theta_2 = ?$

(c) $n = 3 \quad \theta_3 = ?$

Solution: -

$$d = \frac{1}{\text{No. Of lines}} = \frac{1}{400} = 2.5 \times 10^{-3} \text{ mm} = 5 \times 10^{-6} \text{ m}$$

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

$$\theta_1 = \sin^{-1} \frac{m\lambda}{d}$$

$$\theta_1 = \sin^{-1} \frac{1 \times 6 \times 10^{-7}}{2.5 \times 10^{-6}} = \sin^{-1} 0.24 = 13.9^\circ \quad \text{Ans.}$$

$$\theta_2 = \sin^{-1} \frac{m\lambda}{d}$$

$$\theta_2 = \sin^{-1} \frac{2 \times 6 \times 10^{-7}}{2.5 \times 10^{-6}} = \sin^{-1} 0.48 = 28.7^\circ \quad \text{Ans.}$$

$$\theta_3 = \sin^{-1} \frac{m\lambda}{d}$$

$$\theta_3 = \sin^{-1} \frac{3 \times 6 \times 10^{-7}}{2.5 \times 10^{-6}} = \sin^{-1} 0.72 = 46.1^\circ \quad \text{Ans.}$$

- 9.6** If a diffraction grating produce a 1st order spectrum of light of wavelength $6 \times 10^{-7} \text{ m}$ at an angle of 20° from the normal. What is its spacing?

Data: -

$$n = 1$$

$$\lambda = 6 \times 10^{-7} \text{ m}$$

$$\theta = 20^\circ$$

$$d = ?$$

Solution: -

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

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

$$d = \frac{1 \times 6 \times 10^{-7}}{\sin 20^\circ} = 17.54 \times 10^{-7} \text{ m}$$

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$$\text{No. Of lines} = \frac{1}{d} = \frac{1}{17.54 \times 10^{-7}} = 5.7 \times 10^5 / \text{m}$$

$$\text{No. of lines /mm} = 5.7 \times 10^5 \times 10^{-3} = 5.7 \times 10^2 = 570 \quad \text{Ans.}$$

- 9.7 Newton's rings are formed between a lens and a flat glass surface of wavelength $5.88 \times 10^{-7} \text{ m}$. If the light passes through the gaps at 30° to the vertical and fifth dark ring is 9mm. What is the radius of the curvature of the lens?

Data: -

$$\lambda = 5.88 \times 10^{-7} \text{ m}$$

$$\theta = 30^\circ$$

$$m = 5$$

$$r = 9 \text{ mm}$$

$$R = ?$$

Solution: -

$$r = \sqrt{\frac{m\lambda R}{\cos\theta}}$$

$$R = \frac{r^2}{m\lambda} \cos\theta$$

$$R = \frac{(9 \times 10^{-3})^2}{5 \times 5.88 \times 10^{-7}} \cos 30^\circ$$

$$R = 23.8 \text{ m} \quad \text{Ans.}$$

- 9.8 How far apart are the diffracting planes in a NaCl crystal for which X-rays of wave length $1.54 \text{ \AA}$ makes a glancing angle of $15^\circ - 54'$ in the 1st. order ?

Data: -

$$d = ?$$

$$\lambda = 1.54 \text{ \AA} = 1.54 \times 10^{-10} \text{ m}$$

$$\theta = 15^\circ - 54'$$

$$m = 1$$

Solution: -

$$2d \sin \theta = m\lambda$$

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

$$d = \frac{1 \times 1.54 \times 10^{-10}}{2 \times \sin 15^\circ - 54'}$$

$$d = 2.81 \times 10^{-10} \text{ m} = 2.81 \text{ \AA}$$

Ans.

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- 9.9 A parallel beam of X-rays is diffracted by rock salt crystal the 1st. order maximum being obtained when the glancing angle of incidence is 6 degree and 5 minutes. The distance between the atomic planes of the crystal is 2.81×10^{-10} m. Calculate the wavelength of the radiation.

Data: -

$$m = 1$$

$$\theta = 6^\circ - 5'$$

$$d = 2.81 \times 10^{-10} \text{ m}$$

$$\lambda = ?$$

Solution: -

$$2d \sin \theta = m\lambda$$

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

$$\lambda = \frac{2 \times 2.81 \times 10^{-10}}{1} \sin 6^\circ - 5'$$

$$\lambda = 0.5955 \times 10^{-10} \text{ m} = 6 \times 10^{-10} \text{ m} = 6\text{\AA}$$

Ans.

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

EXAMPLES

Example: 9.1

If the radius of the 14th. Newton's ring is 1mm, when light of wave length 5.89×10^{-7} m is used. What is the radius of curvature of the lower surface of the lens used? .

Data: -

$$\begin{aligned} N &= 14 \\ r &= 1\text{mm} \\ \lambda &= 5.88 \times 10^{-7} \text{ m} \\ R &= ? \end{aligned}$$

Solution: -

$$\begin{aligned} r_N^2 &= R \left(N - \frac{1}{2} \right) \lambda \\ R &= \frac{r_N^2}{\left(N - \frac{1}{2} \right) \lambda} \\ R &= \frac{1^2}{\left(14 - \frac{1}{2} \right) \times 5.88 \times 10^{-7}} = 126 \times 10^3 \text{ m} = 126 \text{ mm} \quad \text{Ans.} \end{aligned}$$

Example: 9.2

A diffraction grating with 10000 lines per centimeter is illuminated by yellow light of wavelength 589nm. At what angle are the 1st. and 2nd. order bright fringes seen?

Data: -

$$\begin{aligned} \text{No of lines /cm} &= 10000 \\ \lambda &= 589\text{nm} = 5.89 \times 10^{-5} \text{ m} \\ \text{(a) } n &= 1 \quad \theta_1 = ? \\ \text{(b) } n &= 2 \quad \theta_2 = ? \end{aligned}$$

Solution: -

$$\begin{aligned} d &= \frac{1}{\text{No. Of lines}} = \frac{1}{10000} = 1 \times 10^{-4} \text{ cm} = 1 \times 10^{-6} \text{ m} \quad d \sin \theta = m\lambda \\ \theta_1 &= \sin^{-1} \frac{m\lambda}{d} = \sin^{-1} \frac{1 \times 589 \times 10^{-3}}{1 \times 10^{-6}} = \sin^{-1} 0.589 = 36.1^\circ \quad \text{Ans} \\ \theta_2 &= \sin^{-1} \frac{m\lambda}{d} = \sin^{-1} \frac{2 \times 589 \times 10^{-3}}{1 \times 10^{-6}} = \sin^{-1} 1.178 = \text{Impossible} \quad \text{Ans} \end{aligned}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

EXAMPLES FROM LAST PAPERS

Example 1.

X-rays of wavelength $1.54^{\circ}\text{\AA}$ are diffracted by a crystal whose planes are $2.81^{\circ}\text{\AA}$ apart. Find the glancing angle for the first order.

Data: -

$$\lambda = 1.54^{\circ}\text{\AA} = 1.54 \times 10^{-10} \text{ m}$$

$$d = 2.81^{\circ}\text{\AA} = 2.81 \times 10^{-10} \text{ m}$$

$$m = 1$$

$$\theta = ?$$

Solution: -

$$2d \sin \theta = m \lambda$$

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

$$\sin \theta = \frac{1 \times 1.54 \times 10^{-10}}{2 \times 2.81 \times 10^{-10}} = 0.274$$

$$\theta = \sin^{-1} 0.274 = 15.9^{\circ} = 15^{\circ} 54' \quad \text{Ans.}$$

Example 2

If the radius of the 12th dark Newton's ring is 1 mm when the light of wavelength $5890^{\circ}\text{\AA}$ is used, what is the radius of curvature of the lower surface of the lens used?

Data: -

$$m = 12$$

$$r = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$$

$$\lambda = 5890^{\circ}\text{\AA} = 5890 \times 10^{-10} \text{ m}$$

$$R = ?$$

Solution: -

$$r = \sqrt{m\lambda R}$$

$$r^2 = m\lambda R$$

$$R = \frac{r^2}{m\lambda}$$

$$R = \frac{(1 \times 10^{-3})^2}{12 \times 5890 \times 10^{-10}} = 0.141 \text{ m}$$

$$R = 141 \text{ mm} \quad \text{Ans.}$$

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Example 3

When a light of wavelength 6000Å falls on a diffraction grating, it produced a second order spectrum at an angle of 30° from the normal, Find:

- (i) The grating element.
- (ii) The number of lines per millimeter ruled on it.

Data: -

$$\lambda = 6000\text{Å} = 6000 \times 10^{-10} \text{ m}$$

$$m = 2$$

$$\theta = 30^\circ$$

$$d = ?$$

$$\text{No. of lines} = ?$$

Solution: -

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

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

$$d = \frac{2 \times 6000 \times 10^{-10}}{\sin 30} = \frac{2 \times 6000 \times 10^{-10}}{0.5}$$

$$d = 2.4 \times 10^{-6} \text{ m}$$

$$\text{No of lines} = \frac{1}{d} = \frac{1}{2.4 \times 10^{-6}} = 4.17 \times 10^5 \text{ lines/m} = 417 \text{ lines/mm} \quad \text{Ans.}$$

Example 4

How much should the moveable mirror of the michelson's interferometer be moved in order to observe 400 fringes with reference to a point? The wavelength of the light used is 5890Å .

Data: -

$$X = ?$$

$$m = 400$$

$$\lambda = 5890\text{Å} = 5890 \times 10^{-10} \text{ m}$$

Solution: -

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

$$= \frac{400 \times 5890 \times 10^{-10}}{2} = 1.178 \times 10^{-4} \text{ m}$$

$$X = 0.1178 \text{ mm} \quad \text{Ans.}$$

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Example 5

Monochromatic light of wavelength 5892°A is used to illuminate two narrow slits 1 mm apart, find the position of the second bright and dark fringes on a screen 120 cm away. Also find the fringe spacing.

Data: -

$$\lambda = 5892^{\circ}\text{A} = 5892 \times 10^{-10} \text{ m}$$

$$d = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$$

$$m = 2$$

$$L = 120 \text{ cm} = 1.2 \text{ m}$$

$$Y = ?$$

$$\Delta x = ?$$

Solution: -

$$Y_{\text{Bright}} = m \frac{L\lambda}{d} \quad \text{Ans}$$

$$= 2 \times \frac{1.2 \times 5892 \times 10^{-10}}{1 \times 10^{-3}} = 1.414 \times 10^{-3} \text{ m}$$

$$Y_{\text{Dark}} = \left(m + \frac{1}{2}\right) \frac{L\lambda}{d} \quad \text{Ans.}$$

$$= \left(2 + \frac{1}{2}\right) \times \frac{1.2 \times 5892 \times 10^{-10}}{1 \times 10^{-3}} = 1.77 \times 10^{-3} \text{ m}$$

$$\Delta x = \frac{L\lambda}{d} \quad \text{Ans.}$$

$$= \frac{1.2 \times 5892 \times 10^{-10}}{1 \times 10^{-3}} = 7.07 \times 10^{-3} \text{ m}$$

Example 6

271 fringes pass a reference point when the moveable mirror of the michelson's interferometer is moved by 0.08 mm. Find the wavelength of the light used in angstrom.

Data: -

$$m = 271$$

$$X = 0.08 \text{ mm} = 0.08 \times 10^{-3} \text{ m}$$

$$\lambda = ?$$

Solution: -

$$\lambda = \frac{2X}{m} = \frac{2 \times 0.08 \times 10^{-3}}{271} = 5.9 \times 10^{-7} \text{ m}$$

$$\lambda = 5900 \times 10^{-10} \text{ m} = 5900^{\circ}\text{A} \quad \text{Ans.}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

Example 7

When the light of 5400Å falls normally on a grating, the first order spectrum is produced at 10° from the normal. Find the grating element and the number of lines/m of the grating.

Data: -

$$\lambda = 5400\text{Å} = 5400 \times 10^{-10}\text{ m}$$

$$m = 1$$

$$\theta = 10^\circ$$

$$d = ?$$

Solution: -

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

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

$$= \frac{1 \times 5400 \times 10^{-10}}{\sin 10^\circ} = \frac{5400 \times 10^{-10}}{0.174}$$

$$d = 6.9 \times 10^{-6}\text{ m} \quad \text{Ans.}$$

Example 8

Determine the wavelength of a monochromatic light used if 14th bright Newton's ring has radius of 1mm when a plano-convex lens of radius of curvature 126mm is used.

Data: -

$$\lambda = ?$$

$$N = 14$$

$$r = 1\text{mm} = 1 \times 10^{-3}\text{m}$$

$$R = 126\text{ mm} = 126 \times 10^{-3}\text{m}$$

Solution: -

$$r_N = \sqrt{R \left(N - \frac{1}{2} \right) \lambda}$$

$$r^2 = R \left(N - \frac{1}{2} \right) \lambda$$

$$\lambda = \frac{r^2}{R \left(N - \frac{1}{2} \right)}$$

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$$= \frac{(1 \times 10^{-3})^2}{126 \times 10^{-3} \left(14 - \frac{1}{2}\right)}$$

$$\lambda = 5.88 \times 10^{-7} \text{ m} = 5880 \text{ \AA} \quad \text{Ans.}$$

Example 9

Interference fringes were produced by light coming from two slits 0.3mm apart. If five fringes occupied 1.75mm on a screen at 200mm from the slits, find the wavelength of light used.

Data: -

$$d = 0.3 \text{ mm} = 0.3 \times 10^{-3} \text{ m}$$

$$m = 5$$

$$Y = 1.75 \text{ mm} = 1.75 \times 10^{-3} \text{ m}$$

$$L = 200 \text{ mm} = 200 \times 10^{-3} \text{ m}$$

$$\lambda = ?$$

Solution: -

$$Y_{\text{Bright}} = m \frac{L\lambda}{d}$$

$$\lambda = \frac{Yd}{mL}$$

$$= \frac{1.75 \times 10^{-3} \times 0.3 \times 10^{-3}}{5 \times 200 \times 10^{-3}} = 5.27 \times 10^{-7} \text{ m}$$

Ans.

