Syllabus for Test 11: L 25 (partial), L26, L27 (partial).

L25 (partial): Diffraction of Light, Definition, Diffraction of waves, Types of Diffraction, Fresnel and Fraunhofer diffractions and difference between them; Arago ort Poisson spot, single-slit diffraction, condition for minima in single-slit diffraction, intensity pattern of single-slit diffraction, positions of minima and maxima of intensity pattern, Numerical examples of single-slit diffraction pattern: ratio of intensities of diffraction peaks, angular and linear separations between minima and maxima, width of dark and bright fringes; Intensity distribution of double-slit diffraction pattern, interference factor and diffraction factor, comparison of single-slit and double-slit diffraction patterns.

L26: Review of:
Definition of diffraction of waves, types of diffraction and their differences, Arago or Poisson spot, single-slit diffraction pattern, conditions for minima and maxima in single-slit diffraction pattern, intensity distribution of single-slit diffraction pattern, Positions of maxima and minima in single-list diffraction pattern; Double-slit diffraction pattern, combination of the effects of interference and diffraction, interference factor and diffraction factor, comparison of single-slit and double-slit diffraction patterns.

Double-slit diffraction pattern: Limiting cases to (a) double-slit interference pattern, (b) single-slit diffraction pattern, Positions of maxima and minima in double-slit diffraction pattern; Missing orders, Numerical examples of double-slit diffraction pattern: Missing order, good missing order. Multiple-slit diffraction pattern, interference factor and diffraction factor; Intensity distribution of N-slit diffraction pattern, Resultant intensity as a modulation of N-slit interference pattern and a single-slit diffraction pattern; Special cases of N-slit diffraction pattern: (a) N=1 i.e. single-slit diffraction pattern, (b) N=1 i.e. double-slit diffraction pattern; Types of maxima and minima: Interference maxima and minima, diffraction maxima and minima; Positions of interference maxima and minima, Condition of combined minima; Different types of maxima and minima: (a) Principal maxima, (b) Secondary minima between two principal maxima, (c) Secondary maxima between two principal maxima; Condition for maxima: (a) Condition for principal maxima, order of principal maxima, finiteness of the order of principal maxima, (b) Conditions for central and non-central principal maxima, (c) Condition for secondary/subsidiary maxima; Number of subsidiary minima and subsidiary maxima, Positions of subsidiary maxima; Diffraction grating, grating constant, Numerical examples of diffraction grating.

Polarization of light: Definition, polarization of transverse waves; Methods of polarization: Polarization by selective absorption, transmission axis, polarizer.

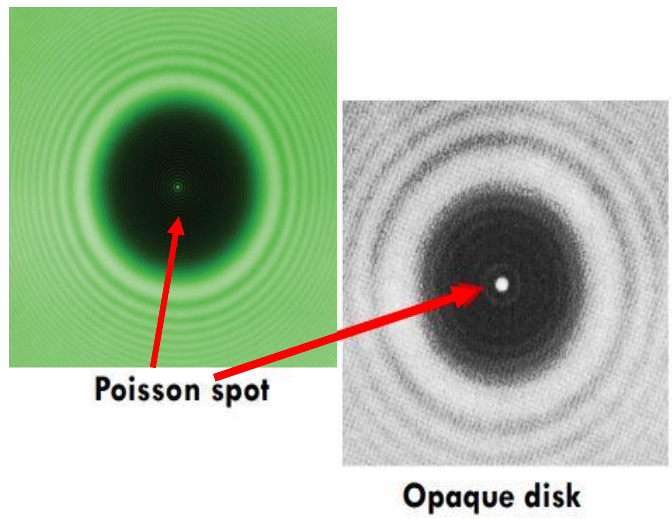
L27 (partial): Linearly polarized light, Methods of polarization: Polarization by selective absorption, transmission axis, polarizer, Malus' law, crossed polarizers, Numerical examples of Malus' law; Polarization by reflection, Brewster's law, Brewster angle, Polarization by double-refraction, Optic axis, Nicol prism, O- and e-rays, Retarders, full-wave plate, half-wave plate, quarter-wave plate; Circular polarization; Right- and left-circular polarizations, polarization by scattering.

1. Radio waves are easily diffracted around buildings and big structures, whereas light waves are not or negligibly diffracted around buildings. This is because radio waves:

are plane-polarized
have wavelengths of the order of the dimension of the buildings
have much shorter wavelengths than light waves
are nearly monochromatic (single frequency)
are amplitude modulated

Ans: have wavelengths of the order of the dimension of the buildings. **Explanation**: For effective or appreciable diffraction, the dimension of the structure through or around which diffraction occurs have to have dimension of the order of the wavelength of the wave that is diffracted.

2. A point source of monochromatic light is placed in front of an opaque disk at a suitable distance and a screen is placed behind the disk. The light intensity pattern on the screen is best described as:



a dark disk
a dark disk with bright/dark rings outside
a dark disk with bright spot at the center of the shadow
a dark disk with bright spot at the center of the shadow with bright/dark rings outside
a dark disk with bright rigs at the center

Ans: a dark disk with bright spot at the center of the shadow with bright/dark rings outside
Explanation: The central spot is due to Fresnel type of diffraction and is called the Arago or Poisson spot. The bright and dark rings outside are due to diffraction at an edge.

3. The equation $\sin(\theta)=\lambda/a$, for a single-slit diffraction gives:

the angular position θ of the first minimum
the angular position θ of the first maximum
the angular position θ of the second minimum
the phase angle between the extreme rays
$(N+ 1/2)\pi$ where N is an integer

Ans: the angular position θ of the first minimum. **Explanation**: The equation for the minimum in a single-slit diffraction pattern is: $\sin(\theta\_dark) = m\, \lambda/a$,
where a= width of the slit, λ is the wavelength of light and m is the order of the minimum. Hence the answer. The extreme rays implies the rays that are diffracted from the edges of the slit. The phase difference between two rays originating from two points in the slit separated by a distance Δy is equal to: $\Delta\varphi = (2\pi/\lambda)\, \Delta y \sin(\theta)$.
This gives for $\Delta y=a$, the phase difference between the extreme rays is: $\Delta\varphi\_ext = (2\pi a/\lambda) \sin(\theta)$

4. In a single slit diffraction pattern, the condition for minima is: $\sin(\theta\_dark) = m\, \lambda/a$, while that for the maxima is: $\tan(\beta)=\beta$, where $\beta= (\pi a/\lambda) \sin(\theta)$. No fringe is seen in single-slit diffraction pattern if:

the screen is far away compared to the slit-width
the slit width is greater than the wavelength
the slit width is less than the wavelength
the wavelength is less than the distance to the screen
none of the mentioned; fringes are always seen.

Ans: the slit width is less than the wavelength. **Explanation**: For the single-slit diffraction pattern, the central position is always a bright spot. The first minimum occurs when

$$\sin(\theta\_dark) = \lambda/a.$$

Now for a real θ_dark, we must have $\sin(\theta\_dark)<=1$ i.e. $\lambda/a \le 1$ i.e. $\lambda \le a$. Hence if $a< \lambda$, no fringe is seen.

5. Consider the second minimum adjacent to the central maximum in a single-slit diffraction pattern. The ray coming to this point from the top edge of the slit is 180° out of phase with a ray coming from (the position of):

a point one-fourth of the slit-width away (i.e. inside) from the top of the slit
the midpoint of the slit
a point one-fourth of the slit-width away (i.e. inside) from the bottom of the slit
the bottom of the slit
none of the others mentioned

Ans: a point one-fourth of the slit-width away (i.e. inside) from the top of the slit.

Explanation: The phase difference between two rays originating from two points in the slit separated by a distance Δy is equal to:

$$\Delta\varphi = (2\pi/\lambda)\, \Delta y \sin(\theta)$$

Now if the phase difference between rays coming from the top of the slit and from a point at a distance Δy inside the slit from the top is equal to 180°, then we have:

$$\Delta\varphi = \pi = (2\pi/\lambda)\, \Delta y \sin(\theta)$$

If the point on the screen is the second minimum adjacent to the central maximum, then we get form the condition of minima:

$$\sin(\theta\_dark) = 2\, \lambda/a$$

This gives:

$$\Delta\varphi = \pi = (2\pi/\lambda)\, \Delta y \sin(\theta\_dark) = (2\pi/\lambda)\, \Delta y\, (2\, \lambda/a) = 4\pi\, (\Delta y/a)$$

$$\Rightarrow 4\pi\, (\Delta y/a) = \pi \quad \Rightarrow \quad \Delta y = a/4$$

Thus the other ray is coming at a point one-fourth of the slit-width inside the slit from the top edge.

6. Consider a single-slit diffraction pattern produced by a long narrow slit illuminated by monochromatic light. In the source, only the wavelength λ is increased with NO other parameters changed. Then:

Intensity of the central maximum decreases and the pattern expands away from the center
Intensity of the central maximum increases and the pattern contracts toward the center
Intensity of the central maximum does not change but the pattern expands away from the center
Intensity of the central maximum does not change but the pattern contracts toward the center
Intensity of the central maximum increases and the pattern expands away from the center

Ans: Intensity of the central maximum does not change but the pattern expands away from the center. **Explanation**: Intensity pattern of single-slit diffraction pattern is:

$$I = I_0 \sin^2(\beta)/(\beta^2) = I_0 (\sin(\beta)/\beta)^2$$

where $\beta = (\pi a/\lambda) \sin(\theta)$ and $I_0 = E_0^2$, where E_0 is the amplitude of the electric field at the point on the screen. Intensity of the central maximum is I_0. This is because, at the central maximum, $\theta=0$ giving $\beta = (\pi a/\lambda)\sin(\theta)=0$ and $\lim_{\theta \to 0} (\sin(\beta)/\beta)^2 = \lim_{\beta \to 0} (\sin(\beta)/\beta)^2 = 1$.

Thus the intensity of the central maximum does not depend on the wavelength, rather depends only on the amplitude of the electric field at the point of illumination.

If NO other parameters than the wavelength λ is changed, i.e. everything else kept constant, then I_0 will remain constant. The position of the first minimum on either side are given by:

$$\sin(\theta_{dark}) = \pm \lambda/a$$

which gives the angular separation between the first minima on either sides as:

$$\Delta \theta_{dark} \approx \Delta [\sin(\theta_{dark})] = (\lambda/a) - (-\lambda/a) = 2\lambda/a$$

Hence as λ increases, the pattern expands away from the center.

7. Light of wavelength 600 nm is incident on a slit of width 0.01 mm. A diffraction pattern is formed on a wall 5 m away from the slit. The width of the central maximum is:

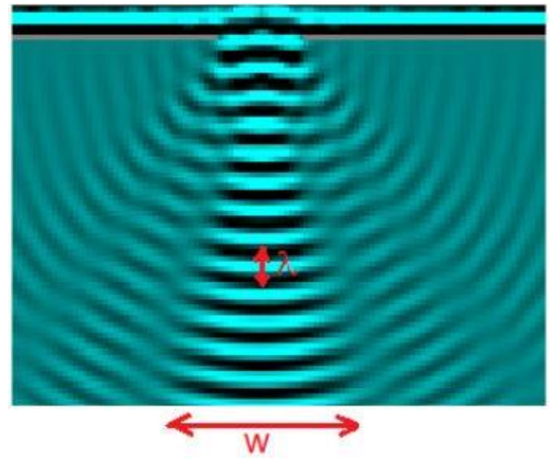
3 cm
6 cm
12 cm
30 cm
60 cm

Ans: 60 cm. **Explanation**: The condition for the minima in single-slit diffraction pattern is:
$\sin(\theta_{dark}) = m\lambda/a$. For central maxima, $m = \pm 1$.
The angular width of the central maxima is thus:
$\Delta \theta = (\theta_{dark\_m=1}) - (\theta_{dark\_m=-1}) \approx \sin(\theta_{dark\_m=1}) - \sin(\theta_{dark\_m=-1}) = (1-(-1)) \lambda/a = 2\lambda/a$

Again, linear separation of the first order minima (on both sides) on the screen is (with L = perpendicular distance from the slit to the screen): $\Delta y = \Delta\theta L = 2\lambda L/a$

Thus we get: $\Delta y = 2 (600 \text{ nm}) (5 \text{ m})/(0.01\text{mm}) = 6 (10^{(-9)}) 1000 \text{ m}/(1/100000) = 6 \cdot 10^{(-9+3+5)}$ m $= 6 (10^{-1})$ m $= 60$ cm.

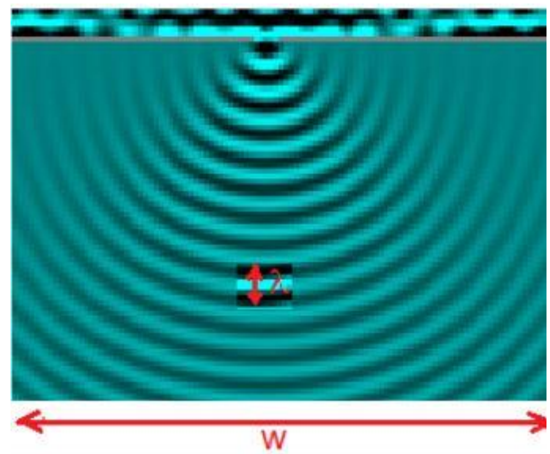
8. The figure shows single-slit diffraction in a water tank with a wave of wavelength λ and width of the central maximum w. The slit is made narrower. What will happen to the diffraction of water waves?



w will decrease and λ will increase
w will increase and λ will remain the same
w will decrease and λ will remain the same
w will stay the same and λ will increase
w and λ both will increase but their ratio w/λ will remain the same.

Ans: w will increase and λ will remain the same.

Explanation: The wavelength λ depends on the frequency at which the source is creating the wave and the speed of the wave in water. It is independent of the slit-width.



The condition for the minima in single-slit diffraction pattern is:

$$\sin(\theta\_dark) = m\lambda/a$$

For central maxima, m= ±1. The angular width of the central maxima is thus:

$$\Delta\ \theta = (\theta\_dark\_m{=}1) - (\theta\_dark\_m{=}{-1})$$
$$\approx \sin(\theta\_dark\_m{=}1) - \sin(\theta\_dark\_m{=}{-1}) = (1-(-1))\ \lambda/a = 2\lambda/a$$

Again, linear separation of the first order minima (on both sides) on the screen is (with L = perpendicular distance from the slit to the screen): $\Delta y = w = \Delta\theta\ L = 2\lambda L/a$

As the slit-width is decreased, the width of the central maximum Δy = w increases.

9. Consider an N-slit diffraction pattern produced by a diffraction grating that has slit-separation d and slit-width a. Plane waves of intensity I and wavelength λ, are incident normally on the diffraction grating. The angular separation depends on

a and N
a and λ
N and λ
d and λ
a and d

Ans: d and λ . **Explanation**: For diffraction by a grating, the condition for principal maxima is given by: $d \sin(\theta) = m\ \lambda.$

The angular separation of the lines corresponding to the PRINCIPAL MAXIMA in a diffraction pattern of the multiple-slit diffraction is given by:

$$\Delta\ \theta\_max \approx \Delta\ [\sin(\theta\_max)] = (\Delta m)\ \lambda/d = \lambda/d$$

10. Consider a double-slit diffraction pattern. If the wavelength of light λ is increased, with all other parameters kept constant then:

width of central peak increases and the number of bright fringes within the central peak increases
width of central peak increases and the number of bright fringes within the central peak decreases
width of central peak decreases and the number of bright fringes within the central peak increases
width of central peak decreases and the number of bright fringes within the central peak decreases
width of central peak increases and the number of bright fringes within the central peak remains constant

Ans: width of central peak increases and the number of bright fringes within the central peak remains constant.

Explanation: The intensity distribution of a double-slit diffraction pattern is given by:

$$I = 4 I_0 [\sin^2 (\beta) / \beta^2] \cos^2 (\gamma)$$

where, $\beta = \pi a \sin(\theta)/\lambda$ and $\gamma = \pi d \sin(\theta)/\lambda$, where a = width of the slit and d = separation between the slits.

The first factor i.e. $[\sin^2 (\beta) / \beta^2]$ is called the diffraction factor while the second factor i.e. $\cos^2 (\gamma)$ is called the interference factor. The diffraction factor represents the diffraction pattern produced by a single slit of width a. The interference factor represents the interference pattern produced by two point sources separated by a distance d.

The width of the central peak is found by considering the first minimum of the diffraction envelope: $\sin(\theta_{dark}) = m \lambda/a \Rightarrow \theta_1 \approx \sin(\theta_1) = \lambda/a$ (for m=1)

The number of interference peaks WITHIN THE CENTRAL DIFFRACTION PEAK is found from the condition of interference minima:

$$\cos(\gamma) = 0 \Rightarrow \gamma = \pi d \sin(\theta)/\lambda = (n+1/2)\pi, \text{ where } n=0,1,2,3,... = \text{ORDER of the interference peak}$$

This gives: $d \sin(\theta_{min\text{-}int}) = (n+1/2) \lambda \Rightarrow \theta_{min\text{-}int} \approx (n+1/2) (\lambda/d)$

Hence the number of interference peaks within the first diffraction minima is found from:

$$\theta_{min\text{-}int} \leq \theta_1 \text{ which gives } (n+1/2) (\lambda/d) \leq \lambda/a \Rightarrow (n+1/2) \leq d/a$$

Hence, as the wavelength of light λ is increased:

A. The width of the central peak in the diffraction pattern increases: $\theta_1 \approx \lambda/a$ increases

B. The number of interference peaks within the central peak of the diffraction pattern remains the same i.e. n = number of interference peaks within the central diffraction peak = $[d/a - 1/2]$, is independent of λ, where $[x]$ represents the greatest integer less than or equal to x.

11. In the equation $d \sin(\theta) = m \lambda$ for a diffraction grating, m represents:

the number of slits
the order of the fringe
the index of refraction of the material of the slit
the ratio of the slit width to the slit separation
none of the others mentioned

Ans: the order of the fringe.

12. Consider an N-slit diffraction pattern produced by a diffraction grating that has slit-separation d and slit-width a. Plane waves of intensity I and wavelength λ, are incident normally on the diffraction grating. Width of the grating is W. The widths of the principal maxima lines can be reduced by:

increasing the wavelength λ of the light
adding more slits i.e. increasing N in the grating with same a and d
decreasing d without changing the number of slits N
decreasing wavelength λ and slit-separation d by the same factor
increasing N and decreasing d such that (Nd) remains constant

Ans: adding more slits i.e. increasing N in the grating with same a and d. **Explanation**: The intensity pattern of multiple-slit diffraction is given by:

$$I = I_0 \left[\sin^2(\beta)/\beta^2 \right] \left\{ \sin^2(N\gamma) / \sin^2(\gamma) \right\}$$

where the first factor $[\sin^2(\beta)/\beta^2]$ is called the diffraction factor while the second factor given by $\{\sin^2(N\gamma) / \sin^2(\gamma)\}$ is called the interference factor. Here, $\beta = \pi a \sin(\theta)/\lambda$ and $\gamma = \pi d \sin(\theta)/\lambda$.
The condition for INTERFERENCE minima is: $[\sin(N\gamma) / \sin(\gamma)] = 0$ which gives $\sin(N\gamma)=0$ but $\sin(\gamma) \neq 0$. This gives: $N\gamma = p\pi$ with $p \neq 0, N, 2N, 3N, \ldots$ giving: $N \pi d \sin(\theta_{min\text{-}int})/\lambda = p\pi$ => $\sin(\theta_{min\text{-}int}) = p (\lambda/d) (1/N)$

Width of the interference fringe is thus: $\Delta(\theta_{min\text{-}int}) \approx \Delta[\sin(\theta_{min\text{-}int})] = (\Delta p) \lambda/(Nd) = \lambda/(Nd)$. But, d = slit-separation and N = total number of slits. Hence, Nd = total width of the grating. Hence width of the principal maxima lines can be reduced by, increasing N (or by increasing d).

13. For a certain diffraction grating, the slit-separation is 4 times the slit-width. For this system in the diffraction pattern:

the orders of the lines that appear are all multiples of 4
the orders of the lines that appear are all multiples of 2
the orders of the missing lines are all multiples of 4
the orders of the missing lines are all multiples of 2
none of the others mentioned

Ans: the orders of the missing lines are all multiples of 4. **Explanation**: For missing order, with d= slit-separation and a=slit-width, the condition is: $m_{missing} = d/a = 4$
Other order lines (principal maxima) will be present.

14. Consider an N-slit diffraction pattern produced by a diffraction grating that has slit-separation d and slit-width a. Plane waves of intensity I and wavelength λ, are incident normally on the diffraction grating. Width of the grating is W and the second order principal maxima has a position given by θ_{2max}. The total number of slits is given by:

$2(W/\lambda) \sin(\theta_{2max})$
$(W/2\lambda) \sin(\theta_{2max})$
$2(Wa/d\lambda) \sin(\theta_{2max})$
$(\lambda W/d) \sin(\theta_{2max})$
$2(\lambda a/d) \sin(\theta_{2max})$

Ans: $(W/2\lambda) \sin(\theta_{2max})$
Explanation: The condition for the principal maxima lines is given by:

$$d \sin(\theta_m) = m \lambda$$

Now the total width of the grating is given by: W= Nd . Hence, $N = W/d = W \sin(\theta_m)/(m \lambda)$ which for second order becomes:

$$N = (W/2\lambda) \sin(\theta_{2max})$$

15. Consider an N-slit diffraction pattern produced by a diffraction grating that has slit-separation d and slit-width a. Plane waves of intensity I and wavelength λ, are incident normally on the diffraction grating. Width of the grating is W. Initially the apparatus is in air. Now the entire apparatus is immersed in a liquid of refractive index 1.33. As a result the pattern on the screen:

spread farther apart (i.e. separation between lines increase) and becomes wider (i.e. the width of the principal maxima lines increase)
move closer together (i.e. separation between lines decrease) and becomes wider
spread farther apart and becomes narrower
move closer together and becomes narrower
disappears because the refractive index is not an integer.

Ans: move closer together (i.e. crowd together) and becomes narrower (i.e. the width of the principal maxima lines decrease).

Explanation: The angular separation of the lines corresponding to the PRINCIPAL MAXIMA in a diffraction pattern of the multiple-slit diffraction is given by:

$$\Delta \theta_{max} \approx \Delta [\sin(\theta_{max})] = (\Delta m) \lambda/d = \lambda/d$$

As the whole apparatus id immersed in a liquid, the effective wavelength becomes $\lambda' = \lambda/1.33$ i.e. the wavelength decreases. Hence also $\Delta \theta_{max}$ decreases i.e. the principal maxima lines crowd together.

Again, width of the interference fringe i.e. the width of the principal maxima lines is:

$$\Delta (\theta_{min-int}) \approx \Delta [\sin(\theta_{min-int})] = (\Delta p) \lambda/(Nd) = \lambda/(Nd)$$

But, d = slit-separation and N = total number of slits. Hence, W= Nd = total width of the grating. Hence, the width of the principal maxima lines decreases.

16. What principle is responsible for the fact that certain sunglasses can reduce glare from reflected surfaces?

refraction
polarization
diffraction
interference
total internal reflection

Ans: polarization.

17. Unpolarized light is incident on a plane glass surface. What should be the angle of incidence (approximately) such that the reflected and refracted rays are perpendicular to each other?

36°
42°
45°
53°
56°

Ans: 57° . Explanation: Using Brewster's law, $\mu = \tan(ip)$ In this case, $i + r$ is equal to $\pi/2$.
For glass, $\mu = 1.5$.

Therefore, $ip = \tan^{-1}(\mu) = 56.3°$.

18. A polarizer made off a clear sheet of Polaroid material is placed on top of another such sheet. Their polarization axes make an angle of 30° with each other. The ratio of the intensities of the emerging light from the second sheet to the incident unpolarized light, I_2/I_0 is:

1:2
1:4
3:2
3:4
3:8

Ans: 3:8. **Explanation**: Unpolarized light may be thought of having electric field in two perpendicular directions. One of the directions may be chosen parallel to the transmission axis of the first polarizer.

Hence, after the first polarizer, only half of the intensity will pass through. The light incident on the first polarizer is unpolarized, so the angle is irrelevant – the intensity is reduced by a factor of 2.

Thus $I_1 = I_0/2$. After the first polarizer, the intensity of light is $I_0/2$.

From Malus law, we get intensity of the final emerging light as:

$$I_2 = I_1 \cos^2 (30°) = (I_0/2) \cos^2 (30°) = (I_0/2) (\sqrt{3} /2)^2 = I_0\, 3/8$$

19. When light was observed through a plane polarizer, the intensity of light was observed to remain constant on rotating the polarizer in a perpendicular plane to the incident ray. The light:

is unpolarized
is elliptically polarized
is circularly polarized
has any of the polarizations mentioned
has none of the polarizations mentioned

Ans: has any of the polarizations mentioned. **Explanation**: For both elliptically (or circularly) polarized and unpolarized light falling on an ideal linear polarizer, the emergent intensity is half of the incident intensity. This does not depend on the orientation of the axis of transmission of the linear polarizer in a perpendicular plane to the incident ray.

20. Three ideal plane polarizing sheets are placed in a sequence where the polarization axes of the first and the third sheets are perpendicular to each other. Initially unpolarized light falls on the first sheet. At what angle of the transmission axis of the second intermediate polarizing sheet, making with the transmission axis of the FIRST polarizing sheet, the final transmitted intensity would be the minimum?

0°
30°
45°
60°
Not possible, all angles allow light to pass through.

Ans: 0° **Explanation**: The initial light is unpolarized. After the first polarizer the transmitted intensity is: $I_1 = I_0/2$
Let the angle between the transmission axes of the FIRST and the SECOND polarizers be θ. Then the transmitted intensity after the second polarizer is: $I_2 = I_1 \cos^2(\theta) = (I_0/2) \cos^2(\theta)$

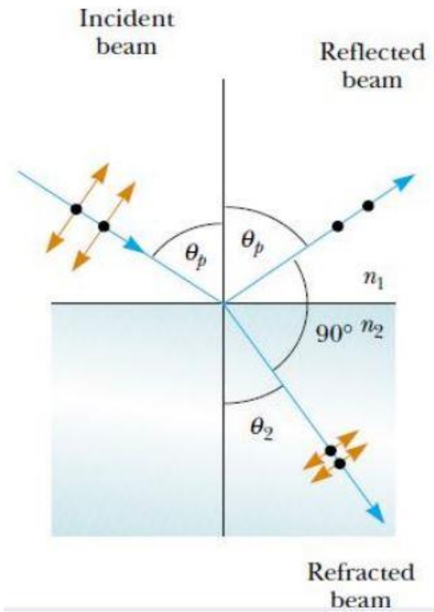
Light of this intensity is incident on the THIRD polarizer. Now, the angle between the transmission axes of the second and the third polarizers is: $90° - \theta$.
Hence the final emergent intensity is: $I_3 = I_2 \cos^2(90° - \theta) = [(I_0/2) \cos^2(\theta)] \sin^2(\theta)$
$\Rightarrow I_3 = (I_0/2) \cos^2(\theta) \sin^2(\theta) = (I_0/2)(1/4) \sin^2(2\theta) = (I_0/8) \sin^2(2\theta)$

To get the minimum emergent polarization we need to minimize $\sin^2(2\theta)$, by varying θ. This is done simply by differentiation:

$\frac{d}{d\theta} [\sin^2(2\theta)]_{\theta=\theta_{min}} = 0 \Rightarrow 2 \sin(2\theta_{min}) \cos(2\theta_{min}) = 0 \Rightarrow \sin(4\theta_{min}) = 0 \Rightarrow 4\theta_{min} = 0°$ or $360° \Rightarrow \theta_{min} = 0°$ or $90°$

Thus the angle that the transmission axis of the second polarizer makes with that of the FIRST polarizer is 0° or 90°. Thus the transmission axis of the middle polarizer must be parallel to that of either the first polarizer or the third polarizer (of course the first and the third polarizers are crossed to each other).

21. Unpolarized light is incident on a glass surface at an angle of incidence equal to the Brewster's angle. As a result:



the reflected wave is linearly polarized and the transmitted wave is partially polarized
the transmitted wave is linearly polarized and the reflected wave is partially polarized
both reflected and transmitted waves are linearly polarized
both reflected and transmitted waves are partially polarized
both reflected and transmitted waves are unpolarized

Ans: the reflected wave is linearly polarized and the transmitted wave is partially polarized.
Explanation: At the Brewster's angle of incidence, the reflected wave has only perpendicular polarization to the plane of incidence. The electric field component lying in the plane of incidence is completely absent in the reflected wave.

The transmitted wave has both polarizations, i.e. electric field of the transmitted wave has both parallel and perpendicular components to the plane of incidence.

22. The phenomenon of polarization of light proves that light is:

a longitudinal wave
a transverse wave
an electromagnetic wave
composed of streams of particles called photons
a wave that carries energy

Ans: a transverse wave. **Explanation**: Polarization can occur for transverse waves only. Other types of transverse waves than light also show polarization.

23. Linearly polarized light is incident on a block of glass from air with the angle of incidence equal to the Brewster angle. The electric field in the incident light is confined in the plane of incidence. As a result:

the reflected wave is polarized with the electric field confined in the plane of incidence
the reflected wave is polarized with the electric field confined perpendicular to the plane of incidence
the refracted wave is polarized with the electric field confined perpendicular to the plane of incidence
there is no reflected wave
there is no refracted wave

Ans: there is no refracted wave.

24. A half-wave plate introduces a path difference between the o- and e-waves upon emerging from the retarder:

$\lambda/4$
$\lambda/2$
$\lambda/3$
λ
$3\lambda/2$

Ans: $\lambda/2$.
Explanation: The phase difference introduced by the retarder is given by:

$$\Delta\varphi = (2\pi/\lambda\_0)\ d\ (|n\_O - n\_E|) = (2\pi f\_0/c)\ d\ (|n\_O - n\_E|)$$

For a half-wave plate the phase difference introduced is π which corresponds to a path difference of $\lambda/2$.

25. The index of refraction for the extra-ordinary ray in a birefringent crystal depends on:

how the crystal is cut
the direction of propagation relative to the surface
the direction of propagation relative to the optic axis
the polarization of the incident wave relative to the plane of incidence
the polarization of the incident wave relative to the direction of the optic axis

Ans: the direction of propagation relative to the optic axis.

26. At any fixed point in space along the ray, the electric field in a circularly polarized light has component:

parallel to the ray's direction
that changes direction randomly with time
that rotates in a plane perpendicular to the ray's direction of propagation
that is perpendicular to the ray's direction but parallel to the magnetic field
that rotates in a conical surface with the opening angle of the cone less than 90°

Ans: that rotates in a plane perpendicular to the ray's direction of propagation.

27. Circularly can be produced from incident linearly polarized light using which of the following:

a polarizing sheet
two polarizing sheets with transmission axes placed perpendicular to each other
a quarter-wave plate
a quarter wave plate and then a polarizing sheet
a half-wave plate

Ans: a quarter-wave plate.

28. Circularly polarized light with intensity I_0 passes through a plane polarizer. As a result, the intensity of the emerging light is:

I_0
$I_0/2$
$2I_0$
$I_0/4$
$I_0/8$

Ans: $I_0/2$

Explanation: Circularly polarized light may be thought of consisting of two linearly polarized light with the electric fields in the perpendicular directions having a phase difference of $\pi/2$:

$$E(z,t) = E_0 [\hat{i} \cos(kz-\omega t) + \hat{j} \sin(kz-\omega t)]$$

This wave passing through a linear polarizer with the transmission axis along any of the above component waves, will pass only half of the intensity. The other perpendicular component will be blocked.