30 Wave Optics

BRIEF REVIEW

Interference When two light waves emitted from two coherent sources superpose then it results in variation of intensity with distance. At certain places intensity is maximum and at other places intensity is minimum.

Coherent Sources Two sources/wave trains are said to be coherent if there is a constant or zero phase difference between them. No two different sources (except lasers) could be coherent. Coherent sources are to be derived from a single source. Their state of polarisation remains same. Laser is considered highly coherent.

If ϕ is phase shift then $\phi \neq f(t)$ and $\frac{d\phi}{dt} = 0$. Coherent sources can be obtained by division of wave front or by division of amplitude.

Young's double slit experiment (YDSE, Lloyd's mirror, Fresnel biprism are examples in which coherent sources are obtained by division of wave front.

In Newton's rings, thin films and interferometer, division of amplitude is used to obtain coherent sources.

Wave front is the locus of all adjacent parts at which the phase of vibration of a physical quantity associated with the wave is the same. That is, at any instant, all points on a wave front are at the same part of the cycle of their vibration. Wave fronts in general may be of three types: (a) Spherical (b) Cylindrical (c) Plane

Spherical wave fronts results from a **point source** or **circular slit.**

Cylindrical wave front results from a line source or rectangular slit.

Plane wave front is either of the two if the source is at infinity.

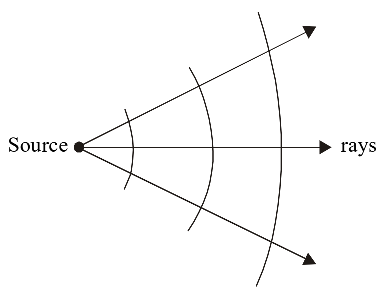

Fig. 30.1 (a) **Wave front (Spherical)**

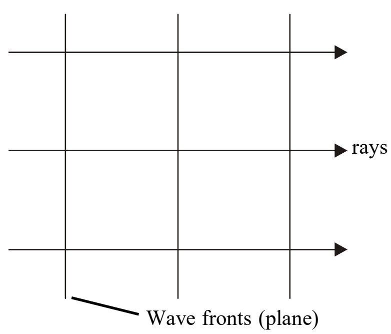

Fig. 30.1 (b) **Illustrations of plane wave front**

Constructive interference occurs when the coherent waves **superpose in phase** or the **path difference** is **integral** multiple of the **wavelength** or even multiple of half the wavelength. This type of interference is also called reinforcement as light intensity increases, i.e., bright fringes are formed. We may call such points or curves as **antinodal**. See Fig 30.2 (a)

Destructive interference occurs when the coherent waves **superpose out of phase** or **path difference** is an odd multiple of half the wavelength. Dark fringes are formed. We may call such points or curves as **nodal** as illustrated in Fig 30.2 (b)

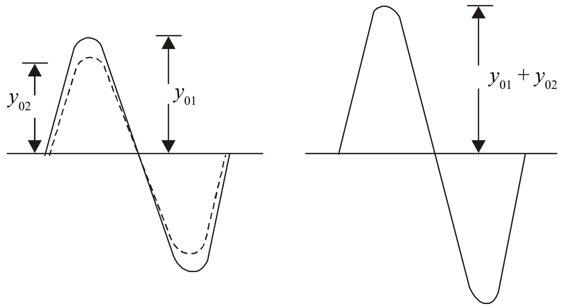

Fig. 30.2 (a) **Constructive Interference**

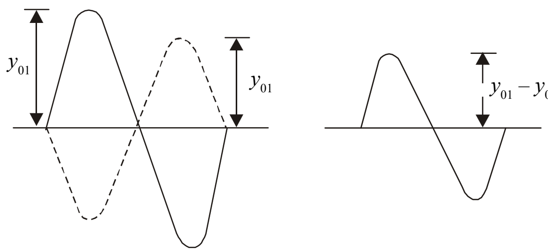

Fig. 30.2 (b) **Destuctive Interference**

Path differences $\Delta x = n\lambda$ for constructive interference

Path difference $\Delta x = (2n+1)\,\dfrac{\lambda}{2}$ for destructive interference

$$\frac{I_{\text{bright}}}{I_{\text{dark}}} = \frac{I_{\max}}{I_{\min}} = \left(\frac{y_{01}+y_{02}}{y_{01}-y_{02}}\right)^2 = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2$$

Conditions to obtain sustained interference

Necessary condition Sources emitting wave must be coherent.

Desirable conditions (i) Sources should be monochromatic having same frequency. (ii) They shall have same amplitude (iii) They shall emit light continuously (iv) The separation between the two sources shall be small.

In YDSE

Fringe width $\beta = \dfrac{\lambda D}{d}$ (Difference between two successive dark or bright fringes, i.e., $\beta = x_n - x_{n-1} = \dfrac{\lambda D}{d}$

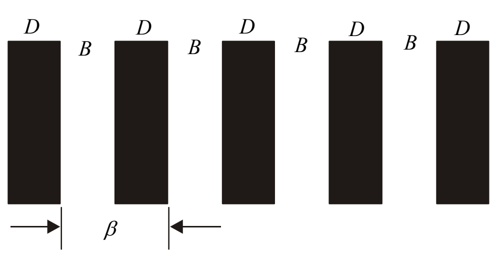

Fig. 30.3 **Fringe pattern in YDSE**

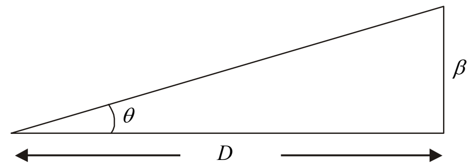

Fig. 30.4 **Angular Fringe Width**

$$x_n = \frac{n\lambda D}{d} \text{ for nth bright fringe}$$

$$x_n = \frac{(2n-1)\lambda D}{2d} \text{ for nth dark fringe}$$

Angular fringe width $\theta = \dfrac{\lambda}{d} = \dfrac{\beta}{D}$ (in radian)

$$= \frac{\lambda}{d} \times \frac{180}{\pi} \text{ (in degrees)}$$

Fringe Visibility $= \dfrac{I_{\max}-I_{\min}}{I_{\max}+I_{\min}} = \dfrac{\sqrt{2I_1I_2}}{I_1+I_2}$

Intensity at any point $I = 2y_0^2(1+\cos\delta) = 4I'\cos^2(\delta/2)$. Assuming both sources emit waves of equal amplitude y_0 or equal intensity I'. δ is phase shift between two superposing waves

$$I = I_1 + I_2 + 2\sqrt{I_1}\,\sqrt{I_2}\,\cos\delta$$

$$= \left(y_{01}^2 + y_{02}^2 + 2y_{01}y_{02}\cos\delta\right)$$

if intensities or amplitude of superposing waves are unequal.

If YDSE is immersed in a liquid of refractive index μ then fringes shrink and hence fringe pattern shrinks.

$$\beta_{\text{new}} = \frac{\beta}{\mu} = \frac{\lambda D}{\mu d} \quad \text{or } x_{n(\text{new})} = \frac{x_n}{\mu} = \frac{n\lambda D}{\mu d} \text{ for } n\text{th}$$

bright fringe.

If a thin slice of thickness t and refractive index μ is inserted in front of one of the slits in YDSE, then central fringe shifts to a position where originally nth fringe was formed such that $(\mu - 1)\,t = n\,\lambda$ or $\Delta x = \dfrac{D(\mu-1)t}{d}$

In Fresnel biprism both the sources S_1 and S_2 are virtual as shown in Fig. 30.5.

$D = a + b$

$d = 2a\,\delta = 2a\,(\mu - 1)\,\alpha$

where α is angle of biprism.

$$\beta = \frac{\lambda D}{d} = \frac{\lambda(a+b)}{2a(\mu-1)\alpha}$$

$$x_n = \frac{n\lambda D}{d} = \frac{n\lambda(a+b)}{2a(\mu-1)\alpha} \text{ for } n\text{th bright fringe.}$$

$$x_n = \frac{(2n-1)\lambda D}{2d} = \frac{(2n-1)\lambda(a+b)}{4\alpha(\mu-1)\alpha} \text{ for } n\text{th dark}$$

fringe.

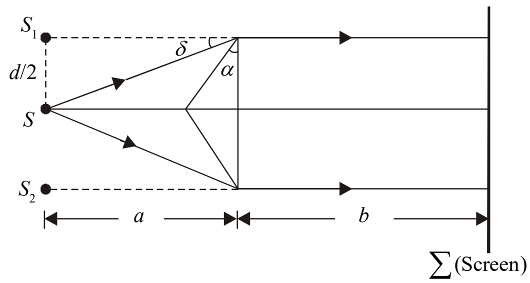

Fig. 30.5 **Fringe pattern in fresnel biprism**

If displacement method is used then $d = \sqrt{d_1 d_2}$

If Fresnel biprism is immersed in a liquid of refractive index μ', then

$$\beta_{new} = \frac{\frac{\lambda}{\mu'}(a+b)}{2a\left(\frac{\mu}{\mu'}-1\right)\alpha} = \frac{\lambda(a+b)}{2a(\mu-\mu')\alpha}$$

In Lloyd's Mirror: Condition of nth bright and dark fringe obtained in Lloyd's mirror gets reversed to what was obtained in YDSE; because of reflection an additional phase shift of π or an additional path difference $\frac{\lambda}{2}$ is achieved.

That is, $x_n = \frac{n\lambda D}{d}$ for nth dark fringe

and $x_n = \frac{(2n-1)\lambda D}{2d}$ for nth bright fringe.

In Lloyd's mirror one of the sources is real and other is virtual or image source.

Path difference = $2\,\mu t \cos r = (2n+1)\,\frac{\lambda}{2}$ for nth bright fringe and $2\,\mu t \cos r = n\lambda$ for nth dark fringe. In reflected light

$$\left.\begin{aligned} \text{Path difference } 2\,\mu t \cos r &= n\lambda \\ 2\mu t \cos r &= (2n+1)\frac{\lambda}{2} \end{aligned}\right] \text{for refracted or transmitted light}$$

Wedge Shaped Film

Fringe Width $\beta = \frac{\lambda}{2\theta}$, since

$$\theta = \frac{t}{x_n}, \text{ Therefore } \beta = \frac{\lambda x_n}{2t}$$

If plates are kept in a liquid of refractive index μ

$$\beta = \frac{\lambda}{2\mu\theta} = \frac{\lambda x_n}{2\mu t} \text{ or } 2\,\mu t = n\lambda$$

$t_{min} = \frac{\lambda}{2}$. It is due to interference that a soap bubble appears bright colour or oil drops spilled on road in rainy season appear of brilliant hue.

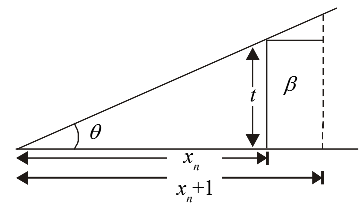

Fig. 30.6 **Wedge shaped film**

Time of coherence (t_c) is the time during which electric field vector is in the sinusoidal form. Its value is 10^{-10} *s*. **Coherence Length** $L_C = C\,t_c$. Note that if path difference > L_C, coherence nature is lost. Therefore we cannot keep distance between two slits or sources > 3 *cm*.

Diffraction The bending of wave from the obstacles of size of the order of wavelength is termed as diffraction. Planar or plane wave front is required for diffraction to take place. Diffraction is of two types (a) Fresunel's class of diffraction (b) Fraunhoffer class of diffraction.

Table. 30.1

	Fresnel class	Fraunhoffer class
1.	The source is at a finite distance.	The source is at infinite distance.
2.	No optical aid is required.	Optical aid in the form of collimating lens and focusing lens are required.
3.	Fringes are not sharp and well defined.	Fringes are sharp and well defined

Table. 30.2

	Interference	Diffraction
1.	Fringes are formed due to superposition of wave trains emitted from two coherent sources.	Fringes are formed due to superposition of bent rays or due to superposition of secondary wavelets.
2.	Intensity of each fringe is equal	Intensity falls as the fringe order increases.
3.	Number of fringes is and quite large.	Number of fringes is finite (small).
4.	Fringe width is equal for each fringe.	Fringe width of primary and secondary maxima are different.

Huygen's Principle

1. Each point on the primary wavefront is a source of secondary wavelets.
2. Secondary wavelets move only in forward direction.
3. Secondary wavelets can superpose to produce disturbances.

4. Secondary wavelets as well as primary wavefronts move with c (speed of light).

Diffraction from a single slit

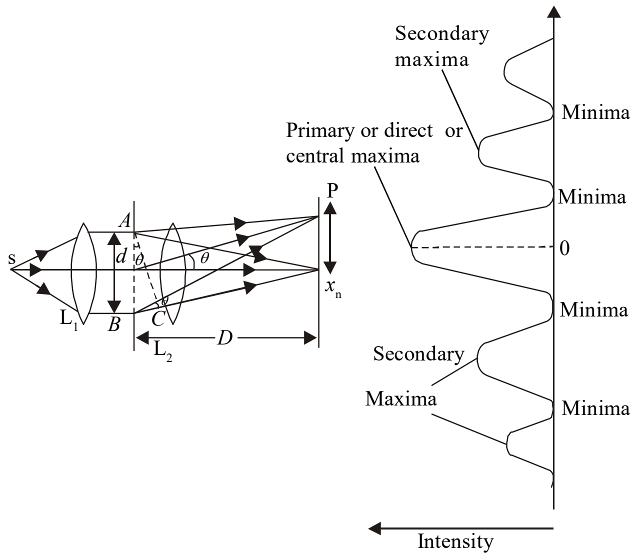

Fig. 30.7 **Single slit diffraction**

Path difference = $BC = AB \sin\theta$

$= d \sin\theta$

For minima

$d \sin\theta = n\lambda$

$\sin\theta = \tan\theta = \dfrac{x_n}{D}$. Thus $\dfrac{dx_n}{D} = n\lambda$

or $x_n = \dfrac{n\lambda D}{d}$ for nth minima.

Note $D = f$ (of focussing lens)

Fringe width $\beta_{\text{primary}} = \dfrac{2\lambda D}{d}$ and

$\beta_{\text{secondary}} = \dfrac{\lambda D}{D}$ (fringe width for secondary maxima is half the primary maixma)

Angular fringe width $\beta_{\text{primary}} = \dfrac{2\lambda}{d}$ (radian)

$= \dfrac{2\lambda}{d} \times \dfrac{180}{\pi}$ (degrees)

Angular fringe width $\beta_{\text{secondry}} = \dfrac{\lambda}{d}$ (radian)

$= \dfrac{\lambda}{d} \times \dfrac{180}{\pi}$ (degree)

If $\beta = \dfrac{\pi d \sin\theta}{\lambda}$ then $I = \dfrac{I_0 \sin^2\beta}{\beta^2}$

If aperture is circular then $\sin\theta = \dfrac{1.22\lambda}{r}$ where r is radius of aperture.

Radius of first dark ring $R = \dfrac{1.22\lambda D}{r} = \dfrac{1.22\lambda f}{r}$

Polarisation If plane of vibration is fixed then light will travel in a single direction. Such a state is called plane polarised light.

In the Fig. 30.8 electric field varies along y-axis and magnetic field along z-axis, wave travels along x-axis, plane of polarisation is $y - z$.

If $E_y = E_o \sin(\omega t - kx)$ is the electric field along y-axis and $B_z - B_o \sin(\omega t - kx)$ is the magnetic field active along z-axis then wave progresses in x-direction.

Only transverse waves can be polarised, longitudinal waves cannot be polarised. Plane polarised light can be achieved using

(a) reflection (b) refraction
(c) scattering (d) Nicol prism
(e) birefracting crystals.

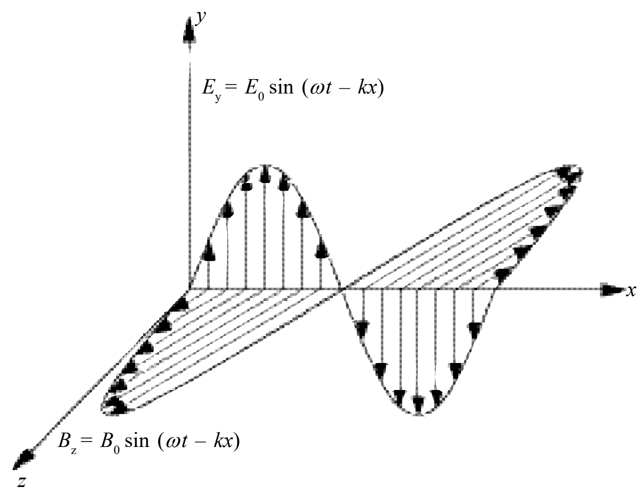

Fig. 30.8 **Plane polarised light**

Brewester's Law If light is incident on the interface of two media such that the angle between reflected and refracted radiations is 90° then reflected rays are completely polarised. Angle of incidence is called angle of polarisation (θ_p).

Then $\mu = \tan\theta_p$

Malus Law When the plane of polarisation is rotated by an angle θ then intensity of emergent light is given by $I = I_o \cos^2\theta$. I_o is intensity of incident polarised light. In birefracting analysis there are two rays – ordinary and extraordinary. The extraordinary ray does not follow law of refraction. If the **velocity** of **extraordinary ray** is **greater** than that of **ordinary ray** such crystals are called **negative crystals**. Examples of negative crystal are Iceland spar, tourmaline, sapphire, ruby, emerald and apatite. If the **ordinary ray** has **higher velocity** than the **extraordinary ray** then such crystals are called **positive crystals**. Examples of positive crystals are quartz, iron oxide.

If the amplitude of two waves are unequal and angle between the two is $\dfrac{\pi}{2}$ or path difference is $\dfrac{\lambda}{4}$ then an elliptically polarised wave front results, it could be elliptically polarised if amplitudes are equal but the angle between the two is $0 < \theta < \pi/2$.

SHORT CUTS AND POINTS TO NOTE

1. Coherent sources are those in which wave trains have constant or zero phase difference. The coherent sources cannot be two separate sources except lasers. Normally they are derived from a single source either by division of wave front or by division of amplitude.
2. If two slits have unequal sizes (they act like intensity, the intensity of the resultant is

$$I = \left(\sqrt{I_1}\right)^2 + \left(\sqrt{I_2}\right)^2 + 2\sqrt{I_1}\sqrt{I_2}\cos\theta$$
$$= I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\theta$$
$$= k\,(S_1 + S_2 + 2\sqrt{S_1 S_2}\cos\theta)$$ where S_1 and S_2 are size of the slits.

3. Coherent length $l_{coherence} = \dfrac{\lambda^2}{\Delta\lambda}$. Coherence radius

$$\rho_{coh} = \frac{\lambda}{\phi},\ \beta = \frac{\phi}{2}.$$

4. In YDSE maximum intensity occurs at $d\sin\theta = n\lambda$ and minimum intensity occurs at $d\sin\theta = (2n+1)\lambda/2$.

When interference from narrow slit is studied (slit width << λ) Then

$E(\theta) = E_m\cos\beta = 2E_o\cos\beta$ and

$I(\theta) = I_m\cos^2\beta = 4I_o\cos^2\beta$.

When slit is not so narrow then, position of nth bright fringe $x_n = \dfrac{n\lambda D}{d}$ fringe width $\beta = \dfrac{\lambda D}{d}$ and angular fringe width $= \dfrac{\lambda}{d}$ (rad) $= \dfrac{\lambda}{d}\times\dfrac{180}{\pi}$ (degree)

$$x_n = \frac{(2n-1)\lambda D}{2d}$$ for nth dark fringe.

5. If the light reaching the point P is direct, or transmitted (not reflected) from two sources then P will be a bright fringe if the path difference $= n\lambda$. On the other hand, if the light reaching P after reflection forms a bright fringe (at P) then path difference $= (2n+1)\lambda/2$ because reflection causes an additional path difference of $\lambda/2$ (or phase difference π radian).
6. If the interference occurs due to reflected light, central fringe (or ring in Newton's rings) will be dark.

If the interference occurs due to transmitted or direct light, central fringe will be bright.

7. If white light is used in YDSE, central fringe is white surrounded by coloured fringes in VIBGYOR order as illustrated in Fig. 30.9.

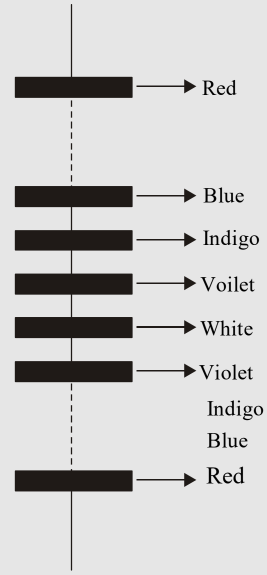

Fig. 30.9 **Interference due to white light**

8. Each fringe in YDSE has equal intensity while in diffraction intensity falls as the fringe order increases.
9. To locate the central fringe in YDSE, illuminate it with white light. The central fringe is white.
10. Fringes can be displaced by introducing a thin slice in front of one of the slits or in front of both the slits. If t is the thickness of the slice in front of one of the slits and μ its refractive index then $(\mu-1)t = n\lambda$ describes the shift. (The central fringe now occupies the position which was previoulsy possessed by nth fringe) OR $\Delta x = \dfrac{D}{d}(\mu-1)t$.
11. The fringes shrink by $1/\mu$ if YDSE is immersed in a liquid of refractive index $\mu > 1$.
12. Fresnel distance is the distance travelled by a beam without much broadening by diffraction. $z_F = \dfrac{a^2}{\lambda}$

Size of the Fresnel zone $a_F = \sqrt{\lambda z}$. Note that a is slit width.

13. In Fresuel biprism $d = 2a(\mu-1)\alpha$ and $D = a + b$ so

$$x_n = \frac{n\lambda(a+b)}{2a(\mu-1)\alpha}$$ for nth bright fringe. If displacement method is employed to find d then $d = \sqrt{d_1 d_2}$ where d_1 and d_2 are distance between

images of virtual source in magnified and diminished cases.

14. In Newton's rings experiment, radius of nth ring is given by $r_n = \sqrt{n\lambda R}$ where R is radius of curvature of plano convex lens.

15. For nth dark fringe in thin films, $2\ \mu t \cos r = n\lambda$ for nth dark fringe in reflected light. For nth dark fringe in thin films in refracted or transmitted light $2\ \mu t = (2n+1)\ \dfrac{\lambda}{2}$.

In wedge shaped films, for nth dark fringe $2\ \mu t = n\lambda$ if immersed in a liquid of refractive index μ.

In air $\mu = 1$, $t = \dfrac{n\lambda}{2}$ or $t_{\min} = \dfrac{\lambda}{2}$

[Maximum number of fringes = 1,50,000 called Haidenger fringes]. Thickness of non reflective coating on a glass is $t = \dfrac{\lambda_{air}}{\mu 4}$ where μ is refractive index of coating.

16. In a zone plate $f_n = \dfrac{r_n^2}{(2p+1)n\lambda}$.

17. Diffraction occurs due to planar wave front. Fresnel diffraction is near field diffraction while Fraunhoffer diffraction is far-field diffraction.

18. Bragg's Law in diffraction of X-rays from crystals. $2d \sin \theta = n\ \lambda$

19. In diffraction grating if there are N slits/lines per inch then grating element $(a + b) = \dfrac{2.54}{N}$ and $(a + b) \sin \theta = n\ \lambda$ where n is order of the spectrum resolving power of grating is $\dfrac{\lambda}{d\lambda} = n$N.

20. If white light is used in single slit experiment, central fringe will be white followed by coloured fringes in VIBGYOR order.

21. Resolving power of a prism $\dfrac{td\mu}{d\lambda}$ where t is length of the base.

22. Only transverse waves can be polarised. Sound waves being longitudinal cannot be polarised.

23. The crystals in which **ordinary ray travels faster** than **extraordinary ray** or $\mu_{\text{extraordinary}} > \mu_{\text{ordinary}}$ are called **positive** crystals.
The crystals in which extraordinary ray travels faster than ordinary ray or $\mu_{\text{ordinary}} > \mu_{\text{extraordinary}}$ are called **negative** crystals.

24. The substances which rotate the plane of polarisation are called optically active. The substances which rotate the plane of polarisation to its **left** or **anti-clockwise** are called **Leveo rotatory** and the substances which rotate the plane of polarisation to its **right** or **clockwise** are called **dextrorotatory**.

25. According to Brewester's law $\mu = \tan \theta_p$ where θ_p is polarising angle (angle of incidence when angle between reflected and refracted rays is 90°).

26. The intensity of plane polarised light is $I_o/2$ if incident unpolarised light has intensity I_o. Malus law is $I = I_o \cos^2 \theta$.

27. The sources like lasers are highly monochromatic and coherent.

28. Though sodium light gives a doublet, D_1 and D_2 lines of wavelength 589 $A°$ and 5896 $A°$. It may be considered monochromatic for most of the experiments.

29. For point sources or spherical wave fronts, intensity $I \propto \dfrac{I}{r^2}$. For cylindrical sources, amplitude $A \propto \dfrac{1}{\sqrt{r}}$, r being distance from the source.

30. If aperture is circular then radius of first dark ring $R = \dfrac{1.22\lambda D}{d} = \dfrac{1.22\lambda f}{d}$ where f is focal length of focussing lens.

In single slit diffraction fringe width $\beta_{\text{primary}} = \dfrac{2\lambda D}{d}$

$\beta_{\text{sec}} = \dfrac{\lambda D}{d}$.

$d \sin \theta = n\ \lambda$ for nth minima.

CAUTION

1. Considering path difference $= n\ \lambda$ for bright fringes in all cases.

⇒ Path difference $= n\ \lambda$ for bright fringes for transmitted or refracted light. If interference occurs due to reflected light, path difference $= n\ \lambda$ for dark fringe i.e destructive interference.

2. Considering slit width as amplitude of the wave.

⇒ Slit width acts like intensity. Therefore to find resultant intensity use

$$I = k\,(S_1 + S_2 + 2\sqrt{S_1 S_2} \cos\phi) \quad \text{and}$$

$$\frac{I_{\max}}{I_{\min}} = \left(\frac{\sqrt{S_1}+\sqrt{S_2}}{\sqrt{S_1}-\sqrt{S_2}}\right)^2$$

3. Applying same formula $x_n = \dfrac{n\lambda D}{d}$ even when sources are placed horizontally.

⇒ As illustrated in Fig. 30.10 path difference $S_1L = d \cos \theta$.
Use $d \cos \theta = n\ \lambda$ for nth bright fringe.

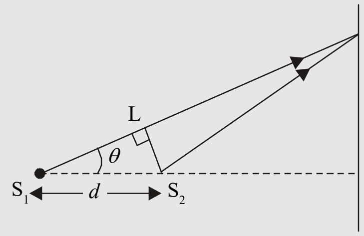

Fig. 30.10

4. Applying Malus Law even to unpolarised light when incident on a polariser.

⇒ Fig. 30.11 illustrates that if I_o was the intensity of unpolarised light then intensity of polarised light is

$\frac{I_o}{2}$ after passing through first poloroid (P_1) and

$\frac{I_o}{2}\cos^2\theta$ after passing through second poloroid P_2 inclined at an angle θ.

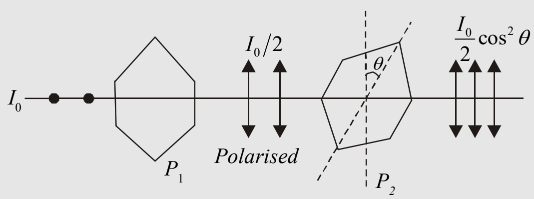

Fig. 30.11

Note that Malus law can be applied only to polarised light.

5. Considering any wavefront meeting an obstacle causes diffraction.

⇒ Planar wave front meeting an obstacle of the size of the order of wavelength will cause diffraction.

6. Considering interference and diffraction are alike.

⇒ For interference one needs coherent sources which can be derived from a single source by division of wave front or by division of amplitude. In diffraction bent rays or secondary wavelets superpose to form fringes.

7. Considering equal amplitudes of superposing waves is necessary for interference.

⇒ It may be a desirable condition. If amplitudes are unequal interference does occur and

$$\frac{I_{max}}{I_{min}} = \frac{I_{bright}}{I_{dark}} = \left(\frac{y_{01}+y_{02}}{y_{01}-y_{02}}\right)^2$$

Note: Dark fringe will not be completely dark if amplitudes y_{01} and y_{02} are not equal. However, intensity will be less at dark fringe positions as compared to bright fringe positions.

8. Considering only monochromatic light is needed for intereference or for diffraction to occur.

⇒ Interference and diffraction do occur with white light.

In YDSE central fringe will be white surrounded by coloured fringes in VIBGYOR order. Same is the case for single slit diffraction experiment.

9. Not remembering the effect of refractive index of the medium (μ')

⇒ In YDSE fringes shrink by a factor of μ' while in Fresnel biprism the situation is not simple.

$$\beta_{new} = \frac{\lambda(a+b)}{2a(\mu-\mu')\alpha}.$$

10. Considering even two circular slits, illuminated with a source will give straight line fringes.

⇒ In such cases shape of fringes is hyperbola.

11. Assuming the intensity of primary maxima will increase in single slit experiment for increasing slit width.

⇒ Intensity of principal maxima is independent of slit width.

SOLVED PROBLEMS

1. In YDSE, an electron beam is used to obtain interference pattern. If speed of electrons is increased
   (a) no interference pattern will be observed
   (b) distance between the consecutive fringes will increase
   (c) distance between two consecutive fringes will decrease
   (d) distance between two consecutive fringes remains same

[IIT Screening 2005]

Solution (c) $\lambda = \frac{h}{mv}$; if v increases, λ decreases.

Therefore $\beta = \frac{\lambda D}{d}$ will decreases.

2. In YDSE the angular position of a point on the central maxima whose intensity is $\frac{1}{4}$th of the maximum intensity.

   (a) $\sin^{-1}\left(\frac{\lambda}{d}\right)$ (b) $\sin^{-1}\left(\frac{\lambda}{2d}\right)$

   (c) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$ (d) $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

[IIT Screening 2005]

Solution (c) $2\cos\theta/2 = 1$

$\cos\theta/2 = \frac{1}{2}$ or $\phi = 2\pi/3$

$\frac{2\pi}{\lambda} d \sin\theta = \frac{2\pi}{3}$ or $\phi = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

3. A YDSE uses a monochromatic source. The shape of the fringe formed on the screen, is

(a) hyperbola (b) circle
(c) straight line (d) perabola

[AIEEE, 2005]

Solution (c)

4. When an unpolarised light of intensity, I_o is incident on a polarising sheet, the intensity of the light which does not get transmitted is

(a) $\frac{I_o}{2}$ (b) $I_o/4$
(c) zero (d) I_o

[AIEEE, 2005]

Solution (a)

5. The intensity of principal maxima in the single slit diffraction pattern is I_o? What will be its intensity when slit width is doubled?

(a) $2I_o$ (b) $4I_o$
(c) I_o (d) $I_o/2$

[AIEEE, 2005]

Solution (c)

6. Two waves of intensity I undergo interference. The maximum intensity obtained is

(a) $I/2$ (b) $2I$
(c) I (d) $4I$

[BHU, 2005]

Solution (d) $I_{max} = I + I + 2\sqrt{I}\ \sqrt{I}\ \cos\theta = 4I$. (for $\theta = 0$)

7. The wave theory in its original form was first postulated by

(a) Issac Newton (b) Thomas Young
(c) Christian Huygens (d) Augustin Jean Fresnel.

[Karnataka, 2005]

Solution (c)

8. Two coherent light beams of intensity I and $4I$ are superposed. The minimum and maximum possible intensities in the resulitn beam are

(a) $9I$ and I (b) $9I$ and $3I$
(c) $5I$ and I (d) $5I$ and $3I$

[CET Karnataka, 2005]

Solution (a) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{4I}+\sqrt{I}}{\sqrt{4I}-\sqrt{I}}\right)^2 = \frac{9}{1}$

9. A single slit of width a is illuminated by violet light of wavelength 400 nm and width of the diffraction pattern is measured as y. Half of the slit is covered and illuminated with 600 nm. The width of the diffraction pattern will be

(a) $y/3$
(b) pattern vanishes and width is zero
(c) $3y$ (d) none of these.

[CET Karnataka, 2005]

Solution (c) $\beta = \frac{2\lambda D}{d}\quad \frac{y}{y'} = \frac{\frac{2\times 400D}{d}}{\frac{2\times 600D}{d/2}}$ or $y' = 3y$

10. When unpolarised light beam is incident in air into glass ($n = 1.5$ ` at polarising angle)

(a) reflected beam is 100% polarised
(b) reflected and refracted beam are partially polarised
(c) the reason for (a) is that almost all the light is reflected
(d) all the above

[CET Karnataka, 2005]

Solution (a)

11. Select the right option.

(a) Christian Huygens, a contemporary of Newton established the wave theory of light by assuming that light waves are transverse.
(b) Maxwell provided the compelling theoretical evidence that light is transverse in nature.
(c) Thomas Young experimentally proved the wave behaviour of light and Huygens assumption.
(d) All the statements given above correctly answer the question, what is light.

[CET Karnataka, 2005]

Solution (b)

12. In placing a thin sheet of mica of thickness 12×10^{-5} cm in the path of one of the interfering beams in YDSE, the central fringe shifts equal to a fringe width. Find the refractive index of mica. Given $\lambda = 600$ nm.

(a) 1.5 (b) 1.48
(c) 1.61 (d) 1.56

Solution (a) $\frac{\lambda D}{d} = (\mu - 1)\, t\, \frac{D}{d}$ or $\mu = \frac{\lambda}{t} + 1 = .5$

13. The waves emitted by a radio transmitter are

(a) linearly polarised (b) unpolarised
(c) monochromatic (d) elliptically polarised

Solution (a)

14. Dichorism means

(a) Selective absorption of unpolarised light
(b) Selective absorption of dispersed light
(c) Selective absorption of scattered light
(d) Selective absorption of one of the polarised components

Solution (d)

15. Two nicol prisms are kept perpendicular. One of them is illuminated with a light intensity (natural) I_o. Two more nicol prisms are introduced in between symmetrically. Find the light intensity emitted from the last nicol prism.

(a) $\frac{27I_o}{64}$ (b) $\frac{27I_o}{128}$

(c) $9\frac{I_0}{32}$ (d) $\frac{9I_o}{64}$

Solution (b) $I = \frac{I_o}{2}\cos^6 30 = \frac{I_o}{2}\left(\frac{\sqrt{3}}{2}\right)^6 = \frac{27I_o}{128}$

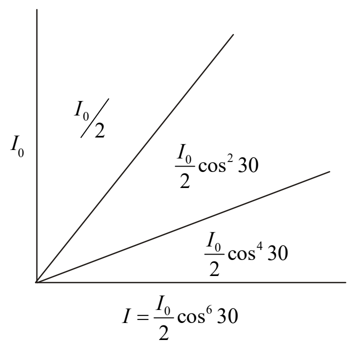

Fig. 30.12

16. The angle between reflected and refracted beams is 90° in the water air interface. The angle of incidence in water is

(a) 60° (b) 53°
(c) 30° (d) 37°

Solution (d) $\tan\theta = \frac{3}{4}$ $\theta = 37°$

17. In a birefracting crystal ordinary ray travels faster than extraordinary ray. The crystal is called

(a) positive crystal (b) negative crystal
(c) no such demarcation exists
(d) dextro rotatory (e) leveo rotatory.

Solution (a)

18. If in a birefracting crystal the magnitude of E_x and E_y are equal and phase angle between the two is 60° then the waves are

(a) linearly polarised (b) plane polarised
(c) circularly polarised (d) elliptically polarised

Solution (d)

19. Antinodal curves correspond to ______ interference.

(a) constructive (b) destructive
(c) where intensity is less than maximum but not completely zero
(d) none of these

Solution (a)

20. A radio station operating at a frequency 100 KHz has two vertical dipole antennas spaced 400 m apart oscillating in phase. In which directions is the intensity greatest?

(a) $0, \pm 30°, \pm 90°$ (b) $0, \pm 30°, \pm 60°$
(c) $0, \pm 45°, \pm 90°$ (d) $\pm 30°, \pm 60°, \pm 90°$

Solution (a) $\lambda = \frac{c}{f} = \frac{3\times 10^8}{1.5\times 10^6} = 200\ m$ $\sin\theta =$

$$\frac{n\lambda}{d} = \frac{n(200)}{400} = \frac{n}{2}, \text{ i.e., } \theta = 0, \pm 30°, \pm 90°.$$

21. In the above question where will minimum intensities be found?

(a) ± 14.5°, ± 48.6° (b) ± 30°, ± 45°
(c) ± 14.5°, ± 68.5° (d) ± 14.5°, ± 79.6°

Solution (a) $\sin\theta = \frac{(2n+1)}{4}$ $\theta = \sin^{-1}\frac{1}{4}$ or $\theta = \pm 14.5°$

$$\theta = \sin^{-1}\frac{3}{4} = \pm 48.6°$$

22. When exposed to sunlight, thin films of oil on water often exhibit brilliant colours due to the phenomenon of

(a) dispersion (b) interference
(c) diffraction (d) angular acceleration

Solution (b)

23. Two glass plates are 10 cm long. At one end a piece of paper 0.02 mm thick is placed to make a wedge as shown in Fig 30.13. Find the separation between the two fringes. Assume $\lambda = 500$ nm

(a) 1.25 nm (b) 1.5 nm
(c) 2.5 nm (d) none of these

Solution (a) $2t = n\lambda$; $\frac{t}{x} = \frac{h}{l}$

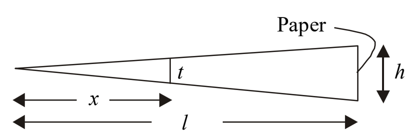

Fig. 30.13

$$\frac{2x_n h}{l} = n\lambda;\ x_n - x_{n-1} = \frac{\lambda l}{2h} = \frac{500\times 10^{-9}\times .1}{2\times 2\times 10^{-5}}$$

$$= 1.25\times 10^{-3} m$$

24. A commonly used lens coating material is $Mg\,F_2$ with $n = 1.38$. Find the thickness of non-reflective coating one shall have for 550 nm light if it is applied to glass of $n = 1.52$.

(a) 400 nm (b) 200 nm
(c) 300 nm (d) 100 nm

Solution (d) 550 nm wavelength in $Mg\,F_2$ will be

$$\lambda = \frac{\lambda_{\text{air}}}{n} = \frac{550}{1.38} = 400 \text{ nm}$$

$$l = \frac{\lambda}{4} = 100 \text{ nm}$$

25. A *CD* (Compact disc) is read from the bottom by a semiconductor laser with wavelength 790 *nm* passing through a plastic substrate of refractive index 1.8. When the beam encounters 0 pit, part of the beam is reflected from the pit and part from the flat region. These two beams interfere with each other. What must be the minimum depth of the pit so that part of the beam reflected from the pit and part reflected from the flat surface cancel out? (This cancellation allows the player to recognise beginning and end of a pit).

(a) 0.197 μm (b) 0.395 μm
(c) 0.22 μm (d) 0.11 μm

Solution (d) $\lambda = \frac{\lambda_{air}}{\mu}$ and $t = \frac{\lambda}{4} = \frac{\lambda_{air}}{4\mu} = \frac{790}{4 \times 1.8}$

$= 110\ nm = 0.11\ \mu m.$

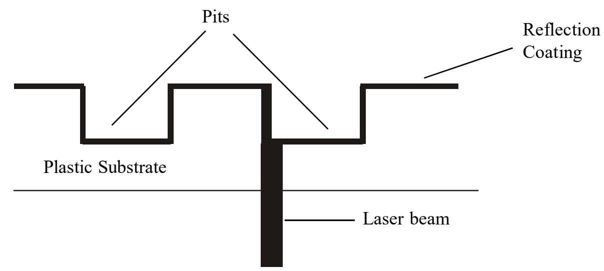

Fig. 30.14

TYPICAL PROBLEMS

26. In a single slit diffraction pattern, (a) find the intensity at a point where the total phase difference between the wavelets from top to bottom of the slit is 66 rad. (b) If this point is 7° away from the central maxima. Find the width of slit. Given: $\lambda = 600\ nm$.

Solution (a) $I = I_o \left[\frac{\sin(33\text{ rad})}{33\text{ rad}}\right]^2 = 9.2 \times 10^{-4}\ I_o$

(b) $a = \frac{B\lambda}{2\pi \sin\theta} = \frac{(66\text{ rad})600 \times 10^{-9}}{2\pi \sin 7°}$

$= 5.16 \times 10^{-5}\ m$ or 0.052 mm (nearly).

27. Consider the arrangement shown in Fig 30.15 (a). The distance *D* is large compared to *d*. Find minimum value of *d* so that there is a dark fringe at *O*. For the same value of *d* find *x* at which next bright fringe is formed.

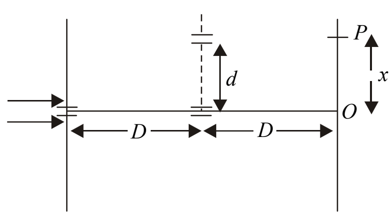

Fig. 30.15 (a)

Solution Path difference = AB + BO – 2D

$$2\sqrt{(D^2 + d^2)} - 2D = \frac{\lambda}{2}$$

or $$2\sqrt{(D^2 + d^2)} = \frac{\lambda}{2} + 2D$$

or $$4(D^2 + d^2) = \frac{\lambda^2}{4} + 4D^2 + 2\lambda D$$

Eliminate $\frac{\lambda^2}{4}$ as $\lambda << D$. or $d = \sqrt{\frac{\lambda D}{2}}$

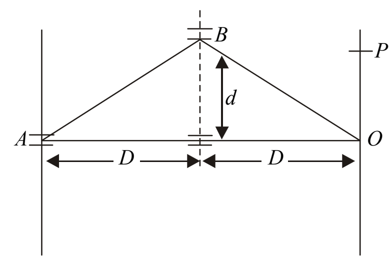

Fig. 30.15 (b)

Fig 30.15 (c) illustrates that if $PO = x = d$, path differnece will be zero and we will observe first maxima.

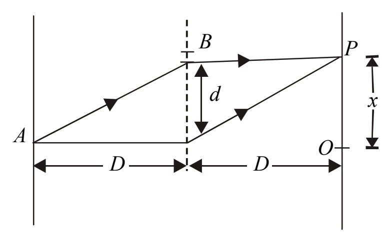

Fig. 30.15 (c)

28. A narrow slit *S* transmitting light of wavelength λ is placed a distance *d* above a large plane mirror as shown in Fig 30.16 (a). The light coming directly from the slit and that after reflection interfere converge at *P* on the screen placed at a distance *D* from the slit. What will be the intensity at a point just above *O*? What will be *x* for which first maxima occurs?

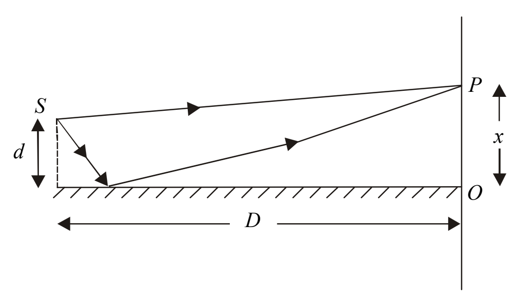

Fig. 30.16 (a)

Solution At just above O intensity is zero because reflection inttroduces an additional path difference of $\frac{\lambda}{2}$

$$x_n = \frac{(2n-1)\lambda d}{2d}$$

Put $n = 1$ and $d = 2d$ as image of s will be $2d$ apart as illustrated in Fig. 30.16 (b).

$$x_1 = \frac{\lambda D}{2(2d)} = \frac{\lambda D}{4d}$$

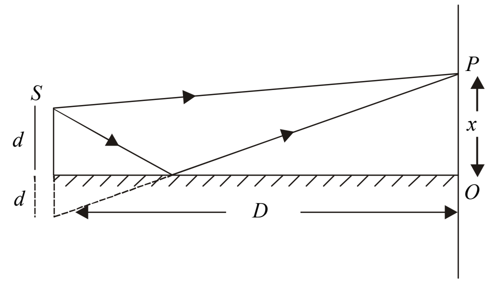

Fig. 30.16 (b)

29. Fig 30.17 (a) shows two coherent sources S_1 and S_2 which emit light of wavelength λ in phase. The separation between the sources is 3λ. A circular wire of radius $R >> I$ is placed symmetrically to S_1 and S_2 as illustrated. Find the angular positions θ on the wire for which constructive interference occurs.

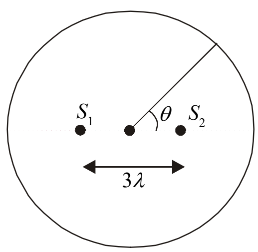

Fig. 30.17 (a)

Solution From Fig 30.17 (b) the path difference $S_1K = S_1S_2 \cos\theta = 3\lambda \cos\theta$

For constructive interference $3\lambda \cos\theta = n\lambda$

Putting $n = 0, 1, 2$ and 3.

$$\theta = 90^\circ,\ \theta = \cos^{-1}\frac{1}{3},\ \cos^{-1}\frac{2}{3},\ 0^\circ$$

We have listed positions of one quardrant. In other quadrants these positions will repeat.

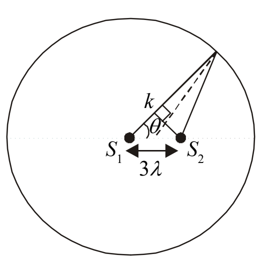

Fig. 30.17 (b)

30. Two coherent point sources S_1 and S_2 vibrating in phase emit light of wavelength λ. The separation between them is 2λ. The light is collected on a screen Σ placed at a distance $D >> \lambda$ from the slit S_1 as shown in Fig 30.18 (a). Find the minimum distance so that intensity at P is equal to intensity at O.

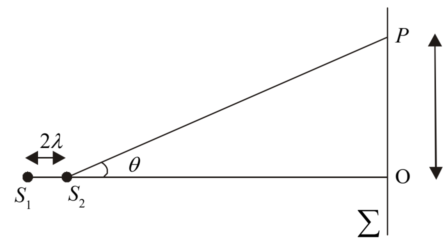

Fig. 30.18 (a)

(a) D (b) $D/3$

(c) $\sqrt{3}D$ (d) $D/2$

Solution (c) $S_1S_2\cos\theta = n\lambda$

$2\lambda\cos\theta = \lambda$

$\theta = 60^\circ$

$x = D\tan 60^\circ = \sqrt{3}D$.

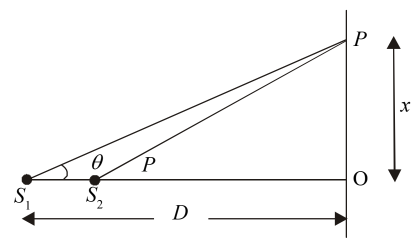

Fig. 30.18 (b)

31. Two trees are 1m apart. A person sees them from a distance of 1 km. Will he see the trees resolved?

(a) Yes (b) No

(c) May be resolved (d) None

[MNR 1996]

Solution (a) For trees to be resolved

$\frac{d}{D} \geq$ resolution power of eye $\frac{d}{D} = \frac{1}{10^3}$

$$RP = \left(\frac{1}{60}\right)^\circ = \frac{1}{60} \times \frac{\pi}{60} = \frac{3.14}{10.8} \times 10^{-3}$$

Since $\frac{d}{D}$ > resolution power of eye.

$\therefore$ Tree appear resolved.

32. Light of wavelength 560 nm goes through a pinhole of 0.2 mm and falls on a wall at a distance of 2 m. What is the radius of the central bright spot formed on the wall?

Solution $R = \frac{1.22\lambda D}{r} = \frac{1.22 \times 560 \times 2 \times 10^{-9}}{0.1 \times 10^{-9}}$

$= 1.37$ cm

33. In a Lloyd's mirror experiment a light wave emitted directly by the source S interferes with reflected light from the mirror. The screen is 1m away form the source S. The size of fringe width is 0.25 mm. The source is moved 0.6 mm above the initial position, the fringe width decreases by 1.5 times. Find the wavelength of light.

[Olympiad 1998]

Solution $\beta = \frac{\lambda D}{d} = 0.25 \times 10^{-3}$ or $\lambda D = \frac{d}{4} \times 10^{-3}$

Case (ii) $\beta = \frac{\lambda D}{d + 1.2 \times 10^{-3}} = \frac{0.25 \times 10^{-3} d}{1.5} = \frac{10^{-3}}{6}$

or $\lambda D = \frac{10^{-3} d}{6} + \frac{1.2 \times 10^{-3} \times 10^{-3}}{6}$

$$\lambda = \frac{d \times 10^{-3}}{4D} = \frac{0.6 \times 10^{-3} \times 10^{-3}}{1.0} = 0.6\ \mu\text{m}$$

$$\frac{d}{4} = \frac{d}{6} + \frac{1.2 \times 10^{-3}}{6} \text{ or } d = 2.4 \text{ mm}$$

34. A convex lens of diameter 8 cm is used to focus a parallel beam of light of wavelength 620 nm. Light is focussed at a distance 20 cm. from the lens. What would be the radius of central bright fringe?

Solution (a) $R = \frac{1.22\lambda D}{r} = \frac{1.22 \times 620 \times 10^{-9} \times 0.2}{4 \times 10^{-2}}$

$= 3.8 \times 10^{-6}$ m.

35. A glass plate (n = 1.53) that is 485μm thick and surrounded by air is illuminated by a beam of white light normal to the plate. (a) What wavelengths in the visible spectrum (400 to 700 nm) are intensified in the reflected beam? (b) What wavelengths are intensified in transmitted beam?

Solution (a) **In reflected light** $2\,\mu t = (2n + 1)\,\frac{\lambda}{2}$

$$\lambda = \frac{4\mu t}{2n+1} = \frac{2970}{2n+1}\ nm = 594\ nm,\ 424\ nm$$

(b) **In transmitted light** $2\,\mu t = n\,\lambda$ or $\lambda = \frac{2\mu t}{n} = \frac{1485}{n}$

$= 495\ nm$

36. In case of linearly polarised light the magnitude of electric field vector

(a) varies periodically with time

(b) increases and decreases linearly with time

(c) does not change with time

(d) is parallel to the direction of propagation

Solution (a) $\because\ E = E_o \sin(\omega t - kx)$, it varies periodically with time.

PASSAGE 1

Read the following passage and answer the questions given at the end.

It is convenient to represent a wave of any sort by means of wave fronts. A wave front is defined as the locus of all points at which the phase of vibration of a physical quantity is the same. Thus, in the case of sound waves spreading out in all direction from a point source, any spherical surface concentric with the source is a possible wave front. Some of these spherical surfaces are the loci of points at which the pressure is a maximum, others where it is a minimum and so on; but the phase of the pressure variations is the same over any spherical surface. It is customary to draw only a few wave fronts, usually those that pass through the maxima and minima of the disturbance. Such wave fronts are separated from one another by one half wavelength.

If the wave is a light wave, the quantity corresponding to the pressure in a sound wave is the electric or magnetic field. It is usually unnecessary to indicate in a diagram either the magnitude or direction of the field, but simply to show the shape of the wave by drawing the wave fronts or their intersections with some reference plane. For example, the electro magnetic waves radiated by a small light source may be represented by spherical surfaces concentric with the source or, as in Figure 30.19 (a) by the intersections of these surfaces with the plane of the diagram. At a sufficiently great distance from the source, where the radii of the sphere have become very large, the spherical surfaces can be considered planes and we have a plane wave as in Figure 30.19 (b).

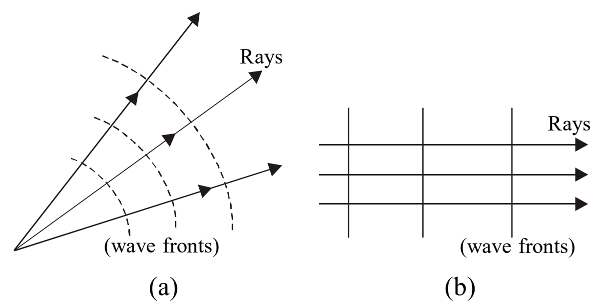

Fig. 30.19

1. The possible type of wave front with a line source is

(a) elliptical (b) spherical

(c) cylindrical (d) planar

2. Antinodal curves represent the points joining

(a) destructive interference

(b) constructive interference

(c) equal phase curves

(d) equal pressure curves

(e) zero pressure curvese

3. The shape of nodal curves is

(a) elliptical (b) parabolic

(c) hyperbolic (d) circular

4. Why do cellular phones sometimes have poor reception inside steel frame office buildings?

(a) The em waves used for cellular phones get reflected from the metals.

(b) The em waves are absorbed by the metal.

(c) Electric field intensity inside the shell is zero.

(d) Metal frame acts like a capacitor and conduction current is not formed.

5. Most cellular phones use frequencies between 806 to 902 MHz. PCS (personal communication systems) work on frequency range.

(a) 550 kHz to 1650 kHz

(b) 3 MHz to 30 MHz

(c) 80 MHz to120 MHz

(d) 1850 to 1990 MHz

Solution **1.** (c), (d)

Solution **2.** (b)

Solution **3.** (c)

Solution **4.** (a)

Solution **5.** (d)

PASSAGE 2

Read the following passage and answer the questions given at the end.

The phenomenon of interference is utilised in non reflective coating for glass. A thin layer or film of hard transparent material with an index of refraction smaller than that of the glass is deposited on the surface of the glass, as in Fig. 30.20 30.20. If the coating has the proper index of refraction, equal quantities of light will be reflected from its outer surface and from the boundary surface between it and the glass. Further more, since in both reflections the light is reflected from a medium of greater index than that in which it is traveling, the same phase change occurs in each reflection. It follows that if the film thickness is $\frac{1}{4}$ wave length in the film (normal incidence is assumed), the light reflected from the first surface will be 180° out of phase with that reflected from the second, and complete distructive interference will result.

The thickness can, of course, be $\frac{1}{4}$ wavelength for only one particular wavelength. This is usually chosen in the yellow green portion of the spectrum (about 550 nm) where the eye is most sensitive. Some reflection then takes place at both longer and shorter wavelengths, and the reflected light has a purple hue. The overall reflection from a lens or prism surface can be reduced in this way from 4 or 5% to a fraction of 1%. The treatment is extremely effective in eliminating stray reflected light and increasing the contrast in an image formed by highly corrected lenses having a large number of air glass surfaces. A commonly used material is magnesium fluoride, MgF_2, with an index of 1.38.

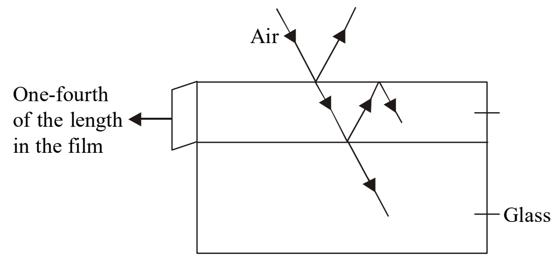

Fig. 30.20

1. Using visible light what is the shortest wavelength which can be measured?

(a) 200 nm (b) 100 nm

(c) 350 nm (d) 175 nm

(e) none of these

2. To achieve maximum reflection

(a) single layer coating be made

(b) alternating multiple layers be used

(c) high refractive index coating be used

(d) highly anti-reflecting coating be made

3. If instead of MgF_2, the coating of a substance whose refractive index is larger than the refractive index of glass was made then interference

(a) would not have occured

(b) would have occured due to reflection of light

(c) would have occured due to refracting light

(d) would have occured due to strong reflection

4. If thickness is variable instead of uniform then interference

(a) will not be observable

(b) the alternate dark and bright fringes will have same form as contour of the film if monochromatic light of wavelength λ such that $t = \lambda/4$ is incident

(c) coloured fringes will be formed if white light is incident

(d) no fringes are formed if white light is incident

5. MgF_2 is coated on lenses used in camera

(a) to make the light beam parallel

(b) to make the transmitted beam more intense

(c) to reflect the undesired light

(d) because the photographic emulsion is more sensitive to modified wavelength (by MgF_2)

Solution **1.** (b) $t = \frac{\lambda}{4} = \frac{400}{4} = 100$ nm.

Solution **2.** (b)

Solution **3.** (c)

Solution **4.** (b), (c) If $t = (2n + 1)\dfrac{\lambda}{4}$ then bright fringe appears. If t varies, different values of λ will satisfy condition at different points.

Solution **5.** (b)

PASSAGE 3

Read the following passage and answer the questions given at the end.

The progress of a wave train through a homogeneous isotropic medium, such as glass, may be determined graphically by Huygens construction. The secondory wavelets in such a medium are spherical surfaces. There exist, however, many transparent crystalline substances which, while homogeneous, are anisotropic. That is, the velocity of a light wave in them is not the same in all directions. Crystals having this property are said to be doubly refracting or birefringent. Two sets of Huygens wavelets propagate from every wave surface in such a crystal, one set being spherical and the other ellipsoidal.

A consequence of this property of anisotropic crystals is that a ray of light striking such a crystal at normal incidence is broken up into two rays as it enters the crystal. The ray that corresponds to wave surfaces tangent to the spherical wavelets is undeviated and is called the ordinary ray. The ray corresponding to the wave surfaces tangent to the ellipsoids is deviated even though the incident ray is normal to the surface, and is called the extraordinary ray. If the crystal is rotated about the incident ray as an axis, the ordinary ray remains fixed but the extraordinary ray revolves around it.

1. If $v_{\text{ordinary}} > v_{\text{extraordinary}}$ then crystal is said to be

(a) positive (b) negative

(c) neutral (d) birefringent

2. In calcite the wave front formed is

(a) spherical (b) elliptical

(c) planar (d) cylindrical

3. The extraordinary waves in Iceland spar

(a) travel faster than speed of light

(b) travel slower than speed of light

(c) wave fronts follow laws of refraction

(d) only ellipsiodal wave fronts observe laws of refraction.

4. Which statement is true?

(a) The secondary wavelets cause interference in YDSE

(b) The secondary wavelets cause diffraction in single slit experiment.

(c) If the collimating and focussing lens are used secondary wavelets do not exist.

(d) Secondary wavelets travel in a straight line.

5. Birefringent crystals can _______.

(a) polarise (plane) light

(b) linearly polarize light

(c) bend incident light

(d) spherically polarise light

6. Which of the following is not anisotropic?

(a) zinc blend (b) quartz

(c) sapphire (d) iron oxide

(e) apatite

7. Electrons can be diffracted (Davisson and Germer's expt.). Can electrons be polarised?

(a) Yes, as their wave is transverse.

(b) Yes, as their wave is longitudinal.

(c) No, as their wave is longitudinal.

(d) No, as they travel in a straight line.

8. Raman effect shows

(a) polarisation (b) quantum nature

(c) Brillouin zone scattering

(d) wave nature of light (e) none of these

9. To measure thickness of a thin film we use

(a) diffraction (b) Interference

(c) $C - V$ measurement (d) colour pattern

Solution **1.** (a), (d)

Solution **2.** (b)

Solution **3.** (a)

Solution **4.** (b)

Solution **5.** (a), (c)

Solution **6.** (a)

Solution **7.** (d)

Solution **8.** (e)

Solution **9.** (a, b, c, d)

PASSAGE 4

Read the following passage and answer the questions given at the end.

A process in which no heat enters or leaves a system is called an adiabatic process. For every adiabatic process, $Q = 0$. This prevention of heat flow may be accomplished either by surrounding the system with a thick layer of heat - insulating material (such as cork, asbestos, fire brick or styrofoam), or by performing the process quickly. The flow of heat requires finite time. So any process performed quickly enough will be practically adiabatic. Applying the first law to an adiabatic process, we get.

$U_2 - U_1 = \nabla U = -W$ (adiabatic process)

Thus the change in the internal energy of a system, in an adiabatic process is equal in magnitude to the work done by the system. If the work W is negative, as when a system is compressed, then W is positive, U_2 is greater then U_1 and the internal energy of the system increases. If W is positive, as when system expands, the internal energy of the system decreases. An increase of internal energy is usually (but not always) accompained by a rise in temperature, and a decrease in internal energy by a temperature drop.

1. A tyre having volume 0.02 m^3 and pressure 2.5 atm suddenly bursts. What is the new volume occupied by the air present?

   (a) 0.036 m^3 (b) 0.063 m^3
   (c) 0.072 m^3 (d) none

2. W_1, W_2, W_3 are work done in adiabatic, isobaric and isothermal process respectively during an expansion process. Arrange them in increasing order.

   (a) $W_1 > W_2 > W_3$ (b) $W_2 > W_1 > W_3$
   (c) $W_3 > W_1 > W_2$ (d) $W_2 > W_3 > W_1$

3. In a thermos bottle cold coffee is rigorously shaken then

   (a) No work is done
   (b) temp remains unchanged
   (c) temp rise (d) temp falls
   (e) work done is numerically equal to gain in internal energy

Solution 1. (a) $P_1 V_1^r = P_2 V_2^r$

or $$V_2 = \left(\frac{P_1 V_1^r}{P_2}\right)^{1/r}$$

$$= \left(\frac{2.5}{1}\right)^{1/1.4} (.02) = .036\text{ m}^3$$

Solution 2. (d)

Solution 3. (c), (e)

QUESTIONS FOR PRACTICE

1. In a Young's double-slit experiment, the fringe width is β. If the entire arrangement is now placed inside a liquid of refractive index μ, the fringe width will become

   (a) $\mu\beta$ (b) $\dfrac{\beta}{\mu}$
   (c) $\dfrac{\beta}{\mu+1}$ (d) $\dfrac{\beta}{\mu-1}$

2. In a Young's double slit experiment, let S_1 and S_2 be the two slits, and C be the centre of the screen. If $\angle S_1CS_2 = \theta$ and λ is the wavelength, the fringe width will be

   (a) $\dfrac{\lambda}{\theta}$ (b) $\lambda\theta$
   (c) $\dfrac{2\lambda}{\theta}$ (d) $\dfrac{\lambda}{2\theta}$

3. When a drop of oil is spread on a water surface, it displays beautiful colours in daylight because of

   (a) disperson of light (b) reflection of light
   (c) polarisation of light (d) interference of light.

4. A light wave can travel

   (a) in vacuum (b) in vacuum only
   (c) in a material medium
   (d) in a material medium only.

5. Two coherent sources of different intensities send waves which interfere. The ratio of maximum intensity to the minimum intensity is 25. The intensities of the sources are in the ratio

   (a) 25 : 1 (b) 5 : 1
   (c) 9 : 4 (d) 625 : 1.

6. Which of the following properties of light conclusively support wave theory of light ?

   (a) Light obeys laws of reflection.
   (b) Speed of light in water is smaller than the speed in vacuum.
   (c) Light shows interference.
   (d) Light shows photoelectric effect.

7. A thin transparent sheet is placed in front of a Young's double slit. The fringe-width will

   (a) increase (b) decrease
   (c) remain same (d) become nonuniform.

8. Four light waves are represented by

   (i) $y = a_1 \sin \omega t$. (ii) $y = a_2 \sin(\omega t + \varepsilon)$.
   (iii) $y = a_1 \sin 2\omega t$. (iv) $y = a_2 \sin 2(\omega t + \varepsilon)$.

Interference fringes may be observed due to superposition of

(a) (i) and (ii) (b) (i) and (iii)

(c) (ii) and (iv) (d) (iii) and (iv).

9. The slits in a Young's double slit experiment have equal width and the source is placed symmetrically with respect to the slits. The intensity at the central fringe is I_0. If one of the slits is closed, the intensity at this point will be

(a) I_0 (b) $\frac{I_0}{4}$

(c) $\frac{I_0}{2}$ (d) $4I_0$.

10. Huygen's principle of secondary wavelets may be used to

(a) find the velocity of light in vacuum

(b) explain the particle behaviour of light

(c) find the new position of a wave front

(d) explain Snell's law.

11. Three observers A, B and C measure the speed of light coming from a source as v_A, v_B and v_C. Observer A moves towards source, C moves away from source and B stays stationary. The surrounding medium is water. Then

(a) $v_A > v_B > v_C$ (b) $v_A < v_B < v_C$

(c) $v_A = v_B = v_C$ (d) $v_B = \frac{1}{2}(v_C + v_A)$

12. If the source of light used in a Young's double slit experiment is changed from red to violet,

(a) the fringes will become brighter

(b) consecutive fringes will come closer

(c) the intensity of minima will increase

(d) the central bright fringe will become a dark fringe

13. When light propagates in vacuum there is an electric field and a magnetic field. These fields

(a) are constant in time

(b) have zero average value

(c) are perpendicular to the direction of propagation of light.

(d) are mutually perpendicular

14. A Young's double slit experiment is performed with white light.

(a) The central fringe will be white.

(b) There will not be a completely dark fringe.

(c) The fringe next to the central will be red.

(d) The fringe next to the central will be violet.

15. Three observers A, B and C measure the speed of light coming from a source to be υ_A, υ_B and υ_C. The observer A moves towards the source and C moves away from the source at the same speed. The observer B stays stationary. The surrounding space is vacuum everywhere.

(a) $\upsilon_A > \upsilon_B > \upsilon_C$. (b) $\upsilon_A < \upsilon_B < \upsilon_C$.

(c) $\upsilon_A = \upsilon_B = \upsilon_C$. (d) $\upsilon_B = \frac{1}{2}(\upsilon_A + \upsilon_C)$.

16. Light waves travel in vacuum along the X-axis. Which of the following may represent the wave fronts ?

(a) $x = c$. (b) $y = c$.

(c) $z = c$. (d) $x + y + z = c$.

17. A light of wavelength 6000 Å in air enters a medium of refractive index 1.5. Inside the medium, its frequency is ν its wavelength is λ.

(a) $\nu = 5 \times 10^{14}$ Hz (b) $\nu = 7.5 \times 10^{14}$ Hz

(c) $\lambda = 4000$ Å (d) $\lambda = 9000$ Å

18. In a Young's double slit experiment let A and B be two slits. Films of thicknesses t_A and t_B and refractive indices μ_A and μ_B, are placed in front of A and B respectively. If $\mu_A t_A = \mu_B t_B$, the central maximum will

(a) not shift (b) shift towards A

(c) shift towards B

(d) option (b), if $t_B > t_A$; option (c) $t_B < t_A$.

19. In a Young's double slit experiment, let A and B be the two slits. A thin film of thickness t and refractive index μ is placed in front of A. Let β = fringe width. The central maximum will shift

(a) towards A (b) towards B

(c) by $t(\mu - 1)\frac{\beta}{\lambda}$ (d) by $\mu t \frac{\beta}{\lambda}$

20. When lights of different colours move through water, they must have different

(a) wavelengths (b) frequencies

(c) velocities (d) amplitudes

21. If white light is used in a Young's double slit experiment,

(a) bright white fringe is formed at the centre of the screen

(b) fringes of different colours are observed clearly only in the first order

(c) the first-order violet fringes are closer to the centre of the screen than the first-order red fringes

(d) the first-order red fringes are closer to the centre of the screen than the first-order violet fringes

22. In a Young's double slit experiment, let β be the fringe width, and let I_0 be the intensity at the central bright fringe. At a distance x from the central bright fringe, the intensity will be

(a) $I_0 \cos\left(\frac{x}{\beta}\right)$ (b) $I_0 \cos^2\left(\frac{x}{\beta}\right)$

(c) $I_0 \cos^2\left(\frac{\pi x}{\beta}\right)$ (d) $\left(\frac{I_0}{4}\right)\cos^2\left(\frac{\pi x}{\beta}\right)$.

23. Choose the correct statement—

(a) Brewster's angle is independent of wavelength of light.

(b) Brewster's angle is independent of nature of reflecting surface.

(c) Brewster's angle is different for different wavelengths.

(d) Brewster's angle depends on wavelength but not on the nature of reflecting surface.

24. A ray of light strikes a glass plate at an angle of 60°. If the reflected and refracted rays are perpendicular to each other the index of refraction of glass is

(a) $\frac{1}{2}$ (b) $\frac{\sqrt{3}}{2}$

(c) $\frac{3}{2}$ (d) 1.732

25. When unpolarised light is incident on a plane glass plate at Brewster's angle, then which of the following statements is correct?

(a) Reflected and refracted rays are completely polarised with their planes of polarisation parallel to each other.

(b) Reflected and refracted rays are completely polarized with their planes of polarization perpendicular to each other.

(c) Reflected light is plane polarised but transmitted light is partially polarised.

(d) Reflected light is partially polarised but refracted light is plane polarised.

26. A ray of light is incident on the surface of a glass plate of refractive index 1.55 at the polarising angle. The angle of refraction is

(a) 0° (b) 147° 11'

(c) 32°49' (d) 57°11'

27. A calcite crystal is placed over a dot on a piece of paper and rotated. On viewing through calcite, one will see

(a) a single dot (b) two stationary dots

(c) two rotating dots

(d) one dot rotating about the other

28. From Brewster's law, it follows that the angle of polarisation depends upon

(a) the wavelength of light

(b) orientation of plane of polarisation

(c) orientation of plane of vibration

(d) none of these

29. Optically active substances are those which

(a) produce polarised light

(b) rotate the plane of polarisation of polarised light

(c) produce double refraction

(d) convert plane polarised light into circularly polarised light

30. Light transmitted by Nicol prism is

(a) unpolarised (b) plane polarised

(c) circularly polarised (d) elliptically polarised

31. A beam of light AO is incident on a glass slab (μ = 1.54) in a direction as shown in Fig 30.21. The reflected ray OB is passed through a Nicol prism. On rotating the Nicol prism we observe that

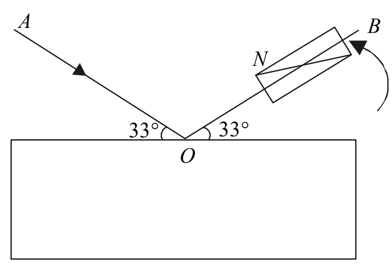

Fig. 30.21

(a) the intensity is reduced to zero and remains zero

(b) the intensity reduces somewhat and rises again

(c) there is no change in intensity

(d) the intensity gradually reduces to zero and then again increases

32. In the propagation of electromagnetic waves the angle between the direction of propagation and the plane of vibration is

(a) π (b) $\frac{\pi}{2}$

(c) $\frac{\pi}{4}$ (d) 0

33. An unpolarised beam of intensity $2a^2$ passes through a thin poloroid. Assuming zero absorption in the poloroid, the intensity of emergent plane polarised light will be

(a) $2a^2$ (b) a^2

(c) $\sqrt{2}a^2$ (d) $\frac{a^2}{\sqrt{2}}$

34. Two Nicols are oriented with their principal planes making an angle of 60°. The percentage of incident unpolarized light which passes through the system is

(a) 50% (b) 100%
(c) 12.5% (d) 37.5%

35. Unpolarised light falls on two polarising sheets placed one on top of the other. What must be the angle between the characteristic directions of the sheets if the intensity of the final transmitted light is one-third the maximum intensity of the first transmitted beam?

(a) 75° (b) 55°
(c) 35° (d) 15°

36. In the above problem if the final intensity is one third the intensity of incident beam, then the corresponding angle will be

(a) 75° (b) 55°
(c) 35° (d) 15°

37. Unpolarised light of intensity $32 Wm^{-2}$ passes through three polarisers such that the transmission axis of the last polarizer is crossed with that of the first. The intensity of final emerging light is $3 Wm^{-2}$. The intensity of light transmitted by first polariser will be

(a) $32\ Wm^{-2}$ (b) $16\ Wm^{-2}$
(c) $8 Wm^{-2}$ (d) $4 Wm^{-2}$

38. In the above problem, the angle between the transmission axes of the first two polarisers will be—

(a) 10° (b) 30°
(c) 45° (d) 60°

39. In YDSE find the missing wavelength in front of one of the slits

(a) $\frac{d^2}{2D}$ (b) $\frac{2d^2}{D}$

(c) $\frac{d^2}{3D}$ (d) $\frac{d^2}{4D}$

40. If YDSE is immersed in a liquid of refractive index μ then fringewidth β

(a) decreases by μ (b) increases by μ
(c) remains unchanged (d) none of these

41. In the visible region of the spectrum the rotation of the plane of polarization is given by

$$\theta = a + \frac{b}{\lambda^2}$$

The optical rotation produced by a particular material is found to be 30° per mm at λ = 500Å and 50° per mm at λ = 4000 Å. The value of *constant a* will be

(a) $+\frac{50°}{9°}$ per mm (b) $-\frac{50°}{9°}$ per mm

(c) $+\frac{9°}{50°}$ per mm (d) $-\frac{9°}{50°}$ per mm

42. In the above problem, the value of constant b in degree Å^2 per mm, will be

(a) $\frac{8}{9}\times 10^9$ (b) $-\frac{8}{9}\times 10^9$

(c) $\frac{9}{8}\times 10^8$ (d) $-\frac{9}{8}\times 10^8$

43. In a diffraction (single slit experiment), slit is exposed by white light. The fringe surrounding the central fringe is

(a) Red (b) Yellow
(c) Violet (d) Green

44. A beam of natural light falls on a system of 6 polaroids, which are arranged in succession such that each polaroid is turned through 30° with respect to the preceding one. The percentage of incident intensity that passes through the system will be—

(a) 100% (b) 50%
(c) 30% (d) 12%

45. A beam of unpolarised light is passed first through a tourmaline crystal A and then through another tourmaline crystal B oriented so that its principal plane is parallel to that of A. The intensity of final emergent light is I. The value of I is

(a) $\frac{I_0}{2}$ (b) $\frac{I_0}{4}$

(c) $\frac{I_0}{8}$ (d) none of these

46. In the above problem, if A is rotated by 45° in a plane perpendicular to the direction of incident ray, then intensity of emergent light will be

(a) $\frac{I}{8}$ (c) $\frac{I}{4}$

(c) $\frac{I}{2}$ (d) none of these

47. A beam of plane polarised light falls normally on a polariser of cross sectional area $3 \times 10^{-4}\ m^2$. The polariser rotates with an angular frequency of 31.4 rad/s. The energy of light passing through the polariser per revolution will be—

(a) 10^{-4} Joule (b) 10^{-3} Joule
(c) 10^{-2} Joule (d) 10^{-1} Joule

48. In the above problem, the intensity of the emergent beam, if flux of energy of the incident ray is 10^{-3} W, will be (in W/m^2)

(a) $\frac{1}{3}$ (b) $\frac{2}{3}$

(c) $\frac{4}{3}$ (d) $\frac{5}{3}$

49. An unpolarised beam of light is incident on a group of four polarising sheets which are arranged in such a way that the characteristic direction of each polarising sheet makes an angle of 30° with that of the preceding sheet. The percentage of incident light transmitted by the first polariser will be

(a) 100% (b) 50%

(c) 25% (d) 12.5%

50. In the above problem, the percentage of incident light transmitted by the second polariser will be—

(a) 12.5% (b) 25%

(c) 37.5% (d) 50%

51. In Q. 49, the percentage of incident light transmitted by the third polarizer will be

(a) 11.5% (b) 17.125%

(c) 22.7% (d) 28.125%

52. In Q. 49, the percentage of incident light transmitted by the fourth polarizer will be

(a) 21.1% (b) 28.125%

(c) 37.5% (d) 50%

53. In Fresnel's biprism experiment the amplitude of second coherent source is four times that of the first. The ratio of their intensities will be

(a) 4 : 1 (b) 1 : 4

(c) 16 : 1 (d) 1 : 16

54. In Young's double slit experiment the distance between two slits S_1 and S_2 is d. Interference pattern is obtained by these slits on a screen distant D from the slits. A dark fringes is produced at point P just in front of S_1, The wavelength of light used is

(a) $\lambda = \frac{D}{d^2}$ (b) $\lambda = \frac{d^2}{D}$

(c) $\lambda = \frac{D}{d}$ (d) $\lambda = \frac{d}{D}$

55. In Fresnel biprism experiment, when light of wavelength 6000 Å is used then 16th bright fringe is obtained at point P. If light of wavelength 4800 Å is used then the order of fringe obtained at point P will be—

(a) 16th (b) 20th

(c) 18th (d) 24th

56. The maximum intensity produced by two coherent waves of intensity I_1 and I_2 will be

(a) $I_1 + I_2$ (b) $I_1^2 + I_2^2$

(c) $I_1 + I_2 + 2$ (d) zero

57. Two independent monochromatic sodium lamps can not produce interference because

(a) The frequencies of the two sources are different

(b) The phase difference between the two sources changes with respect to time

(c) The two sources become coherent

(d) The amplitudes of two sources are different

58. The path difference between two wave fronts emitted by coherent sources of wavelength 5460 Å is 2.1 micron. The phase difference between the wavefronts at that point is

(a) 7.692 (b) 7.692 π

(c) $\frac{7.692}{\pi}$ (d) $\frac{7.692}{3\pi}$

59. The path of difference between two interfering waves at a point on the screen is $\lambda/8$. The ratio of intensity at this point and that at the central fringe will be

(a) 0.853 (b) 8.53

(c) 85.3 (d) 853

60. The two coherent sources of equal intensity produce maximum intensity of 100 units at a point. If the intensity of one of the sources is reduced by 36% by reducing its width then the intensity of light at the same point will be

(a) 90 (b) 89

(c) 67 (d) 81

61. White light is incident on a soap film of thickness 15×10^{-5} cm and refractive index 1.33. Which wavelength is reflected maximum in the visible region?

(a) 26000 Å (b) 8866 Å

(c) 5320 Å (d) 3800 Å

62. If the whole biprism experiment is immersed in water then the fringe width becomes, if the refractive indices of biprism material and water are 1.5 and 1.33 respectively,

(a) 3 times (b) $\frac{3}{4}$ times

(c) $\frac{4}{3}$ times (d) $\frac{1}{3}$ times

63. In a biprism experiment fifth dark fringe is obtained at a point. If a thin transparent film is placed in the path of one of waves, then seventh bright fringe is obtained at the same point. The thickness of the film in terms of wavelength X and refractive index μ will be

(a) $\frac{1.5\lambda}{(\mu-1)}$ (b) $1.5\,(\mu-1)\lambda$

(c) $2.5\,(\mu-1)\lambda$ (d) $\frac{2.5\lambda}{(\mu-1)}$

64. Light of wavelength 7500 Å is incident on a thin glass plate (μ = 1.5) so that the angle of refraction obtained is 30°. If the plate appears dark then the minimum thickness of plate will be

(a) $4000\sqrt{3}$ Å (b) $\frac{8000}{\sqrt{3}}$ Å

(c) $\frac{5000}{\sqrt{3}}$ Å (d) $1000\sqrt{3}$ Å

65. In Fresnel biprism experiment the refractive index for the biprism is μ =3/2 and fringe width obtained is 0.4 mm. If the whole apparatus is immersed as such in water then the fringe width will become ________. (refractive index of water is 4/3)

(a) 0.3 mm (b) 0.225 mm

(c) 0.4 mm (d) 1.2 mm

66. The distance between slit and biprism and that between biprism and screen each is 0.4 m. The obtuse angle of biprism is 179° and refractive index is 1.5. If the fringe width is 1.8×10^{-4} m then the distance between imaginary sources will be

(a) 8.7 mm (b) 4.36 mm

(c) 1.5 mm (d) 3.5 mm

67. In the above problem, the wavelength of light will be

(a) 7850 Å (b) 6930 Å

(c) 5890 Å (d)3750 Å

68. In Young's double slit experiment one slit is covered with red filter and another slit is covered by green filter, the interference pattern will be

(a) red (b) green

(c) yellow (d) invisible

69. In biprism experiment, fringes are obtained by white light source. The fringe nearest the central fringe will be

(a) yellow (b) green

(c) violet (d) red

70. The distance between two coherent sources produced by a biprism is 1.0 mm. When distance between the source and the screen is 0.9 m the fringe width obtained is 0.12 mm. If the screen is placed at a distance of 1.8 m then fringe width will be

(a) 0.6 mm (b) 0.8 mm

(c) 0.9 mm (d) 0.24 mm

71. In Young's double slit experiment 62 fringes are visible in the field of view with sodium light (λ = 5893Å). If green light (λ = 5461Å) is used then the number of visible fringes will be.

(a) 62 (b) 67

(c) 85 (d) 58

72. In Young's double slit experiment two light beams of wavelengths λ_1 = 6000 Å and λ_2 = 4800 Å are used. The distance between two slits is 2.5 mm. The distance between slits and the screen is 1.5 m. The distance between the central maxima obtained with two beams will be

(a) zero (b) 1.872 mm

(c) 2.872 mm (d) 2.652 mm

73. In the above problem the distance of seventh dark fringe for λ_2 from central maximum will be

(a) 1.652 mm (b) 1.872 mm

(c) 2.872 mm (d) 2.652 mm

74. Tenth fringe of wavelength 4000 Å coincides with 8th fringe of wavelength λ. Then λ is

(a) 50 nm (b) 555 nm

(c) 450 nm (d) none

75. Which of the following formula is incorrect in a biprism?

(a) $d = \sqrt{d_1 d_2}$ (b) $d = 2a(\mu - 1)\alpha$

(c) $d = \frac{D\lambda}{\beta}$ (d) $d = \frac{d_1^2}{d_2}$

76. The ratio of phase difference and path difference is

(a) $2p$ (b) $\frac{2\pi}{\lambda}$

(c) $\frac{\lambda}{2\pi}$ (d) $\frac{\pi}{\lambda}$

77. The correct relation between time interval ∂ and phase difference δ is

(a) $\partial = \frac{T}{2\pi}\delta$ (b) $\partial = \frac{2\pi}{T}\delta$

(c) $\partial = 2\pi\delta$ (d) $\partial = \frac{\delta}{2\pi}$

78. If the amplitude of two light waves are 1 and 2 units respectively then the average intensity will be

(a) 3 units (b) 1 units

(c) 5 units (d) $\sqrt{3}$ units

79. Interference event is observed

(a) only in transverse waves

(b) only in longitudinal waves

(c) in both types of waves

(d) none

80. The nature of light which is verified by the interference event is

(a) particle nature (b) wave nature
(c) dual nature (d) quantum nature

81. In the phenomenon of interference, energy is
(a) destroyed at bright fringes
(b) created at dark fringes
(c) conserved, but it is redistributed
(d) same at all points

82. For which colour is the fringe width minimum?
(a) violet (b) red
(c) green (d) yellow

83. How many colours comprise white light?
(a) infinite (b) seven
(c) three (d) fourteen

84. Monochromatic light is that light in which
(a) single wavelength is present
(b) various wavelengths are present
(c) red and violet light is present
(d) yellow and red light is present.

85. The refracting angle of biprism is
(a) 179° (b) 1°
(c) 1/2° (d) 90°

86. In biprism experiment the light source is
(a) extended (b) narrow
(c) multichromatic (d) all of above

87. A very thin film in reflected white light appears
(a) coloured (b) white
(c) black (d) red

88. The time of coherence is of the order of
(a) 10^{-4} s (b) 10^{-8} s
(c) 10^{-6} s (d) 10^{-2} s

89. If the frequency of light emitted by a source in an interference experiment is made four times then the fringe width will become-
(a) four times (b) three times
(c) one fourth (d) half

90. In Young's double slit experiment if the maximum intensity of light is I_{max} then the intensity at path difference $\lambda/2$ will be
(a) I_{max} (b) $\frac{I_{max}}{2}$
(c) $\frac{I_{max}}{4}$ (d) Zero

91. The correct curve between fringe width β and distance between the slits (d) is

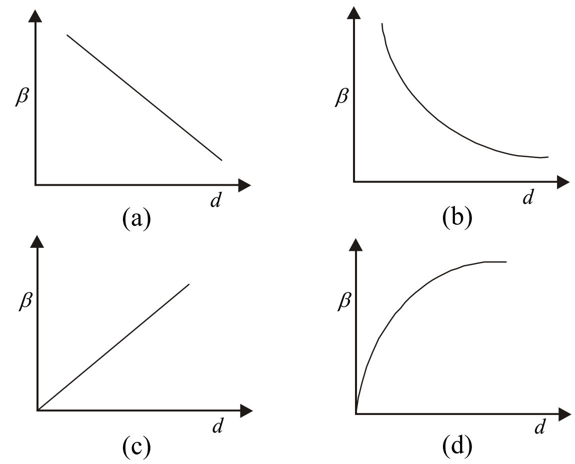

Fig. 30.22

92. Two coherent waves are represented by $y_1 = a_1 \cos \omega t$ and $y_2 = a_2 \sin \omega t$. The resultant intensity due to interference will be
(a) $(a_1 + a_2)$ (b) $(a_1 - a_2)$
(c) $\left(a_1^2 + a_2^2\right)$ (d) $\left(a_1^2 + a_2^2\right)$

93. Interference pattern can be produced by two identical sources. Here the identical sources mean that
(a) their size is same
(b) their wavelength is same
(c) the intensity of light emitted by them is same
(d) the amplitudes of light waves emitted by them are same

94. In biprism experiment when the slit and the eyepiece are set at 1cm and 100 cm, the width of 10 fringes is found to be 9.72 mm. If the distances between the images formed in the eyepiece in two positions of lens are 0.3 mm and 1.2 mm respectively then the wavelength of light used is
(a) 5832 Å (b) 5840 Å
(c) 5820 Å (d) 5700 Å

95. If in Young's double slit experiment, the distance between the slits is halved and the distance between slit and screen is doubled, then the fringe width will become
(a) half (b) double
(c) four times (d) unchanged

96. In coherent sources it is necessary that their
(a) amplitudes are same
(b) wavelengths are same
(c) frequencies are same
(d) initial phase remains constant

97. The intensity of central fringe in the interference pattern produced by two identical slits is I. When one of the slits is closed then the intensity at the same point is I_0. The relation between I and I_0 is

(a) $I = 4I_0$ (b) $I = 2I_0$

(c) $I = I_0$ (d) $I = \frac{I_0}{2}$

98. The fringe width for red colour as compared to that for violet colour is approximately

(a) three times (b) double

(c) four times (d) eight times

99. Light of wavelength 6.5×10^{-7} meter is made incident on two slits 1mm apart. The distance between third dark fringe and fifth bright fringe on a screen distant 1 m from the slits will be

(a) 0.35 mm (b) 0.65 mm

(c) 1.63 mm (d) 3.25 mm

100. The oil layer on the surface of water appears coloured due to interference. For this effect to be visible the thickness of oil layer will be

(a) 1 mm (b) 1 cm

(c) 100 Å (d) 1000 Å

101. In Young's double slit experiment the ratio of the slit widths is 1 : 4. The ratio of maximum and minimum intensities in the interference pattern will be

(a) 4 : 9 (b) 9 : 4

(c) 9 : 1 (d) 1 : 9

102. In Young's double slit experiment the ratio of maximum and minimum intensity in the interference experiment is 9. It means that the

(a) ratio of their amplitudes is 4

(b) ratio of their amplitudes is 2

(c) intensities due to two slits are 4 units and 1 unit respectively

(d) intensities due to two slits are 5 units and 4 units respectively

103. Intensity of light depends on

(a) amplitude (b) frequency

(c) wavelength (d) velocity

104. In Young's double slit experiment the source *S* and two slits *A* and *B* are lying in a horizontal plane. The slit *A* is above slit *B*. The fringes are obtained on a vertical screen *K*. The optical path from *S* to *B* is increased by putting a transparent material of higher refractive index. The path from *S* to *A* remains unchanged. As a result of this the fringe pattern moves some what

(a) upwards (b) downwards

(c) towards left horizontally

(d) towards right horizontally

105. In Fresnel's biprism experiment the coherent sources are obtained by

(a) interference (b) reflection

(c) refraction (d) total internal reflection

106. The colour of bright fringe nearest the central achromatic fringe in the interference pattern with white light will be

(a) violet (b) red

(c) green (d) yellow

107. In Young's double slit experiment the intensities of dark and bright fringes are I and 41 respectively. The ratio of amplitudes of sources is

(a) 4 : 1 (b) 1 : 3

(c) 3 : 1 (d) 1 : 2

108. When a thin film of thickness *t* is placed in the path of light wave emerging out of S_1 then increase in the length of optical path will be

(a) $(\mu - 1)t$ (b) $(\mu + 1)t$

(c) μt (d) $\frac{\mu}{t}$

109. A thin sheet of mica is placed in the path of S_2.The fringes will get shifted towards

(a) S_1 (b) S_2

(c) both sides

(d) first towards S_2 and then towards S_1

110. Two coherent waves of light will not produce constructive interference if the phase difference between them, is

(a) 0° (b) 360°

(c) 720° (d) 90°

111. In Young's double slit experiment, the interference pattern obtained with white light will be

(a) the central fringe bright and alternate bright and dark fringes

(b) the central fringe achromatic and coloured fringes for small path difference

(c) the central fringe dark

(d) the central fringe coloured

112. Two coherent sources with intensity ratio β produce interference. The fringe visibility will be

(a) $\frac{2\sqrt{\beta}}{1+\beta}$ (b) 2β

(c) $\frac{2}{(1+\beta)}$ (d) $\frac{\sqrt{\beta}}{1+\beta}$

113. In Fresnel's biprism experiment a mica sheet of refractive index 1.5 and thickness 6×10^{-6} m is placed in the path of one of interfering beams as a result of which the central fringe gets shifted through five fringe widths. The wavelength of light used is

(a) 6000 Å (b) 8000 Å

(c) 4000 Å (d) 2000 Å

114. What will be the distance between two slits which, when illuminated by light of wavelength 5000 Å, produce fringes of width 0.5 mm on a screen distant 1 meter from the slits?

(a) 10^{-2} meter (b) 10^{-3} meter

(c) 10^{-4} meter (d) 10^{-6} meter

115. If the ratio of maximum and minimum intensities in an interference pattern is 36 : 1 then the ratio of amplitudes of two interfering waves will be

(a) 5 : 7 (b) 7 : 4

(c) 4 : 7 (d) 7 : 5

116. Fringes are obtained with the help of a biprism in the focal plane of an eyepiece distant 1 meter from the slit. A convex lens produces images of the slit in two positions between biprism and eyepiece. The distances between two images of the slit in two positions are 4.05×10^{-3} m and 2.90×10^{-3} m respectively. The distance between the slits will be

(a) 3.43×10^{-3} m (b) 0.343 m

(c) 0.0343 m (d) 34.3 m

117. The device which produces highly coherent sources is

(a) Fresnel biprism (b) Young's double slit

(c) LASER (d) Lloyd's mirror

118. In Young's double slit experiment, if the sodium light is replaced by violet light of same intensity then in the interference pattern

(a) β will decrease (b) β will increase

(c) I will decrease (d) I will increase

119. The equations of waves emitted S_1, S_2, S_3 and S_4 are respectively $y_1 = 20 \sin(100\pi t)$, $y_2 = 20 \sin(200\pi t)$, $y_3 = 20 \cos(100\ \pi\ t)$ and $y_4 = 20 \cos(100\pi\ t)$. The phenomenon of interference will be produced by

(a) y_1 and y_2 (b) y_2 and y_3

(c) y_1 and y_3

(d) Interference is not possible

120. In double slit experiment the distance between two slits is 0.6 mm and these are illuminated with light of wavelength 4800 Å. The angular width of dark fringe on the screen distant 120 cm from slits will be

(a) 8×10^{-4} Radian (b) 6×10^{-4} Radian

(c) 4×10^{-4} Radian (d) 16×10^{-4} Radian

121. In the above problem the ratio of intensities at the centre and at a distance of 1.2 mm from centre will be

(a) 1 : 2 (b) 1 : 1

(c) 4 : 1 (d) 1 : 4

122. Two coherent sources of wavelength 6.2×10 m produce interference. The path difference corresponding to 10th order maximum will be

(a) 6.2×10^{-6} m (b) 3.1×10^{-6} m

(c) 1.5×10^{-6} m (d) 12.4×10^{-6} m

123. In the above problem the path difference corresponding to the dark fringe between third and fourth maxima will be-

(a) 4.17×10^{-6} m (b) 2.17×10^{-6} m

(c) 6.17×10^{-6} m (d) 8.17×10^{-6} m

124. In Fresnel biprism experiment the distance between the source and the screen is 1m and that between the source and biprism is 10 cm. The wavelength of light used is 6000 Å. The fringe width obtained is 0.03 cm and the refracting angle of biprism is 1. The refractive index of the material of biprism is

(a) 1.531 (b) 1.573

(c) 1.621 (d) 1.732

125. A mica sheet of thickness 1.964 micron and refractive index 1.6 is placed in the path of one of the interfering waves. Now the mica sheet is removed and the distance between the slit and the screen is doubled. If this state the distance between two consecutive maxima or minima is equal to the displacement of fringe pattern on placing mica sheet, the wavelength of monochromatic light used is

(a) 5892 Å (b) 5269 Å

(c) 6271Å (d)3875 Å

126. The slits in Young's double slit experiment, are 0.5 mm apart and interference pattern is observed on a screen distant 100 cm from the slits. It is found that the 9th bright fringe is at a distance of 8.835 mm from the second dark fringe. The wavelength of light will be

(a) 7529 Å (b) 6253 Å

(c) 6779 Å (d) 5890 Å

127. In double slit experiment fringes are obtained using light of wavelength 4800 Å. One slit is covered with a thin glass film of refractive index 1.4 and another slit is covered by a film of same thickness but refractive index 1.7. By doing so the central fringe is shifted to fifth bright fringe in the original pattern. The thickness of glass film is

(a) 2×10^{-3} mm (b) 4×10^{-3} mm

(c) 6×10^{-3} mm (d) 8×10^{-3} mm

128. A glass plate of thickness 12×10^{-3} mm is placed in the path of one of the interfering beams in Young's double slit arrangement. Light of wavelenght 60000 Å is used in the arrangement. If the central band is displaced by a distance equal to the width of 10 bands then the refractive index of glass will be

(a) $\frac{5}{4}$ (b) $\frac{4}{3}$

(c) $\frac{3}{2}$ (d) $\frac{2}{1}$

129. In the above problem, what should be the thickness of a diamond plate of refractive index 2.5 which will restore the central band to its original position?

(a) 2×10^{-3} mm (b) 4×10^{-3} mm

(c) 8×10^{-3} mm (d) 6×10^{-3} mm

130. Light of wavelength 5880A is incident on a thin glass plate ($\mu = 1.5$) such that the angle of refraction in the plate is 60°. The minimum thickness of the plate, so that it appears dark in the reflected light will be

(a) 3920 Å (b) 4372 Å

(c) 5840 Å (d) 6312 Å

131. The parallel rays of white light are made incident normally on an air film of uniform thickness. 250 fringes are seen in the transmitted light between 4000 Å and 6500 Å. Thickness of air film is

(a) 0.17mm (b) 0.15mm

(c) 0.13 mm (d) 0.11mm

132. White light is normally incident on a soap film. The thickness of the film is 5×10^{-7} meter and its refractive index is 1.33. Which wave length will be reflected maximum in the visible region?

(a) 26600 Å (b) 8860 Å

(c) 5320 Å (d) 3800 Å

133. In Young's double slit experiment the phase difference between the waves reaching the central fringe and third bright fringe will be

(a) zero (b) 2π

(c) 4π (d) 6π

134. The ratio of slit widths in Young's double slit experiment is 4 : 9. The ratio of maximum and minimum intensities will be

(a) 169 : 25 (b) 81 : 16

(c) 13 : 5 (d) 25 : 1

PASSAGE 1

Read the following passage and answer the questions given at the end.

Your friend who is quite brilliant in studies and has solved quite good numbers of problems in physics. He visited you at your house one day. You had initially some gossip and after a few minutes your friend asked you to solve a problem on YDSE. He said assume two sources S_1 and S_2 placed at $y = -d$ and $y = +d$ respectively. These point sources are monochromatic and emit coherent waves of wavelength λ. See Fig 30.23.

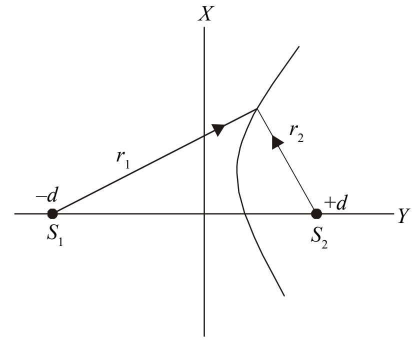

Fig. 30.23

1. The nodal curves are ____.

(a) hyperbolic (b) parabolic

(c) elliptic (d) none of these

2. The antinodal curves are ____.

(a) parabolic (b)circular

(c) hyperbolic (d) elliptic

3. The curves which are made with constant phase difference for r_1 and r_2 rays are

(a) circular (b) parabolic

(c) elliptic (d) hyperbolic

Solution **1.** (a)

Solution **2.** (c)

Solution **3.** (d)

PASSAGE 2

Read the following passage and answer the questions given at the end.

Figure ilustrates the interference experiment with fresnel mirrorr. The angle between the mirrors $\alpha = 12'$. The distances from the mirrors intersection line to the narrow slit S and the screen Σ are equal to $r = 10$ cm and $b = 130$ cm respecitvely. The monochromatic wavelength of light $\lambda = 550$ nm.

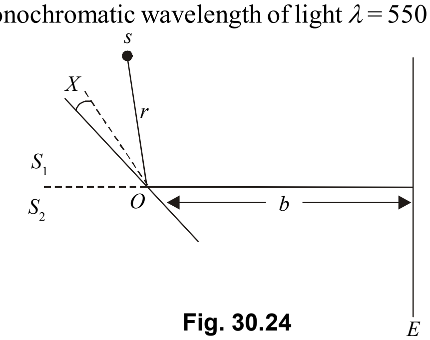

Fig. 30.24

1. Find fringe width and number of possible maxima on the screen Σ.

(a) 1.1 mm, 8 (b) 1.1 mm, 9

(c) 0.9 mm, 8 (d) 0.9 mm, 9

2. The shift of the interference pattern on the screen when the slit is displaced by $Sl = 1$ mm along the arc of radius r with centre at 0.

(a) 4 mm (b) 6 mm

(c) 10 mm (d) 13 mm

3. At what maximum width δ_{max}, of the slit are the interference fringes on the screen observed still sharp?

(a) 42 μm (b) 36 μm

(c) 64 μm (d) none of these

$$D = b + r = 1.4 \text{ m}$$

Solution **1.** (b) $d = S_1 S_2 = 2r\delta = \dfrac{2\times.1\times1}{5\times57}$ rad

$$\beta = \frac{\lambda D}{d} = \frac{550\times10^{-9}\times1.4}{\frac{.2}{5\times57}} = 1.1 \text{ mm}$$

Number of possible maxima

$$= \frac{2b\alpha}{\beta} = \frac{2\times1.3\times.2}{1.1\times10^{-3}\times5\times57} = 8.3$$

$$n = 1 + 8.3 = 9$$

Solution **2.** (d) The mirror will rotate by $\dfrac{\Delta l}{r}$ or rotation of reflected ray = $\dfrac{\Delta l}{r}$ shift in fringe magnitude

$$= \frac{b\Delta l}{r} = 1.3\times(10)^2 = 13 \text{ mm}$$

Solution **3.** (a) $\dfrac{b\delta_{max}}{r} = \dfrac{\beta}{2}$

$$\Rightarrow \quad \delta_{max} = \frac{\beta r}{2b} = \frac{10^{-3}\times1.1\times(.1)}{2\times1.3} = 42\,\mu m$$

PASSAGE 3

Read the following passage and answer the questions given at the end.

Interference of light refers to the modification in the intensity distribution of light in a region due to superposition of light waves. Points where the waves arrive in phase are points of maximum intensity (called maxima), whereas minima are obtained when two waves arrive at a point out of phase. For production of interference pattern on a screen, it is essential that the sources producing interference be coherent sources.

1. The interference of light was first demonstrated experimentally by

(a) Sir Isaac Newton (b) Michelson

(c) Fraunhoffer (d) Thomas Young

2. For bright fringes, the path difference due to reflected light is must be equal to

(a) $2n\pi$ (b) $(2n+1)\dfrac{\pi}{2}$

(c) $n\lambda$ (d) $(2n+1)\dfrac{\lambda}{2}$

3. Coherent sources are those

(a) whose wavelength is same

(b) whose frequency is same

(c) whose phase is same

(d) which maintain a constant phase difference

Solution **1.** (d)

Solution **2.** (d)

Solution **3.** (d)

PASSAGE 4

Read the following passage and answer the questions given at the end.

The working of a LASER can be understood from the principles of ordinary light emission. A photon of light is emitted when an electron falls from a higher energy level to a lower energy level. The usual methods of atomic excitations results in these downward jumps in a random way, resulting in incoherent light emission.

To obtain a coherent beam of light, electrons in the ground state are trapped in a metastable state at an energy level midway between the ground state and the excited state. Electrons can exist in the metastable state for a long enough time. When the number of electrons in metastable state becomes greater than those in the ground state. The phenomenon is called population inversion. Then the electrons from metastable state make transition to ground state.

1. Light produced by LASER is

(a) monochromatic but not coherent

(b) monochromatic and coherent

(c) coherent but not monochromatic

(d) neither coherent nor monochromatic

2. If the wavelength of light emitted when an electron falls from the first excited state to the ground state is λ, the wavelength of emitted radiation when an electron fall from metastable state to the ground state will be

(a) greater than λ (b) less than λ

(c) λ (d) cannot be determined

3. In Young's double slit experiment, interference pattern will not be seen if one uses

(a) a LASER as the source of light

(b) two LASER sources in front of two slits

(c) two sodium light lamps in front of two slits

(d) in both (b) and (c) above

4. A three dimensional photograph of an object is obtained using

(a) spectrography (b) holography

(c) photography (d) shadow photography

Solution **1.** (b)

Solution **2.** (d)

Solution **3.** (d)

Solution **4.** (b)

Answers to Questions for Practice

1.	(b)	**2.**	(a)	**3.**	(d)	**4.**	(a,c)	**5.**	(c)	**6.**	(b,c)	**7.**	(c)
8.	(a,d)	**9.**	(b)	**10.**	(c,d)	**11.**	(a,d)	**12.**	(b)	**13.**	(b,c,d)	**14.**	(a,b,d)
15.	(c,d)	**16.**	(b)	**17.**	(a,c)	**18.**	(d)	**19.**	(a,c)	**20.**	(a,b,c)	**21.**	(a,b,c)
22.	(c)	**23.**	(c)	**24.**	(d)	**25.**	(c)	**26.**	(c)	**27.**	(d)	**28.**	(a)
29.	(b)	**30.**	(b)	**31.**	(d)	**32.**	(d)	**33.**	(b)	**34.**	(c)	**35.**	(b)
36.	(c)	**37.**	(b)	**38.**	(b)	**39.**	(c)	**40.**	(c)	**41.**	(b)	**42.**	(a)
43.	(c)	**44.**	(d)	**45.**	(a)	**46.**	(c)	**47.**	(a)	**48.**	(d)	**49.**	(b)
50.	(c)	**51.**	(d)	**52.**	(a)	**53.**	(d)	**54.**	(b)	**55.**	(b)	**56.**	(c)
57.	(b)	**58.**	(b)	**59.**	(a)	**60.**	(d)	**61.**	(c)	**62.**	(a)	**63.**	(d)
64.	(c)	**65.**	(d)	**66.**	(d)	**67.**	(a)	**68.**	(d)	**69.**	(c)	**70.**	(d)
71.	(b)	**72.**	(a)	**73.**	(b)	**74.**	(a)	**75.**	(d)	**76.**	(b)	**77.**	(a)
78.	(c)	**79.**	(c)	**80.**	(b)	**81.**	(c)	**82.**	(a)	**83.**	(b)	**84.**	(a)
85.	(c)	**86.**	(b)	**87.**	(c)	**88.**	(b)	**89.**	(c)	**90.**	(d)	**91.**	(b)
92.	(c)	**93.**	(b)	**94.**	(a)	**95.**	(c)	**96.**	(d)	**97.**	(a)	**98.**	(b)
99.	(c)	**100.**	(d)	**101.**	(c)	**102.**	(c)	**103.**	(a)	**104.**	(b)	**105.**	(c)
106.	(a)	**107.**	(c)	**108.**	(a)	**109.**	(b)	**110.**	(d)	**111.**	(a)	**112.**	(b)
113.	(a)	**114.**	(a)	**115.**	(b)	**116.**	(d)	**117.**	(a)	**118.**	(c)	**119.**	(a)
120.	(d)	**121.**	(a)	**122.**	(b)	**123.**	(a)	**124.**	(b)	**125.**	(b)	**126.**	(a)
127.	(d)	**128.**	(d)	**129.**	(c)	**130.**	(b)	**131.**	(a)	**132.**	(c)	**133.**	(c)
134.	(d)												

EXPLANATION

18(d) Additional path difference due to the two films

$= (\mu_B - 1)t_B - (\mu_A - 1)t_A = t_A - t_B.$

19(a,c) Let d = distance between the slits,

λ = wavelength of light,

D = distance from the slits to the screen.

For a point P on the screen at a distance x from the centre of the screen, path difference $= \Delta = x\dfrac{d}{D}$.

Path difference introduced due to film $= t(\mu - 1)$.

For central maximum at P, $x\dfrac{d}{D} = t(\mu - 1)$

or $x = t(\mu - 1)\dfrac{D}{d}$.

Now, $\beta = \dfrac{\lambda D}{d}$

or $\dfrac{D}{d} = \dfrac{\beta}{\lambda}$

$\therefore \quad x = t(\mu - 1)\dfrac{\beta}{\lambda}$.

22(c) $\Delta = x\dfrac{d}{D}$

$\therefore \quad$ phase difference $= \phi = \dfrac{2\pi}{\lambda}\Delta$.

Let a = amplitude at the screen due to each slit.

$\therefore \quad I_0 = k(2a)^2 = 4ka^2$, where k is a constant.

For phase difference ϕ, amplitude $= A = 2a\cos(\phi/2)$.

Intensity, $I = kA^2 = k(4a^2)\cos^2(\phi/2) = I_0\cos^2\left(\dfrac{\pi}{\lambda}\Delta\right)$

$= I_0\cos^2\left(\dfrac{\pi}{\lambda}\cdot\dfrac{xd}{D}\right) = I_0\cos^2\left(\dfrac{\pi x}{\beta}\right)$.