PHYSICS CLASS-XII –WAVE OPTICS

Chapter–10: Wave Optics

Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light, diffraction due to a single slit, width of central maximum, resolving power of microscope and astronomical telescope, polarisation, plane polarised light, Brewster's law, uses of plane polarised light and Polaroids.

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601*. Define a wavefront. How is it different from a ray ?   **CBSE (AI)-2017,2016,2015,2010,(D)-2013,2011**
   [**Ans. Wavefront :** Continuous locus of all the particles of a medium vibrating in the same phase is called wavefront
   Difference from a ray :
   (i) A ray is always normal to the wavefront at each point.
   (ii) A ray gives the direction of propagation of light wave while the wavefront is the surface of constant phase

602*. State Huygen's principle.   **CBSE (AI)-2016,2015,2010,2006,(D)-2013,2011,2008**
   [**Ans. Huygen's Principle :**
   (i) Each point on the wave front acts as a fresh source of new disturbance, called secondary wavelets, which spread out in all directions with the same velocity as that of the original wave
   (ii) The forward envelope of these secondary wavelets drawn at any instant, gives the shape and position of new wave front at that instant
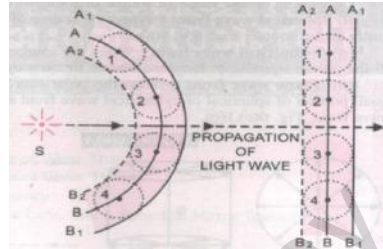
603*. (i) Sketch the wavefront that will emerge from a distance source of light like a star.
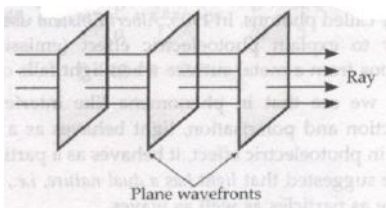   **CBSE (F) -2010,(D)-2009,(AI)-2001,(AIC)-2004,2003**
   (ii) Sketch the shape of wavefront emerging/diverging from a point source of light and also mark the rays.
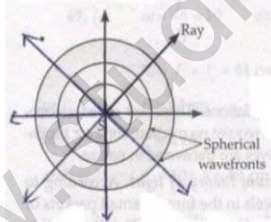   **CBSE (F) -2009,2002,(D)-2009,2005, (AI)-2003,2001**
   (iii) Sketch the wavefront that will emerge from a linear source of light like a slit.
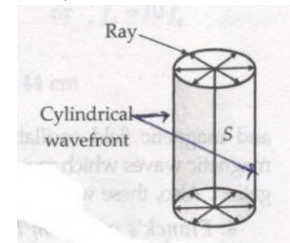   **CBSE (D)-2009,(F)-2002,(AI)-2001**

   [**Ans. (i) Plane wavefront**   **(ii) Spherical wavefront**   **(iii) Cylindrical Wavefront**

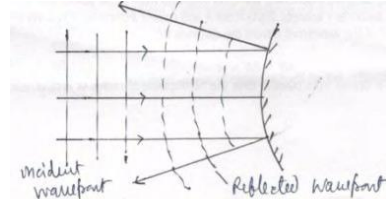===
604*. Sketch the reflected wavefront emerging from a (i) concave mirror (ii) convex mirror, if plane wavefront is incident normally on it.   **CBSE (AI)-2015,2006, (Sample Paper)-2011**
   [**Ans. (i) reflected wavefront from a concave mirror**   **(ii) reflected wavefront from a convex mirror**

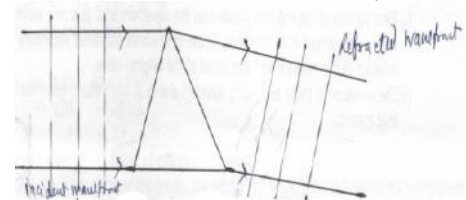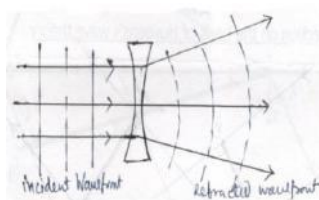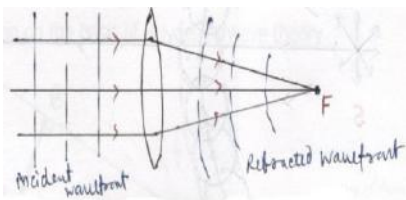===
605*. Sketch the refracted wavefront emerging from a convex/concave lens/prism, if plane wavefront is incident normally on it.   **CBSE (AI)-2016,2015,2006,2003,(AIC)-2004**
   [**Ans. (a) refracted wavefront from a convex/concave lens**   **(b) refracted wavefront from a prism**

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606*. What is interference of light ? Give one example of interference in daily life.   **CBSE (AIC)-2012,(D)-2007**
   [**Ans. Interference of light :** It the phenomenon of non-uniform distribution of resultant intensity when two light waves from two coherent sources superimpose on each other
     Example in daily life : colours in bubbles of soap solution/ in thin oil films in white light

607*. What are coherent sources of light ? Why are coherent sources necessary to produce a sustained interference pattern?   **CBSE (D)-2012,2007,(F)-2009**
   [**Ans. Coherent sources :** Two sources producing light waves of same frequency and zero or constant initial phase difference are called coherent sources of light
     Necessity : Coherent sources produce waves with constant phase difference, due to which positions of and minima does not change with time and a sustained interference pattern is obtained

608*. What are the essential conditions for two light sources to be coherent ?   **CBSE (AIC)-2004**
   [**Ans.** (i) Two sources must produce waves of same frequency/ wavelength, and
     (ii) phase difference between the waves must be zero or constant

609*. What happens to the interference pattern if phase difference between two light sources varies continuously ?   **CBSE (AI)-2012,2009**
   [**Ans.** Positions of bright and dark fringes would change rapidly hence the interference pattern shall not be sustained

610*. Why cannot two independent monochromatic sources produce sustained interference pattern ?   **CBSE (AI)-2015, (D)-2015**
   [**Ans.** Two independent sources do not maintain constant phase difference, therefore the interference pattern will also change with time

611*. In Young's double slit experiment, the two slits are illuminated by two different lamps having same wavelength of light. Explain with reason, whether interference pattern will be observed on the screen or not **CBSE (AIC)-2017**
   [**Ans.** Interference pattern will not be observed as two independent lamps are not coherent sources

612*. Does the appearance of bright and dark fringes in the interference pattern violate, in any way, law of conservation of energy ? Explain.   **CBSE (AIC)-2015**
   [**Ans. No** , Appearance of the bright and dark fringes is simply due to a redistribution of energy

613*. Why does a soap bubble show beautiful colours when illuminated by white light ? Explain.   **CBSE (AIC)-2004**
   [**Ans. Due to Interference of light**
     Reason : Light waves reflected from outer and inner surfaces of soap bubble interfere. For different wavelengths, conditions for constructive interference are satisfied at different positions. This is why beautiful colours are seen

614*. In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. What information can one obtain from the slope of the curve ?   **CBSE (AI)-2015**
   [**Ans.** $\beta = \dfrac{D\lambda}{d}$ $\Rightarrow$ $\beta \propto D$
     Slope $= \dfrac{\beta}{D} = \dfrac{\lambda}{d}$ $\Rightarrow$ $\lambda = $ (Slope) $\times d$
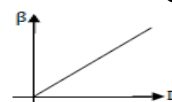
615*. How would the angular separation of interference fringes in Young's double slit experiment change when the distance between the slits and screen is doubled/ halved ?   **CBSE (AI)-2009**
   [**Ans.** Angular separation ($\theta = \lambda/d$) remains unchanged as it does not depend on D

616*. In the Young's double slit experiment, how does the fringe width get affected if the entire experimental apparatus is immersed in water ?   **CBSE (AI)-2011**
   [**Ans.** fringe width will decrease,   **Reason :** $\beta = \dfrac{D\lambda}{d}$ & $\beta_{water} = \dfrac{D\lambda/\mu_w}{d} = \dfrac{\beta}{\mu_w}$

617*. In the Young's double slit experiment, how does the fringe width get affected if the entire experimental apparatus is immersed in water (refractive index $4/3$) ?   **CBSE (D)-2011,2008**
   [**Ans.** $\beta_{water} = \dfrac{\beta}{\mu_w} = \dfrac{\beta}{4/3} = \dfrac{3}{4}\beta$, so fringe width decreases to 3/4 times

618*. Two identical coherent waves each of intensity I_0 are producing interference pattern. What are the values of resultant Intensity at a point of (i) constructive interference (ii) destructive interference pattern ?   **CBSE (DC)-2004**
   [**Ans.** (i) $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = \left(\sqrt{I_0} + \sqrt{I_0}\right)^2 = \left(2\sqrt{I_0}\right)^2 = 4 I_0$
     (ii) $I = \left(\sqrt{I} - \sqrt{I}\right)^2 = \left(\sqrt{I} - \sqrt{I}\right)^2 = 0$

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619*. What is diffraction of light ? State the essential condition for diffraction of light.   **CBSE (F)-2016**
  [Ans. Diffraction : The phenomenon of bending of light round the corners of small obstacles or apertures is called diffraction of light.
    Essential condition : Size of slit/ aperture must be of the order of wavelength of light
                    i,e, $a \approx \lambda$

620*. Why do secondary maxima get weaker in intensity with increasing the order ?Explain.**CBSE(AI)-2016,2014,2009**

OR

  Explain how the intensity of diffraction pattern changes as the order (n) of the diffraction band varies.   **CBSE(AIC)-2017**
  [Ans. Intensity of diffraction pattern drops rapidly with order n because every higher order maxima gets intensity only
    from $\frac{1}{2n+1}$ part of the slit. The central maxima gets intensity from the whole slit $(n = 0)$
    1st secondary maxima gets its intensity only from 1/3 of slit
    2nd secondary maxima gets its intensity only from 1/5 of slit
    and so on.

621*. Why do we not encounter diffraction effects of light in everyday observations ? **SE (AI)-2010,(F)-2009**

OR

  Diffraction is common in sound but not common in light waves why ?   **CBSE (D)-2002,(AI)-2000**
  [Ans. This is because objects around us are much bigger in size as compared to the wavelength of visible light$(\simeq 10^{-6} m)$

622*. How would the width of central maximum in diffraction pattern due to a single slit be affected, when the width of the slit is doubled ?   **CBSE (F) -2009**

  [Ans. $y_0 = 2D\lambda/a$ $\Rightarrow$ Width of central maximum will be halved

623*. How is the width of central maxima in diffraction pattern due to a single slit affected if the entire apparatus is immersed in water. Justify your answer.   **CBSE (F)-2009**

  [Ans. $y'_0 = 2D\lambda'/a = \frac{2D\lambda/\mu}{a} = \frac{y_0}{\mu}$

624*. If the width of the slit is made double to original width in diffraction at a single slit, how does it affect the size and ntensity of the central band ?   **CBSE (F) -2016,2012, (AI)-2012,2008, (D)-2012**

  [Ans. $y_0 = 2D\lambda/a$ & $I \propto a^2$
    Hence y_0 will become half and the intensity becomes 4 times

625*. How would the diffraction pattern due to a single slit be affected when the width of the slit is decreased ?
  [Ans. $\theta_n = n\lambda/a$ **CBSE (F) -2013**
    On decreasing a, θ_n will increase hence, diffraction pattern is spread out

626*. How would the width of central maximum in diffraction pattern due to a single slit be affected, If the wavelength of the light used is increased ?   **CBSE (F) -2009**

  [Ans. $y_0 = 2D\lambda/a$ $\Rightarrow$ Width of central maximum will be increased

627*. How does the angular separation between fringes in single slit diffraction experiment change when the distance of separation between the slit and screen is doubled ?   **CBSE (AI) -2012**

  [Ans. $\theta_n = n\lambda/a$, remains unchanged as it does not depend on D

628*. How would the diffraction pattern due to a single slit be affected when the monochromatic source of light is replaced by white light.   **CBSE (F) -2013,2011, (AI)-2009**

  [Ans. (i) The diffraction pattern is coloured. As $\beta \propto \lambda$ so red fringe is wider than violet fringe
    (ii) the central maxima is bright
    (iii) more dispersion is obtained for higher order spectra, it causes an overlapping of different colours

629*. Show that the fringe pattern on the screen in Young's double slit experiment is actually a superposition of single slit diffraction from each slit.   **CBSE (AI)-2015,(D)-2012**

  [Ans. It is shown in figure, there is a broader diffraction peak in which
    there appear several fringes of smaller width due to double slit
    Interference pattern. In the limit of slit width 'a' becoming very
    small, the diffraction pattern become very flat and will observe the
   two slit interference pattern.
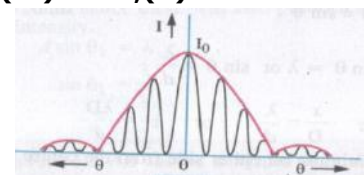
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630*. What is polarization of light ? **CBSE (AI)-2013,2009,2008,(F)-2013,(D)-2010**
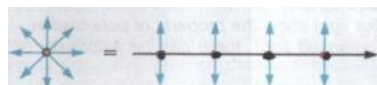
[**Ans. Polarization of light** : The phenomenon of restricting the vibrations of electric vectors in a plane perpendicular to the direction of propagation of light, is known as polarization of light

631. Define the term 'linearly polarised light' and 'unpolarised light'.**CBSE (AI)-2017,2013,2009,(F)-2013,(D)-2010**

[**Ans. Linearly Polarised light** : The light having vibrations of electric field vector in only one direction perpendicular to the direction of propagation of light is called plane or linearly polarised light

(Vibrations in the plane of paper)   (Vibrations ⊥ to the plane of paper)
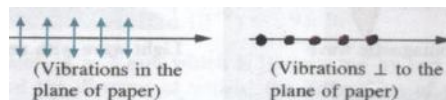
Unpolarised light : The light having vibrations of electric field vector in all possible directions perpendicular to the direction of propagation of light is called unpolarised light or ordinary light

632*. Which special characteristic of light is demonstrated only by the phenomenon of polarization ? **CBSE (AIC)-2004**

[**Ans.** Transverse nature of light

633*. Which type of waves show the property of polarization ? **CBSE (AIC)-2001**

[**Ans.** Transverse waves

634*. Name the phenomenon which proves transverse wave nature of **CBSE (Sample Paper)-2015**

[**Ans.** polarization

635*. Good quality sung-lasses made of polaroids are preferred over ordinary coloured glasses. Why ? Justify your answer.

CBSE (DC)-2015

[**Ans.** because they are more effective in reducing the glare due to reflections from horizontal surfaces/ provide better protection to our eyes / more effective in cutting off harmful UV rays of sun

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636*. (i) State law of Malus. **CBSE (AI)-2016**

   (ii) Draw a graph showing the variation of intensity (I) of polarised light transmitted by an analyser with angle (θ) between polariser and analyser **CBSE (AI)-2017,2016**

[**Ans. Law of Malus** : When a beam of completely plane polarised light is incident on an analyser, intensity of transmitted light varies as the square of cosine of angle between plane of transmission of analyser and polariser

   i,e, $I \propto cos^2\theta$

   or $I = I_0 \ cos^2\theta$

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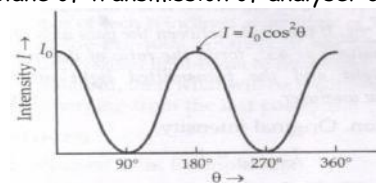
637*. Why does unpolarised light from a source show a variation in intensity when viewed through a Polaroid which is rotated ? **CBSE (AI)N-2016**

[**Ans.** By the law of Malus, $I = I_0 \ cos^2\theta$

   Hence the transmitted intensity will show a variation as per $cos^2\theta$

638*. Does the intensity of polarised light emitted by a Polaroid depend on its orientation ? Explain briefly.

[**Ans. yes,** By Malus' law. transmitted intensity $I = I_0 \ cos^2\theta$ **CBSE (F)-2016**

639*. The vibrations in a beam of polarised light make an angle of 60^0 with the axis of the Polaroid sheet. What percentage of light is transmitted through the sheet ? **CBSE (F)-2016**

[**Ans.** $I = I_0 \ cos^2\theta = I_0 \ cos^2 60 = I_0 \ (1/2)^2 = \frac{I_0}{4}$ $\Rightarrow \frac{I}{I_0}$ X 100 = $\frac{1}{4}$ X 100 = 25%

640*. Unpolarised light of intensity I is passed through a Polaroid. What is intensity of light transmitted by the Polaroid ?

[**Ans.** $\frac{I}{2}$, as it will get polarised **CBSE (F)-2009**

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641*. Unpolarized light is incident on a polaroid. How would the intensity of transmitted light change when the Polaroid is rotated ? **CBSE (AI)-2013**

[**Ans**. It will not change and remain $I_0/2$

642*. State Brewster's law. **CBSE (AI) -2016,(D)-2016,2002**

[**Ans**. **Brewster's law :** The refractive index of a refracting medium is numerically equal to the tangent of angle of polarization. i,e, $\mu = \tan i_\beta$

643*. What is Brewster's angle/Polarizing angle ? **CBSE (D)-2016,(F)-2013,(AIC)-2008**

[**Ans. Brewster's Angle** (i_β) **:** The angle of incidence of unpolarised light falling on a transparent surface, at which the reflected light is completely plane polarised light, is called Brewster's angle or polarizing angle i_β

644*. The value of Brewster angle for a transparent medium is different for light of different colours. Give reason

[**Ans**. We have $\mu = \tan i_\beta$ $\Rightarrow i_\beta = \tan^{-1}\mu$ **CBSE (D)-2016,(F)-2013**

Since μ is different for different colours, hence Brewster's angle (i_β) is different for different colours

645*. Show that the Brewster angle i_B for a given pair of transparent media, is related to the critical angle i_c through the relation, $i_c = sin^{-1}(\cot i_B)$. **CBSE (AIC)-2008**

[**Ans**. $\mu = \tan i_B = \frac{1}{\cot i_B}$ Also $\mu = \frac{1}{\sin i_c}$ $\Rightarrow \sin i_c = \cot i_B$ $\Rightarrow i_c = sin^{-1}(\cot i_B)$

646*. When unpolarised light passes from air to a transparent medium, under what condition does the reflected light get plane polarised ? **CBSE (D)-2011**

[**Ans**. when unpolrised light is incident at Brewster's angle

647*. What is the value of refractive index of a medium of polarizing angle 60^0 ? **CBSE (AI)-2016,(D)-2016,2002**

[**Ans**. $\mu = \tan i_\beta = \tan 60 = \sqrt{3}$

648*. What is the value of polarizing angle of a medium of refractive index $\sqrt{3}$? **CBSE (F)-2008**

[**Ans**. $\mu = \tan i_\beta$ $\Rightarrow \sqrt{3} = \tan i_\beta$ $\Rightarrow i_\beta = \tan^{-1}\sqrt{3} = 60^0$

649*. Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other ? **CBSE (AIC)-2010,NCERT-2017**

OR

Find the Brewster angle for air – glass interface, when the refractive index of glass = 1·5. **CBSE (AI)-2017**

[**Ans**. $\mu = \tan i_\beta$ $\Rightarrow i_\beta = \tan^{-1}\mu = \tan^{-1}1.5 = 56.3^0$

650*. A ray of light falls on a transparent slab of $\mu = 1.732$, if reflected and refracted rays are mutually perpendicular, what is the angle of incidence ? **CBSE (D)-2009**

[**Ans**. $\mu = \tan i_\beta$ $\Rightarrow i_\beta = \tan^{-1}\mu = \tan^{-1}1.732 = 60^0$

651*. The refractive index of a material is $\sqrt{3}$. What is the angle of refraction if the unpolarised light is incident on it at the polarizing angle of the medium ? **CBSE (D)-2002**

[**Ans**. $\mu = \tan i_\beta =$ $\Rightarrow i_\beta = \tan^{-1}\sqrt{3} = 60^0$ but $r + i_\beta = 90^0$ $\Rightarrow r = 90^0 - i_\beta = 90^0 - 60^0 = 30^0$

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652*. A partially plane polarised beam of light passed through a Polaroid. Show graphically the variation of the transmitted light intensity with angle of rotation of Polaroid. **CBSE (F)-2014**

[**Ans**.
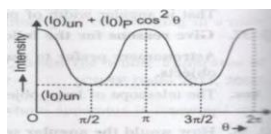
653*. If the angle between the pass axis of polarizer and analyser is 45^0, write the ratio of intensities of original light and the transmitted light after passing through the analyzer. **CBSE (D) -2009**

[**Ans**. $I_{original} = I_0$ & $I_{polariser} = I_1 = I_0 \overline{cos^2\theta} = \frac{I_0}{2}$

$I_{transmitted} = I_1 cos^2 45 = \frac{I_0}{2}(\frac{1}{\sqrt{2}})^2 = \frac{I_0}{4}$ $\Rightarrow \frac{I_{original}}{I_{transmitted}} = \frac{I_0}{I_0/4} = 4:1$

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654*. Using Huygen's construction draw a figure showing the propagation of a plane wavefront reflecting at a plane surface. Show that the angle of incidence is equal to the angle of reflection.　　　**CBSE (D)-2008,2003**

[**Ans.** <u>Explanation of reflection on the basis of Huygen's wave theory</u>

Let a plane wavefront AB is incident on a reflecting surface XY as shown. By the Huygens's principle, in the time disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius AD = BC = ct. Hence tangent CD be the reflected wavefront

In Δ ABC & Δ ADC,

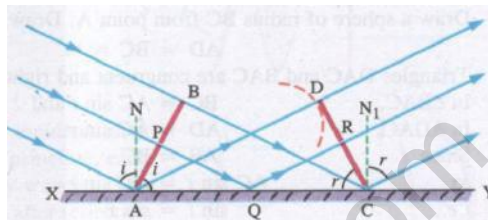$\qquad$ AC = common

$\qquad\quad$ $\angle B$ = $\angle D$ = 90^0

$\qquad$ AD = BC = c t

$\Rightarrow \qquad \Delta$ ABC $\cong \Delta$ ADC

$\therefore \qquad \angle i = \angle r$

655*. Use Huygens' principle to verify the laws of refraction.　　　**CBSE (AI)-2017**

OR

Derive Snell's law on the basis of Huygen's wave theory when light is travelling from a **rarer to a denser** medium/ **Denser to rarer** medium.　　**CBSE (AI)-2016,2015,2006,2002,(D)-2013,2011,2008,2005 (AIC)-2011**

[**Ans.** <u>Explanation of refraction on the basis of Huygen's wave theory</u>
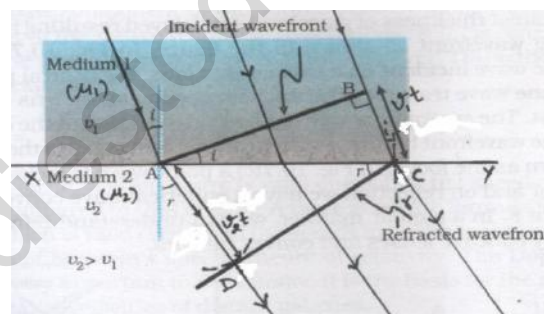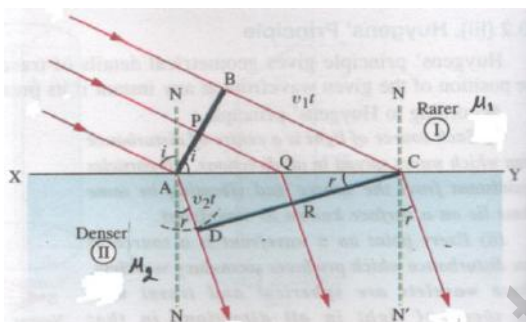
Let a plane wavefront AB is incident on a refracting surface XY as shown. By the Huygens's principle, in the time $\left(t = \frac{BC}{v_1}\right)$ disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius $AD = v_2 t$. Hence tangent CD be the refracted wavefront

Obviously, $\quad \dfrac{\sin i}{\sin r} \; = \; \dfrac{BC/AC}{AD/AC} \; = \dfrac{BC}{AD} = \dfrac{v_1 t}{v_2 t} = \dfrac{v_1}{v_2}$ = constant

This is Snell's law of refraction

56*. Two harmonic waves of monochromatic light　　　**CBSE (AI)S -2016,(AIC)-2015,2014,(D)-2014**

$\qquad y_1 = a \cos \omega t$ and $y_1 = a \cos(\omega t + \phi)$

are superimposed on each other. Show that the maximum intensity in interference pattern is four times the intensity due to each slit. Hence write the condition for constructive and destructive interference in terms of the phase angle ϕ.

[**Ans.** $y_1 = a \cos \omega t$ & $y_1 = a \cos(\omega t + \phi)$

$\Rightarrow \quad Y = Y_1 + Y_2 = a \cos \omega t + a \cos (\omega t + \phi) = 2a \cos \left(\frac{\phi}{2}\right) \cos \left(\omega t + \frac{\phi}{2}\right)$

$\Rightarrow \quad A = 2a \cos \left(\frac{\phi}{2}\right) \quad \Rightarrow$ Resultant intensity,

$\qquad I = 4 \, a^2 \, \cos^2 \left(\frac{\phi}{2}\right) = 4 \, I_0 \, \cos^2 \left(\frac{\phi}{2}\right) \quad$ where $I_0 = a^2$ is the intensity of each monochromatic wave

Obviously, $I_{max} = 4 \, I_0 = 4$ X intensity due to one slit

For constructive interference, $\cos^2 \left(\frac{\phi}{2}\right) = 1$

$\Rightarrow \quad \frac{\phi}{2} = n \, \pi \quad$ or $\phi = 2n\pi \quad$ where n = 0,1,2,3,------- and $I_{max} = 4 \, I_0$

For destructive interference, $\cos^2 \left(\frac{\phi}{2}\right) = 0$

$\Rightarrow \quad \frac{\phi}{2} = (2n - 1)\frac{\pi}{2} \quad$ or $\phi = (2n - 1)\pi \quad$ where n = 1,2,3,------- and $I_{min} = 0$

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657*. Derive an expression for path difference in Young's double slit experiment and obtain the conditions for Constructive and destructive interference at a point on the screen. Hence find the expression for fringe width. Also draw a graph howing the variation of intensity in the interference pattern.

CBSE (AI)-2016,2015,2014,2012, (D)-2016,2012,2011, (F)-2015

[**Ans.** Let 'S ' be a monochromatic source of light of wavelength λ

The path difference

$$\Delta x = S_2P - S_1P$$

Now, $S_2P^2 - S_1P^2 = D^2 + \left(y + \frac{d}{2}\right)^2 - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right]$

$\Rightarrow (S_2P - S_1P)(S_2P + S_1P) = D^2 + y^2 + 2y\frac{d}{2} - D^2 - y^2 + 2y\frac{d}{2} = 2yd$

$\Rightarrow \Delta x = \dfrac{2yd}{(S_2P + S_1P)}$

If point P is very close to point O then

$$S_2P \simeq S_1P \simeq D$$

$\Rightarrow \Delta x = \dfrac{2yd}{(D + D)} = \dfrac{2yd}{2D} = \dfrac{yd}{D}$

For constructive interference at P

$\Delta x = n\lambda$ where n = 0,1,2,3,------

$\Rightarrow \dfrac{yd}{D} = n\lambda$

$\Rightarrow$ for n^{th} bright fringe, $\boldsymbol{y_n = \dfrac{nD\lambda}{d}}$

For destructive interference at P

$\Delta x = (2n - 1)\lambda/2$ where n = 1,2,3,---------

$\Rightarrow \dfrac{yd}{D} = (2n - 1)\lambda/2$

$\Rightarrow$ for n^{th} dark fringe, $\boldsymbol{y_n = \dfrac{(2n-1)D\lambda}{2d}}$

Fringe width

Width of a dark fringe

$$\beta = y_n - y_{n-1} = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{nD\lambda}{d} - \frac{nD\lambda}{d} + \frac{D\lambda}{d} = \frac{D\lambda}{d} \qquad \Rightarrow \boxed{\beta = \frac{D\lambda}{d}}$$

Width of a bright fringe

$$\beta = y_n - y_{n-1} = \frac{(2n-1)D\lambda}{2d} - \frac{[2(n-1)-1]D\lambda}{d} = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-3)D\lambda}{d}$$

$$\beta = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-1)D\lambda}{d} + \frac{2D\lambda}{2d} = \frac{D\lambda}{d} \qquad \Rightarrow \boxed{\beta = \frac{D\lambda}{d}}$$

658*. (i) What is sustained interference pattern ? Write the necessary conditions to obtain sustained interference fringes.

[**Ans. Sustained interference pattern :**   **CBSE (AI)-2015**

An interference pattern, in which the positions of maxima and minima on the screen does not change with time, is called sustained interference

Conditions : (i) Two sources must be coherent

(ii) Waves emitted by two sources should have same frequency and equal or nearly equal amplitude

(iii) Two sources should be quite narrow and the separation between them (d) should be small

(iv) Distance of screen (D) from the sources should be large

659*. (ii) What is the effect on interference fringes in a Young's double slit experiment when the monochromatic source of light is replaced by a source of white light ? Explain.   **CBSE (F)-2012**

[**Ans.** The interference pattern consists of a central white fringe having on both sides a few coloured fringes and then a general illumination

Reason : Due to zero path difference, all the waves of different colour produce bright fringes at the centre which overlap and we get central white fringe.

As, $\beta \propto D\lambda/d$, so closest fringe on either side of the central white fringe is violet and the farthest fringe is red. After a few fringes, the interference pattern is lost due to large overlapping of the fringes and uniform white illumination is seen on the screen.
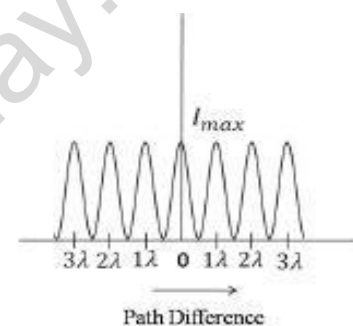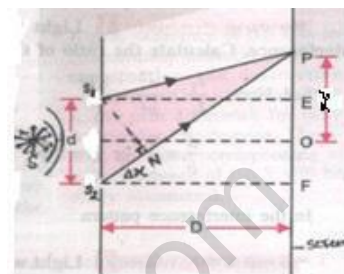
PHYSICS CLASS-XII –WAVE OPTICS

660*. When a parallel beam of monochromatic source of light of wavelength λ is incident on a single slit of width a, show how the diffraction pattern is formed at the screen by the interference of the wavelets from the slit.

(i) Show that, besides the central maximum at $\theta = 0$, secondary maxima are observed at $\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$ & minima at $\theta_n = n\lambda/a$

(ii) Show that angular width of central maximum is twice the angular width of secondary maximum and hence find the relation for linear width of central maximum. **CBSE (F)-2017,2016,2013,2012,2011,(AI)-2016,2014,(D)-2012**

[Ans. When a parallel beam of monochromatic light is incident on a single slit, By the Huygen's principle, secondary wavelets from each point on the slit superpose on each other and diffraction pattern is obtained on the screen.
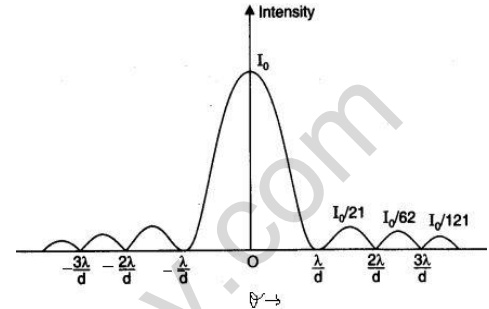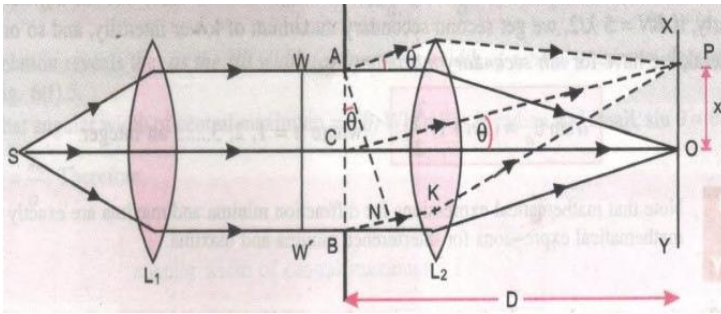
Central maximum : Wavelets from any two corresponding points of the two halves of the slit reach the central point in the same phase to produce maxima ($\theta = 0$). The entire incident wavefront contributes to this central maxima

Positions of minima :

$$\text{Path difference, } \Delta x = BN = AB \sin\theta = a \sin\theta$$

Wavelets from upper half of the slit and the corresponding points in the lower half is received with path difference $\frac{\lambda}{2}$ at P. Thus destructive interference takes place and we get first minimum.

i,e, for first secondary minimum

$$a \sin\theta_1 = \frac{\lambda}{2} + \frac{\lambda}{2} = \lambda$$

$\Rightarrow$ for n^{th} secondary minimum ,

$$a \sin\theta_n = n\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary minima

$$\theta_n = n\lambda/a$$

Positions of secondary maxima :

Dividing the slit in to three equal parts, wavelets from two parts will meet with phase difference $\frac{\lambda}{2}$ each and produce destructive interference and the wavelets from third part will produce first secondary maximum

i,e, for first secondary maximum

$$a \sin\theta_1 = \frac{3\lambda}{2}$$

$\Rightarrow$ for n^{th} secondary maximum

$$a \sin\theta_n = \left\{n + \frac{1}{2}\right\}\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary maxima

$$\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$$

Width of central maximum :

for the first minima, $\theta_1 = \lambda/a$

& for the second minima, $\theta_2 = 2\lambda/a$

$\Rightarrow$ linear width of first minimum $y_1 = D\,\theta_1 = D\lambda/a$

Angular width of central maximum $\theta_0 = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right) = \frac{2\lambda}{a} = 2\theta_1$

Angular width of secondary maxima $= \theta_2 - \theta_1 = \frac{2\lambda}{a} - \frac{\lambda}{a} = \frac{\lambda}{a} = \frac{1}{2}\text{X}$ Angular width of central maxima
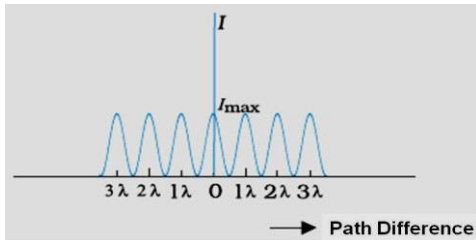
$\Rightarrow$ linear width of central maxima $\boldsymbol{y_0 = D\,(2\theta_1) = 2D\lambda/a}$ $\Rightarrow$ $\boxed{\boldsymbol{y_0 = 2D\lambda/a}}$
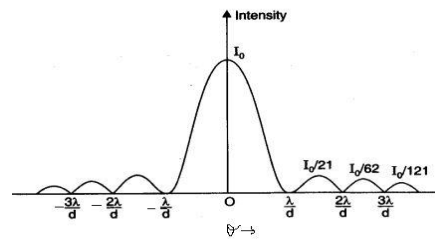
PHYSICS CLASS-XII –WAVE OPTICS

661*. Draw the intensity pattern for single slit diffraction and double slit interference. **CBSE (AI)-2017,2004**

[**Ans.** Interference   Diffraction

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662*. State two differences between interference and diffraction patterns. **CBSE (AI)-2017,(D)-2017**

[**Ans.**

Interference	Diffraction
1. It is due to superposition of two waves from two coherent sources	1. It is due to superposition of secondary wavelets from different parts of the same wavefront
2. Width of fringes/ bands is equal	2. Width of fringes/bands is not equal
3. All maxima have same intensity	3. Maxima have different intensity and intensity decreases rapidly with the order of maxima

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663*. Explain with reason, how the resolving power of an astronomical telescope will change when - **CBSE (AI)-2002**
(i) frequency of the incident light on the objective lens is increased
(ii) the focal length of the objective lens is increased ?
(iii) aperture of the objective lens is halved
(iv) the wavelength of the incident light is increased ? Justify your answer in each case.

[**Ans.** R. P. of a Telescope $= \dfrac{D}{1.22\,\lambda} = \dfrac{D\,v}{1.22\,c}$

(i) R.P. increases as R.P. $\propto v$
(ii) R.P. does not change as it does not depend on focal length of the objective lens
(iii) R.P. is halved as R.P. $\propto D$
(iv) R.P. decreases as R.P. $\propto 1/\lambda$

664*. How does the resolving power of a microscope change when **CBSE (AI)-2015,2008,2005**
(i) the diameter/aperture of the objective lens is decreased,
(ii) the wavelength of the incident light is increased ?
(iii) refractive index of the medium between the object and the objective lens increases
(iv) the focal length of the objective lens is increased ? Justify your answer in each case.

[**Ans.** $R.P. = \dfrac{2\,\mu\,sin\theta}{\lambda}$

(i) R.P. decreases because as D decreases, θ also decreases and R.P. $\propto sin\theta$
(ii) R.P. decreases as R.P. $\propto 1/\lambda$
(iii) R.P. increases as R.P. $\propto \mu$
(iv) R.P. does not change as it does not depend on focal length of the objective lens

665*. Why is no interference pattern is observed when two coherent sources are- **CBSE (AI)-2001**
(i) infinitely close to each other   (ii) far apart from each other

[**Ans.** $\beta = \dfrac{D\lambda}{d}$

(i) when sources are placed infinitely close to each other, $d \to 0 \Rightarrow \beta \to \infty$
Even a single fringe may occupy the entire screen. Hence no interference pattern will be observed
(ii) when the distance d becomes too large, fringe width becomes too small to be detected. Hence no interference pattern will be observed

666*. Two slits are made $1\,mm$ apart and the screen is placed $1\,m$ away. What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern ? **CBSE (AI)-2016,2015**

[**Ans.** $\beta = \dfrac{D\lambda}{d}$ & $y_0 = \dfrac{2D\lambda}{a}$

Given, $y_0 = 10\beta$ $\Rightarrow$ $\dfrac{2D\lambda}{a} = 10\,\dfrac{D\lambda}{d}$ $\Rightarrow$ $a = \dfrac{d}{5} = \dfrac{1}{5}mm = 0.5\,mm$

PHYSICS CLASS-XII –WAVE OPTICS

667*. (i) What is a Polaroid ? What does a polaroid consist   **CBSE (AI)-2015,(DC)-2013,(AIC)-2001**

    (ii) How does one demonstrate, using a suitable diagram, that unpolrised light when passed through a polaroid gets polarized ?   **CBSE (D)-2014, (AI)-2012,2010**

  (iii) How will you use it to distinguish between unpolarised light and plane polarised light ?   **CBSE (AI)-2015**

[**Ans. (i) Polaroid** : A Polaroid is a thin commercial sheet which makes use of the property of selective absorption to produce an intense beam of plane polarised light

    A Polaroid consists of a long chain of molecules aligned in a particular direction

  (ii) Plane Polarized light from Polaroid :

        When an unpolarised light falls on it, the electric vectors oscillating along the direction of aligned molecules get absorbed and those oscillating in the direction perpendicular to the direction of alignment of molecules are passed through it. Hence the emergent light is plane polarised or linearly polarised
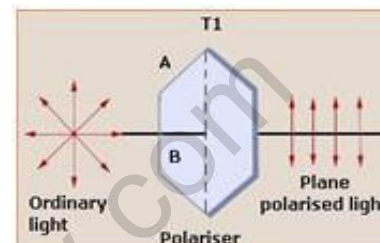
  (iii) Distinction :

        When unpolarised light is seen through a rotating Polaroid, intensity of transmitted light does not change, it remains $I_0/2$

        When plane polarised light is seen through a rotating Polaroid, the intensity of transmitted light varies. It becomes twice maximum and twice zero in each rotation

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668*. When unpolarised light is incident on the boundary separating the two transparent media, explain, with the help of a suitable diagram, the conditions under which the reflected light gets polarised. Hence derive the relation of Brewster's angle in terms of the relative refractive index of the two media.   **CBSE (AI)-2016,2014,2012,2008,(F)-2013,(D)-2014,2010**

[**Ans.** <u>Polarization of light by reflection</u>

        When unpolarised light falls on a transparent surface, both the reflected and refracted light are found partially polarised. It is observed that, the degree of polarization of reflected light varies with angle of incidence. At Brewster's angle i_β, reflected light is completely plane polarised when the refracted and reflected rays make a right angle with each other.

i,e, when $i = i_\beta$, $i_\beta + r = 90$ $\Rightarrow$ $r = 90 - i_\beta$

By Snell's law, $\mu = \dfrac{\sin i_\beta}{\sin r} = \dfrac{\sin i_\beta}{\sin(90 - i_\beta)} = \dfrac{\sin i_\beta}{\cos i_\beta} = \tan i_\beta$

$\Rightarrow$ $\boldsymbol{\mu = \tan i_\beta}$ This equation is called Brewster's law

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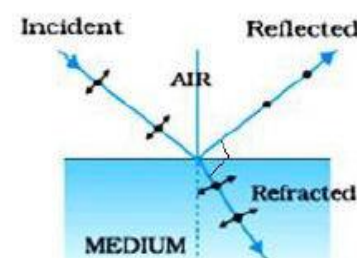
669*. Show, with the help of a suitable diagram, how unpolarized sunlight gets polarized due to scattering ?
      CBSE (AI)-2017,2014,2013,(F)-2014

[**Ans.** <u>Polarization of sunlight due to scattering</u>

        Scattered light is found to be plane polarized perpendicular to the original direction.

        Under the influence of electric field of incident wave, the electrons in the air molecules acquire components of motion in both the directions, parallel as well as perpendicular to the plane of paper ($\updownarrow$ as well as •). Charges accelerating parallel to $\updownarrow$, do not radiates energy towards observer since their acceleration has no transverse component. Hence the radiation, scattered towards the observer gets linearly polarized.

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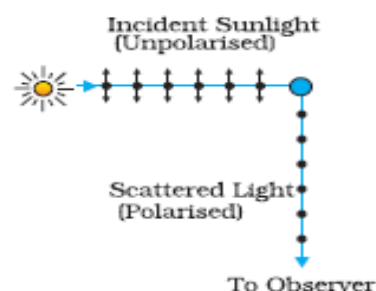
PHYSICS CLASS-XII –WAVE OPTICS

670*. The light from a clear blue portion of the sky shows a rise and fall in intensity when viewed through a polaroid which is rotated. Why ? **CBSE (AI)-2015**

[**Ans**. It is due to polarization of sunlight by scattering

Reason : When unpolarized sunlight falls on air molecules, it gets scattered and is found to be plane polarized $\perp$ to the original direction hence shows rise & fall in intensity when viewed through a rotating polaroid.

671*. Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. **CBSE (AI)-2017**

[**Ans**. $I = \frac{I_0}{2} cos^2\theta$

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672*. Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum ? **CBSE (D)-2015,2010**

[**Ans**. Let I_0 = Intensity of polarised light passing through P_1

$\Rightarrow$ Intensity of light after passing through second polarizer P_2

$I_2 = I_0 \, cos^2\theta$ Now, Intensity of light after passing through third polarizer P_3
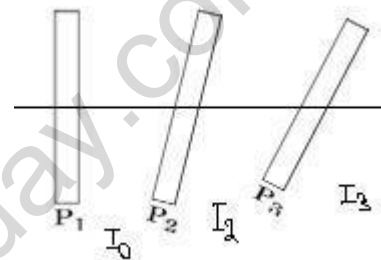
$I_3 = I_2 \, cos^2(90-\theta) = I_0 \, cos^2\theta \, cos^2(90-\theta)$

$\Rightarrow$ $I_3 = I_0 \, cos^2\theta \, sin^2\theta = \frac{I_0}{4} \, (2\sin\theta\cos\theta)^2$

$$\boxed{I_3 = \frac{I_0}{4} \, (\sin 2\theta)^2}$$

$\Rightarrow$ Transmitted intensity will be –

(i) minimum when $\sin 2\theta = 0$ or $\theta = 0^0$ (ii) maximum when $\sin 2\theta = 1$ or $2\theta = 90^0$ or $\theta = 45^0$

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673*. A narrow beam of unpolarised light of intensity I_0 is incident on a Polaroid P_1. The light transmitted by it then incident on a second Polaroid P_2 with its pass axis making an angle of 60^0 with relative to the pass axis of P_1. Find the intensity of light transmitted by P_2. **CBSE (D)-2017**

[**Ans**. Intensity through P_1, $I_1 = I_0 \, \overline{cos^2\theta} = \frac{I_0}{2}$ Intensity through P_2, $I_2 = I_1 cos^2 60 = \frac{I_0}{2} (\frac{1}{2})^2 = \frac{I_0}{8}$

674*. Two Polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third Polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60^0 with that of P_1. Determine the intensity of light transmitting through P_1, P_2 and P_3. **CBSE (AI) -2014**

[**Ans**. Intensity through P_1, $I_1 = I_0 \, \overline{cos^2\theta} = \frac{I_0}{2}$

Intensity through P_3, $I_3 = I_1 cos^2 60 = \frac{I_0}{2} (\frac{1}{2})^2 = \frac{I_0}{8}$

Intensity through P_2,

$I_2 = I_3 cos^2(90-60) = \frac{I_0}{8} cos^2 30 = \frac{I_0}{8} (\frac{\sqrt 3}{2})^2 = \frac{3I_0}{32}$
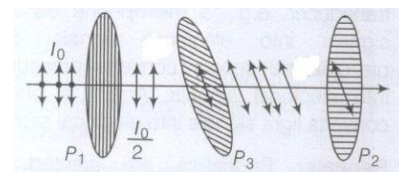
675*. Light waves from two coherent sources arrive at two points on a screen with path differences of 0 and $\lambda/2$. Find the ratio of intensities at these points. **CBSE (AIC)-2017**

[**Ans. (i)** $\Delta x = 0$ $\Rightarrow$ $\phi = \frac{2\pi}{\lambda} \times \lambda = 0$ **(ii)** $\Delta x = \frac{\lambda}{2}$ $\Rightarrow$ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$

$\Rightarrow$ $I_1 = 4I_0 \, cos^2 (\frac{\phi}{2}) = 4I_0 \, cos^2 0 = 4I_0$

& $I_2 = 4I_0 \, cos^2 (\frac{\phi}{2}) = 4I_0 \, cos^2 (\frac{\pi}{2}) = 0$ $\Rightarrow$ $\frac{I_1}{I_2} = \frac{4I_0}{0} = \infty$

676*. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of (i) $\lambda/4$, and (ii) $\lambda/3$. **CBSE (F)-2017**

[**Ans. (i)** $\Delta x = \frac{\lambda}{4}$ $\Rightarrow$ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$ **(ii)** $\Delta x = \lambda/3$ $\Rightarrow$ $\phi = \frac{2\pi}{\lambda} \times \lambda/3 = 2\pi/3$

$I_1 = 4I_0 cos^2 (\frac{\phi}{2}) = 4I_0 \, cos^2 (\frac{\pi}{4}) = 4I_0 (\frac{1}{\sqrt 2})^2 = 2I_0$ $\Rightarrow$ $I_2 = 4I_0 \, cos^2 (\frac{\phi}{2}) = 4I_0 \, cos^2(\pi/3) = 4I_0 (1/2)^2 = I_0$

4

PHYSICS CLASS-XII –WAVE OPTICS

677*. In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

[**Ans.** (i) $\Delta x = \lambda$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi$ **CBSE (D)-2015,2012,NCERT-2017**

⇨ $I_1 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi) = 4I_0 (-1)^2 = 4I_0 = K$ (given)

(ii) $\Delta x = \lambda/3$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda/3 = 2\pi/3$ ⇨ $I_2 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi/3) = 4I_0 (1/2)^2 = I_0 = K/4$

678*. Two coherent sources have intensities in the ratio 25 : 16. Find the ratio of intensities of maxima to minima after interference of light occurs. **CBSE (DC)-2003**

[**Ans. Given,** $\frac{I_1}{I_2} = \frac{25}{16}$ ⇨ $\frac{a_1^2}{a_2^2} = \frac{25}{16}$ ⇨ $\frac{a_1}{a_2} = \frac{5}{4}$ $\frac{I_{max}}{I_{min}} = ?$

⇨ $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(a_{1/a_2}+1)^2}{(a_{1/a_2}-1)^2} = \frac{\left(\frac{5}{4}+1\right)^2}{\left(\frac{5}{4}-1\right)^2} = 81:1$

679*. In Young's double slit experiment, two slits are $1\,mm$ apart and the screen is placed $1\,m$ away from the slits. Calculate the fringe width when light of wavelength $500\,nm$ is used. **CBSE (AI)E -2016**

[**Ans. Given,** $d = 1.\,mm = 1 \times 10^{-3}m$, $D = 1\,m$, $\lambda = 500\,nm = 500 \times 10^{-9}m$, $= ?$

fringe width, $\beta = \frac{D\lambda}{d} = \frac{1 \times 500 \times 10^{-9}}{1 \times 10^{-3}} = 5 \times 10^{-4}\,m = 0.5\,mm$

680*.-A beam of light consisting of two wavelengths, $800\,nm$ and $600\,nm$, is used to obtain the interference fringes in a Young's double slit experiment on a screen is placed $1.4\,m$ away. If two slits are separated by $0.28\,mm$, Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

[**Ans. Given,** $\lambda_1 = 800\,nm = 800 \times 10^{-9}m$, $\lambda_2 = 600\,nm = 600 \times 10^{-9}m$, $D = 1.4\,m$, **CBSE (AI)-2012**

$d = 0.28\,mm = 0.28 \times 10^{-3}m$,   Least distance of coincide $y = ?$

condition for coincide is

$n\beta_1 = (n+1)\beta_2$ ⇨ $n\frac{D\lambda_1}{d} = (n+1)\frac{D\lambda_2}{d}$ ⇨ $n\,\lambda_1 = (n+1)\lambda_2$

⇨ $n \times 800 \times 10^{-9} = (n+1) \times 600 \times 10^{-9}$

⇨ $n \times 8 = 6n + 6$ ⇨ $n = 3$ ⇨   Required least distance

$y = n\beta_1 = 3\frac{D\lambda_1}{d} = 3 \times \frac{1.4 \times 800 \times 10^{-9}}{0.28 \times 10^{-3}} = \frac{3 \times 1.4 \times 8 \times 10^{-3}}{2.8} = 1.2 \times 10^{-2}\,m$

681*. A slit of width $'a'$ is illuminated by red light of wavelength $6500\,A^0$. For what value of $'a'$ will -

(i) the first minimum fall at an angle of diffraction of 30^0 **CBSE (AI)-2009, (F)-2006**

(ii) the first maximum fall at an angle of diffraction of 30^0

[**Ans. Given,** $\lambda = 6500\,A^0 = 6500 \times 10^{-10}m$

(i) $a \sin\theta_1 = \lambda$

⇨ $a = \frac{\lambda}{\sin\theta_1} = \frac{6500 \times 10^{-10}}{\sin 30} = \frac{6500 \times 10^{-10}}{1/2} = 2 \times 6500 \times 10^{-10} = 1.3 \times 10^{-6}m$

(ii) $a \sin\theta_1 = 3\lambda/2$

⇨ $a = \frac{3\lambda}{2\sin\theta_1} = \frac{3 \times 6500 \times 10^{-10}}{2 \times \sin 30} = \frac{3 \times 6500 \times 10^{-10}}{2 \times 1/2} = 3 \times 6500 \times 10^{-10} = 1.95 \times 10^{-6}m$

682*.-The wavelengths of two Sodium light of $590\,nm$ and $596\,nm$ are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6}m$. The distance between the slit and the screen is $1.5\,m$. Calculate the separation between the positions of first maxima of the diffraction pattern observed in the two cases.

CBSE (AIC)-2017,(AI)-2014,(D)-2013,(DC)-2006

[**Ans. Given,** $\lambda_1 = 590\,nm = 500 \times 10^{-9}m$, $\lambda_1 = 596\,nm = 596 \times 10^{-9}m$, $D = 1.5\,m$, $a = 2 \times 10^{-6}m$, $y_2 - y_1 = ?$

for first maxima, $y_1 = \frac{3D\lambda}{2a}$

⇨ $y_2 - y_1 = \frac{3D}{2a}(\lambda_2 - \lambda_1) = \frac{3 \times 1.5}{2 \times 2 \times 10^{-6}}(596 \times 10^{-9} - 590 \times 10^{-9}) = \frac{3 \times 1.5 \times 6 \times 10^{-3}}{4} = 6.75 \times 10^{-3}m$

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