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WAVE OPTICS

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WAVE THEORY OF LIGHT

This theory was enunciated by Hygen in a hypothetical medium known as luminiferrous ether.

Ether is that imaginary medium which prevails in all space, in isotropic, perfectly elastic and massless.

The different colours of light are due to different wave lengths of these waves.

The velocity of light in a medium is constant but changes with change of medium.

This theory is valid for all types of waves.

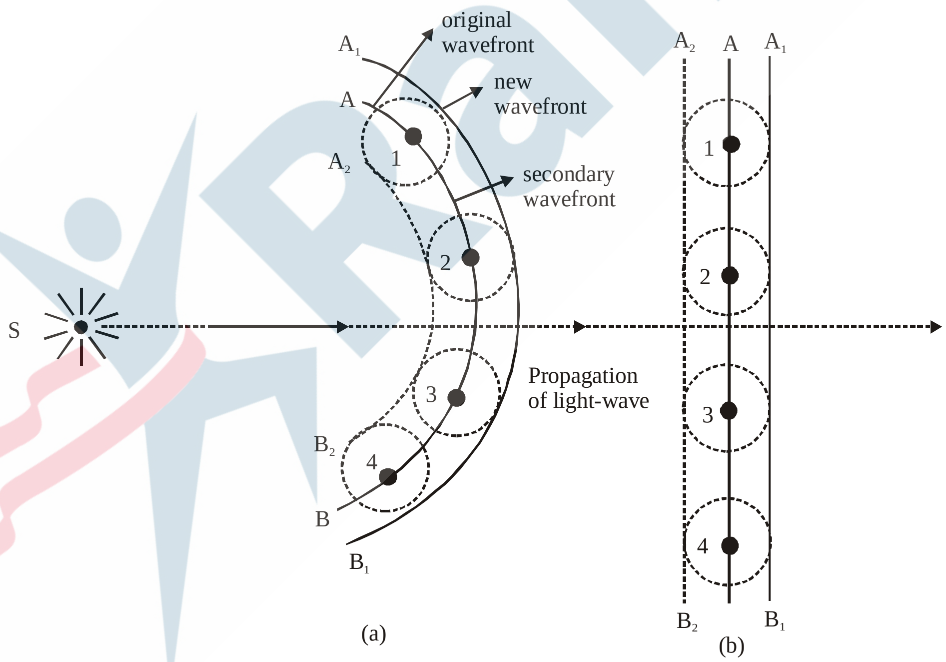
(i) The locus of all ether particles vibrating in same phase is known as wavefront.

(ii) Light travels in the medium in the form of wavefront.

(iii) When light travels in a medium then the particles of medium start vibrating and consequently a disturbance is created in the medium.

(iv) Every point on the wave front becomes the source of secondary wavelets. It emits secondary wavelets in all directions which travel with the speed of light (v),

The tangent plane to these secondary wavelets represents the new position of wave front.



The phenomena explained by this theory

(i) Reflection, refraction, interference, diffraction, polarisation and double refraction.

(ii) Rectilinear propagation of light.

(iii) Velocity of light in rarer medium being grater than that in denser medium.

Phenomena not explained by this theory

(i) Photoelectric effect, Compton effect and Raman effect.

(ii) Backward propagation of light.

WAVE FRONT, VARIOUS TYPES OF WAVE FRONT AND RAYS

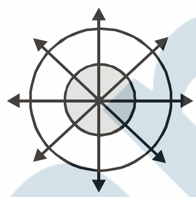
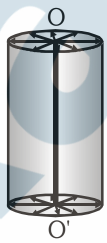
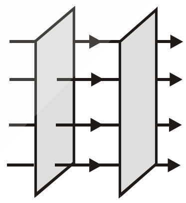
- **Wavefront**

  The locus of all the particles vibrating in the same phase is known as wavefront.

- **Types of wavefront**

  The shape of wavefront depends upon the shape of the light source originating that wavefront. On the basis of there are three types of wavefront.

Comparative study of three types of wavefront

S.No.	Wavefront	Shape of light source	Diagram of shape of wavefront	Variation of amplitude with distance	Variation of intensity with distance
1.	Spherical	Point source		$A \propto \frac{1}{d}$ or $A \propto \frac{1}{r}$	$I \propto \frac{1}{r^2}$
2.	cylindrical	Linear or slit		$A \propto \frac{1}{\sqrt{d}}$ or $A \propto \frac{1}{\sqrt{r}}$	$I \propto \frac{1}{r}$
3.	Plane	Extended large source situated at very large distance		A = constant	I = constant

CHARACTERISTIC OF WAVEFRONT

(a) The phase difference between various particles on the wavefront is zero.

(b) These wavefronts travel with the speed of light in all directions in an isotropic medium.

(c) A point source of light always gives rise to a spherical wavefront in an isotropic medium.

(d) In an anisotropic medium it travels with different velocities in different directions.

(e) Normal to the wavefront represents a ray of light.

(f) It always travels in the forward direction of the medium.

RAY OF LIGHT

The path of the light energy from one point to another is known as a ray of light.

(a) A line drawn at right angles to the wavefront is defined as a ray of light, which is shown by arrows in previous diagram of shape of wavefront.

(b) It represents the direction of propagation of light.

1. INTERFERENCE OF LIGHT

When two light waves of same frequency with zero initial phase difference or constant phase difference superimpose over each other, then the resultant intensity in the region of superposition is different from the sum of intensity of individual waves.

This modification in intensity in the region of superposition is called interference.

(a) Constructive interference

When resultant intensity is greater than the sum of two individual wave intensities $[I > (I_1 + I_2)]$, then the interference is said to be constructive.

(b) Destructive interference

When the resultant intensity is less than the sum of two individual wave intensities $[I < (I_1 + I_2)]$, then the interference is said to destructive. There is no violation of the law of conservation of energy in interference. Here, the energy from the points of minimum energy is shifted to the points of maximum energy.

2. TYPES OF SOURCES

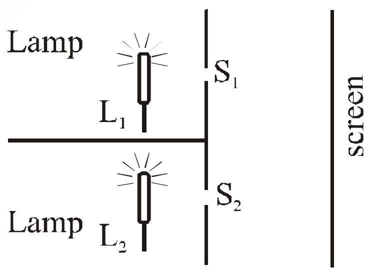
(a) Coherent sources

Two sources are said to be coherent if they emit light waves of the same wave length and start with same phase or have a constant phase difference.

Note : Laser is a source of monochromatic light waves of high degree of coherence.

(b) Incoherent sources

Two independent monochromatic sources, emit waves of same wavelength. But the waves are not in phase. So they are incoherent. This is because, atoms cannot emit light waves in same phase and these sources are said to be incoherent sources.



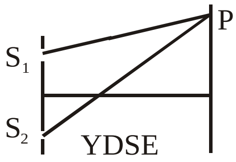
independent source
(noncoherent source)

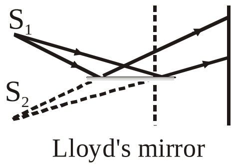
3. **METHOD FOR OBTAINING COHERENT SOURCES**

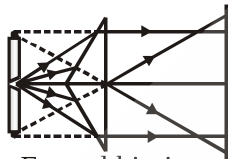
(a) Division of wavefront

In this method, the wavefront is divided into two or more parts by use of mirrors, lenses or prisms.

Example : Young's double slit experiment. Fresnel's Biprism and Lloyd's single mirror method.



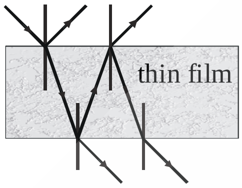


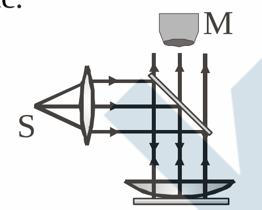


(b) Division of amplitude

The amplitude of incoming beam is divided into two or more parts by partial reflection or refraction. These divided parts travel different paths and are finally brought together to produce interference.

Example : The brilliant colour seen in a thin film of transparent material like soap film, oil film, Michelson's Interferro Meter, Newtons' ring etc.





Newton's rings

4. If two coherent waves with intensity I_1 and I_2 are superimposed with a phase difference of ϕ, the resulting wave intensity is

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

5. **The phase difference between two waves at a point will depend upon**

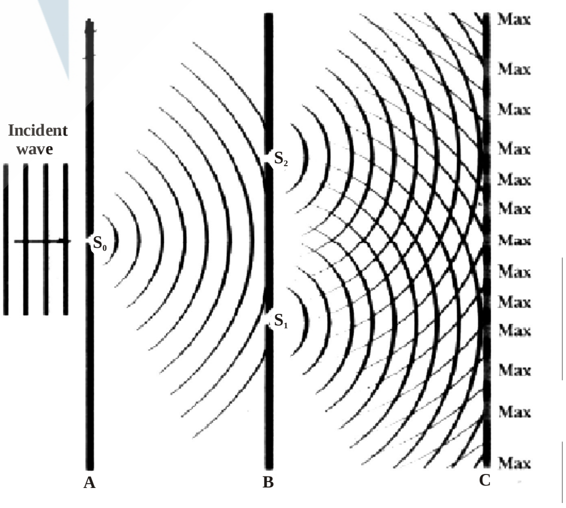
(i) the difference in path lengths of two waves from their respective sources.(geometrical path difference)

(ii) the refractive index of the medium (media)

(iii) phase difference at source (if any).

(iv) In case, the waves suffer reflection, the reflected wave differs in phase by π with respect to the incident wave if the incidence occurs in rarer medium. There would be no phase difference if incidence occurs in denser medium.

6. **YOUNG'S DOUBLE SLIT EXPERIMENT**

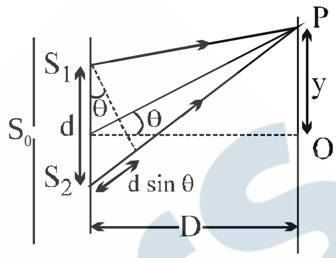


(i) If $d << D$

$\Delta x = S_2P - S_1P = d \sin\theta$

If $\lambda << d$ then $\sin\theta \approx \theta \approx \tan\theta$ as when P is close to D so θ is small.

$$\Delta x = d\left(\frac{y}{D}\right) = \frac{yd}{D}$$



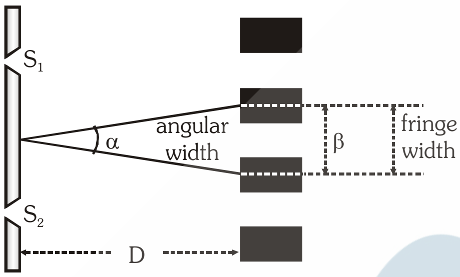
(ii) For maxima $\frac{yd}{D} = n\lambda$

or $y = 0, \pm \frac{D\lambda}{d}, \pm \frac{2D\lambda}{d}$

(iii) For minima $\frac{yd}{D} = [n + (1/2)]\lambda$ or $y = \pm \frac{D\lambda}{2d}, \pm \frac{3D\lambda}{2d}, \pm \frac{5D\lambda}{2d}$, so on

(iv) Fringe width = the distance between two successive maximas or minima $\beta = \frac{\lambda D}{d}$

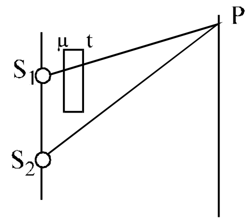
(v) **Angular Fringe width**



Angular Fringe Width $\alpha = \frac{\beta}{D}, \ \alpha = \frac{\lambda}{d} \ \left[\because \frac{\beta}{D} = \frac{\lambda}{d}\right]$

7. DISPLACEMENT OF FRINGE PATTERN

When a film of thickness t and refractive index μ is introduced in the path of one of the source's of light, then fringe shift occurs as the optical path difference changes.



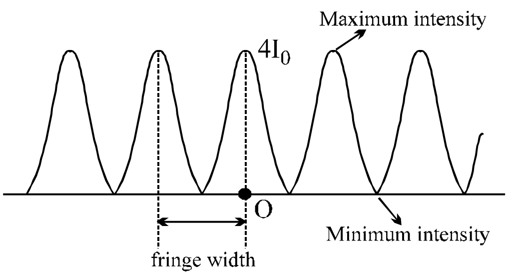
Optical path difference at P is

$\Delta x = S_2P - [S_1P + \mu t - t] = S_2P - S_1P - (\mu - 1)\,t = y.\,(d/D) - (\mu - 1)t$

$\Rightarrow$ The fringe shift is given by $\Delta y = \frac{D(\mu - 1)t}{d}$

8. INTENSITY VARIATION ON SCREEN

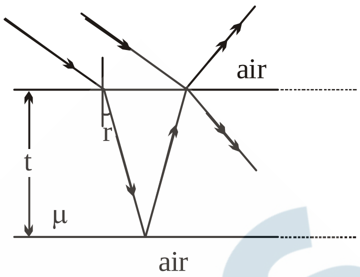
If I_0 is the intensity of light beam coming from each slit, the resultant intensity at a point where they have a phase difference of ϕ is $I = 4I_0 \cos^2 \frac{\phi}{2}$, where $\phi = \frac{2\pi(d \sin\theta)}{\lambda}$



9. INTERFERENCE AT THIN FILM

optical path difference $= 2\mu t \cos r$

$= 2\mu t$ (in case of near normal incidence)



(a) For interference in reflected light

(i) Condition of minima $2\mu t \cos r = n\lambda$

(ii) Condition of maxima $2\mu t \cos r = \left(n+\frac{1}{2}\right)\lambda$

(b) For interference in transmitted light

(i) Condition of maxima $2\mu t \cos r = n\lambda$

(ii) Condition of minima $2\mu t \cos r = \left(n+\frac{1}{2}\right)\lambda$

Ampere Law :

The general form of Ampere's law (sometimes called the **Ampere-Maxwell law**) as

$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0\left(I + I_0\right) = \mu_0\left(I + \epsilon_0 \frac{d\Phi_E}{dt}\right)$$

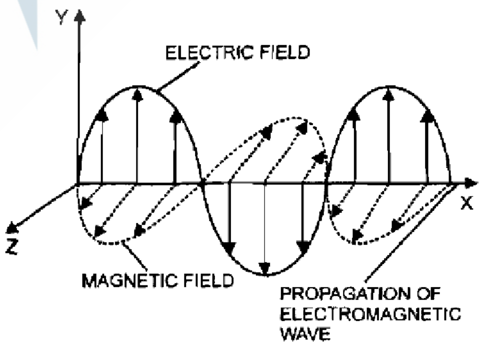
Hence, the displacement current through any surface is given by

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

By considering surface S_2, we can identify the displacement current as the source of the magnetic field

ELECTROMAGNETIC WAVES:

In electromagnetic waves, both the field vectors ($\vec{E}$ and $\vec{B}$) vary with time and space and have the same frequency and same phase. In figure, the electric field vector $\left(\vec{E}\right)$ and magnetic field vector $\left(\vec{B}\right)$ are vibrating along Y and Z directions and propagation of electromagnetic wave is shown in X-direction.



According to Maxwell the electromagnetic waves are of transverse in nature and they can pass through vacuum with the speed of light ($= 3 \times 10^8$ ms^{-1}).

The velocity of eletromagnetic wave in a medium is given by

$$v = \frac{1}{\sqrt{\mu_0 \mu_r \in_0 \in_r}}$$

where, μ_0, μ_r = absolute permeability of space and relative permeability of medium,
$\in_0$, $\in_r$ = absolute permittivity of space and relative permittivity of medium
The velocity of electromagnetic waves ofdifferent frequency in vacuum is same but in a medium is different. It is more for red light and less for violet light.
The energy is shared equally between electric field vector and magnetic field vector.

$$U_{av} = \frac{1}{2} \in_0 E_0^2 = \frac{1}{2} \frac{B_0^2}{\mu_0}$$

It has been found that the velocity (c) of electromagnetic wave in free space is equal to the ratio of amplitude of electric field vector (E_0) and magnetic field vector (B_0) i.e $c = E_0/B_0$.
It was found that the accelerated charge or oscillating charge is a source of electromagnetic waves.

If the plane of electric field is oriented horizontally in respect to the earth, the electromagnetic wave is said to be horizontally polarised. On the other hand, if the plane of electric field vector is oriented vertically the electromagnetic wave is said to be vertically polarised.

The polarisation of electromagnetic wave is mainly the function of the antenna orientation.

Light may be polarized by passing it through a sheet of commercial material called Polaroid

Malus' Law
Suppose we have a second piece of Polaroid whose transmission axis makes an angle θ with that of the first one.

If $I_0 \cong E^2$ is the intensity between the two Polaroids, the intensity transmitted by both of them would be: $I(\theta) = I_0 \cos^2 \theta$.

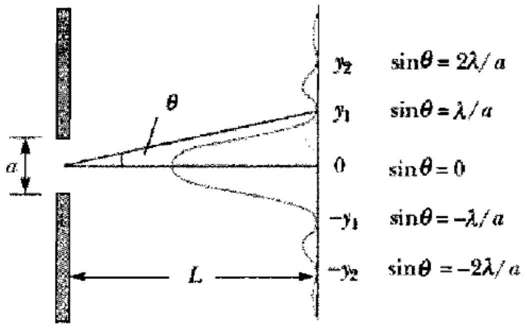
Brewster's law

$$\tan \theta_p = \frac{n_2}{n_1}$$: **Brewster's law**

θ_p is the angle of incidence of unpolarized light which makes the reflected light completely polarized in the perpendicular direction to the plane of incidence (Sir David Brewster, 1812). When the angle of incidence of the initially unpolarized light is θ_p, the reflected and refracted rays are perpendicular to each other.

DIFFRACTION
When light passes through a narrow slit of width comparable to the wavelength of light, the light flares out of the slit; this bending or spreading of waves is called diffraction.

Properties of dark & bright fringes:



(a) It results from superposition of secondary wavelets originating from various parts of single coherent source.

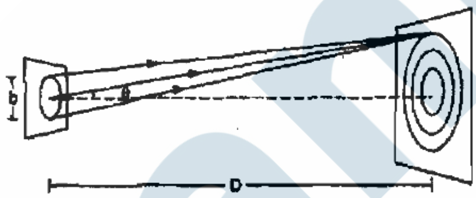
(b) Diffraction fringes are never of equal width.

(c) Intensity of all the bright fringes is not the same.

(d) Dark fringes are not perfectly dark.

FRAUNHOFER DIFFRACTION BY A CIRCULAR APERTURE

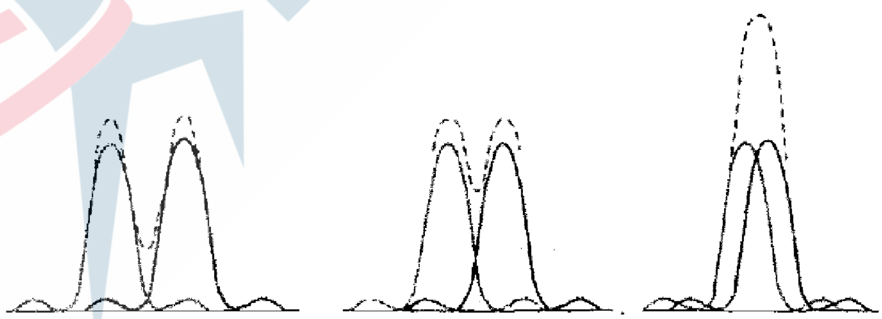
The mathematical analysis shows that the first dark ring is formed by the light diffracted from the hole at an angle θ with the axis $\sin\theta = \frac{1.22\lambda}{b}$.



The radius of the diffraction disc is given by $R = \frac{1.22\lambda D}{b}$,

LIMIT OF RESOLUTION

The fact that a lens forms a disc image of a point source, puts a limit on resolving two neighboring points imaged by a lens.



well resolved just resolved unresolved.

For two objects to be barely resolved, the angular separation between them should be at least:

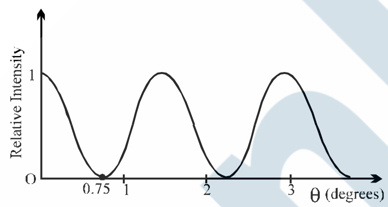
$$\theta_R = \sin^{-1}\left(\frac{1.22\lambda}{b}\right)$$

EXERCISE (S-1)

1. In a Young's double slit experiment for interference of light, the slits are 0.2 cm apart and are illuminated by yellow light (λ = 600 nm). What would be the fringe width on a screen placed 1 m from the plane of slits if the whole system is immersed in water of index 4/3?

2. In Young's double slit experiment the slits are 0.5 mm apart and the interference is observed on a screen at a distance of 100 cm from the slit. It is found that the 9th bright fringe is at a distance of 7.5mm from the second dark fringe from the centre of the fringe pattern on same side. Find the wavelength of the light used.

3. Light of wavelength 520 nm passing through a double slit, produces interference pattern of relative intensity versus angular position θ as shown in the figure. Find the separation d between the slits.



4. In a Young's double slit experiment, two wavelengths of 500 nm and 700 nm were used. What is the minimum distance from the central maximum where their maximas coincide again? (Take $D/d = 10^3$. Symbols have their usual meanings.) **[IIT-JEE 2004]**

5. In a YDSE apparatus, d = 1mm, λ = 600 nm and D = 1m. The slits individually produce same intensity on the screen. Find the minimum distance between two points on the screen having 75% intensity of the maximum intensity.

6. The distance between two slits in a YDSE apparatus is 3mm. The distance of the screen from the slits is 1m. Microwaves of wavelength 1 mm are incident on the plane of the slits normally. Find the distance of the first maxima on the screen from the central maxima. Also find the total number of maxima on the screen.

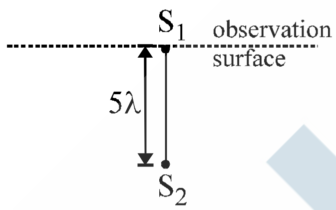
7. One slit of a double slit experiment is covered by a thin glass plate of refractive index 1.4 and the other by a thin glass plate of refractive index 1.7. The point on the screen, where central bright fringe was formed before the introduction of the glass sheets, is now occupied by the 5^{th} bright fringe. Assuming that both the glass plates have same thickness and wavelength of light used is 4800 Å, find their thickness.

8. A monochromatic light of λ = 5000 Å is incident on two slits separated by a distance of 5×10^{-4} m. The interference pattern is seen on a screen placed at a distance of 1 m from the slits. A thin glass plate of thickness 1.5×10^{-6} m & refractive index μ = 1.5 is placed between one of the slits & the screen. Find the intensity at the centre of the screen, if the intensity there is I_0 in the absence of the plate. Also find the lateral shift of the central maximum.

9. In a biprism experiment with sodium light, bands of width 0.0195 cm are observed on screen at 100cm from slit. On introducing a convex lens 30 cm away from the slit between biprism and screen, two images of the slit are seen 0.7 cm apart on screen. Calculate the wavelength of sodium light.

10. A long narrow horizontal slit lies 1mm above a plane mirror as in Lloyd's mirror. The interference pattern produced by the slit and its image is viewed on a screen distant 1m from the slit. The wavelength of light is 600nm. Find the distance of first maximum above the mirror.

11. Two microwave coherent point sources emitting waves of wavelength λ are placed at 5λ distance apart. The interference is being observed on a flat non-reflecting surface along a line passing through one source, in a direction perpendicular to the line joining the two sources (refer figure). Considering λ as 4 mm, calculate the positions of maxima and draw shape of interference pattern. Take initial phase difference between the two sources to be zero.

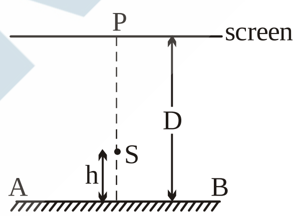


12. A point source *S* emitting light of wavelength 600 nm is placed at a very small height h above the flat reflecting surface *AB* (see figure). The intensity of the reflected light is 36% of the incident intensity. Interference fringes are observed on a screen placed parallel to the reflecting surface at a very large distance *D* from it. **[IIT-JEE 2002]**

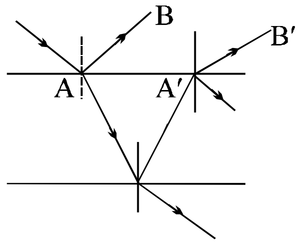
(i) What is the shape of the interference fringes on the screen?

(ii) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point P (shown in the figure).

(iii) If the intensities at point P corresponds to a maximum, calculate the minimum distance through which the reflecting surface AB should be shifted so that the intensity at P again becomes max.



13. A ray of light of intensity I is incident on a parallel glass-slab at a point A as shown in figure. It undergoes partial reflection and refraction. At each reflection 20% of incident energy is reflected. The rays AB and A′ B′undergo interference. Find the ratio I_{max}/I_{min}. [Neglect the absorption of light]

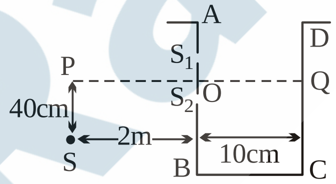


EXERCISE (S-2)

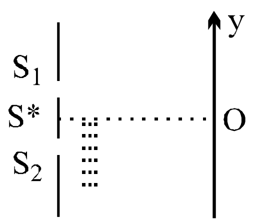
1. A thin glass plate of thickness t and refractive index μ is inserted between screen & one of the slits in a Young's experiment. If the intensity at the centre of the screen is I, what was the intensity at the same point prior to the introduction of the sheet.

2. In Young's experiment, the source is red light of wavelength 7×10^{-7} m . When a thin glass plate of refractive index 1.5 at this wavelength is put in the path of one of the interfering beams, the central bright fringe shifts by 10^{-3} m to the position which was previously occupied by the 5^{th} bright fringe. Find the thickness of the plate. When the source is now changed to green light of wavelength 5×10^{-7} m, the central fringe shifts to a position initially occupied by the 6^{th} bright fringe due to red light without the plate. Find the refractive index of glass for the green light. Also estimate the change in fringe width due to the change in wavelength. **[IIT-JEE 1997 C]**

3. A vessel $ABCD$ of 10 cm width has two small slits S_1 and S_2 sealed with identical glass plates of equal thickness. The distance between the slits is 0.8 mm. POQ is the line perpendicular to the plane AB and passing through O, the middle point of S_1 and S_2. A monochromatic light source is kept at S, 40cm below P and 2 m from the vessel, to illuminate the slits as shown in the figure below. Calculate the position of the central bright fringe on the other wall CD with respect to the line OQ. Now, a liquid is poured into the vessel and filled up to OQ. The central bright fringe is found to be at Q. Calculate the refractive index of the liquid. **[IIT-JEE 2001]**

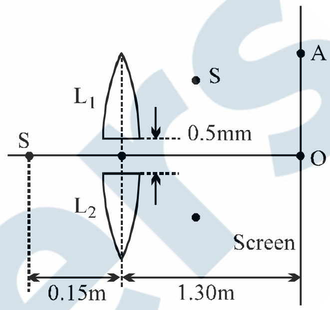


4. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown **[IIT-JEE'99]**
(i) Find the location of the central maximum (bright fringe with zero path difference) on the y-axis.
(ii) Find the light intensity at point O relative to the maximum fringe intensity.
(iii) Now, if 600 nm light is replaced by white light of range 400 to 700 nm, find the wavelengths of the light that form maxima exactly at point O. [All wavelengths in this problem are for the given medium of refractive index 4/3. Ignore dispersion]



5. In a Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4 while the lower slit is covered by another glass plate having the same thickness as the first one but having refractive index 1.7. Interference pattern is observed using light of wavelength 5400 Å. It is found that the point P on the screen where the central maximum (n = 0) fell before the glass plates were inserted now has 3/4 the original intensity. It is further observed that what used to be the 5th maximum earlier, lies below the point P while the 6th minimum lies above P. Calculate the thickness of the glass plate. (Absorption of light by glass plate may be neglected). **[IIT-JEE 1997]**

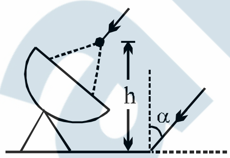
6. In the figure shown S is a monochromatic point source emitting light of wavelength λ = 500 nm. A thin lens of circular shape and focal length 0.10 m is cut into two identical halves L_1 and L_2 by a plane passing through a diameter. The two halves are placed symmetrically about the central axis SO with a gap of 0.5 mm. The distance along the axis from S to L_1 and L_2 is 0.15 m, while that from L_1 & L_2 to O is 1.30 m. The screen at O is normal to SO. **[IIT-JEE 1993]**



(i) If the third intensity maximum occurs at the point A on the screen, find the distance OA.

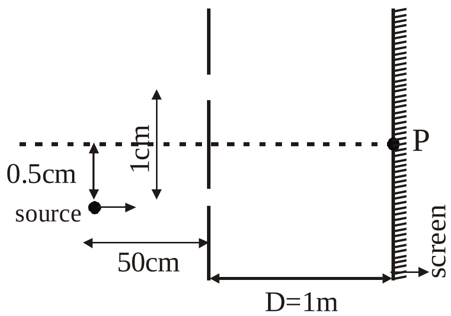
(ii) If the gap between L_1 & L_2 is reduced from its original value of 0.5 mm, will the distance OA increase, decrease or remain the same ?

7. Radio waves coming at angle α to vertical are recieved by a radar after reflection from a nearby water surface & directly. What should be height of antenna from water surface so that it records a maximum intensity. (wavelength = λ).



8. One radio transmitter A operating at 60.0 MHz is 10.0 m from another similar transmitter B that is 180° out of phase with transmitter A. How far must an observer move from transmitter A toward transmitter B along the line connecting A and B to reach the nearest point where the two beams are in phase?

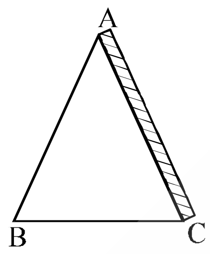
9. In a typical Young's double slit experiment a point source of monochromatic light is kept as shown in the figure. If the source is given an instantaneous velocity v = 1 mm per second towards the screen, then the instantaneous velocity of central maxima is given as $\alpha \times 10^{-\beta}$ m/s upward. Find the value of $\alpha+\beta$.



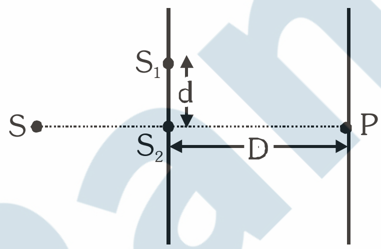
10. A prism ($\mu_p = \sqrt{3}$) has an angle of prism $A = 30°$. A thin film ($\mu_f = 2.2$) is coated on face AC as shown in the figure. Light of wavelength 550 nm is incident on the face *AB* at 60° angle of incidence. Find **[IIT-JEE 2003]**

(i) the angle of its emergence from the face *AC* and

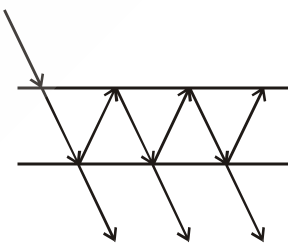
(ii) the minimum thickness (in nm) of the film for which the emerging light is of maximum possible intensity.



11. In a YDSE experiment two slits S_1 and S_2 have separation of d = 2 mm. The distance of the screen is D = 8/5 m. Source S starts moving from a very large distance towards S_2 perpendicular to S_1S_2 as shown in figure. The wavelength of monochromatic light is 500 nm. The number of maximas observed on the screen at point P as the source moves towards S_2 is 3995 + n. Find the value of n.



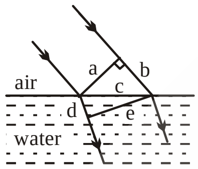
12. A narrow beam of light has entered a large thin glass plate. Each refraction is accompanied by reflection of one third of the beam's energy. What percentage of the light energy is transmitted through the plate?



EXERCISE (O-1)

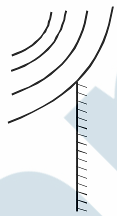
SINGLE CORRECT TYPE QUESTIONS

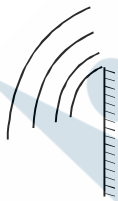
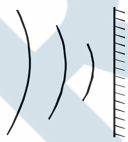
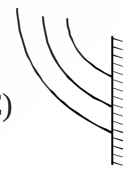
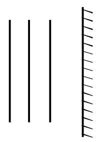
1. Figure shows plane waves refracted from air to water using Huygen's principle (where a, b, c, d, e are lengths on the diagram). The refractive index of water wrt air is the ratio :-



(A) a/e (B) b/e (C) b/d (D) d/b

2. Spherical wavefronts shown in figure, strike a plane mirror. Reflected wavefronts will be as shown in



(A)  (B)  (C)  (D) 

3. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is : **[IIT-JEE (Scr.) 2001]**

(A) 2I (B) 4I (C) 5I (D) 7I

4. In a young double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by **[IIT-JEE (Scr.) 2001]**

(A) 12 (B) 18 (C) 24 (D) 30

5. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are :

(A) $5I$ and I (B) 5I and 3I (C) $9I$ and I (D) $9I$ and $3I$

6. When light is refracted into a denser medium,

(A) its wavelength and frequency both increase

(B) its wavelength increases but frequency remains unchanged

(C) its wavelength decreases but frequency remains unchanged

(D) its wavelength and frequency both decrease.

7. In YDSE how many maxima can be obtained on the screen if wavelength of light used is 200nm and d = 700 nm:

(A) 12 (B) 7 (C) 18 (D) none of these

8. In a YDSE, the central bright fringe can be identified :

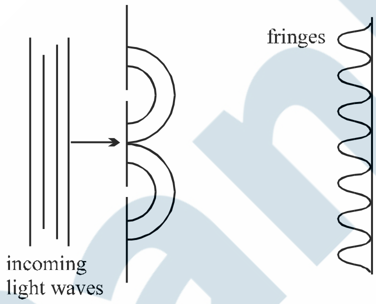
(A) as it has greater intensity than the other bright fringes.

(B) as it is wider than the other bright fringes.

(C) as it is narrower than the other bright fringes.

(D) by using white light instead of single wavelength light.

9. In a Young's double slit experiment, green light is incident on the two slits. The interference pattern is observed on a screen. Which of the following changes would cause the observed fringes to be more closely spaced?



(A) Reducing the separation between the slits

(B) Using blue light instead of green light

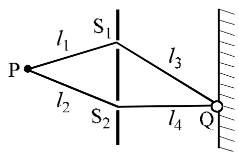
(C) Used red light instead of green light

(D) Moving the light source further away from the slits.

10. In Young's double slit experiment, the wavelength of red light is 7800 Å and that of blue light is 5200 Å. The value of n for which n^{th} bright band due to red light coincides with $(n + 1)^{th}$ bright band due to blue light, is :

(A) 1 (B) 2 (C) 3 (D) 4

11. Two identical narrow slits S_1 and S_2 are illuminated by light of wavelength λ from a point source P. If, as shown in the diagram, the light is then allowed to fall on a screen, and if n is a positive integer, the condition for destructive interference at Q is :-



(A) $(\ell_1 - \ell_2) = (2n + 1)\lambda/2$ (B) $(\ell_3 - \ell_4) = (2n + 1)\lambda/2$

(C) $(\ell_1 + \ell_2) - (\ell_3 + \ell_4) = n\lambda$ (D) $(\ell_1 + \ell_3) - (\ell_2 + \ell_4) = (2n + 1)\lambda/2$

12. In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and wavelength λ. In another experiment with the same setup the two slits are sources of equal amplitude A and wavelength λ but are incoherent. The ratio of the average intensity of light at the midpoint of the screen in the first case to that in the second case is :-

(A) 1 : 1 (B) 2 : 1 (C) 4 : 1 (D) none of these

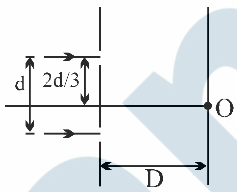
13. In a Young's double slit experiment, a small detector measures an intensity of illumination of I units at the centre of the fringe pattern. If one of the two (identical) slits is now covered, the measured intensity will be :-

(A) 2I (B) I (C) I/4 (D) I/2

14. In a Young's double slit experiment D equals the distance of screen and d is the separation between the slit. The distance of the nearest point to the central maximum where the intensity is same as that due to a single slit, is equal to :-

(A) $\frac{D\lambda}{d}$ (B) $\frac{D\lambda}{2d}$ (C) $\frac{D\lambda}{3d}$ (D) $\frac{2D\lambda}{d}$

15. In the figure shown if a parallel beam of white light is incident on the plane of the slits then the distance of the white spot on the screen from O is [Assume $d << D$, $\lambda << d$]



(A) 0 (B) $d/2$ (C) $d/3$ (D) $d/6$

16. In the above question if the light incident is monochromatic and point O is a maxima, then the wavelength of the light incident cannot be :-

(A) $d^2/3D$ (B) $d^2/6D$ (C) $d^2/12D$ (D) $d^2/18D$

17. In a YDSE bi-chromatic light of wavelengths 400 nm and 560 nm are used. The distance between the slits is 0.1 mm and the distance between the plane of the slits and the screen is 1 m. The minimum distance between two successive regions of complete darkness is :- **[IIT-JEE' 2004 (Scr)]**

(A) 4 mm (B) 5.6 mm (C) 14 mm (D) 28 mm

18. In Young's double slit arrangement, water is filled in the space between screen and slits. Then :

(A) fringe pattern shifts upwards but fringe width remains unchanged.

(B) fringe width decreases and central bright fringe shifts upwards.

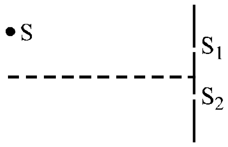
(C) fringe width increases and central bright fringe does not shift.

(D) fringe width decreases and central bright fringe does not shift.

19. Light of wavelength λ in air enters a medium of refractive index μ. Two points in this medium, lying along the path of this light, are at a distance x apart. The phase difference between these points is :

(A) $\frac{2\pi\mu x}{\lambda}$ (B) $\frac{2\pi x}{\mu\lambda}$ (C) $\frac{2\pi(\mu-1)x}{\lambda}$ (D) $\frac{2\pi x}{(\mu-1)\lambda}$

20. In YDSE, the source placed symmetrically with respect to the slit is now moved parallel to the plane of the slits so that it is closer to the upper slit, as shown. Then,

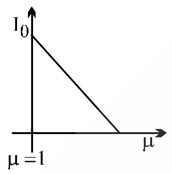


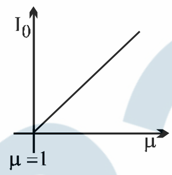
(A) the fringe width will increase and fringe pattern will shift down.
(B) the fringe width will remain same but fringe pattern will shift up.
(C) the fringe width will decrease and fringe pattern will shift down.
(D) the fringe width will remain same but fringe pattern will shift down.

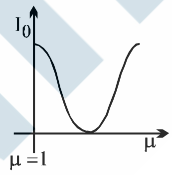
21. In the ideal double–slit experiment, when a glass–plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wavelength λ), the intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass–plate is :– **[IIT-JEE 2002]**

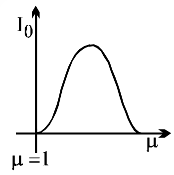
(A) 2λ (B) $\frac{2\lambda}{3}$ (C) $\frac{\lambda}{3}$ (D) λ

22. In a YDSE experiment if a slab whose refractive index can be varied is placed in front of one of the slits then the variation of resultant intensity at mid-point of screen with μ ($\mu \geq 1$)will be best represented by [Assume slits of equal width and there is no absorption by slab]

(A) 

(B) 

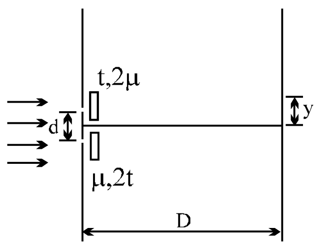
(C) 

(D) 

23. In a Young's double-slit experiment, let A and B be the 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) if $t_B < t_A$

24. In the YDSE shown the two slits are covered with thin sheets having thickness t & $2t$ and refractive index 2μ and μ. Find the position (y) of central maxima



(A) zero (B) $\frac{tD}{d}$ (C) $-\frac{tD}{d}$ (D) None

25. In a double slit experiment, when the width of one slit is made twice as wide as the other in compared to normal YDSE having slits of equal width. Then, in the interference pattern **[IIT-JEE(Scr.) 2000]**

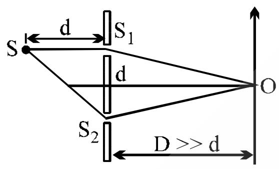
(A) the intensities of both the maxima and the minima increase.

(B) the intensity of the maxima increases and the minima has zero intensity.

(C) the intensity of the maxima decreases and that of the minima increases.

(D) the intensity of the maxima decreases and the minima has zero intensity.

26. To make the central fringe at the centre *O*, a mica sheet of refractive index 1.5 is introduced. Choose the correct statements (s).



(A) The thickness of sheet is $2(\sqrt{2}-1)d$ in front of S_1.

(B) The thickness of sheet is $(\sqrt{2}-1)d$ in front of S_2.

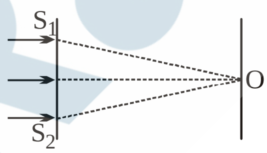
(C) The thickness of sheet is $2\sqrt{2}\,d$ in front of S_1.

(D) The thickness of sheet is $(2\sqrt{2}-1)d$ in front of S_1.

27. **Statement-1 :** In YDSE, as shown in figure, central bright fringe is formed at *O*. If a liquid is filled between plane of slits and screen, the central bright fringe is shifted in upward direction.

and

Statement-2 : If path difference at *O* increases, y-coordinate of central bright fringe will change.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

28. **Statement-1 :** In glass, red light travels faster than blue light.

and

Statement-2 : Red light has a wavelength longer than blue.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

29. **Statement-1 :** In standard YDSE set up with visible light, the position on screen where phase difference is zero appears bright.

and

Statement-2 : In YDSE set up magnitude of electromagnetic field at central bright fringe is not varying with time.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

30. **Statement-1 :** In YDSE, the spacing between any two successive points having intensity half of the maximum intensity is same.

and

Statement-2 : The intensity on the screen in YDSE varies uniformly with distance from central maximum.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

31. In a double slit experiment, the separation between the slits is $d = 0.25$ cm and the distance of the screen D = 100 cm from the slits. If the wavelength of light used is $\lambda = 6000$Å and I_0 is the intensity of the central bright fringe, the intensity at a distance $x = 4 \times 10^{-5}$ m from the central maxima is :-

(A) I_0 (B) $I_0/2$ (C) $3I_0/4$ (D) $I_0/3$

32. Imagine a Young's double slit interference experiment performed with waves associated with fast moving electrons produced from an electron gun. The distance between successive maxima will decrease the most if :-

(A) the accelerating voltage in the electron gun is decreased

(B) the accelerating voltage is increased and the distance of the screen from the slits is decreased

(C) the distance of the screen from the slits is increased.

(D) the distance between the slits is decreased.

33. Two monochromatic and coherent point sources of light are placed at a certain distance from each other in the horizontal plane. The locus of all those points in the horizontal plane which have constructive interference will be

(A) a hyperbola (B) family of hyperbolas

(C) family of straight lines (D) family of parabolas

MULTIPLE CORRECT TYPE QUESTIONS

34. To observe a sustained interference pattern formed by two light waves, it is not necessary that they must have :

(A) the same frequency
(B) same amplitude
(C) a constant phase difference
(D) the same intensity

35. As a wave propagates, **[IIT-JEE 1999]**

(A) the wave intensity remains constant for a plane wave
(B) the wave intensity decreases with distance from source and is proportional to inverse of the distance, for a spherical wave.
(C) the wave intensity decreases with distance from source and proportional to inverse square of the distance, for a spherical wave.
(D) total average power of the spherical wave over any spherical surface centered at the source remains same.

36. In a YDSE apparatus, if we use white light then :

(A) the fringe next to the central will be red
(B) the central fringe will be white.
(C) the fringe next to the central will be violet
(D) there will not be a completely dark fringe.

37. If the source of light used in a Young's Double Slit Experiment is changed from red to blue, then

(A) the fringes will become brighter
(B) consecutive fringes will come closer
(C) the number of maxima formed on the screen increases
(D) the central bright fringe will become a dark fringe.

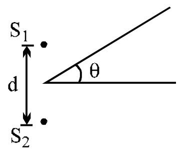
38. In a Young's double-slit experiment, let *A* and *B* be the two slits. A thin film of thickness t and refractive index μ is placed in front of *A*. Let $\beta =$ fringe width. The central maximum will shift :

(A) towards *A*
(B) towards *B*
(C) by $t(\mu - 1)\dfrac{\beta}{\lambda}$
(D) by $\mu t \dfrac{\beta}{\lambda}$

39. If one of the slits of a standard YDSE apparatus is covered by a thin parallel sided glass slab so that it transmit only one half of the light intensity of the other, then :

(A) the fringe pattern will get shifted towards the covered slit.
(B) the fringe pattern will get shifted away from the covered slit.
(C) the bright fringes will be less bright and the dark ones will be more bright.
(D) the fringe width will remain unchanged.

40. In an interference arrangement similar to Young's double- slit experiment, the slits S_1 & S_2 are illuminated with coherent microwave sources, each of frequency 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance $d = 150.0$ m. The intensity $I(\theta)$ is measured as a function of θ at a large distance from S_1 & S_2, where θ is defined as shown. If I_0 is the maximum intensity then $I(\theta)$ for $0 \le \theta \le 90°$ is given by :



(A) $I(\theta) = \dfrac{I_0}{2}$ for $\theta = 30°$
(B) $I(\theta) = \dfrac{I_0}{4}$ for $\theta = 90°$
(C) $I(\theta) = I_0$ for $\theta = 0°$
(D) $I(\theta)$ is constant for all values of θ .

41. In a standard YDSE apparatus, a thin film ($\mu = 1.5$, $t = 2.1$ μm) is placed in front of upper slit. How far above or below the centre point of the screen are two nearest maxima located? Take $D = 1$ m, $d = 1$mm, $\lambda = 4500$Å. (Symbols have usual meaning)

(A) 1.5 mm (B) 0.6 mm (C) 0.15 mm (D) 0.3 mm

42. In a YDSE with two identical slits, when the upper slit is covered with a thin, perfectly transparent sheet of mica, the intensity at the centre of screen reduces to 75% of the initial value. Second minima is observed to be above this point and third maxima below it. Which of the following can be a possible value of phase difference caused by the mica sheet

(A) $\frac{\pi}{3}$ (B) $\frac{13\pi}{3}$ (C) $\frac{17\pi}{3}$ (D) $\frac{11\pi}{3}$

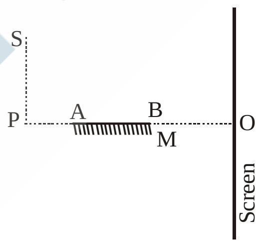
43. A beam of 2000 eV electrons are incident normally on the surface of crystal whose inter atomic separation is 0.11 nm. The mass of the electron can be taken as 9×10^{-31} kg. At what angle to the normal can we observe a diffraction maxima.

(A) $\sin^{-1}\left(\frac{1}{4}\right)$ (B) $2\cos^{-1}\left(\frac{1}{4}\right)$ (C) $\sin^{-1}\left(\frac{1}{2}\right)$ (D) $2\cos^{-1}\left(\frac{1}{2}\right)$

COMPREHENSION TYPE QUESTIONS

Paragraph for Question No. 44 and 45

In an experiment on interference due to single mirror, a light wave emitted directly by the source S (narrow slit) interferes with the wave reflected from the mirror M of length 2 mm. Source and screen are separated by distance 90 cm. Source S is at the height of 3 mm, from the point P and the middle point of mirror is at distance of 2mm from point P. Point P and mirror are in the same plane of screen is perpendicular to this plane.



44. If fringe width is 0.1 mm then what is the wavelength of light used?

(A) 3.3×10^{-7} m (B) 6.7×10^{-7} m (C) 1.0×10^{-7} m (D) 4×10^{-7} m

45. If the mirror is shifted towards left then how does the fringe pattern on screen change?

(A) Fringe width decreases and the region in which interference is formed shifts downward.

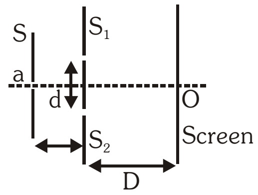
(B) Fringe width decreases and region in which inteference is formed shifts upwards

(C) Fringe width does not change and region in which interference is formed shifts upwards

(D) Fringe width does not change and region in which inteference is formed shifts downwards

Paragraph for Question No. 46 to 48

The figure shows a schematic diagram showing the arrangement of Young's Double Slit Experiment



46. Choose the correct statement(s) related to the wavelength of light used

(A) Larger the wavelength of light larger the fringe width

(B) The position of central maxima depends on the wavelength of light used

(C) If white light is used in YDSE, then the violet colour forms its first maxima closest to the central maxima

(D) The central maxima of all the wavelengths coincide

47. If the distance *D* is varied, then choose the correct statement(s)

(A) The angular fringe width does not change

(B) The fringe width changes in direct proportion

(C) The change in fringe width is same for all wavelengths

(D) The position of central maxima remains unchanged

48. If the distance d is varied, then identify the correct statement(s)

(A) The angular width does not change

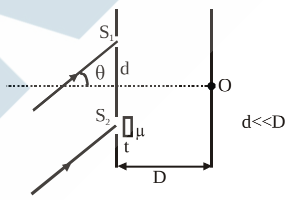
(B) The fringe width changes in inverse proportion

(C) The positions of all maxima change

(D) The positions of all minima change

Paragraph for Question No. 49 to 51

A monochromatic beam of light falls on Young's double slit experiment apparatus as shown in figure. A thin sheet of glass is inserted in front of lower slit S_2.



49. The central bright fringe can be obtained

(A) at *O* only

(B) at O or below *O* only

(C) at *O* or above *O* only

(D) Anywhere on the screen

50. If central bright fringe is obtained on screen at *O* :-

(A) $(\mu-1)\,t = d\sin\theta$

(B) $(\mu-1)\,t = d\cos\theta$

(C) $(\mu-1)t + d\sin\theta = 0$

(D) $\dfrac{t}{\mu-1} = \dfrac{d}{\sin\theta}$

51. The phase difference between the waves interfering at fifth minima is

(A) 5π

(B) $7\,\pi$

(C) 9π

(D) 11π

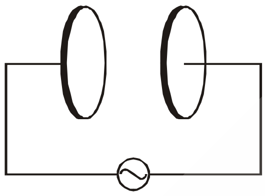
SUPPLEMENT FOR JEE-MAINS

52. A parallel plate capacitor (fig.) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 μF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of 300 rad s^{-1}.

(a) What is the rms value of the conduction current?

(b) Is the conduction current equal to the displacement current?

(c) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.



53. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is B_0 = 510nT. What is the amplitude of the electric field part of the wave?

54. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10}Hz and amplitude 48 V m^{-1}.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) Show that the average energy density of the E field equals the average energy density of the B field. [$c = 3 \times 10^8$ m s^{-1}]

55. Suppose that the electric field part of an electromagnetic wave in vaccum is

$E = \{(3.1\ N/C) \cos [(1.8\ rad/m)\ y + (5.4 \times 10^8\ rad/s)t]\ \hat{i}$.

(a) What is the direction of propagation?

(b) What is the wavelength λ?

(c) What is the frequency v?

(d) What is the amplitude of the magnetic field part of the wave?

(e) Write an expression for the magnetic field part of the wave.

56. A plane electromagnetic wave traveling in the positive direction of x axis in vaccum has components $E_x = E_y = 0$ and $E_z = (2.0\ V/m) \cos [(\pi \times 10^{15}\ S^{-1})\ (t - x/c)]$. (a) What is the amplitude of the magnetic field component? (b) Parallel to which axis does the magnetic field oscillate? (c) When the electric field component is in the positive direction of the z axis at a certain point P, what is the direction of the magnetic field component there?

57. An open circuit consists of a 12 μF parallel plate capacitor charged to 200V and a 10Ω resistor. At the instant when a switch closes the circuit (with no battery in it) the displacement current between the, plates of the capacitor is

58. Two coherent waves are described by the following expressions.

$$E_1 = E_0 \sin\left(\frac{2\pi x_1}{\lambda} - 2\pi ft + \frac{\pi}{6}\right);\ E_2 = E_0 \sin\left(\frac{2\pi x_2}{\lambda} - 2\pi ft + \frac{\pi}{8}\right)$$

Determine the relationship between x_1 and x_2 that produces constructive interference when the two waves are superposed.

59. A nickel crystal is used as a diffraction grating for x-rays. Then the same crystal is used to diffract electrons. If the two diffraction patterns are identical, and the energy of each x-ray photon is E = 20.0 keY. What is the kinetic energy of each electron?

60. The velocity of electromagnetic waves in a dielectric medium ($\in_r = 4$) is :-

(A) 3×10^8 metre/second (B) 1.5×10^8 metre/second

(C) 6×10^8 metre/second (D) 7.5×10^7 metre/second

61. Which of these statements correctly describes the orientation of the electric field $(\vec{E})$, the magnetic field $(\vec{B})$, and and velocity of propagation $(\vec{v})$ of an electromagnetic wave?

(A) $\vec{E}$ is perpendicular to $\vec{B}$; $\vec{v}$ may have any orientation relative to $\vec{E}$.

(B) $\vec{E}$ is perpendicular to $\vec{B}$; $\vec{v}$ may have any orientation perpcndicular to $\vec{E}$

(C) $\vec{E}$ is parallel to $\vec{B}$: $\vec{v}$ is perpendicular to both $\vec{B}$ and $\vec{E}$.

(D) Each of the three vectors is perpendicular to the other two.

62. The amplitude of electric field in a parallel light beam of intensity $4 Wm^{-2}$ is :

(A) 35.5 NC^{-1} (B) 45.5 NC^{-1} (C) 49.5 NC^{-1} (D) 54.8 NC^{-1}

63. Instantaneous displacement current of 1.0A in the space between the parallel plates of 1μF capacitor can be established by changing potential difference of:

(A) 10^{-6} V/s (B) 10^6 V/s (C) 10^{-8} V/s (D) 10^8 V/s

64. A plane electromagnetic wave,

$E_z = 100 \cos(6 \times 10^8 t + 4x)$ V/m

propagates in a medium of dielectric constant:

(A) 1.5 (B) 2.0 (C) 2.4 (D) 4.0

65. A large parallel plane capacitor, whose plates have an area of 1 m^2 and are separated from each other by 1 mm, is being charged at a rate of 25.8 V/s. If the dielectric between the plates has the dielectric constant 10, then the displacement current at this instant is :-

(A) 251 μA (B) 11 μA (C) 2.2 μA (D) 1.1 μA

66. The rms value of the electric field of the light coming from the sun is 720 N/c. The average total energy density of the electromagnetic wave is :

(A) 4.58×10^{-6} J/m^3 (B) 6.37×10^{-9} J/m^3 (C) 81.35×10^{-12} J/m^3 (D) 3.3×10^{-3} J/m^3

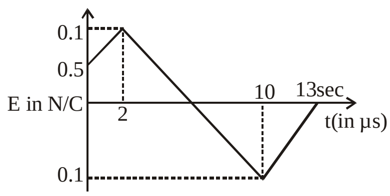
67. A beam of light travelling along x-axis is described by the electric field, $E_y = (600\ Vm^{-1}) \sin \omega (t - x/c)$ then maximum magnetic force on a charge q = 2e, moving along y-axis with a speed of $3.0 \times 10^7\ ms^{-1}$ is ($e = 1.6 \times 10^{-19}$ C) :

(A) 19.2×10^{-17} N (B) 1.92×10^{-17} N (C) 0.192 N (D) None ofthese

68. A plane electromagnertic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3 Vm^{-1}. The magnetic induction is:

(A) 3.1×10^{-8} T (B) 3×10^{-5} T (C) 3.1×10^{-6} T (D) 9.3×10^{-6} T

69. The electric field through an area of 2m^2 varies with time as shown in the graph. The greatest displacement current through the area is at :-



(A) t = 1 sec.

(B) t = 4 sec.

(C) t = 8 sec.

(D) t = 12 sec.

70. A plane electromagnetic wave travelling along the X-direction has a wavelength of 3mm. The variation in the electric field occurs in the Y-direction with an amplitude $66 Vm^{-1}$.The equation for the electric and magnetic fields as a function of x and t are respectively.

(A) $E_y = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$; $B_z = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

(B) $E_y = 11 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$; $B_y = 1.1 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

(C) $E_x = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$; $B_x = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

(D) $E_y = 66 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$; $B_z = 2.2 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

71. In a stack of three polarizing sheets the first and third are crossed while the middle one has its axis at 45° to the axes of the other two. The fraction of the intensity of an incident unpolarized beam of light that is transmitted by the stack is:

(A) 1/2 (B) 1/3 (C) 1/4 (D) 1/8

72. A beam of light strikes a piece of glass at an angle of incidence of 60° and the reflected beam is completely plane polarised. The refractive index of the glass is :-

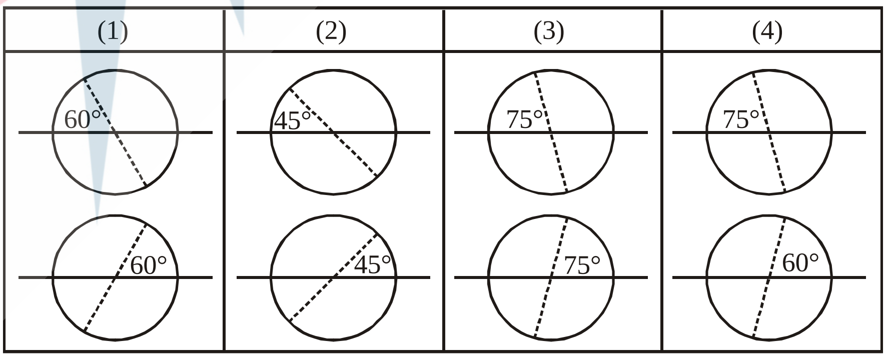
(A) 1.5 (B) $\sqrt{3}$ (C) $\sqrt{2}$ (D)(3/2)

73. The Sun is directly overhead and you are facing toward the north. Light coming to your eyes from the sky just above the horizon is :-

(A) Partially polarized north-south (B) Partially polarized east,west

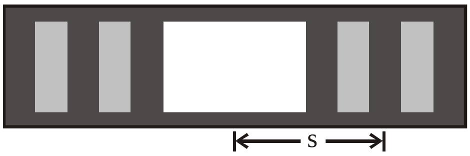
(C) Partially polarized up-down (D) Randomly polarized

74. The diagrams show four pairs of polarizing sheets, with the polarizing directions indicated by dashed lines. The two 'sheets of each pair are placed one behind the other and the front sheet is illuminated by unpolarized light. The incident intensity is the same for all pairs of sheets. Rank the pairs according to the intensity of the transmitted light, least to greatest.



(A) 1,2, 3, 4 (B) 4, 2, 1, 3 (C) 2, 4, 3, 1 (D) 2, 1,4, 3

75. Light of wavelength 600 nm is incident upon a single slit with width 4×10^{-4} m. The figure shows the pattern observed on a screen positioned 2 m from the slits. Determine the distance s.



(A) 0.002 m (B) 0.003 m (C) 0.004 m (D) 0.006 m

76. The image of a star (effectively a point source) is made by a convergent lens of focal length 1m and diameter of aperture 5.0 cm. If the lens is ideal and the effective wavelength in image formation is taken as 5×10^{-5} cm, the diameter of the image formed will be nearest to:

(A) zero (B) 10^{-6} cm (C) 10^{-5} cm (D) 10^{-3} cm

77. In a single slit diffraction pattern, as the width of the slit is increased,

(A) the peak intensity of central maxima increases and its width also increases

(B) the peak intensity of central maxima increases and its width decreases.

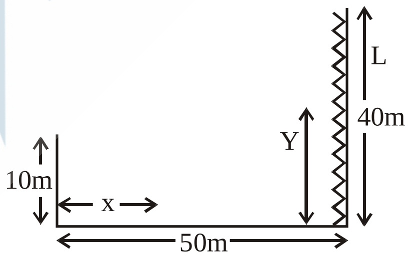
(C) the peak intensity of central maxima decreases and its width increases

(D) the peak intensity of central maxima decreases and its width also decreases.

78. A beam of electrons with de-broglie wavelength of 10^{-4} m pass through a slit 10^{-3} m wide. Calculate the angular spread introduced because of diffraction by slit.

(A) $\frac{9°}{\pi}$ (B) $\frac{18°}{\pi}$ (C) $\frac{36°}{\pi}$ (D) $\frac{4.5°}{\pi}$

79. A person lives in a high-rise building on the bank of a river 50m wide. Across the river is a well lit tower of height 40 m. When the person, who is at a height of 10m, looks through a polarizer at an appropriate angle at light of the tower reflecting from the river surface, he notes that intensity of light coming from distance X from his building is the least and this corresponds to the light coming from light bulbs at height 'Y' on the tower. The values of X and Y are respectively close to (refractive index of water $\simeq$ 4/3)

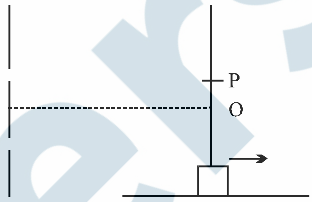


(A) 13 m, 27 m (B) 22 m, 13 m (C) 25 m, 10 m (D) 17 m, 29 m

EXERCISE (O-2)

SINGLE CORRECT TYPE QUESTIONS

1. In a Young's Double slit experiment, first maxima is observed at a fixed point P on the screen. Now the screen is continuously moved away from the plane of slits. The ratio of intensity at point P to the intensity at point O (centre of the screen)



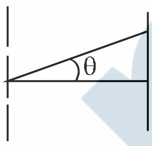
(A) remains constant

(B) keeps on decreasing

(C) first decreases and then increases

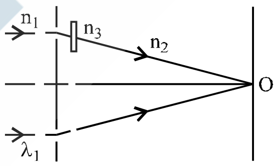
(D) First decreases and then becomes constant

2. Two slits are separated by 0.3 mm. A beam of 500 nm light strikes the slits producing an interference pattern. The number of maxima observed in the angular range $-30° < \theta < 30°$.



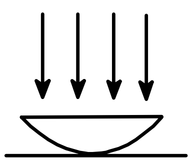
(A) 300 (B) 150 (C) 599 (D) 601

3. In the figure shown in YDSE, a parallel beam of light is incident on the slit from a medium of refractive index n_1. The wavelength of light in this medium is λ_1. A transparent slab of thickness t and refractive index n_3 is put in front of one slit. The medium between the screen and the plane of the slits is n_2. The phase difference between the light waves reaching point 'O' (symmetrical, relative to the slits) is :



(A) $\frac{2\pi}{n_1\lambda_1}(n_3-n_2)\,t$ (B) $\frac{2\pi}{\lambda_1}(n_3-n_2)\,t$ (C) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2}-1\right)t$ (D) $\frac{2\pi n_1}{\lambda_1}(n_3-n_1)t$

4. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate as shown. The observed interference fringes from this combination shall be **[IIT-JEE '99]**



(A) straight

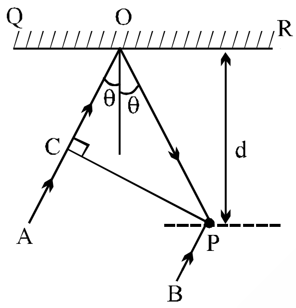
(B) circular

(C) equally spaced

(D) having fringe spacing which increases as we go outwards.

5. In the adjacent diagram, *CP* represents a wavefront and *AO* and *BP*, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray *OP*.

[JEE (Scr.) 2003]



(A) $\cos\theta = \dfrac{3\lambda}{2d}$

(B) $\cos\theta = \dfrac{\lambda}{4d}$

(C) $\sec\theta - \cos\theta = \dfrac{\lambda}{d}$

(D) $\sec\theta - \cos\theta = \dfrac{4\lambda}{d}$

6. Two point monochromatic and coherent sources of light of wavelength λ are placed on the dotted line in front of a large screen. The sources emit waves in phase with each other. The distance between S_1 and S_2 is d while their distance from the screen is much larger.

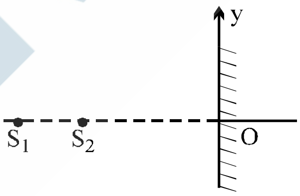
(1) If $d = 7\lambda/2$, *O* will be a minima

(2) If $d = 4.3\lambda$, there will be a total of 8 minima on y-axis.

(3) If $d = 7\lambda$, *O* will be a maxima.

(4) If $d = \lambda$, there will be only one maxima on the screen.

Which is the set of correct statement :



(A) 1, 2 & 3 (B) 2, 3 & 4 (C) 1, 2, 3 & 4 (D) 1, 3 & 4

7. A parallel coherent beam of light falls on Fresnel biprism of refractive index μ and angle α. The fringe width on a screen at a distance D from biprism will be (wavelength = λ)

(A) $\dfrac{\lambda}{2(\mu-1)\alpha}$

(B) $\dfrac{\lambda D}{2(\mu-1)\alpha}$

(C) $\dfrac{D}{2(\mu-1)\alpha}$

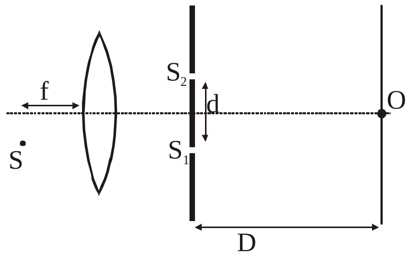
(D) none

MATRIX MATCH TYPE QUESTIONS

8. Column-I shows some modifications in a standard YDSE setup. Column-II shows the associated characteristics.

Column-I | **Column-II**

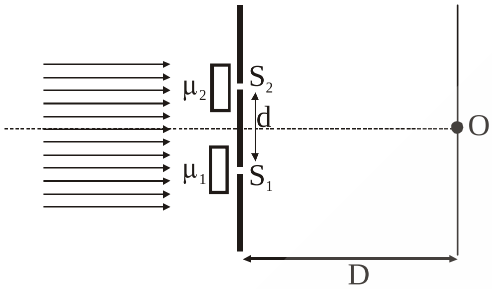
(A) S



monochromatic point source S placed in focal plane.

(P) Zero order maxima lies above O.

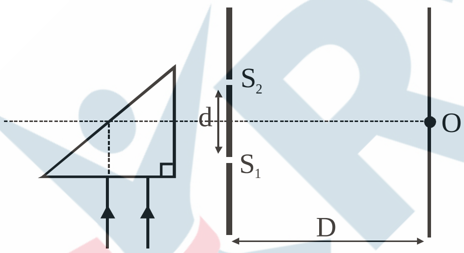
(B)



monochromatic parallel beam incident on S_1S_2 through transparent slabs of same thickness but $\mu_1 > \mu_2$

(Q) If a transparent mica sheet is introduced infront of S_2 central bright fringe can be obtained at O.

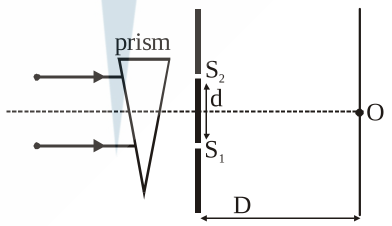
(C)



monochromatic parallel beam incident on a right angled isosceles prism of refractive index 1.50

(R) Fringe width $\beta = \dfrac{\lambda D}{d}$

(D)

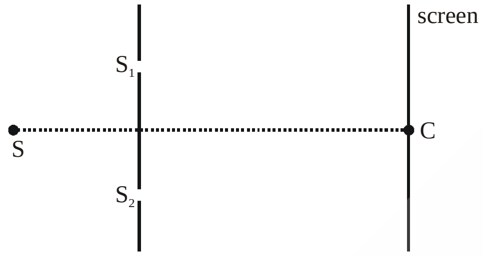


monochromatic parallel beam incident on thin prism

(S) Point O can be a minima

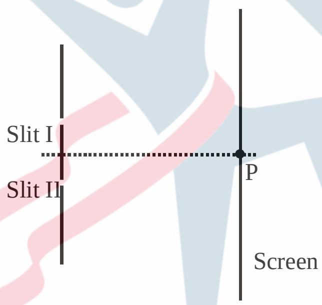
(T) Point O can be a least order minima.

9. In a YDSE setup , light of wavelength 4000 Å is used. Distance of screen from the slits is 2m and distance between slits is 1mm. There are three slabs slab 1(thickness 2mm, $\mu = 2$), slab 2 (thickness 1mm, $\mu = 3$), slab 3(thickness 4mm $\mu = \frac{3}{2}$)



(A)	If slab 1 is placed in front of slit S_1	(P)	Central maxima at C
(B)	If the slab 2 is placed in front of slit S_2 along with condition (A)	(Q)	Central maxima above C
(C)	If slab 3 is placed in front of slab 1 along with condition (B)	(R)	Fringe width is equal to 0.8 mm
		(S)	No. of fringes crossing central maxima as a result of slab placing is 5000

10. A double slit interference pattern is produced on a screen, as shown in the figure, using monochromatic light of wavelength 500nm. Point P is the location of the central bright fringe, that is produced when light waves arrive in phase without any path difference. A choice of three strips *A*, *B* and *C* of transparent materials with different thicknesses and refractive indices is available, as shown in the table. These are placed over one or both of the slits, singularly or in conjunction, causing the interference pattern to be shifted across the screen from the original pattern. In the column–I, how the strips have been placed, is mentioned whereas in the column–II, order of the fringe at point *P* on the screen that will be produced due to the placement of the strips(s), is shown. Correctly match both the column.



Film	A	B	C
Thickness (in μm)	5	1.5	0.25
Refractive index	1.5	2.5	2

	Column I		**Column II**
(A)	Only strip B is placed over slit–I	(P)	First Bright
(B)	Strip A is placed over slit–I and strip C is placed over slit–II	(Q)	Fourth Dark
(C)	Strip A is placed over the slit–I and strip B and strip C are placed over the slit–II in conjunction	(R)	Fifth Dark
(D)	Strip A and strip C are placed over slit–I (in conjuction) and strip B is placed over Slit–II	(S)	Central Bright

EXERCISE-(J-M)

1. A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. From this data, the wavelength of the unknown light is :- **[AIEEE-2009]**
(1) 442.5 nm (2) 776.8 nm (3) 393.4 nm (4) 885.0 nm

2. If a source of power 4kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called **[AIEEE 2010]**
(1) microwaves (2) y-rays (3) X-rays (4) ultraviolet rays

Direction : Questions number 3 to 5 are based on the following paragraph.

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

3. The initial shape of the wavefront of the beam is :- **[AIEEE-2010]**
(1) planar
(2) convex
(3) concave
(4) convex near the axis and concave near the periphery

4. The speed of the light in the medium is :- **[AIEEE-2010]**
(1) maximum on the axis of the beam (2) minimum on the axis of the beam
(3) the same everywhere in the beam (4) directly proportional to the intensity I

5. As the beam enters the medium, it will :- **[AIEEE-2010]**
(1) travel as a cylindrical beam
(2) diverge
(3) converge
(4) diverge near the axis and converge near the periphery

6. At two points P and Q on screen in Young's double slit experiment, waves from slits S_1 and S_2 have a path difference of 0 and $\frac{\lambda}{4}$ respectively. the ratio of intensities at P and Q will be : **[AIEEE-2011]**
(1) 3 : 2 (2) 2 : 1 (3) $\sqrt{2}$: 1 (4) 4 : 1

7. **Statement-1:** On viewing the clear blue portion of the sky through a Calcite Crystal, the intensity of transmitted light varies as the crystal is rotated.
Statement-1: The light coming from the sky is polarized due to scattering of sun light by particles in the atmosphere. The scattering is largest for blue light. **[AIEEE-2011]**
(1) Statement-1 is false, statement-2 is true
(2) Statement-1 is true, statement-2 is false
(3) Statement-1 is true, statement-2 true; statement-2 is the correct explanation of statement-1
(4) Statement-1 is true, statement-2 is true; statement -2 is not correct explanation of statement-1.

8. In a Young's double slit experiment, the two slits act as coherent sources of waves of equal amplitude A and wavelength λ. In another experiment with the same arrangement the two slits are made to act as incoherent sources of waves of same amplitude and wavelength. If the intensity at the middle point of the screen in the first case is I_1 and in the second case I_2, then the ratio $\frac{I_1}{I_2}$ is :- **[AIEEE-2011]**

(1) 4 (2) 2 (3) 1 (4) 0.5

9. Direction :

The question has a paragraph followed by two statement, Statement-1 and statement-2. Of the given four alternatives after the statements, choose the one that describes the statements.

A thin air film is formed by putting the convex surface of a plane-convex lens over a plane glass plate. With monochromatic light, this film gives an interference pattern due to light reflected from the top (convex) surface and the bottom (glass plate) surface of the film **[AIEEE-2011]**

Statement-1:

When light reflects from the air-glass plate interface, the reflected wave suffers a phase change of π.

Statement-2: The centre of the interference pattern is dark :-

(1) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of Statement-1.

(2) Statement-1 is false, Statement-2 is true

(3) Statement-1 is true, Statement-2 is false

(4) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation of statement-1.

10. In Young's double slit experiment, one of the slit is wider than other, so that the amplitude of the light from one slit is double of that from other slit. If I_m be the maximum intensity, the resultant intensity I when they interfere at phase difference ϕ is given by : **[AIEEE-2012]**

(1) $\frac{I_m}{9}(1 + 8\cos^2\frac{\phi}{2})$ (2) $\frac{I_m}{9}(4 + 5\cos\phi)$ (3) $\frac{I_m}{3}(1 + 2\cos^2\frac{\phi}{2})$ (4) $\frac{I_m}{5}(1 + 4\cos^2\frac{\phi}{2})$

11. An electromagnetic wave in vacuum has the electric and magnetic fields $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that ofwave propagation by $\vec{k}$. Then **[AIEEE-2012]**

(1) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{E}\times\vec{B}$ (2) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{B}\times\vec{E}$

(3) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{B}\times\vec{E}$ (4) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E}\times\vec{B}$

12. This question has Statement-l and statement-2. Of the four choices given after the Statements, choose the one that best describes the two statements. **[AIEEE - 2012]**

Statement-1 : Davisson - Germer experiment established the wave nature of electrons.

Statement-2: If electrons have wave nature, they can interfere and show diffraction.

(1) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation for Statement-1.

(2) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of Statement-I

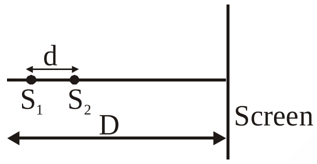
(3) Statement-1 is false, Statement-2 is true.

(4) Statement-1 is true, Statement-2 is false

13. A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The intensity of the emergent light is :- **[JEE-Mains 2013]**

(1) I_0 (2) $I_0/2$ (3) $I_0/4$ (4) $I_0/8$

14. Two coherent point sources S_1 and S_2 are separated by a small distance 'd' as shown. The fringes obtained on the screen will be : **[JEE-Mains 2013]**



(1) points (2) straight lines (3) semicircles (4) concentric circles

15. Match **List-I** (Electromagnetic wave type) with **List-II** (Its association/application) and select the correct option from the choices given below the lists : **[JEE-Mains 2014]**

List-I		**List-II**	
(a)	Infrared waves	(i)	To treat muscular strain
(b)	Radio waves	(ii)	For broadcasting
(c)	X-rays	(iii)	To detect fracture of bones
(d)	Ultraviolet rays	(iv)	Absorbed by the ozone layer of the atmosphere

	(a)	(b)	(c)	(d)
(1)	(iii)	(ii)	(i)	(iv)
(2)	(i)	(ii)	(iii)	(iv)
(3)	(iv)	(iii)	(ii)	(i)
(4)	(i)	(ii)	(iv)	(iii)

16. During the propagation of electromagnetic waves in a medium : **[JEE-Mains 2014]**

(1) Electric energy density is equal to the magnetic energy density

(2) Both electric magnetic energy densities are zero

(3) Electric energy density is double of the magnetic energy density

(4) Electric energy density is half of the magnetic energy density.

17. Two beams, A and B, of plane polarized light with mutually perpendicular planes of polarization are seen through a polaroid. From the position when the beam A has maximum intensity (and beam B has zero intensity), a rotation of polaroid through 30° makes the two beams appear equally bright. If the initial intensitites of the two beams are I_A and I_B respectively, then $\frac{I_A}{I_B}$ equals :**[JEE-Mains 2014]**

(1) 1 (2) $\frac{1}{3}$ (3) 3 (4) $\frac{3}{2}$

18. A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is:- **[JEE-Mains 2015]**

(1) 5.48 V/m (2) 7.75 V/m (3) 1.73 V/m (4) 2.45 V/m

19. Assuming human pupil to have a radius of 0.25cm and a comfortable viewing distance of 25cm, the minimum separation between two objects that human eye can resolve at 500 nm wavelength is :- **[JEE-Mains 2015]**

(1) 100 μm (2) 300 μm (3) 1 μm (4) 30 μm

20. On a hot summer night, the refractive index of air is smallest near the ground and increases with height from the ground. When a light beam is directed horizontally, the Huygens' principle leads us to conclude that as it travels, the light beam : **[JEE-Mains 2015]**

(1) bends downwards (2) bends upwards
(3) becomes narrower (4) goes horizontally without any deflection

21. The box of a pin hole camera, of length L, has a hole of radius a. It is assumed that when the hole is illuminated by a parallel beam of light of wavelength λ the spread of the spot (obtained on the opposite wall of the camera) is the sum of its geometrical spread and the spread due to diffraction. The spot would then have its minimum size (say b_{min}) when :- **[JEE-Mains 2016]**

(1) $a=\frac{\lambda^2}{L}$ and $b_{min} = \sqrt{4\lambda L}$ (2) $a=\frac{\lambda^2}{L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

(3) $a=\sqrt{\lambda L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$ (4) $a=\sqrt{\lambda L}$ and $b_{min} = \sqrt{4\lambda L}$

22. Arrange the following electromagnetic radiations per quantum in the order of increasing energy :-
A : Blue light B : Yellow light C : X–ray D : Radiowave
[JEE-Mains 2016]

(1) B, A, D, C (2) D, B, A, C (3) A, B, D, C (4) C, A, B, D

23. In a Young's double slit experiment, slits are separated by 0.5 mm, and the screen is placed 150 cm away. A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtain interference fringes on the screen. The least distance from the common central maximum to the point where the bright fringes due to both the wavelengths coincide is :- **[JEE-Main 2017]**

(1) 9.75 mm (2) 15.6 mm (3) 1.56 mm (4) 7.8 mm

24. The angular width of the central maximum in a single slit diffraction pattern is 60°. The width of the slit is 1 μm. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what is slit separation distance? (i.e. distance between the centres of each slit.) **[JEE-Main 2018]**

(1) 50 μm (2) 75 μm (3) 100 μm (4) 25 μm

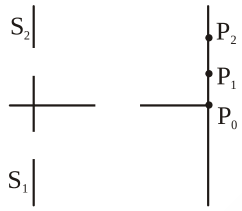
25. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\nu\left(\frac{z}{c}-t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos\left[k(2z-ct)\right]$ in medium, where the wave number k and frequency ν refer to their values in air. The medium is non-magnetic. If ϵ_{r_1} and ϵ_{r_2} refer to relative permittivity of air and medium respectively, which of the following options is correct ? **[JEE-Main 2018]**

(1) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}}=2$ (2) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}}=\frac{1}{4}$ (3) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}}=\frac{1}{2}$ (4) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}}=4$

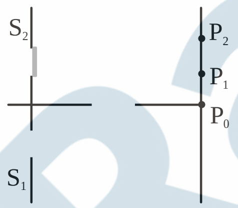
EXERCISE-(J-A)

1. **Column I** shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \lambda/4$ and $S_1P_2 - S_2P_2 = \lambda/3$,, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is pasted on slit S_2. The thicknesses of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by $\delta(P)$ and the intensity by $I(P)$. Match each situation given in **Column I** with the statement(s) in **Column II** valid for that situation. **[IIT-JEE-2009]**

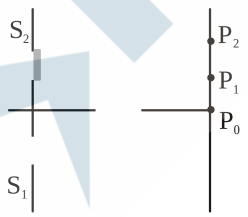
Column-I | **Column-II**

(A) 

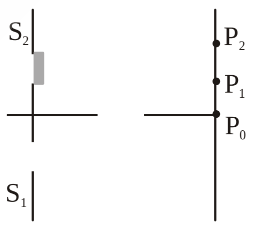
(p) $\delta(P_0) = 0$

(B) $(\mu - 1)\,t = \lambda/4$ 

(q) $\delta(P_1) = 0$

(C) $(\mu - 1)\,t = \lambda/2$ 

(r) $I(P_1) = 0$

(D) $(\mu - 1)\,t = 3\lambda/4$ 

(s) $I(P_0) > I(P_1)$

(t) $I(P_2) > I(P_1)$

2. Young's double slit experiment is carried out by using green, red and blue light, one color at a time. The fringe widths recorded are β_G, β_R and β_B, respectively. Then **[IIT-JEE-2012]**

(A) $\beta_G > \beta_B > \beta_R$

(B) $\beta_B > \beta_G > \beta_R$

(C) $\beta_R > \beta_B > \beta_G$

(D) $\beta_R > \beta_G > \beta_B$

3. In the Young's double slit experiment using a monochromatic light of wavelength λ, the path difference (in terms of an integer n) corresponding to any point having half the peak intensity is :- **[JEE Advanced 2013]**

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

(B) $(2n+1)\frac{\lambda}{4}$

(C) $(2n+1)\frac{\lambda}{8}$

(D) $(2n+1)\frac{\lambda}{16}$

4. A light source, which emits two wavelengths λ_1 = 400 nm and λ_2 = 600 nm, is used in a Young's double slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 and the number of fringes for them within a distance y on one side of the central maximum are m_1 and m_2, respectively, then :- **[JEE Advanced 2014]**

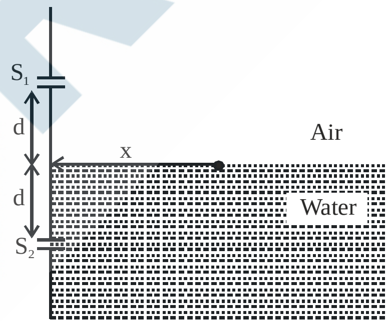
(A) $\beta_2 > \beta_1$

(B) $m_1 > m_2$

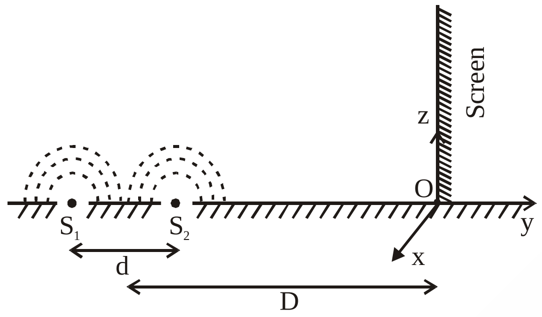
(C) From the central maximum, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1

(D) The angular separation of fringes of λ_1 is greater than λ_2

5. A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index = 4/3) as shown in the figure. The positions of maxima on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), 2d is the separation between the slits and m is an integer. The value of p is. **[JEE Advanced 2015]**

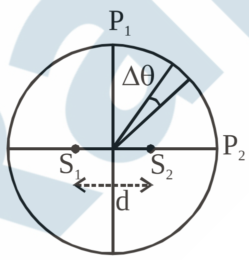


6. While conducting the Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 nm. The student mistakenly placed the screen parallel to the x-z plane (for z > 0) at a distance D = 3m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the sources d = 0.6003 mm. The origin O is at the intersection of the screen and the line joining S_1S_2. Which of the following is (are) true of the intensity pattern on the screen ? **[JEE Advanced 2016]**



(A) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction
(B) Semi circular bright and dark bands centered at point O
(C) The region very close to the point O will be dark
(D) Straight bright and dark bands parallel to the x-axis

7. Two coherent monochromatic point sources S_1 and S_2 of wavelength λ = 600 nm are placed symmetrically on either side of the center of the circle as shown. The sources are separated by a distance d = 1.8mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct ? **[JEE Advanced 2017]**



(A) A dark spot will be formed at the point P_2
(B) The angular separation between two consecutive bright spots decreases as we move from P_1 to P_2 along the first quadrant
(C) At P_2 the order of the fringe will be maximum
(D) The total number of fringes produced between P_1 and P_2 in the first quadrant is close to 3000

WAVE OPTICS
CBSE Previous Year's Questions

1. Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slits is now completely covered. What is the name of the pattern now obtained on the screen? Draw Intensity pattern obtained in the two cases. Also write two differences between the patterns obtained in the above two cases. **[3; CBSE-2004]**

2. Using Huygen's principle, draw a diagram to show propagation of a wave-front originating from a monochromatic point source.
Describe diffraction of light due to a single slit. Explain formation of a pattern of fringes obtained on the screen and plot showing variation of intensity with angle θ in single slit diffraction.
[5; CBSE-2005]

3. What is meant by a linearly polarized light? Which type of waves can be polarised? Briefly explain a method for producing polarised light. " Two Polaroids are placed at 90° to each other and the intensity of transmitted light is zero. What will be the intensity of transmitted light when one more Polaroid is placed between these two bisecting the angle between them? Take intensity of unpolarised light as λ.
[5; CBSE-2005]

4. Name the constituent radiation of electromagnetic spectrum which **[3; CBSE-2005]**
(a) Is used in satellite communication.
(b) Is used for studying crystal structure.
(c) Is similar to the radiations emitted during decay of radioactive nuclei?
(d) Has its wavelength range between 390 nm and 770 nm.
(e) Is absorbed from sunlight by ozone layer.
(f) Produces intense heating effect.

5. Mention the significance of Davisson-Germer experiment. An α particle and a proton are accelerated from rest through the same potential difference V. Find the ratio of de-Broglie wavelengths associated with them. **[3; CBSE-2005]**

6. What are coherent sources of light? State two conditions for two light sources to be coherent.
Derive a mathematical expression for the width of interference fringes obtained in Young's double slit experiment with the help of a suitable diagram. **[5; CBSE-2006]**

7. State Huygens' principle. Using the geometrical construction of secondary wave- lets, explain the refraction of a plane wave front incident at a plane surface. Hence verify Snell's law of refraction. Illustrate with the help of diagrams the action of (i) convex lens and (ii) concave mirror on a plane wave front incident on it. **[5; CBSE-2006]**

8. State the essential condition for diffraction of light to take place. Use Huygen's principle to explain diffraction of light due to a narrow single slit and the formation of a pattern of fringes obtained on the screen. Sketch the pattern of fringes formed due to diffraction at a single slit showing variation of intensity with angle θ. **[3; CBSE-2007]**

9. What are coherent sources of light ? Why are coherent sources required to obtain sustained interference pattern ? State three characteristic features which distinguish the interference pattern due to two coherently illuminated sources as compared to that observed in a diffraction pattern due to a single slit
[3; CBSE-2007]

10. Name the following constituent radiations of electromagnetic spectrum which
(i) produce intense heating effect,
(ii) is absorbed by the ozone layer in the atmosphere.
(iii) is used for studying crystal structure.
Write one more application for each of these radiations. **[2; CBSE-2007]**

11. Draw a schematic diagram of the experimental arrangement used by Davisson and Germer to establish the wave nature of electrons. Explain briefly how the de-Broglie relation was experimentally verified in case of electrons. **[3; CBSE-2007]**

12. How is a wavefront defined? Using Huygen's construction draw a figure showing the propagation of a plane wave refraction at a plane surface separating two media. Hence verify Snell s law of refraction. **[2; CBSE-2008]**

13. (a) What is plane polarised light? Two polaroids are placed at 90° to each other and the transmitted intensity is zero. What happens when one more Polaroid is placed between these two, bisecting the angle between them? How will the intensity of transmitted light vary on further rotating the third Polaroid?
(b) If a light beam shows no intensity variation when transmitted through a polaroid which is rotated, does it mean that the light is unpolarised? Explain briefly, **[5; CBSE-2008]**

14. Name the part of the electromagnetic spectrum of wavelength 10^{-2} m and mention its one application. **[1; CBSE-2008]**

15. The oscillating magnetic field in a plane electromagnetic wave is given by
$B_y = (8 \times 10^{-6}) \sin [2 \times 10^{11} t + 300\pi x] T$
(i) Calculate the wavelength of the electromagnetic wave.
(ii) Write down the expression for the oscillating electric field. **[2; CBSE-2008]**

16. Unpolarized light is incident on a plane surface of glass of refractive index μ at angle i. If the reflected light gets totally polarized, write the relation between the angle i and refractive index μ. **[1; CBSE-2009]**

17. Draw a diagram to show refraction of a plane wavefront incident in a convex lens and hence draw the refracted wave front. **[1; CBSE-2009]**

18. In a single slit diffraction experiment, when a tiny circular obstacle is placed in the path of light from distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why? **[3; CBSE-2009]**

19. State two points of difference between the interference patterns obtained in Young's double slit experiment and the diffraction pattern due to a single slit. **[3; CBSE-2009]**

20. Name the electromagnetic radiation to which waves of wavelength in the range of 10^{-2} m belong. Give on use of this part of EM spectrum. **[l;CBSE-2009]**

21. How does a charge q oscillating at certain frequency produce electromagnetic waves? Sketch a schematic diagram depicting electric and magnetic field for an electromagnetic wave propagating along the Z-direction. **[2; CBSE-2009]**

22. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. the screen is 1.0 m away from the slits. **[3; CBSE-2010]**
(a) Find the distance of the second (i) bright fringe, (ii) dark fringe from the central maximum.
(b) How will the fringe pattern change if the screen is moved away from the slits ?

23. How does an unpolarised light get polarised when passed through a polaroid ?

Two polaroids are set in crossed positions. A third polaroid is placed between the two making an angle θ with the pass axis of the first polaroid. Write the expression for the intensity of light transmitted from the second polaroid. In what orientations will the transmitted intensity be (i) minimum and (ii) maximum ? **[3; CBSE-2010]**

24. Name the part of electromagnetic spectrum whose wavelength lies in the rage of 10^{-10} m. Give its one use. **[1; CBSE-2010]**

25. Draw a sketch of a plane electromagnetic wave propagating along the z-direction. Depict clearly the directions of electric and magnetic field varying sinusoidally with z. **[2; CBSE-2010]**

26. State the importance of coherent sources in the phenomenon of interference.

In Young's double slit experiment to produce interference pattern, obtain the conditions for constructive and destructive interference. Hence deduce the expression for the fringe width. How does the fringes width get affected, if the entire experimental apparatus of Young is immersed in water ?

[5; CBSE-2011]

27. (a) State Huygens' principle. Using this principle explain how a diffraction pattern is obtained on a screen due to a narrow slit on which a narrow beam coming from a monochromatic source of light is incident normally.

(b) show that the angular width ofthe first diffraction fringe is half of that ofthe central fringe.

(c) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern ? **[5; CBSE-2011]**

28. How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit screens is doubled? **[1; CBSE-2012]**

29. (a) In Young's double slit experiment, derive the condition for

(i) constructive interference and

(ii) destructive interference at a point on the screen

(b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4m away. If the two slits are separated by 0.2 8 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelength coincide.

OR

(a) How does an unpolarized light incident on a polaroid get polarized? Describe briefly, with the help of a necessary diagram, the polarization of light by reflection from a transparent medium.

(b) Two polaroids 'A' and 'B' are kept in crossed position. How should a third polaroid 'C' be placed between them so that the intensity of polarized light transmitted by polaroid B reduces to $1/8^{th}$ of the intensity of unpolarized light incident on A? **[5; CBSE-2012]**

30. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves? **[1; CBSE-2012]**

31. A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2-5 mm from the centre of the screen. Calculate the width ofthe slit. **[CBSE-2013]**

32. (a) What is linearly polarized light? Describe briefly using a diagram how sunlight is polarised.

(b) Unpolarised light is incident on a polaroid. How would the intensity of transmitted light change when the polaroid is rotated? **[CBSE-2013]**

33. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency.

[1; CBSE-2013]

34. A capacitor, made of two parallel plates each of plate area A and separation d, is being charged by an external ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor. **[3; CBSE-2013]**

35. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies?

A transmitting antenna at the top of a tower has a height of 20 m and the height of the receiving antenna is 45 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = $6{\cdot}4 \times 10^6$ m) **[3; CBSE-2013]**

36. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong ?

[CBSE-2014]

37. Considering the case of a parallel plate capacitor being charged, show how one i s required to generalize Ampere's circuital law to include the term due to displacement current. **[CBSE-2014]**

38. (1) Show, with the help of a diagram, how unpolarised sunlight gets polarised due to scattering,

(2) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 45° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **[CBSE-2014]**

39. (a) In Young's double slit experiment, describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit. Hence obtain the expression for the fringe width. (b) The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9:25. Find the ratio of the widths of the two slits. **[CBSE-2014]**

OR

(a) Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

(b) Two wavelengths of sodium light of 590nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^6 m. The distance between the slit and the screen is 1.5m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases.

40. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons. Taking other factors, such as numerical aperture etc. to be same, how does the resolving power of an electron microscope compare with that of an optical microscope which uses yellow light? **[CBSE-2014]**

41. Define a wavefront. Using Huygens' principle, draw the shape of a refracted wavefront, when a plane wave is incident on a convex lens. **[CBSE-2015]**

OR

(a) When a wave is propagating from a rarer to a denser medium, which characteristic of the wave does not change and why ?

(b) What is the ratio of the velocity of the wave in the two media of refractive indices μ_1 and μ_2 ?

42. In Young's double slit experiment, the two slits are separated by a distance of 1.5 mm and the screen is placed 1 m away from the plane of the slits. A beam of light consisting of two wavelengths 650nm and 520 nm is used to obtain interference fringes. Find **[CBSE-2015]**

(a) the distance of the third bright fringe for $\lambda = 520$ nm on the screen from the central maximum.

(b) the least distance from the central maximum where the bright fringes due to both the wavelengths coincide.

43. How are electromagnetic waves produced ? What is the source of the energy carried by a propagating electromagnetic wave ? **[CBSE-2015]**

Identify the electromagnetic radiations used

(i) in remote switches of household electronic devices; and

(ii) as diagnostic tool in medicine.

44. Why can't we see clearly through fog ? Name the phenomenon responsible for it. **[1 ; CBSE-2016]**

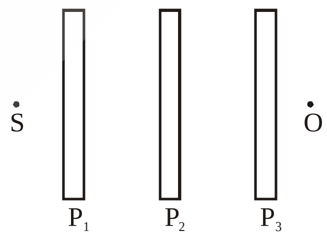
45. (i) Derive Snell's law on the basis of Huygen's wave theory when light is travelling from a denser to a rarer medium. **[3 ; CBSE-2016]**

(ii) Draw the sketches to differentiate between plane wavefront and spherical wavefront.

46. How are electromagnetic waves produced ? What is the source of energy of these waves ? Write mathematical expressions for electric and magnetic fields of an electromagnetic wave propagating along the z-axis. Write any two important properties of electromagnetic waves. **[3 ; CBSE-2016]**

47. (a) Why does unpolarised light from a source show a variation in intensity when viewed through a polaroid which is rotated ? Show with the help of a diagram, how unpolarised light from sun gets linearly polarised by scattering. **[5 ; CBSE-2016]**

(b) Three identical polaroid sheets P_1, P_2 and P_3 are oriented so that the pass axis of P_2 and P_3 are inclined at angles of 60° and 90° respectively with the pass axis of P_1. A monochromatic source S of unpolarized light of intensity I_0 is kept in front of the polaroid sheet P_1 as shown in the figure. Determine the intensities of light as observed by the observer at O, when polaroid P_3 is rotated with respect to P_2 at angles $\theta = 30°$ and 60°.



OR

(a) Derive an expression for path difference in Young's double slit experiment and obtain the conditions for constructive and destructive interference at a point on the screen.

(b) The intensity at the central maxima in Young's double slit experiment is I_0. Find out the intensity at a point where the path difference is $\frac{\lambda}{6}$, $\frac{\lambda}{4}$ and $\frac{\lambda}{3}$.

48. Do electromagnetic waves carry energy and momentum ? **[CBSE-2017]**

49. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns. **[CBSE-2017]**

OR

Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. Draw a plot showing the variation of intensity when θ varies from 0 to 2π.

50. Identify the electromagnetic waves whose wavelengths vary as **[CBSE-2017]**

(a) 10^{-12} m $< \lambda < 10^{-8}$ m

(b) 10^{-3} m $< \lambda < 10^{-1}$ m

Write one use for each.

51. (a) Define wavefront. Use Huygens' principle to verify the laws of refraction.

(b) How is linearly polarised light obtained by the process of scattering of light? Find the Brewster angle for air – glass interface, when the refractive index of glass = 1.5. **[CBSE-2017]**

52. Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery. **[CBSE-2018]**

53. (a) Why are infra-red waves often called heat waves ? Explain. **[CBSE-2018]**

(b) What do you understand by the statement, "Electromagnetic waves transport momentum" ?

54. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern. **[CBSE-2018]**

(b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light ?

55. (a) Define a wavefront. Using Huygen's principle, verify the laws of reflection at a plane surface.

(b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? Explain.

(c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why. **[CBSE-2018]**

56. Show using a proper diagram how unpolarised light can be linearly polarised by reflection from a transparent glass surface. **[CBSE-2018]**

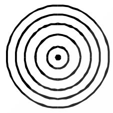
ANSWER KEY

EXERCISE (S-1)

1. Ans. 0.225 mm **2. Ans.** 5000Å **3. Ans.** 1.99×10^{-2} mm

4. Ans. 3.5 mm **5. Ans.** 0.2 mm **6. Ans.** 35.35 cm approximate, 5

7. Ans. 8 μm **8. Ans.** 0 , 1.5 mm **9. Ans.** $\lambda = 5850$ Å

10. Ans. 0.15 mm **11. Ans.** 48, 21, $\frac{32}{3}$, $\frac{9}{2}$, 0 m.m.; 

12. Ans. (i) circular, (ii) $\frac{1}{16}$, (C) 3000Å **13. Ans.** 81 : 1

EXERCISE (S-2)

1. Ans. $I_0 = I\sec^2\left[\frac{\pi(\mu-1)t}{\lambda}\right]$ **2. Ans.** 7 μm, 1.6, $\frac{400}{7}$ μm (decrease)

3. Ans. (i) y = 2 cm, (ii) m = 1.0016

4. Ans. (i) y = – 13/3 mm, (ii) intensity at O = $0.75I_{max}$ (iii) 650 nm, 433.33 nm

5. Ans. 9.3 μm **6. Ans.** (i) 1 mm (ii) increase **7. Ans.** $\frac{\lambda}{4\cos\alpha}$

8. Ans. 1.25 m **9. Ans.** 7 **10. Ans.** 0, 125 nm **11. Ans.** 3

12. Ans. 50

EXERCISE (O-1)

1. Ans. (C) 2. Ans. (C) 3. Ans. (B) 4. Ans. (B) 5. Ans. (C) 6. Ans. (C)

7. Ans. (B) 8. Ans. (D) 9. Ans. (B) 10. Ans. (B) 11. Ans. (D) 12. Ans. (B)

13. Ans. (C) 14. Ans. (C) 15. Ans. (D) 16. Ans. (A) 17. Ans. (D) 18. Ans. (D)

19. Ans. (A) 20. Ans. (D) 21. Ans. (A) 22. Ans. (C) 23. Ans. (D) 24. Ans. (B)

25. Ans. (A) 26. Ans. (A) 27. Ans. (D) 28. Ans. (A) 29. Ans. (C) 30. Ans. (C)

31. Ans. (C) 32. Ans. (B) 33. Ans. (B) 34. Ans. (B,D) 35. Ans. (A,C,D)

36. Ans. (A,B,D) 37. Ans. (B,C) 38. Ans. (A,C) 39. Ans. (A,C,D)

40. Ans. (A,C) 41. Ans. (C,D) 42. Ans. (B,C,D) 43. Ans. (B,D)

44. Ans. (B) 45. Ans. (C) 46. Ans. (A,C,D) 47. Ans. (A,B,D)

48. Ans. (B,D) 49. Ans. (D) 50. Ans. (A) 51. Ans. (C)

52. Ans. (a) $I_{rms} = V_{rms}\,\omega C = 6.9$ A (b) Yes (c) $B_0 = \frac{\mu_0}{2\pi}\frac{r}{R^2}i_0$, $B_0 = 1.63 \times 10^{-5}$ T

53. Ans. 153 N/C

54. Ans. (a) $\lambda = (c/v) = 1.5 \times 10^{-2}$ m

(b) $B_0 = (E_0/c) = 1.6 \times 10^{-7}$ T

(c) Energy density in E field: $u_E = (1/2)\varepsilon_0 E^2$

Energy density in B field: $uB = (1/2\,\mu)\,B^2$

Using $E = cB$, and $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$, $u_E = u_B$

55. Ans.(a) $-\hat{j}$ (b) 3.5 m (b) 86 MHz (c) 10.3 nT (e) $\{(10.3\text{ nT})\cos[(1.8\text{ rad/m})\,y + (5.4 \times 10^8\text{ rad/s})t]\}\,\hat{k}$

56. Ans. (a) 6.7 nT; (b) y ; (c) negative direction of y. **57. Ans.** 20A

58. Ans. $\left(n - \frac{1}{48}\right)\lambda = x_1 - x_2$ **59. Ans.** 391 eV **60. Ans. (B)** **61. Ans. (D)**

62. Ans. (D) **63. Ans. (B)** **64. Ans. (D)** **65. Ans. (C)** **66. Ans. (A)** **67. Ans. (B)**

68. Ans. (A) **69. Ans. (D)** **70. Ans. (D)** **71. Ans. (D)** **72. Ans. (B)** **73. Ans. (B)**

74. Ans. (D) **75. Ans. (D)** **76. Ans. (D)** **77. Ans. (B)** **78. Ans. (C)** **79. Ans. (A)**

EXERCISE (O-2)

1. Ans. (C) **2. Ans. (C)** **3. Ans. (A)** **4. Ans. (A)** **5. Ans. (B)** **6. Ans. (C)**

7. Ans. (A) **8. Ans. (A) (PRST); (B) (QRST); (C) (R); (D) (PRST)**

9. Ans. (A)-Q,R,S ; (B)-P,R ; (C)-Q,R,S **10. Ans. (A) (R) ; (B) (R) ; (C) (S) ; (D) (P)**

EXERCISE-(J-M)

1. Ans. (1) **2. Ans. (3)** **3. Ans. (1)** **4. Ans. (2)** **5. Ans. (3)** **6. Ans. (2)**

7. Ans. (3) **8. Ans. (2)** **9. Ans. (1)** **10. Ans. (1)** **11. Ans. (4)** **12. Ans. (1)**

13. Ans. (3) **14. Ans. (4)** **15. Ans. (2)** **16. Ans. (1)** **17. Ans. (2)** **18. Ans. (4)**

19. Ans. (4) **20. Ans. (2)** **21. Ans. (4)** **22. Ans. (2)** **23. Ans. (4)** **24. Ans. (4)**

25. Ans. (2)

EXERCISE-(J-A)

1. Ans. (A) p, s ; (B) q ; (C) t ; (D) r,s,t **2. Ans. (D)** **3. Ans. (B)** **4. Ans. (A,B,C)**

5. Ans. 3 **6. Ans. (B, C)** **7. Ans. (C), (D)**