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WAVE OPTICS

Contents

Syllabus

Wave Nature of light :

Huygen's principle, interference limited to Young's double-slit experiment.

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WAVE OPTICS

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

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

(i) For maxima, optical path difference = $n\lambda$ [optical path = μ (geometrical path)]

(ii) For minima, optical path difference = $(n - \frac{1}{2})\lambda$ or $(n + \frac{1}{2})\lambda$

(iii) Phase difference $\phi = \frac{2\pi}{\lambda}$(optical path difference)

λ : Wavelength in vacuum

2. **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 occures in denser medium.

3. **Young's Double Slit Experiment**

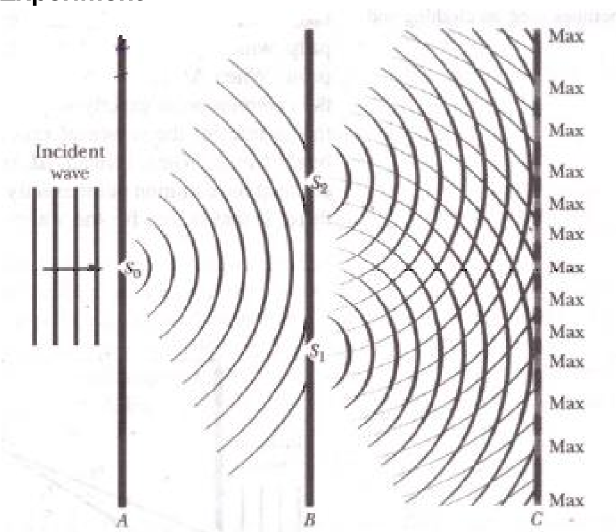


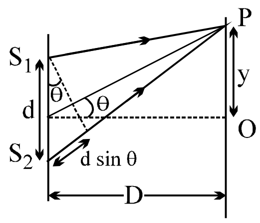
Fig. in Young's interference experiment, incident monochromatic light is diffracted by slit S_0, which then acts as a point source of ligh that emits semicircular wavefronts. As that light reaches screen *B,* it is diffracted by slits S_1 and.S_2, which then act as two point sources of light. The light waves traveling from slits S_1 and S_2 overlap and undergo interference, forming an interference pattern of maxima and minima on viewing screen C. This figure is a cross section; the screens, slits, and interference pattern extend into and out of the page. Between screens *Band* C, the semicircular wavefront's centered on S_2 depict the waves that would be there if only S_2 were open. Similarly, those centered on S_1 depict waves that would be there if only S_1 were open.

(i) If d << D

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

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

$$\Delta x = \frac{dy}{D}$$



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

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

(iii) For minima $\frac{dy}{D} = [n + (1/2)]\lambda$

or $y = \pm \frac{D\lambda}{2d}, \pm \frac{3D\lambda}{2d}, \pm \frac{5D\lambda}{2d}$, so on

(iv) Fringe width, $\beta = \frac{\lambda D}{d}$

4. Displacement of fringe Pattern

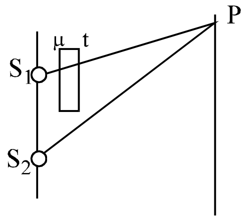
When a film of thickness 't' and refractive index 'μ' is introduced in the path of one of the source's of light, then fringe shift occurs as the optical path difference changes.

Optical path difference at P.

$\Delta x = S_2P - [S_1P + \mu t - t]$

$= S_2P - S_1P \ (\mu - 1)\, t = y.\,(d/D) - (\mu - 1)t$

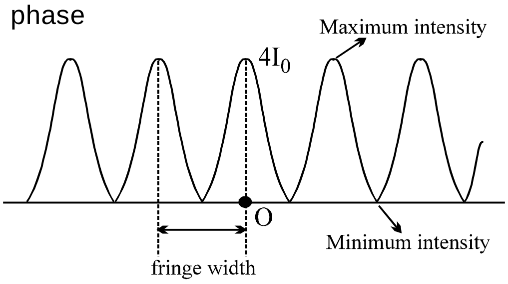
$\Rightarrow$ The fringe shift is given by $\Delta y = \frac{D(\mu-1)t}{d}$



5. 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 $\phi = \frac{2\pi(d\sin\theta)}{\lambda}$



6. Interference at thin film

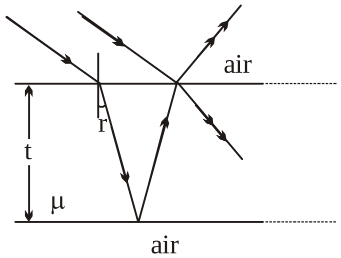
optical path difference $= 2\mu t \cos r$

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

For interference in reflected light

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

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



EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

* ***Marked Questions are having more than one correct option.***

SECTION (A) : PRINCIPLE OF SUPERPOSITION, PATH DIFFERENCE, WAVEFRONTS AND COHERENCE

A-1.* Four light waves are represented by

(i) $y = a_1 \sin \omega t$ (ii) $y = a_2 \sin (\omega t + \phi)$

(iii) $y = a_1 \sin 2\omega t$ (iv) $y = a_2 \sin 2(\omega t + \phi)$

interference fringes may be observed due to superposition of:

(A) (i) and (ii) (B) (i) and (iii)

(C) (ii) and (iv) (D) (iii) and (iv)

A-2.* 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

A-3. When interference of light takes place :

(A) energy is created in the region of maximum intensity

(B) energy is destroyed in the region of maximum intensity

(C) conservation of energy holds good and energy is redistributed

(D) conservation of energy does not hold good and energy is redistributed

A-4. For constructive interference to take place between two monochromatic light waves of wavelength λ, the path difference should be :

(A) $(2n-1)\frac{\lambda}{4}$ (B) $(2n-1)\frac{\lambda}{2}$ (C) $n\lambda$ (D) $(2n+1)\frac{\lambda}{2}$

A-5. Two monochromatic light waves of amplitude A and 2A interfering at a point, have a phase difference of 60º. The intensity at that point will be proportional to :

(A) 3 A^2 (B) 5 A^2 (C) 7 A^2 (D) 9 A^2

A-6. Two light sources are coherent when :

(A) their amplitude are equal

(B) their frequencies are equal

(C) their wavelengths are equal

(D) their frequencies are equal and their phase difference is constant

A-7. Ratio of intensities of two waves is given by 4 : 1. The ratio of the amplitudes of the waves is :

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

A-8. 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) 9 I and I (D) 9 I and 3 I

A-9. An interference is observed due to two coherent sources separated by a distance 5λ along positive y-axis, where λ is the wavelength of light. A detector D is moved along the positive x-axis. The number of points on the x-axis excluding the points x =0 and x = ∞ at which resultant intensity will be maximum are :

(A) 4 (B) 5 (C) ∞ (D) zero

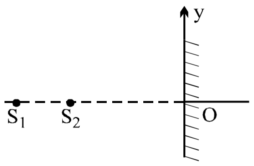
A-10. Two identical coherent sources placed on a diameter of a circle of radius R at separation x (<<R) symmetrically about the centre of the circle. The sources emit identical wavelength λ each. The number of points on the circle with maximum intensity is ($x = 5\lambda$).

(A) 20 (B) 22 (C) 24 (D) 26

A-11. Two waves each of amplitude a_0 interfere and the resultant amplitude is also a_0. The phase difference between the waves is-

(A) 0 (B) $\frac{\pi}{2}$ (C) $\frac{2\pi}{3}$ (D) π

A-12. Two point monochromatic and coherent sources of light of wavelength λ are placed on the dotted line in front of a large screen. The source 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. Then,



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

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

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

(4) $\rightarrow$ 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

SECTION (B) : YDSE WITH MONOCHROMATIC LIGHT

B-1.* In Young's double slit experiment, the interference pattern is found to have an intensity ratio between bright and dark fringes as 9. This implies :

(A) the intensities at the screen due to the two slits are 5 and 4 units

(B) the intensities at the screen due to the two slits are 4 and 1 units

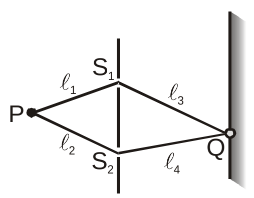
(C) the amplitude ratio is 3

(D) the amplitude ratio is 2

B-2. The maximum intensity in Young's double slit experiment is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance D = 10 d ?

(A) $\frac{I_0}{2}$ (B) $\frac{3}{4}I_0$ (C) I_0 (D) $\frac{I_0}{4}$

B-3. 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 that-



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

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

B-4. In Young's double slit experiment, the maximum intensity is I_0. When one slit is closed, the intensity becomes:

(A) $\frac{I_0}{2}$ (B) $\frac{I_0}{8}$ (C) $\frac{I_0}{4}$ (D) I_0

B-5. Using monochromatic source of light, Young's double slit interference fringes have been obtained for a certain separation of the slits. As the slit separation increases the fringes will become :

(A) circular in shape (B) wider

(C) unchanged in width (D) narrower

B-6. Monochromatic green light of wavelength 5×10^{-7} m illuminates a pair of slits 1 mm apart. The separation of bright lines in the interference pattern formed on a screen 2 m away is

(A) 0.25 mm (B) 0.1 mm (C) 1.0 mm (D) 0.01 mm

B-7. In Young's double slit experiment the angular width of a fringe formed on a distant screen is 1°. The wave-length of light used is 6000 Å. The spacing between the slits is approximately

(A) 1mm (B) 0.054 mm (C) 0.034 mm (D) 0.014 mm

B-8. In Young's double slit experiment carried out with light of wavelength λ = 5000 Å, the distance between the slits is 0.2 mm and the screen is at 200 cm from the plane of slits. The central maximum is at x = 0. The third maximum will be at x equal to :

(A) 1.67 cm (B) 1.5 cm (C) 0.5 cm (D) 5.0 cm

B-9. In Young's experiment, two coherent sources are placed 0.90 mm apart and the fringes are observed one metre away. If it produces the second dark fringe at a distance of 1 mm from central fringe the wavelength of monochromatic light used would be :

(A) 60×10^{-4} cm (B) 10×10^{-4} cm (C) 10×10^{-5} cm (D) 6×10^{-5} cm

B-10. Two slits separated by a distance of 1 mm are illuminated with red light of wavelength 6.5×10^{-7} m. The interference fringes are observed on a screen placed 1 m from the slits. The distance between the third dark fringe and the fifth bright fringe is equal to :

(A) 0.65 mm (B) 1.625 mm (C) 3.25 mm (D) 4.88 mm

B-11. If one of the two slits of a Young's double slit experiment is painted over so that it transmit half the light intensity of the other, then :

(A) the intensity of both maxima and minima increases

(B) the intensity of maxima decreases while the intensity of minima increases

(C) the intensity of maxima decreases while the minima has zero intensity.

(D) the intensity of maxima increases while the minima has zero intensity.

B-12. In a Young's double slit experiment, the fringe width is found to be 4 mm. If the whole apparatus is immersed in water of refractive index (4/3), without disturbing the geometrical arrangement, what is the new fringe width?

(A) 3 mm (B) 4 mm (C) 1.33 mm (D) 5 mm

B-13. In a Young's double–slit experiment, let S_1 and S_2 be the two slits, and C be the centre of the screen. If $\angle S_1CS_2 = \theta$ and λ is the wavelength, the fringe width will be–

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

B-14. In YDSE how many maxima can be obtained on the screen if wavelength of light used is 200 nm and d = 700 nm-

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

B-15. 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) $\frac{2D\lambda}{d}$

SECTION (C) : YDSE WITH POLYCHROMATIC LIGHT

C-1.* 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.

C-2. 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

C-3. Yellow light emitted by sodium lamp in Young's double slit experiment is replaced by monochromatic blue light of the same intensity :

(A) fringe-width will decrease
(B) fringe-width will increase
(C) fringe-width will remain unchanged
(D) fringe will become less intense

C-4. In a certain double slit experimental arrangement, interference fringes of width 1.0 mm each are observed when light of wavelength 5000 Å is used. Keeping the set-up unaltered if the source is replaced by another of wavelength 6000 Å, the fringe-width will be :

(A) 0.5 mm (B) 1.00 mm (C) 1.2 mm (D) 1.5 mm

C-5. The Young's double slit experiment is performed with blue and with green light of wavelength 4360 Å and 5460 Å respectively. If X is the distance of 4th maximum from the central one, then :

(A) X(blue) = X (green)
(B) X (blue) > X(green)
(C) X(blue) < X (green)
(D) $\frac{X(\text{blue})}{X(\text{green})} = \frac{5460}{4360}$

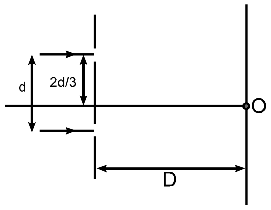
C-6. In a Young's double slit experiment. 12 fringes are observed to be formed in a certain segment of the screen, when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by :

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

C-7. A source emitting two light waves of wavelengths 600 nm and 700 nm is used in a young's double slit interference experiment. The separation between the slits is 0.10 mm and the interference is observed on a screen placed at 100 cm from the slits. Find the linear separation between the first maximum (next to the central maximum) corresponding to the two wavelengths.

(A) 0.5 mm (B) 1 mm (C) 2 mm (D) 3 mm

C-8. In the figure shown if a parallel beam of white light is incident on the plane of the slits then the distance of the nearest white spot on the screen from O is: [assume d << D, λ << d]



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

SECTION (D) : YDSE WITH GLASS SLAB, OPTICAL PATH, YDSE WITH OBLIQUE INCIDENCE AND HUYGEN'S PRINCIPLE :

D-1.* In Young's double-slit experiment, let A and B be the two slits. A thin film of thickness t and refractive index μ is placed in front of A. Let β = fringe width. The central maximum will shift-

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

D-2. In the previous question, 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 $t_B < t_A$

D-3. On introducing a thin sheet of mica (thickness 12×10^{-5} cm) in path of one of the interfering beams in Young's double slit experiment, the central fringe is shifted through a distance equal to the spacing between successive bright fringes. Calculate the refractive index of mica (λ = 600 nm)-

(A) 1.33 (B) 1.4 (C) 1.5 (D) 2.5

D-4. 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) $\frac{2\pi x}{(\mu-1)\lambda}$

D-5. The central fringe of the interference pattern produced by light of wavelength 6000 Å is found to shift to the position of 4th bright fringe after a glass plate of refractive index 1.5 is introduced. The thickness of the glass plate would be :

(A) 4.8 μm (B) 8.23 μm (C) 14.98 μm (D) 3.78 μm

D-6. What happens to the fringe pattern if the path of one of the slits a glass plate which absorbs 50% energy is interposed ?

(A) The bright fringes become brighter and dark fringes become darker

(B) No fringes are observed

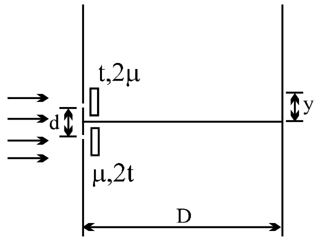
(C) The fringe-width decreases

(D) none of the above

D-7. In Young's double slit experiment the two slits are illuminated by light of wavelength 5890Å and the distance between the fringes obtained on the screen is 0.2°. If the whole apparatus is immersed in water then the angular fringe width will be, if the refractive index of water is $\frac{4}{3}$.

(A) 0.30° (B) 0.15° (C) 15° (D) 30°

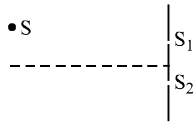
D-8. In the YDSE shown the two slits are covered with thin sheets having thickness t & 2t and refractive index 2μ and μ. Find the position (y) of central maxima



(A) zero (B) $\frac{tD}{d}$

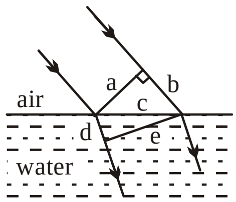
(C) $-\frac{tD}{d}$ (D) None

D-9. 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.

D-10. Figure shows plane waves refracted from air to water using Huygen's principle a, b, c, d, e are lengths on the diagram. The refractive index of water wrt air is the ratio.

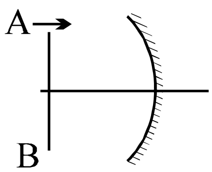


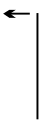
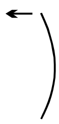
(A) a/e (B) b/e

(C) b/d (D) d/b

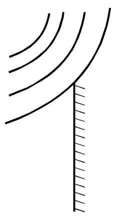
D-11. When light is refracted into a denser medium,
(A) its wavelength and frequeny both increase
(B) its wavelength increases but frequency remains unchanged
(C) its wavelength decreases but frequency remains unchanged
(D) its wavelength and frequency both decrease.

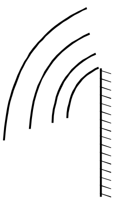
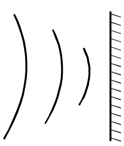
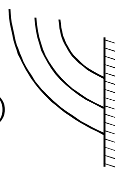
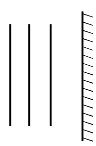
D-12. A plane wavefront AB is incident on a concave mirror as shown. Then, the wavefront just after reflection is



(A)  (B)  (C)  (D) None of the above

D-13. Spherical wave fronts shown in figure, strike a plane mirror. Reflected wave fronts will be as shown in



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

SECTION (E) : THIN FILM INTERFERENCE

E-1. A glass slab of thickness 4 cm contains the same number of waves as 5 cm of water. When both are traversed by the same number of monochromatic light. If the refractive index of water is $\frac{4}{3}$ then the refractive index of glass is-

(A) $\frac{5}{3}$ (B) $\frac{5}{4}$ (C) $\frac{16}{15}$ (D) $\frac{3}{2}$

E-2. When petrol drops from a vehicle fall over rain-water on the road, colours are seen because of

(A) dispersion of light (B) scattering of light (C) interference of light (D) absorption of light

E-3. A thin film of air between a plane glass plate and a convex lens is irradiated with a parallel beam of monochromatic light and is observed under a microscope. You will see

(A) uniform brightness

(B) complete darkness

(C) field crossed over by concentric bright and dark rings

(D) field crossed over by parallel bright and dark bands

E-4. A parallel beam of light of wavelength 560 nm falls on a thin film of oil in air (refractive index = 1.4). What should be the minimum thickness of the film so that it weakly transmits the light?

(A) 100 nm (B) 200 nm (C) 300 nm (D) 400 nm

E-5. White light is incident normally on a glass plate (in air) of thickness 500 nm and refractive index of 1.5. The wavelength (in nm) in the visible region (400 nm - 700nm) that is strongly reflected by the plate is:

(A) 450 (B) 600 (C) 400 (D) 500

E-6. A circular planar wire loop is dipped in a soap solution and after taking it out, held with its plane vertical in air. Assuming thickness of film at the top to be very small, as sunlight falls on the soap film, & observer receive reflected light

(A) the top portion appears dark while the first colour to be observed as one moves down is red.

(B) the top portion appears violet while the first colour to be observed as one moves down is indigo.

(C) the top portion appears dark while the first colour to be observed as one move down is violet.

(D) the top portion appears dark while the first colour to be observed as one move down depends on the refractive index of the soap solution.

E-7. It is necessary to coat a glass lens with a non-reflecting layer. If the wavelength of the light in the coating is λ, the best choice is a layer of material having an index of refraction between those of glass and air and a minimum thickness of

(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{2}$ (C) $\frac{3\lambda}{8}$ (D) λ

PART - II : MISLLANEOUS QUESTIONS

1. COMPREHENSION

COMPREHENSIONS # 1 :

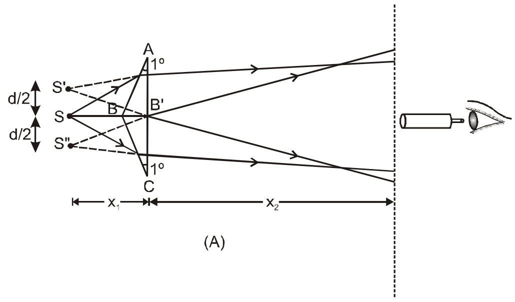
Interference in many systems is equivlent to Young's double slit experiment. In Fig. (A), two small angled prisms ABB' and CBB', each with refracting angle $\theta = 1^\circ$, are cemented along BB'. Combination of two prisms in this manner makes a biprism. It is also possible to make a biprism from a rectangular plate by removing some part of it so that it looks as the section ABC. A source 'S' of monochormatic light is placed x_1 cm from the biprism as shown. Refractive index of a material depedns on wavelength. Here, this dependence for the biprism can be expressed as.

$$\mu = A + \frac{B}{\lambda^2}$$

where $A = 1.4$
$B = 7.2 \times 10^6$ (Å)^2
λ is in Å.

The biprism forms virtual images S' and S" of the source S. The image S' is formed due to refraction at section ABB' and S" forms as a result of refraction at section CBB'. Each small angled prism (ABB' or CBB') produces a deviations $\delta = 36'$. S' and S" act as choerent sources and superposition of waves from the two results in interference, of course, in the region of superposition. Alternate bright and dark fringes are obtained which can be from the biprism. The assembly is obviously equivalent to Young's experiment. This arragement is, in fact, the Fresnel biprim interference experiment.

Assuming a small thickness of the biprim, answer the following questions. (x_1 = 30 cm ; x_2 = 125 cm)



(A)

1. Refractive index of the material of biprism is
(A) 1.82 (B) 1.75 (C) 1.6 (D) 1.5

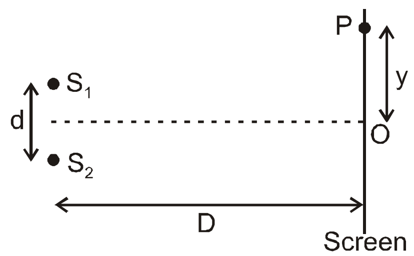
2. Wavelength of light from source S is
(A) 7200 Å (B) 6000 Å (C) 5800 Å (D) 4450 Å

3. d, the separation between S' and S", is
(A) 6.3 mm (B) 9 mm (C) 8.4mm (D) 10.5 mm

4. Width of a fringe in the interference pattern is
(A) 0.12 mm (B) 0.25 mm (C) 0.48 mm (D) 0.55 mm

COMPREHENSIONS # 2 :

The figure shows two coherent point sources of light in same phase and of wavelength λ. The distance between sources S_1 and S_2 is d and the distance between sources and screen is D. O is a point on screen equidistant from both S_1 and S_2. P is a point on screen distant y from O. The intensity at every point on screen due to any individual source is I_0. Then



5. The intensity at point P on screen is

(A) $4I_0\cos^2\frac{\pi d}{\lambda D}y$ (B) $4I_0\cos^2\frac{\pi D}{\lambda d}y$ (C) $4I_0\cos^2\frac{2\pi d}{\lambda D}y$ (D) $4I_0\cos^2\frac{2\pi D}{\lambda d}y$

6. The shortest distance of point P on the screen from O such that intensity at P is half that of intensity at O.

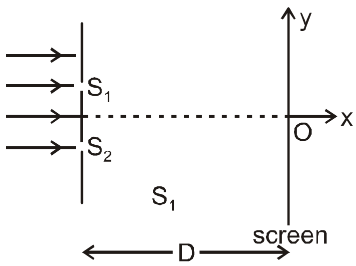
(A) $\frac{\lambda D}{6d}$ (B) $\frac{\lambda D}{3d}$ (C) $\frac{\lambda D}{4d}$ (D) None of these

7. The phase difference between interfering waves from S_1 and S_2 at point P such that $y = \frac{\lambda D}{3d}$

(A) $\frac{\pi}{3}$ (B) $\frac{\pi}{4}$ (C) $\frac{2\pi}{3}$ (D) None of these

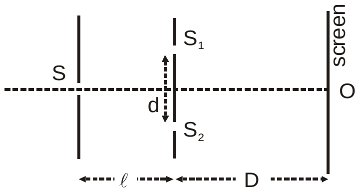
2. MATCH THE COLUMN

8. A monochromatic parallel beam of light of wavelength λ is incident normally on the plane containing slits S_1 and S_2. The slits are of unequal width such that intensity only due to one slit on screen is four times that only due to the other slit. The screen is placed perpendicular to x-axis as shown. The distance between slits is d and that between screen and slit is D. Match the statements in column-I with results in column-II.



Column-I	Column-II
(A) The distance between two points on screen having equal intensities, such that intensity at those points is $\frac{1}{9}$th of maximum intensity.	(p) $\frac{D\lambda}{3d}$
(B) The distance between two points on screen having equal intensities, such that intensity at those points is $\frac{3}{9}$th of maximum intensity.	(q) $\frac{D\lambda}{d}$
(C) The distance between two points on screen having equal intensities, such that intensity at those points is $\frac{5}{9}$th of maximum intensity.	(r) $\frac{2D\lambda}{d}$
(D) The distance between two points on screen having equal intensities, such that intensity at those points is $\frac{7}{9}$th of maximum intensity.	(s) $\frac{3D\lambda}{d}$

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

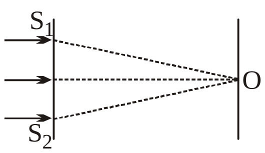


	Column I		**Column II**
(A)	If distance D is decreased keeping other things unchanged	(P)	Angular fringe width remains unchanged
(B)	If the source slit is moved closer to S_1S_2, (i.e. the distance is decreased) keeping other things unchanged	(Q)	Fringe width decreases
(C)	If the distance d (distance between slits S_1 & S_2) is decreased keeping other things unchanged	(R)	Fringe width increases
(D)	If the whole YDSE apparatus is immersed in a liquid keeping everything else unchanged	(S)	Position of central maxima remains unchanged

3. ASSERTION / REASON

10. **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.

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.

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

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.

12. **Statement-1 :** The two slits in YDSE are illuminated by two different sodium lamps emitting light of same wavelength. No interference pattern will be observed.

Statement-2 : Two independent light sources (except LASER) cannot be coherent.

(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.

13. **Statement-1 :** The minimum slit separation d for interference to produce at least one maximum other than central maximum in YDSE is 3λ.

Statement-2 : For a maximum, path difference = $n\lambda$. The maximum value of path difference = d, slit separation.

(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.

14. **Statement-1 :** Thin films such as soap bubble or thin layer of oil spread on water show beautiful colors when illuminated by white light.

Statement-2 : It is due to interference of Sun's light reflected from upper and lower surfaces of the film.

(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.

15. **Statement-1 :** Interference phenomena is based upon conservation of energy principle.

Statement-2 : All the bright fringes are of the same intensity in YDSE.

(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.

4. TRUE OR FALSE

16. (i) The intensity of light at a distance r from the axis of a long cylindrical source is inversely proportional to r.

(ii) The two slits in a Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelengths. No interference pattern will be observed on the screen.

(iii) In Young's double slit experiment, performed with a source of white light, only black and white fringes are observed.

EXERCISE # 2

PART - I : MIXED OBJECTIVE

** Marked Questions are having more than one correct option.*

SINGLE CORRECT ANSWER TYPE

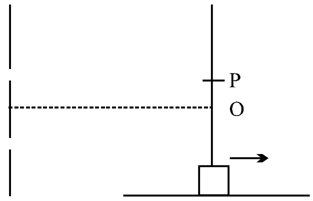
1. Two coherent point sources s_1 and s_2 vibrating in phase emit light of wavelength λ. The separation between the sources is 2λ. The smallest distance from s_2 on a line passing through s_2 and perpendicular to s_1s_2, where a minimum of intensity occurs is

(A) $\frac{7\lambda}{12}$ (B) $\frac{15\lambda}{4}$ (C) $\frac{\lambda}{2}$ (D) $\frac{3\lambda}{4}$

2. The intensity ratio of the two interfering beams of light is β. What is the value of $\frac{I_{max.} - I_{min}}{I_{max.} + I_{min}}$.

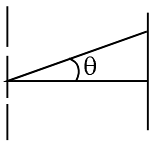
(A) $2\sqrt{\beta}$ (B) $\frac{2\sqrt{\beta}}{1+\beta}$ (C) $\frac{2}{1+\beta}$ (D) $\frac{1+\beta}{2\sqrt{\beta}}$

3. 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

4. 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 $-30° < \theta < 30°$.



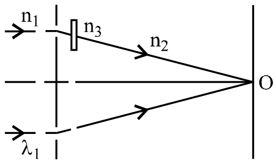
(A) 300 (B) 150 (C) 599 (D) 601

5. In Young's double slit experiment the slits are illuminated by white light. The distance between two slits is b and screen is d distance apart from the slits. Some wavelengths are missing on the screen in front of one of the slits. These wavelengths are-

(A) $\lambda = \frac{b^2}{d}, \frac{b^2}{3d}$....... (B) $\lambda = \frac{2b^2}{d}$ (C) $\lambda = \frac{2b^2}{3d}$ (D) $\lambda = \frac{b^2}{d}, \frac{b^2}{2d}$

6. In a YDSE both slits produce equal intensities on the screen. A 100 % transparent thin film is placed in front of one of the slits. Now the intensity of the geometrical centre of system on the screen becomes 75 % of the previous intensity. The wavelength of the light is 6000Å and $\mu_{glass} = 1.5$. The thickness of the film cannot be:
(A) 0.2 μm (B) 1.0 μm (C) 1.4 μm (D) 1.6 μm

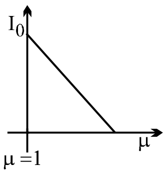
7. In the figure shown in YDSE, a parallel beam of light is incident on the slit from a medium of refractive index n_1. The wavelength of light in this medium is λ_1. A transparent slab of thickness 't' and refractive index n_3 is put infront of one slit. The medium between the screen and the plane of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

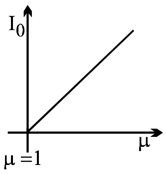


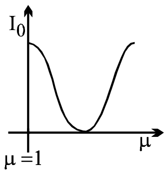
(A) $\frac{2\pi}{n_1\lambda_1}(n_3 - n_2)\,t$ (B) $\frac{2\pi}{\lambda_1}(n_3 - n_2)\,t$

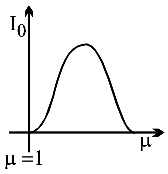
(C) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2}-1\right)t$ (D) $\frac{2\pi n_1}{\lambda_1}(n_3 - n_1)\,t$

8. 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' will be best represented by ($\mu \geq 1$).[Assume slits of equal width and there is no absorption by slab]

(A) 

(B) 

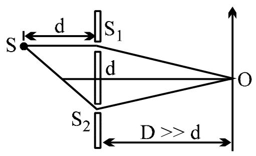
(C) 

(D) 

9. 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 not 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) $\frac{11\pi}{3}$

10. 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.

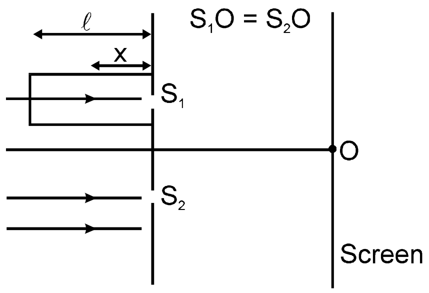
11. The wavefront of a light beam is given by the equation $x + 2y + 3z = c$, (where c is arbitrary constant) then the angle made by the direction of light with the y-axis is :

(A) $\cos^{-1}\frac{1}{\sqrt{14}}$ (B) $\cos^{-1}\frac{2}{\sqrt{14}}$ (C) $\sin^{-1}\frac{1}{\sqrt{14}}$ (D) $\sin^{-1}\frac{2}{\sqrt{14}}$

12. In a Young's double slit experiment, d = 1 mm, λ = 6000 Å & D = 1 m. The slits produce same intensity on the screen. The minimum distance between two points on the screen having 75% intensity of the maximum intensity is:

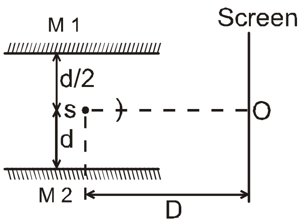
(A) 0.45 mm (B) 0.40 mm (C) 0.30 mm (D) 0.20mm

13. In the figure shown, a parallel beam of light is incident on the plane of the slits of a Young's double slit experiment. Light incident on the slit, S_1 passes through a medium of variable refractive index $\mu = 1 + ax$(where 'x' is the distance from the plane of slits as shown), upto a distance 'ℓ' before falling on S_1. Rest of the space is filled with air. If at 'O' a minima is formed, then the minimum value of the positive constant a (in terms of ℓ and wavelength 'λ' in air) is :



(A) $\frac{\lambda}{\ell}$ (B) $\frac{\lambda}{\ell^2}$ (C) $\frac{\ell^2}{\lambda}$ (D) None of these

14. M1 and M2 are two plane mirrors which are kept parallel to each other as shown. There is a point 'O' on perpendicular screen just infront of 'S'. What should be the wavelength of light coming from monchromatic source 'S'. So that a maxima is formed at 'O' due to interference of reflected light from both the mirrors. [Consider only 1st reflection].



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

MULTIPLE CORRECT ANSWER(S) QUESTIONS

15. In a standard YDSE apparatus a thin film (μ = 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 = 1mm, λ = 4500Å. (Symbols have usual meaning)

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

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

(A) Light obeys laws of reflection (B) Light travels in straight lines

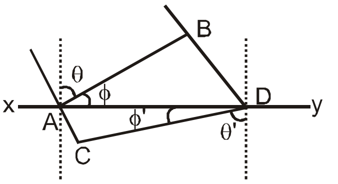
(C) Light shows interference (D) Speed of light in water is less than in air

17. Huygen's concept of secondary wavelets may be used to

(A) find velocity of light in vacuum (B) find new position of wavefront

(C) explain particle behaviour of light (D) explain Snell's law

18. In the given diagram a wavefront AB moving in air is incident on a plane glass surface xy. Its position CD after refraction through the glass slab is shown also along with normals dawn at A and D. The refractive index of glass will be equal to :



(A) (BD/ AC)

(B) (AB /CD)

(C) ($\sin\phi$ / $\sin\phi'$)

(D) ($\cos\theta$ / $\cos\theta'$)

19. Two monochromatic coherent point sources S_1 and S_2 are separated by a distance L. Each source emits light of wavelength λ, where $L >> \lambda$. The line S_1S_2 when extended meets a screen perpendicular to it at a point A :

(A) the interference fringes on the screen are circular in shape.

(B) the interference fringes on the screen are straight lines perpendicular to the line S_1S_2A

(C) the point A is an intensity maxima if $L = n\lambda$

(D) the point A is always an intensity maxima for any separation L

20. A person views the interference pattern, produced by two slits illuminated by white light, on placing a green filter in front of his eyes. Then :

(A) he will see sharply distinguishable dark and bright fringes

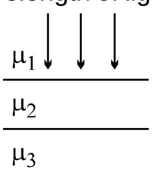
(B) the fringes will not be sharp but are differentiable

(C) on replacing the green filter by a blue filter, the fringes will be again shapr but closer than those by the green filter

(D) on using both the filters simultaneously, the central bands will be maximum bright.

21. 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.

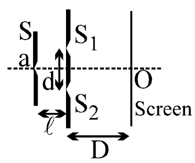
22. Consider a case of thin film interference as shown. Thickness of film is equal to wavelength of light in μ_2.



(A) Reflected light will be maxima if $\mu_1 < \mu_2 < \mu_3$
(B) Reflected light will be maxima if $\mu_1 < \mu_2 > \mu_3$
(C) Transmitted light will be maxima if $\mu_1 > \mu_2 > \mu_3$
(D) Transmitted light will be maxima if $\mu_1 > \mu_2 < \mu_3$

23. 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.

Question No. 24 to 25 (2 questions)
The figure shows a schematic diagram showing the arrangement of Young's Double Slit Experiment

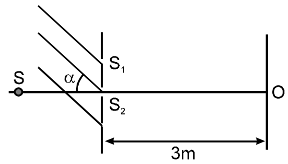


24. Choose the correct statement(s) related to the wavelength of light used
(A) Larger the wavelength of light larger the fringe width
(B) The position of central maxima depends on the wavelength of light used
(C) If white light is used in YDSE, then the violet colour forms its first maxima closest to the central maxima
(D) The central maxima of all the wavelengths coincide

25. 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

26. If the distance d is varied, then identify the correct statement
(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

27. A parallel beam of light (λ =5000 Å) is incident at an angle α = 30° with the normal to the slit plane in a young's double slit experiment. Assume that the intensity due to each slit at any point on the screen is I_0. Point O is equidistant from S_1 & S_2.The distance between slits is 1mm. Then :
(A) the intensity at O is $4I_0$
(B) the intensity at O is zero
(C) the intensity at a point on the screen 4m from O may be $4I_0$
(D) the intensity at a point on the screen 4m from O may be zero



PART - II : SUBJECTIVE QUESTIONS

* ***Marked Questions are having more than one correct option.***

1. 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 set-up the two slits are sources of equal amplitude 'A' and wavelength 'λ', but are incoherent. Find the ratio of the intensity of light at the midpoint of the screen in the first case to that in the second case.

2. A glass surface is coated by an oil film of uniform thickness 1.00 × 10^{-4} cm. The index of refraction of the oil is 1.20 and that of the glass is 1.55. Find the number of different wavelengths of light in the visible region (400nm-750nm) which are weakly transmitted by the oil film under normal incidence.

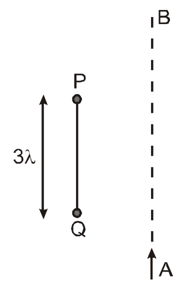
3. White light is used in a Young's double slit experiment. Find the minimum non zero order of the blue fringe (λ = 500 nm) which overlaps with a red fringe (λ = 700 nm).

4. In a two – slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-5} m. If the distance between the slits is 10^{-3} m. The wavelength of the light used is = n × 10^{-7} m. Find the value of n?

5. In a Young's double slit inteference experiment, the separation between the slits is 2.0 mm, the wavelength of light used is 5.0 × 10^{-7} m and the distance of the screen from the slits is 1.0m. Bright fringes are formed in one centimeter width on the screen are 10 n then find the value of n?

6. Two light waves are given by, $E_1 = 2\sin(100\pi t - kx + 30^o)$ and $E_2 = 3\cos(200\pi t - k'x + 60^o)$
The ratio of intensity of first wave to that of second wave is n/9, then the value of n?

7. Two coherent light sources each of wavelength λ are separated by a distance 3λ. The total number of minima formed on line AB which runs from $-\infty$ to $+\infty$ is:

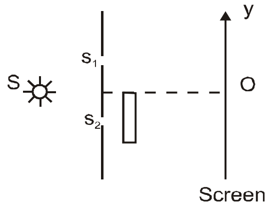


EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. 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 form the slits as shown. **[JEE 1999 (Main), 5+3+2/200]**



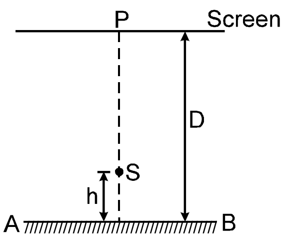
(a) Find the location of central maximum (bright fringe with zero path difference) on the y-axis.
(b) Find the light intensity at point O relative to the maximum fringe intensity.
(c) Now if 600 nm light is replaced by white light of range 400 nm to 700 nm, find the wavelengths of the light that form maxima exactly at point O.
[All wavelengths in the problem are for the given medium of refractive index 4/3. Ignore dispersion]

2. In a wave motion y = a sin(kx-ωt), y can represent **[JEE '99 (Screening), 3/200]**
(A) electric field (B) magnetic field (C) displacement (D) pressure

3. In a double slit experiment, instead of taking slits of equal widths, one slit is made twice as wide as the other. Then, in the interference pattern **[JEE' 2000 (Screening), 1/35]**
(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.

4. A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and the lower surface of the layer and the two reflected rays interfere. Write the condition for their constructive interference. If λ = 648 nm, obtain the least value of t for which the rays interfere constructively. **[JEE' 2000 (Main), 4/100]**

5. A point source S emitting light of wavelength 600 nm is placed at a very small height h above a flat reflecting surface AB as shown in 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. **[JEE 2002 Mains, 1+3+1/60]**



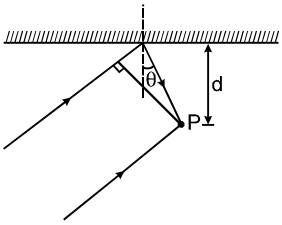
(a) What is the shape of the interference fringes on the screen?
(b) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point P. (Shown in the figure)
(c) If the intensity at point P corresponds to a maximum, calculate the minimum distance through which the reflecting surface AB should be shifted so that the intensity at P again becomes maximum.:

6. 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:

[JEE 2002 Screening, 3/90]

(A) 2λ (B) $2\lambda/3$ (C) $\lambda/3$ (D) λ

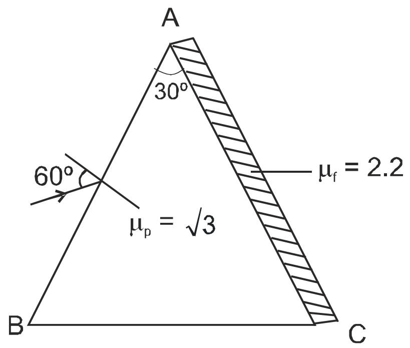
7. A parallel beam of light of wavelength λ is incident on a plane mirror at an angle θ as shown in the figure. With maximum intensity at point P, which of the following relation is correct.



(A) $\cos\theta - \sec\theta = \frac{\lambda}{4d}$ (B) $\cos\theta = \frac{\lambda}{4d}$

(C) $\cos\theta - \sin\theta = \frac{\lambda}{d}$ (D) $\cos\theta = \frac{\lambda}{2d}$ **[JEE 2003 Screening, 3/90]**

8. A prism of refracting angle 30º is coated with a thin film of transparent material of refractive index 2.2 on face AC of the prism. A light of wavelength 6600 Å is incident on face AB such that angle of incidence is 60º, find



[JEE 2003 (Main), 4/60]

(a) the angle of emergence, and (b) the minimum value of thickness of the coated film on the face AC for which the light emerging from the face has maximum intensity. [Given refractive index of the material of the prism is $\sqrt{3}$]

9. In a YDSE arrangement composite lights of different wavelengths λ_1 = 560 nm and λ_2 = 400 nm are used.If D = 1m, d = 0.1 mm. Then the distance between two completely dark regions is

[JEE 2004 Screening, 3/84]

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

10. In a Young's double slit experiment, two wavelength of 500 nm and 700 nm are 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. **[JEE 2004 Mains, 4/60]**

11. In Young's double slit experiment an electron beam is used to form a fringe pattern instead of light. If speed of the electrons is increased then the fringe width will : **[JEE 2005 Screening 3/84]**

(A) increase (B) decrease

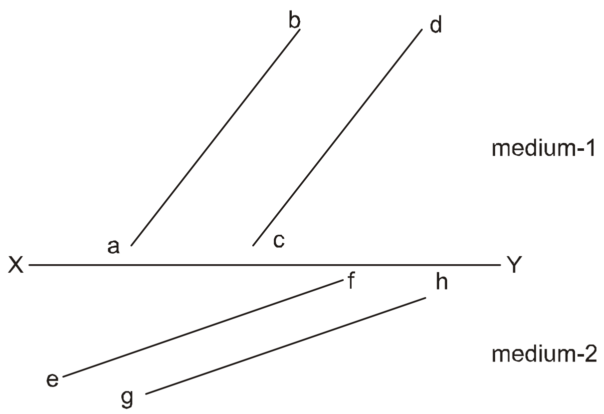
(C) remains same (D) no fringe pattern will be formed

12. In Young's double slit experiment maximum intensity is I than the angular position where the intensity becomes $\frac{I}{4}$ is : **[JEE 2005 Screening 3/84]**

(A) $\sin^{-1}\left(\frac{\lambda}{d}\right)$ (B) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$ (C) $\sin^{-1}\left(\frac{\lambda}{2d}\right)$ (D) $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

Paragraph :

The figure shows surface XY separating two transparent media, medium–1 and medium–2. The lines ab and cd represent wavefronts of a light wave travelling in medium–1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium–2 after refraction. **[JEE 2007 , 4+4+4/162 conducted by IIT Bombay]**



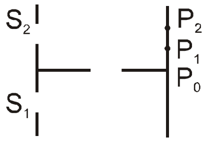
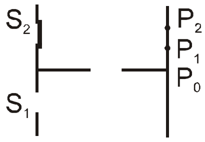
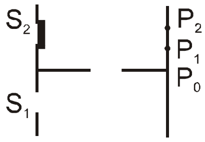
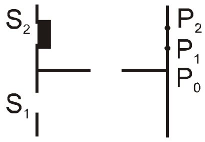
13. Light travels as a
(A) parallel beam in each medium
(B) convergent beam in each medium
(C) divergent beam in each medium
(D) divergent beam in one medium and convergent beam in the other medium

14. The phases of the light wave at c,d,e and f are ϕ_c, ϕ_d, ϕ_e and ϕ_f respectively. It is given that $\phi_c = \phi_f$:
(A) ϕ_c cannot be equal to ϕ_d
(B) ϕ_d can be equal to ϕ_e
(C) $(\phi_d - \phi_f)$ is equal to $(\phi_c - \phi_e)$
(D) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$

15. Speed of light is
(A) the same in medium–1 and medium–2
(B) larger in medium–1 than in medium–2
(C) larger in medium–2 than in medium–1
(D) different at b and d

16. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s). **[JEE 2008, 3/163 conducted by IIT Roorkee]**
(A) If $d = \lambda$, the screen will contain only one maximum
(B) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen
(C) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase
(D) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

17. **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. **[JEE 2009, 8/240 conducted by IIT Guwahati]**

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

18. 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 rspectively. Then **[JEE 2012 (3, –1)/136] [conducted by IIT Dehli]**

(A) $\beta_G > \beta_B > \beta_R$ (B) $\beta_B > \beta_G > \beta_R$ (C) $\beta_R > \beta_B > \beta_G$ (D) $\beta_R > \beta_G > \beta_B$

19. 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 (P-1) 2013]**

(A) $(2n + 1)\frac{\lambda}{2}$ (B) $(2n + 1)\frac{\lambda}{4}$ (C) $(2n + 1)\frac{\lambda}{8}$ (D) $(2n + 1)\frac{\lambda}{16}$

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. Wavelength of light used in an optical instrument are $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is - **[AIEEE - 2002]**

(1) 16 : 25 (2) 9 : 1 (3) 4 : 5 (4) 5 : 4

2. Electromagnetic waves are transverse in nature is evident by **[AIEEE-2002]**

(1) polarization (2) interference (3) reflection (4) diffraction

3. To demonstrate the phenomenon of interference we require two sources which emit radiation of **[AIEEE-2003]**

(1) nearly the same frequency

(2) the same frequency

(3) different wavelength

(4) the same frequency and having a definite phase relationship

4. The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment is **[AIEEE - 2004]**

(1) infinite (2) five (3) three (4) zero

5. A young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is **[AIEEE - 2005]**

(1) Straight line (2) Parabola (3) Hyperbola (4) Circle

6. If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled ? **[AIEEE - 2005]**

(1) $I_0\pi/\omega$ (2) $I_0/2$ (3) $2I_0$ (4) $4I_0$

7. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is **[AIEEE - 2005]**

(1) zero (2) I_0 (3) $\frac{1}{2}I_0$ (4) $\frac{1}{4}I_0$

8. In a Young's double slit experiment the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ being the wavelength of the light used) is I. If I_0 denotes the maximum intensity, I/I_0 is equal to: **[AIEEE - 2007]**

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

9. Direction :

The question has a paragraph followed by two statements, Statements-1 and Statement-2. Of the given four alternatives after the statements, choose the one that describe 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 surfers a phase change of π.

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

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

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

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

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

10. In Young's double slit experiment, one of the slit is wider than other, so that 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) $\frac{I_m}{9}(4 + 5\cos\phi)$

(2) $\frac{I_m}{3}\left(1+2\cos^2\frac{\phi}{2}\right)$

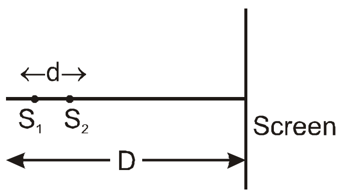
(3) $\frac{I_m}{5}\left(1+4\cos^2\frac{\phi}{2}\right)$

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

11. 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) $I_0/8$

12. 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) semi-circles (4) concentric circles

EXERCISE # 4

NCERT QUESTIONS

1. (a) The refractive index of glass is 1.5. What is the speed of light in glass?
(speed of light in vacuum is 3.0 x 10^{-8} m s^{-1})
(b) Is the speed of light in glass independent of the colour of light? If not, which of the two colours red and violet travels slower in a glass prism ?

2. In a Young's double-slit experiment, the slits are separated by 0.28 mm and the screen os placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

3. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5)

4. The 6563 Å H_α line emitted by hydrogen in a star is found to be red-shifted by 15 Å Estimate the speed the speed with which the star is receding form the Earth.

5. Explain how Newton's corpuscular theory predicts the speed of light in a medium, say, water, to be greater than the speed of light in bvacuum. Is the prediction confirmed by experimental determination of the speed of light in water? If not, which alternative picture of light is consistent with experiment?

6. You have learnt in the text how Huygens' principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a mirror produces a virtual image whose distance from the mirror is equal to the object distance from the mirror.

7. Let us list some of the factors, which could possibly influence the speed of wave propagation:
(i) nature of the source. (ii) direction of the propagation.
(iii) motion of the source and/or observe. (iv) wavelenght.
(v) intensity of the wave.
On which of these factors,if any,does
(a) the speed of light in vacuum,
(b) the speed of light in a medium (say, glass or water),depend?

8. For sound waves, the Doppler formula for frequency shift slightly between the two sutuations: (i) source at rest; observer moving, and (ii) source moving;observer at rest. The exact Dopplar formulas for the case of light waves in vacuum are, however,strictly indentical for these situation. Explain why this should be so. Would you expect the formulas to be strictly identical for the two situations in case of light travelling in a medium?

9. Answer the following questions:
(a) When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.
(b) As you have learnt in the text, the principle of linear superposition of wave displacement is basic to understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle ?

10. In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of $n\lambda$ /a. Justify this by suitify this by suitably dividing the slit to bring out the canellation.

ANSWERS

Exercise # 1

PART-I

A-1.*	(AD)	**A-2.***	(BD)	**A-3.**	(C)	**A-4.**	(C)	**A-5.**	(C)	**A-6.**	(D)	**A-7.**	(A)
A-8.	(C)	**A-9.**	(A)	**A-10.**	(A)	**A-11.**	(C)	**A-12.**	(C)	**B-1.***	(BD)	**B-2.**	(A)
B-3.	(D)	**B-4.**	(C)	**B-5.**	(D)	**B-6.**	(C)	**B-7.**	(C)	**B-8.**	(B)	**B-9.**	(D)
B-10.	(B)	**B-11.**	(B)	**B-12.**	(A)	**B-13.**	(A)	**B-14.**	(B)	**B-15.**	(C)	**C-1.***	(BCD)
C-2.	(B)	**C-3.**	(A)	**C-4.**	(C)	**C-5.**	(C)	**C-6.**	(B)	**C-7.**	(B)	**C-8.**	(D)
D-1.*	(AC)	**D-2.**	(D)	**D-3.**	(C)	**D-4.**	(A)	**D-5.**	(A)	**D-6.**	(D)	**D-7.**	(B)
D-8.	(B)	**D-9.**	(D)	**D-10.**	(C)	**D-11.**	(C)	**D-12.**	(C)	**D-13.**	(C)	**E-1.**	(A)
E-2.	(C)	**E-3.**	(C)	**E-4.**	(A)	**E-5.**	(B)	**E-6.**	(C)	**E-7.**	(A)		

PART-II

1.	(C)	**2.**	(B)	**3.**	(A)	**4.**	(A)	**5.**	(A)	**6.**	(C)	**7.**	(C)

8. (A) q,r,s (B) p,q,r,s (C) q,r,s (D) p,q,r,s

9. (A) p,q,s (B) p,s (C) r,s (D) q,s

10.	(D)	**11.**	(C)	**12.**	(A)	**13.**	(D)	**14.**	(A)	**15.**	(B)

16. (i) True, (ii) True, (iii) False

Exercise # 2

PART-I

1.	(B)	**2.**	(B)	**3.**	(C)	**4.**	(C)	**5.**	(A)	**6.**	(D)	**7.**	(A)
8.	(C)	**9.**	(A)	**10.**	(A)	**11.**	(B)	**12.**	(D)	**13.**	(B)	**14.**	(B)
15.	(CD)	**16.**	(CD)	**17.**	(BD)	**18.**	(ACD)	**19.**	(AC)	**20.**	(AC)	**21.**	(BC)
22.	(AD)	**23.**	(ACD)	**24.**	(ACD)	**25.**	(ABD)	**26.**	(ABCD)	**27.**	(AC)		

PART-II

1.	2	**2.**	3	**3.**	7	**4.**	6	**5.**	4	**6.**	1	**7.**	6

Exercise # 3

PART-I

1. (a) y = – 4.33 mm (b) $I_0 = \frac{3}{4} I_{max}$ (c) λ = 650 nm, 433.3 nm **2.*** (ABC) **3.** (A)

4. $2\mu t = \left(n + \frac{1}{2}\right)\lambda$ with μ = 1.8 and n = 0,1,2,3....... ; 90 nm

5. **(a)** circular, **(b)** $\frac{I_{min}}{I_{max}} = \frac{1}{16}$, **(c)** 300 nm **6.** (A) **7.** (B) **8.** (a) 0º (b) $t_{min} = \frac{\lambda}{2\mu_f}$ =150 nm

9. (D) **10.** 3.5 mm. **11.** (B) **12.** (B) **13.** (A) **14.** (C)

15. (B) **16.** (AB) **17.** (A) p, s; (B) q; (C) t ; (D) r, s, t **18.** (D) **19.** (B)

PART-II

1. (4) **2.** (1) **3.** (4) **4.** (2) **5.** (1) **6.** (3) **7.** (3)

8. (4) **9.** (3) **10.** (4) **11.** (3) **12.** (4)

Exercise # 4

1. (a) 2.0×10^8 ms^{-1} (use $k = \frac{c}{\eta}$)

(b) No. The refractive index , and hence the speed of light in a medium, depends on wavelength. [When no particular wavelength or colour of light is specified, we may take the given refractive index to reter to yellow colour] Now we know violet colour deviates more than red in a glass prism, i.e., $n_\upsilon = n_r$. Therefore , the viloet component of white light travels slower than the red component.

2. $I = \frac{1.2 \times 10^{-2} \times 0.28 \times 10^{-3}}{4 \times 1.4}$ = 600 nm

3. $\tan^{-1}(1.5) \sim 56.3^0$

4. Use the formula

$$\lambda' - \lambda = \frac{\upsilon}{c}\lambda$$

i.e., $\upsilon = \frac{c}{\lambda}(\lambda' - \lambda)$

$$= \frac{3 \times 10^8 \times 15}{6563}$$

$= 6.86 \times 10^5$ ms^{-1}

5. In Newton's corpuscular (particle) picture of refraction, particles of light incident from a rarer to a denser medium experience a force of attraction normal to the surface. This results in an increase in the normal component of the velocity but the component along the surface is unchanged.This means

$$c \sin i = \upsilon \sin r \text{ or } \frac{\upsilon}{c} = \frac{\sin i}{\sin r} = \eta > 1, \upsilon > c.$$

The prediction is opposite to the experimental results ($\upsilon < c$) .The wave picture of light is consistent with the experiment.

6. With the point object at the centre, draw a circle touching the mirror.This is a plane section of the spherical wavefront from the object that has just reached the mirror. Next draw the locations of this same wavefront after a time t in the presence of the mirror, and in the absence of the mirror.You will get two arcs symmetrrically located on either side of the mirror. Using simple geometry, the centre of the reflected wavefront (the image of the object) is seen to be at the same distance from the mirror as the object.

7. (a) The speed of light in vacuum is a universal constant independent of all the factors listed and anything else.In particular, note the surprising fact that it is independent of the relative motion between the source and the onserver.This fact is a basic axiom of Einstein's special theory of relativity.
(b) Dependence of the speed of light in a medium :
(i) does not depend on the nature of the source (wave speed is determined by the properties of the medium of propagation.This is also true for other waves , e.g., sound waves, water waves etc.).
(ii) independent of the direction of propagation for isotropic media.
(iii) independent of the motion of the source relative to the medium but depends on the motion of the observer relative to the medium.
(iv) depends on wavelength.
(v) independent of intensity .[For high intensity beams, however, the situation is more complicated and need not concern us here.]

8. Sound waves require a medium for propagation.Thus even though the situations (i) and (ii) may correspond to the same relative motion (between the source and the observer), the are not identical physically since the motion of the observer relative to the medium is different in the two situations.Therefore, we cannot expect Doppler formulas for sound to be identical for (i) and (ii). For light waves in vacuum, there is clearly nothing to distinguish between (i) and (ii). Here only the relative motion between the source and the observer counts and the relativistic Doppler formula is the same for (i) and (ii). For light propagation in a medium, once again like for sound waves,the two situations are not indentical and we should expect the Doppler formulas for this case to be different for the two situations (i) and (ii).

9. (a) Interference of the direct signal received by the anjtenna with the (weak) signal reflected by the passing aircraft.
(e) Superposition principle follows from the linear character of the (differential) equaltion governing wave motion. If y_1 and y_2 are solutions of the wave equation, so is any linear combination of y_1 and y_2. When the amplitudes are large (e.g. high intensity laser beams) and non-linear effects are important, the situation is far more complicated and need not concern us here.

10. Divide the single slit into n smaller slits of width a' = a/n. The angle q = nλ/a = λ/a'. Each of the smaller slits sends zero intensity in the direction θ. The combination gives zero intensity as well.