Chapter = 9

Physical Optics

Physical optics: The branch of Physics which deals with study of light and its different phenomenon is called physical optics.

Light: A type of energy which produce the sensation of vision is called light.

What is Wave front, spherical and plane wave front. Also define ray of light.

Wave front: The surface on which all the points of waves have same phase of vibration is called wave front.

Spherical wave front: The wave front in which the light waves are propagated in spherical form with the source is called spherical.

Plane wave front: At very large distance from the source, a small portion of spherical wave front will becomes very nearly plane wave front. As light reaches from sun to earth.

Wavelength and ray of light: The distance b/w two consecutive wave fronts is called wavelength.

Ray of light: The line normal to wave front is called ray of light.

In 1678, a Dutch scientist Huygens proposed that light consists of wave nature.

State Huygens's principle.

Huygens's principle is used to find shape and location of wave front. It has two parts

i. Every point of wave front may be consider as a source of secondary Wavelets which spread out in forward direction with speed equal to speed of wave

ii. The new position of the wave front after a certain interval of time can Be found by constructing a surface that touches all the secondary wavelets.

What is Interference of light? Also define its types and condition for detection of interferometer.

Interference of light: The phenomenon in which when two identical waves travelling in the same direction are superimposed is called interference.

Constructive interference: If the crest of one wave falls on the crest of wave and trough of wave fall on trough then it is called constructive interference.

Destructive interference: If crest of one wave falls on the trough of other wave then they cancel each other such interference is called destructive interference.

Condition for detection of interference: Following conditions are necessary for detection of interference. (i) Monochromatic (ii) coherent etc.

Explain Young Double slit experiment.

Definition: Such an experiment which was performed by Thomas Young in 1801 by applying the principle of interference and prove the wave nature of light is called young Double slit experiment.

Experimental arrangement: A screen having two narrow slits is illuminated by a beam of monochromatic light and portion of wave fronts incidents on the slits behave as source of secondary wavelets and superposition of these waves' results in a series of bright and dark fringes and are seen on screen placing at distance L from slits. The bright fringes are called maxima and dark fringes are called minima

Equation of path difference for maxima and minima: let us consider an arbitrary point P on the screen on one side of central point O. The path Difference b/w wavelets leaving the slits and arriving at point P is BD

For maxima or constructive interference: If point P is to have bright fringe then path difference must be an integral multiple of wavelength

$$\text{Path difference} = BD = m\lambda \text{ ------(1)} \quad \text{where m is order of fringes} \quad m = 0,1,2,...$$

$$\text{from the fig}, \sin\theta = \frac{BD}{d}$$

$$BD = d\sin\theta \text{ ----------(2)}$$

comparing both equations

$d\sin\theta = m\lambda$ This is the equation for path differnce of maxima or bright fringes

For Destructive interference or minima: In case of dark fringes then path difference must half integral multiple of wavelength so above equation for minima becomes $d\sin\theta = (m+1/2)\lambda$.

Position of dark and bright fringes: Let Y is the distance of point P from central point O and a bright fringe is formed at P then using triangle POC.

$$\text{Tan}\theta = \frac{OP}{OC} = \frac{Y}{L}$$

$Y = L\,\text{Tan}\theta$ For small value of angle $\sin\theta \approx \tan\theta$

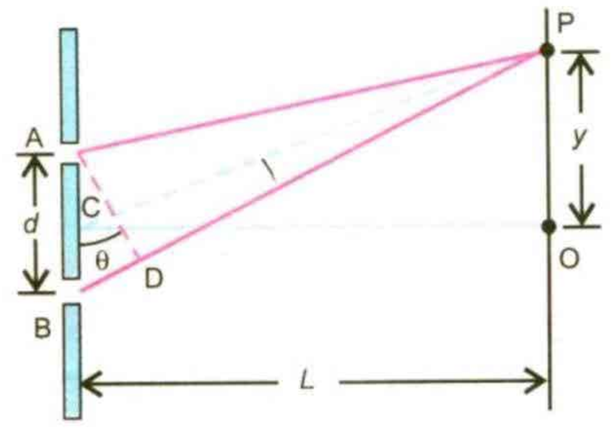
$Y = L\text{Sin}\,\theta$ ----------(3)

using path difference equation $d\sin\theta = m\lambda\lambda$ $\sin\theta = m\lambda\lambda/$ puttingin eq (3)

$Y = L(m\lambda(m\lambda$

$$Y = \frac{m\lambda\lambda}{d}$$ This is the position for bright fringes

$$Y = (m + 1/2)\frac{\lambda L}{d}$$ This is the position for dark fringes



Fringe spacing: The distance b/w two consecutive bright or dark fringes is called fringe spacing.

For bright fringes : For mth order $Y_m = \frac{m\lambda L}{d}$ and $(m+1)$th fringe $Y_{m+1} = \frac{(m+1)\lambda L}{d}$

$\Delta y = Y_{m+1} - Y_m$

$$\Delta y = \frac{(m+1)\lambda L}{d} - \frac{m\lambda L}{d} = \frac{m\lambda L}{d} + \frac{\lambda L}{d} - \frac{m\lambda L}{d}$$

$$\Delta y = \frac{\lambda L}{d}$$

Similarly same results will obtained for dark fringes $\Delta y = \frac{\lambda L}{d}$.

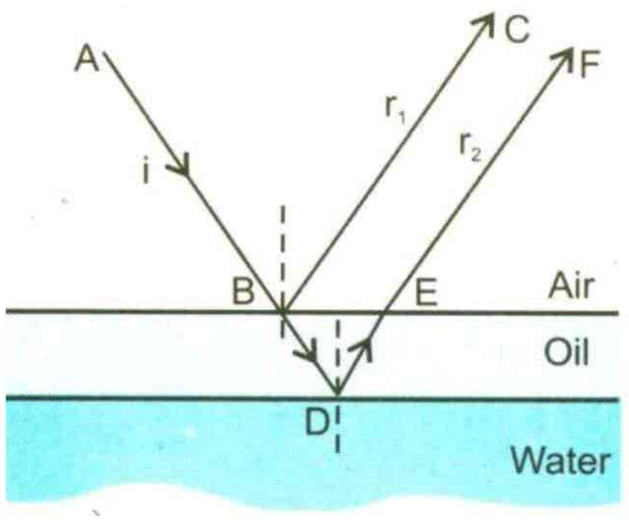
What is Thin film? Give the factors upon which path difference of thin film depend.

Definition: A transparent medium whose thickness is very small as comparable to the wavelength of light is called thin film.

For example,

- Oil film on the surface of water.
- Surface of soap bubble etc
- The vivid iridescence of peacock feathers due to interference of light.

Explanation: Brilliant and beautiful colors in soap bubbles and oil film on the Surface of water due to interference of light reflected from the Two surfaces of the film as shown if fig.



Factors upon path difference depends: Path difference depends upon

i. Thickness of the film
ii. Nature of the film
iii. Angle of incidence

Write a note on Newton Rings.

Definition: Circular and bright fringes obtained by Newton which are concentric circles are called Newton rings.

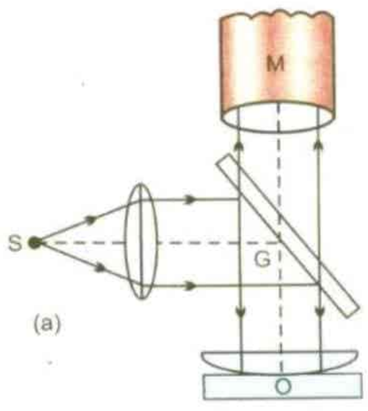
Explanation: When a Plano-convex lens of long focal length is placed in contact with a plane glass plate, air film is enclosed b/w them to form circular dark and bright fringes due to interference of light, these fringes are in the form of concentric circles termed as newton rings.

When a monochromatic light is incident on the Plano convex lens system, light rays reflect And interfere constructively and destructively.

From upper and lower layers of the air present b/w lens and glass plate.

Central spot in newton rings is dark when observed with reflected light

Central spot in newton rings is bright when observed with transmitted light.



Why central spot is dark in Newton rings: At the point of contact of lens and glass Plate. The thickness of film is zero due to reflection at lower surface of air film from Denser Medium an additional path difference $\lambda/2$ is introduced so center of newton rings Is dark due to destructive interference.

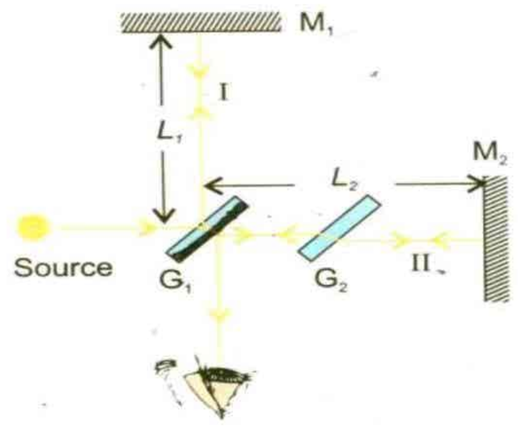
What is Michelson Interferometer? Explain its principle, construction and working.

Definition: An instrument that can be used for ultra-precise measurement of wavelength light and distance is called Michelson interferometer. It was devised by Michelson in 1881

Principle: Working principle of Michelson interferometer is interference. i.e when light from a single source is splitted into two parts and then interfere, it forms interference pattern.

Construction: Michelson interferometer consists of following parts

Source of light
Two glass plate(beam splitter and compensator)
One fixed mirror
One moveable mirror
Telescope



Explanation: let us consider a monochromatic light from a light source falls on half silver glass plate G1(beam splitter) G1 that partially reflects it and partially transmit it towards the fixed and moveable mirror. Both beams reflects from both mirrors and interfere constructively and destructively observed by observer's eye through telescope.
If mirror is moved
If mirror M1 is displaced through a distance equal to λ/2, a path difference of double of this displacement is produced equal to λ.

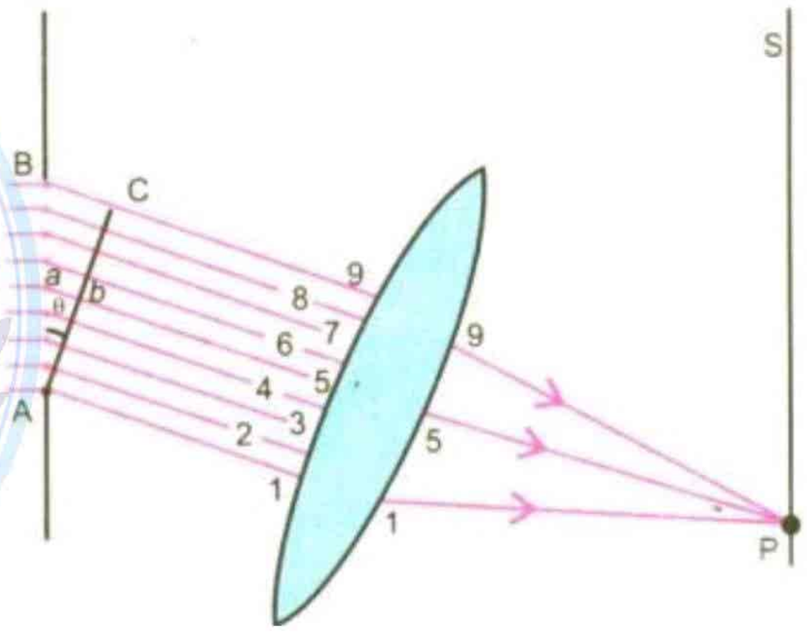
By counting the number of fringes m, shifted displacement of mirror L can by calculated by formula $L = \frac{m\lambda}{2}$.

Definition of standard meter: "Standard meter is equal to 1553163.5 times the wavelength of red cadmium light".

What is Diffraction of light? Explain diffraction due to narrow.

The phenomenon of bending of light around obstacles and spreading of light into geometrical shadow of an obstacle is called diffraction. Diffraction is also a special case of interference.
Diffraction is prominent when the wavelength of light is large as compared to size of obstacle. Smaller the size of object or obstacle the higher degree of diffraction is observed.

Diffraction due to narrow slit: The slit AB of width d is illuminated by a parallel beam of monochromatic light of wavelength. The screen S is placed parallel to the slit AB. Rays of light are brought to focus on the screen. A small portion of the incident wave front passes through the narrow slit. Diffraction due to a narrow slit has central Maxima and alternate minima and maxima.
In order to find the value of path difference ab we consider the Right angle triangle aAb as shown in fig.



$$\text{Sin}\,\theta = \frac{ab}{AB/2} = \frac{ab}{d/2}$$

$$ab = \frac{d}{2}\sin\theta$$

$$\text{As path difference } ab = \lambda/2 \text{ so}$$

$$\lambda/2 = \frac{d}{2}\sin\theta$$

$$\lambda = d\sin\theta \text{ This is the equation for first minima and for mth order}$$

$$d\sin\theta = m\lambda \text{ where } m = 0, \pm1, \pm2, \ldots$$

Diffraction grating: A diffraction grating consists of a glass plate having number of slit ruled on it
A typical diffraction has 400 to 5000 lines per centimeter.
Grating element: the distance b/w the centers of two adjacent lines is called grating element. d=L/N
Grating equation: the path difference for constructive interference b/w two consecutive rays should be integral multiple of wavelength so path difference difference=ab=λ and equation is $d\sin\theta = m\lambda$, m is order of fringes.

What are X-rays? Explain Diffraction of X rays through crystals and derive Bragg's law.

X-rays: A type of electromagnetic waves of much shorter wavelength having order of 10^{-10}m called X-rays.

Diffraction of X-rays through crystals: The study of atomic structure of crystals by X-rays was initiated in 1914 by WH Bragg and his son WL Bragg and found that a monochromatic beam of X-rays was reflected from a crystal plane as if it acted like mirror.

Let us consider an X-rays beam is incident at angle Θ on one of the planes. The beam can be reflected from both the upper and lower planes of atoms. The beam reflected from the lower plane travel some extra distance as compared to the beam reflected from the upper plane.

Bragg law: let an X-rays beam is incident at angle Θ the beam reflected from the lower plane travels some extra distance (BC+CB') as an effective path difference. From triangle ABC we have

$$\text{Sin}\,\theta = \frac{BC}{AC}$$

$BC = AC\sin\theta \qquad AC = d$

$BC = d\sin\theta$ ---------- (1)

Similarly from triangle ACB', we have

$$\text{Sin}\,\theta = \frac{CB'}{AC}$$

$BC = AC\sin\theta \qquad AC = d$

$CB' == d\sin\theta$ ---------- (2)

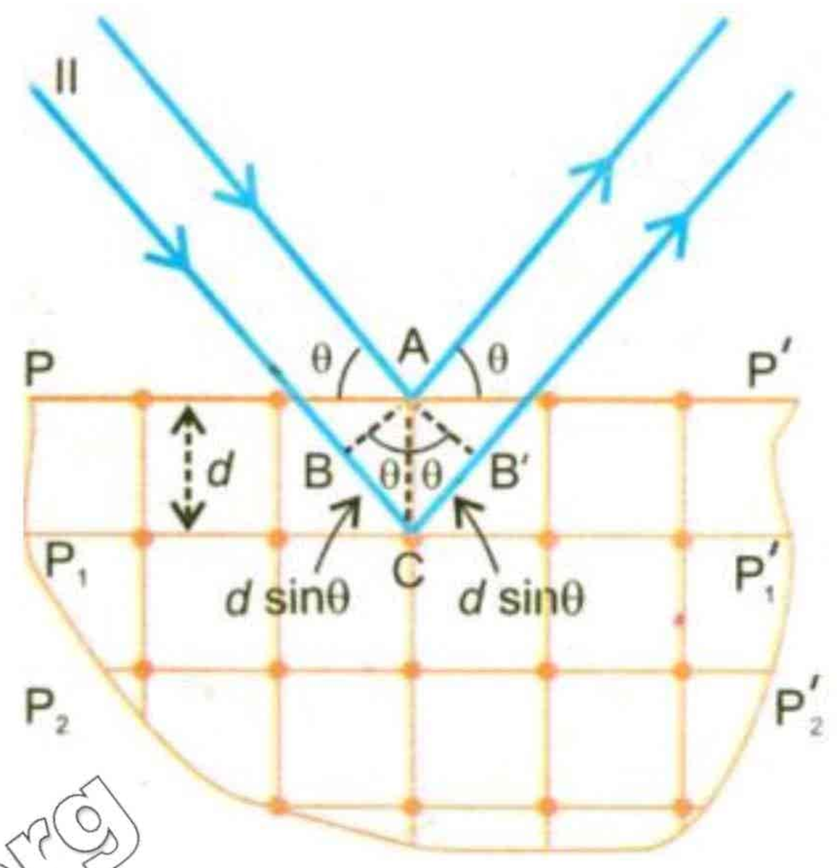
Adding both equations

$BC + CB' = d\sin\theta + d\sin\theta$

$\text{total path difference} = 2d\sin\theta$

also we know that $\text{path difference} = n\lambda$ and comparing with above eq

$2d\sin\theta = n\lambda$ This is called Bragg's equation



Uses of X-rays diffraction/Bragg equation.

i. This is used to find inter planer spacing
ii. It is used to determine the structure of biologically important molecule such as hemoglobin.
iii. It is used to find wavelength of light.

What is Polarization? Steps for detection and production of plane polarized light.

Polarization: The process of confining the beam of light into one plane of vibration is called polarization.

Polarized and un-polarized light:

A beam of ordinary light consisting of large number of planes of vibration is called un-polarized light.

A beam of light in which all vibration confined in one plane is called polarized light.

Steps for detection and production of plane polarized light:

i. Selective absorption
ii. Reflection from different surfaces
iii. Scattering by small particles
iv. Refraction through crystal

Light waves are transverse in nature: light waves are transverse wave. If the light waves were longitudinal then they would never disappear even if the two Polaroid's were mutually perpendicular.

Optical rotation: Such a process in which a plane polarized light passes through certain crystals and they rotate the plane of polarization. e.g. Quartz crystals and sodium chlorate.

Polarizer/concentration in solution: A few millimeter thickness of such crystals will rotate the plane of polarization by many degrees and they show optical rotation when they are in solution this property of optical active substance is used to find concentration in solutions. This device is called Polari meter.

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Exercise short questions

1. ***Under what conditions two or more sources of light behave as coherent sources?***

Two or more waves having a constant phase difference (same λ & T) are called coherent sources.

i. One method of producing two coherent light beams is to use monochromatic source to illuminate a two holes screen. The light emerging from the two slits is coherent because a single source produces two parts.

ii. Light with its mirror image also show coherent beam.

2. ***How is the distance between interference fringes affected by the separation between the slits of Young's experiment? Can fringes disappear?***

We have Fringe spacing = $\Delta y = \lambda L / d$ The relation shows that fringe spacing is inversely proportional to the separation 'd' between the slits. If separation is increased the distance between fringes will decrease. Ultimately fringes disappear for larger distance between the slits.

3 ***Can visible light produce interference fringes? Explain.***

Yes. Visible light can produce interference fringes, if it has phase coherence. White light will produce colored interference fringes.

4.In the Young's experiment, one of the slits is covered with blue filter and other with red filter. What would be the pattern of light intensity on the screen?

No interference pattern will be observed as blue and red light not being in phase coherence.

5 ***Explain whether the Young's experiment is an experiment for studying interference or diffraction effects of light.***

Diffraction is a special type of interference. Young's experiment is basically for studying interference. But diffraction is observed. Light is diffracted from two slits. So it is a combination of diffraction and interference.

6 ***An oil film spreading over a wet footpath shows colors. Explain how does it happen?***

Due to interference of light waves, colours are seen on the oil film. At a certain place of the film, its thickness and the angle of incidence of light are such that the condition of destructive interference of one colour is being satisfied.

7. ***Could you obtain Newton's rings with transmitted light? If yeas, would the pattern be different from that obtained with reflected light?***

Yes. We can obtain Newton's rings with transmitted light. The difference will be that, the central spot will be bright.

8.***In the white light spectrum obtained with a diffraction grating, the third order image of a wavelength coincides with the fourth order image of a second wavelength. Calculate the ratio of the two wavelengths.***

Ans. $d \sin\theta = n\lambda$; $d \sin\theta = 3\lambda 1$, & $d \sin\theta = 4\lambda 2 \Rightarrow$

$3\lambda 1 = 4\lambda 2$ or $\lambda 1 / \lambda 2 = 4/3$

9.***How would you manage to get more orders of spectra using a diffraction grating?***

We have, $d \sin\theta = m\lambda$ To increase more orders of spectra (m), we should increase the grating element (d), i.e. a grating with lesser number of ruled lines.

10.***Why the Polaroid sunglasses are better than ordinary sunglasses?***

Polaroid sunglasses reduces glare, as they produce plane polarized light and they protect the eyes from bright rays of sun light.

11 ***How would you distinguish between un-polarized and plan-polarized lights?***

If a Polaroid is rotated in front of un-polarized light, a component of light will pass for each angle. But for plane-polarized light, at certain orientation, no light will pass

Multiple Choice Questions

1) Small segments of large spherical wave fronts approximate a

Spherical wave front	**Plane wave fronts**	Both A&B	None

2) Sodium chloride in a flame gives out pure---

Ordinary light	Red light	green light	**Yellow light**

3) The value of sinθ and tanθ are equal/comparable upto angle

6°	8°	**10°**	4°

4) Colors seen on oily water surface are due to ----- incident white light

Diffraction	Reflection	**Interference**	Polarization

5) The vivid iridescence of peacock feathers due to--- of light reflected from its complex layered surface?

Diffraction	Reflection	**Interference**	Polarization

6) The fine ruling each --- wide on CD function as a diffraction grating

0.5 m	0.5 mm	0.5 cm	**0.5μm**

7) Light reflected from smooth surface of water is ----- parallel to the surface

Completely polarized	**Partially polarized**	Both A&B	None

8) Which part of polarimeter stops the light when rotated from vertical positions

Polarizer	**Analyser**	Both A&B	None

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Previous all Punjab Board Exams Solved MCQs

	Questions	Option A	Option B	Option C	Option D
1)	Bending of light around the obstacle of light is called	Refraction	Reflection	Interference	**Diffraction**
	The equation of Michelson interferometer	**$L=m\lambda/2$**	$L=m\lambda$	$L=m\lambda/4$	$L=2m/\lambda$
2)	The distance between two adjacent dark fringes is given by	**$\Delta y = \lambda L / d$**	$\Delta y = m\lambda L / d$	$\Delta y = (m+1/2)\lambda L / d$	$\Delta y = \lambda d / L$
3)	The phase difference between two points on a wave front is	**0**	π	$\pi/2$	$\pi/4$
4)	If a polarized light is made incident on a sheet of polariod then transmitted beam of light will be	Non plane polarized	**Plane polarized**	Un polarized	Diffraction
5)	Diffraction is special case of	Polarization	Reflection	Refraction	**Interference**
6)	Which property of travelling wave differ from stationary wave	Amplitude of wave	Frequency of wave	Direction of wave	Propagation of energy
7)	For destructive interference path difference between two sound waves is	$s = n\lambda + \lambda$	**$s = (2n+1)\frac{\lambda}{2}$**	$s = (2 + \frac{1}{\lambda})$	None of these
8)	The distance between two consecutive wave front is called	Time period	Frequency	**Wavelength**	Displacement
9)	The distance between two adjacent bright fringes is	**$\Delta y = \lambda L / d$**	$\Delta y = m\lambda L / d$	$\Delta y = (m+1/2)\lambda L / d$	$\Delta y = \lambda d / L$
10)	In diffraction grating the distance between two adjacent slits is called	**Grating element**	Normal to grating	Diffraction	Fringes
11)	In the diffraction of light around an obstacle, the angle of diffraction is increased then	**The wavelength of incident light wave is increased**	The amplitude of the incident light wave is increased	The wavelength of incident light wave is decreased	The amplitude of the incident light wave is decreased
12)	Color seen on oily water surface due to ---- property of light	**Interference**	Diffraction	Polarization	Refraction
13)	When one mirror of Michelson interferometer is moved a distance of 0.50mm,2000 fringes are observed the wavelength of light used is	5000 nm	**5000 A°**	500cm	2000A°
	L=0.5 mm, m=2000, by apply $\lambda=2L/m$ putting the values to get the result where $A°=10^{-10}m$				
14)	Sodium chloride in a flame gives out pure	Blue light	**Yellow light**	Red light	White light
15)	Which phenomenon shows that light waves are transverse waves	Interference	Diffraction	**Polarization**	Refraction
	One angstrom is equal to	10^{-9} m	10^{-8} m	**10^{-10} m**	10^{-12} m
16)	Polarization proves that light waves are	Longitudinal	**Transverse**	EM	Monochromatic
17)	Light from sun reaches the earth in the form of -------- spherical wavefront	Spherical	**Plane**	Elliptical	Hyperbolic
18)	The theory of wave nature of light proposed by	Thomas young	**Huygen**	Marwel	Fresnel

19)	The distance between atoms is 0.30 nm. What will be the wavelength of X-rays at angle θ = 30o for 1st order diffraction?	λ = 0.60 nm	λ = 0.20 nm	**λ = 0.30 nm**	λ = 0.90 nm
By using $2d\sin\theta = n\lambda$ put angle=30°,n=1,d=0.30nm, 2*0.30nmsin30°=1λ, λ=2*0.30nm*1/2=0.30 nm					
	Sound waves cannot be	Reflected	Refracted	**Polarized**	Diffracted
20)	Which property of light is evident of polarization of light	Wave nature	Particle nature	Dual nature	**Light waves are transverse Waves**
21)	Newton rings are formed as a result of	**Interference**	Dispersion	Diffraction	Polarization
22)	In Young's Double Slit Experiment, slit separation x = 0.05 cm, distance between screen and slit D = 200 cm, fringes separation x = 0.13 cm, then the wavelength 'λ' of light is	λ = 1.23 x 10-2 m	λ = 4.55 x 10-5 m	**λ= 3.25 x 10-7 m** put d=0.05*10-2m L=2m, Δy=0.13*10-2m λ=Δyd/L to get result	λ = 5.1 x 10-7 m
23)	Phase angle of 180o is equailent to path difference of	λ/4	**λ/2**	λ	2λ
24)	first dark fringe appears from 'm' will be equal to in (m+1/2)λ	1	**0**	3	2
25)	According to modern idea about the nature of light shows	Wave nature of light	Particle nature of light	**Dual nature of light**	None of these
26)	A maxima is produced at points where path difference of monochromatic wave is	λ/4	λ/2	**λ**	2λ/3
27)	What happens to the interference pattern produced by double slit arrangement by doubling the slit spacing	Fringe spacing is doubled	**Fringe spacing is halved**	Intensity increase	Fringe spacing is not changed
Fringe spacing is inversely proportional to slit separation					
28	Michelson interferometer is used to	**Measure distance with high precision**	Find speed of light	Study interference in thin films	Study diffraction of light
29)	A surface on which all the points have same phase of vibration is known as	Crest	Trough	**Wave front**	Wavelength
30)	The process of confining the beam of light to vibrate in one plane is called	Interference	Diffraction	Total internal reflection	**Polarization**
31)	When Newton rings are observed with reflected light, the central spot	Red	Blue	**Dark**	Bright
32)	The wavelength of light which produces second order spectrum on diffraction grating on which 5000 lines/cm are ruled at an angle of 30° will be:	6 x 10-7 m	**5 x 10-7 m**	4 x 10-6 m	3 x 10-6 m
dsinθ=mλ L/Nsinθ=mλ, θ=30°, m=2 L=1cm, N=5000 put in formula to get the result					
33)	Angle between ray of light and wave front is	0o	**90o**	60o	120o
34)	Basic principle of beats are	**Interference**	Diffraction	Total internal reflection	Polarization
35)	In case of point source the shape of wave front is:	Plane	**Spherical**	Circular	Elliptical
36)	Fringe spacing increases if we use	**Red light**	Blue light	Yellow light	Green light

37)	In 10min sun light covers a distance of	$0.18*10^{10}$ m	$18*10^{10}$ m	**$1.8*10^{10}$ m**	$0.018*10^{1}$m
Time=10 min=10*60=600 sec, S=vt=$3*10^{8}*600=1800*10^{8}=1.8*10^{8+2}=1.8*10^{10}$ v is speed of light					
38)	Vivid iridescence of peacock feather due to	Reflection	Refraction	**Interference**	Diffraction
39)	Fine ruling each wide on CD function	0.5 cm	0.5 mm	0.5 m	**0.5µm**
40)	A typical diffraction grating has lines per centimeter	400-500	**400-5000**	40-50	400-50000
41)	When newton rings are observed with transmitted light then central ring is	Dark	**Bright**	Blue	Red
42)	An object 15 cm from a lens produces a real image 30 cm from the lens. What is the focal length of the lens?	+15 cm	**+10 cm**	+20 cm	+25 cm
43)	In Newton ring apparatus, at the point of contact of the lens and glass plate, the additional path difference introduced is	λ/4	λ	**λ/2**	λ/3
44)	The image of an object placed inside the focal length of a convex lens will be largest and clearest when it is at the	Less than 25 cm	Greater than 25 cm	**Near point**	Infinity
45)	What is the formula for critical angle in case of light through two mediums having refractive indexes n_1 and n_2 such that $n_1 > n_2$?	**$\sin^{-1}(n_2/n_1)$**	$\cos^{-1}(n1/n2)$	$\cos^{-1}(n2/n1)$	$\sin^{-1}(n\ 1/n2)$
46)	The concentration of a sugar solution can be determined by	Un-polarized light	Interference of light	**Plane polarized light**	Diffraction of light
47)	In Young's Double Slit Experiment, if the distance between slits and screen is doubled, then fringe spacing becomes	Zero	**Doubles** $\Delta y \propto L$	One	Half
48)	In Michelson's interferometer 792 bright fringes pass across the field of view when its movable mirror is displaced through 0.233 mm using the equation $l = m\lambda/2$ the wavelength of light used is:	**588 nm** See solution of numerical no 9.4	348 nm	620 nm	400 nm
49)	A yellow light of wavelength 500 mm emitted by a single source passes through two narrow slits 1 mm apart. How far apart are two adjacent bright fringes when interference is observed on a screen 10 m away?	**5000m** $\Delta y=\lambda L/d$ Put $\lambda=500mm$ L=10m,d=1mm	0.5 mm	1.33 mm	50 mm
50)	According to Huygen principle, each point on a wave front acts as a source of	**Secondary wavelet**	Primary wavelet	New wave front	Sound
51)	Blue color of sky is due to	**Scattering**	Reflection	Diffraction	Polarization
52)	Fringe spacing is inversely proportional to	**Slit separation**	Wavelength	L	Frequency
53)	Newton rings are formed as result of	**Interference**	Dispersion	Diffraction	Polarization
54)	Michelson interferometer is used to find	**Wavelength of light**	Wavelength of sound	Velocity of sound	Velocity of light
55)	Light is polarized by using	Nacl	**Dichoric substance**	Optical fiber	Plane glass