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Bismah Noor
Batch-I (1st year)
Soch Badlo by MAK

1. NATURE OF LIGHT :-

main points

→ light is a form of high frequency electromagnetic waves.

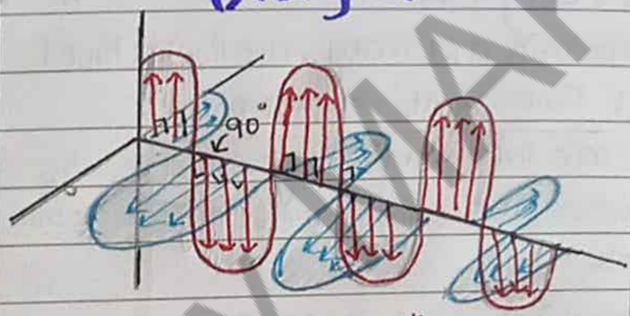
→ light does not require any medium for its propagation.

→ light waves have a velocity of about $3 \times 10^8 ms^{-1}$

→ Electric and magnetic fields are oscillating perpendicular to each other.

→ light has dual nature ; particle nature and wave nature.

'Diagram'



• Electric component
• Magnetic component

2. WAVE FRONT :-

Definition

" Portion of a wave which shows the pattern of propagation of the whole wave is called as the wavefront"

→ Spherical wave front : A portion of spherical wave

→ Plane wave front : Straight portion of a spherical wave front. (small portion of a spherical wave front will become nearly plane surface).

3. HUYGEN'S PRINCIPLE :-

Introduction

→ There's one primary wavefront from which arises a secondary wave front, then tertiary wave front and so on.

→ Wave lets are small constituents of a wave (wave کے چھوٹے ٹکے)

→ Knowing shape and location of a wave front at any instant of time 't', the shape and location of new wave front after time 't + Δt' can be determined using this principle.

Statement

Part one ; " every point of a wavefront may be considered as a source of secondary spherical wavelet, which spread out in forward direction with a speed equal to the speed of propagation of the wave."

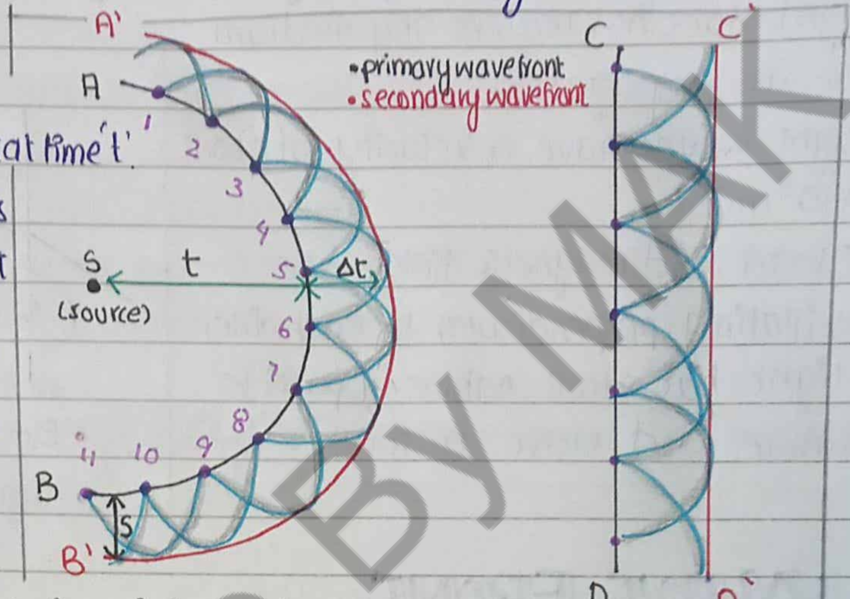
part two; "The new Position of the wavefront after time 't + Δt' can be found by drawing tangential to all the secondary wavelets."

'Diagram'

→ AB represents a primary wave front at time 't'.

→ After time 't + Δt' several points 1, 3, .. 11 are taken on primary wavefront which serve as a source of secondary wavelets.

→ The spherical waves emitted are shown by drawing hemispheres having radius $s = vt = c\Delta t$.



(a) Spherical wavefront (b) plane wave front

→ a surface A'B' is drawn tangent to all secondary wavelets. A'B' is the new position of wavefront AB after time Δt.

→ The whole procedure can be done to determine secondary wavefront for a plane wave as well.

4. COHERENT SOURCES :-

Definition

"The sources which produce waves having the same frequency, equal or comparable amplitude and a constant phase difference are called coherent sources."

Main points

→ Phase difference occurs due to wavelength variation

→ Monochromatic light sources (light having only one wavelength) are coherent

→ To a huge extent, majority light sources are not coherent except for laser

→ This is because phase changes occur abruptly in light sources and are very random.

Methods for obtaining coherent waves from a point source

→ Division of wavelength ; as in Young's double slits, Fresnel's byprism and Lloyd's mirror.

→ Division of Amplitude ; by partial reflection and transmission at a boundary.

1, INTERFERENCE OF LIGHT:-

Definition

"Interference is described as the effect produced by the superposition of waves from two coherent sources passing through the same region. They reinforce each other at some points while cancel out the effect of each other at other points."

Conditions for interference

→ light waves must be coming from coherent sources.

→ The amplitude of the waves must be equal or nearly equal.

→ The light waves should be perfectly monochromatic

→ The path difference of the waves must be small.

→ The principle of linear superposition should be applicable.

Constructive interference

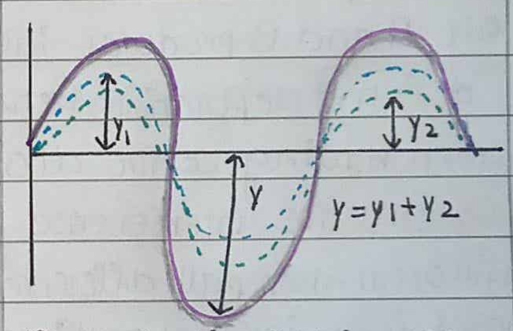
→ Occurs when two sets of coherent waves of light meet in phase.

→ They reinforce each other and brightness is appeared on the screen.

→ In terms of constructive interference path difference's condition is $d = m\lambda$

(where $m = 0, 1, 2, 3 \ldots$)

'Diagram'



(a) constructive interference.

Destructive interference

→ Occurs when two set of waves meet in opposite phase

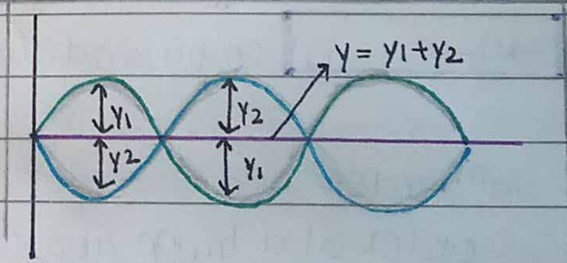
→ They cancel out the effect of each other and dark friges appear on the screen.

→ Condition for path difference of destructive interference is

$$d = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$$

$$d = \left(m + \frac{1}{2}\right)\lambda$$

$(m = 0, 1, 2, 3 \ldots)$



(b) destructive interference

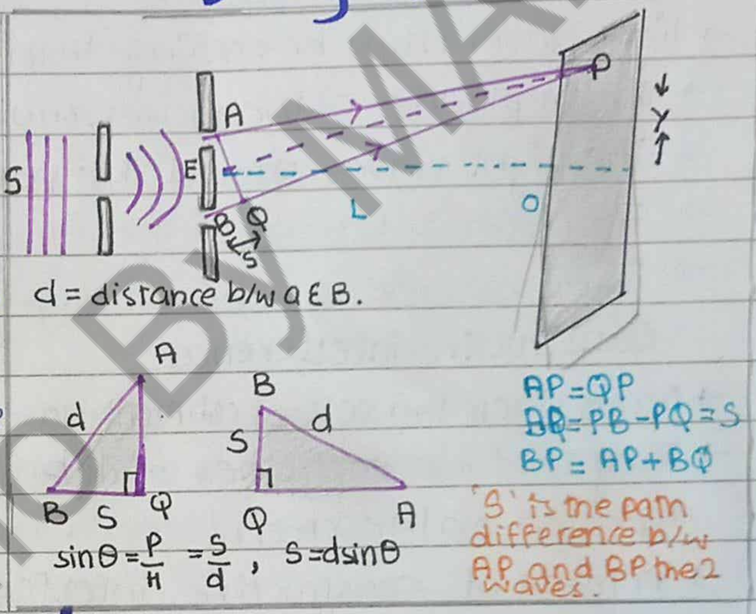
4, YOUNG'S DOUBLE SLIT EXPERIMENT :-

Introduction

→ Experimental evidence in favour of wave theory about the nature of light.
→ The principle of this experiment is based on the division of a wavefront.
→ Wave fronts of the same monochromatic light are splitted in this experiment and then made to interfere.

Experimental arrangements

'Diagram'



→ Monochromatic light is projected on a single slit C.
→ Light after passing through first slit is made to pass through two more vertical slits which are very close to each other and are parallel to C. Wavelets appearing from A and B are coherent.
→ The super position of waves from slit A and B produces interference.

'd' is the separation between slit A and B and L is their distance from the screen having centre at O.

Constructive interference

→ will occur when path difference 'S' b/w two waves is an integral multiple of wave length.

→ $BP - AP = S = 0, \lambda, 2\lambda$

$BQ = S = m\lambda$ (i).

$BQ = S = d\sin\theta$ (ii) (from diagram)

$d\sin\theta = m\lambda$ (by (i) and (ii))

Destructive interference

→ will occur when path difference 'S' b/w two waves arriving at point A is an odd integral multiple of half wavelength.

→ $d\sin\theta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$

$d\sin\theta = (m + \frac{1}{2})\lambda$

$m = 0, \pm 1, \pm 2, \ldots$

m^{th} order

order of a fringe above or below the central point 'O' on the screen.
'O' order is when $m = 0$. $m = \pm 1$ shows first order of fringe and so on.

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Position of Fringes on screen

→ For locating m^{th} order bright or dark fringe on the screen we'll derive an expression for its vertical distance y from the central point O.

→ Comparing ABQ and PEO (similar right angled triangles) we have $s/y = \frac{AB}{PE} = \frac{d}{PE}$

→ as $y << L$ and $PE \approx EO = L$ so

$$s/y = d/L \quad , \quad y = L\frac{s}{d}.$$

→ For m^{th} bright fringe

$$y_{m\,(bright)} = mL\frac{\lambda}{d}$$

[By putting value of 's']

→ For m^{th} dark fringe

$$y_{m\,(dark)} = (m+\frac{1}{2})\,L\frac{\lambda}{d}$$

Fringe spacing

→ Distance between two consecutive bright or dark fringes is called fringe spacing.

→ Fringe spacing between first and 2nd order of both bright and dark fringes is $\frac{L\lambda}{d}$.

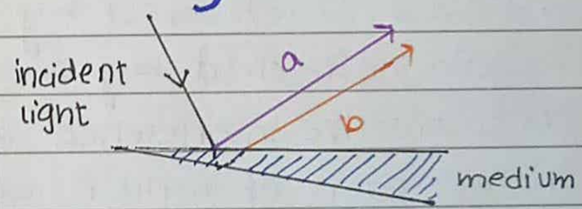
4) INTERFERENCE IN THIN FILM :-

Main Points

→ Principle of interference through a thin film is based on the division of amplitude.

→ When a beam of monochromatic light of wavelength λ is incident on a thin film it's splitted into two parts. Part 'a' is reflected from upper surface and Part 'b' is reflected from lower surface.

'Diagram'



→ When a wave travels from a medium of lower refractive index to higher refractive index it undergoes a phase change of 180° (π rad) after reflection.

→ Path difference between ray 'a' and 'b' is quite small thus interference pattern will be observed.

→ If white light is incident on the thin film, the certain place where destructive interference for a colour is satisfied, that colour won't appear while the place where constructive interference for a colour is satisfied, that colour will appear.

→ Due to this same reason different colours can be seen on a soap bubble.

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1. MICHELSON'S INTERFEROMETER:-

Main Points

→ It's an optical instrument used to study the interference of light waves and find its wavelength.

→ Principle of this instrument is based on division of amplitude, usually by partial reflection and transmission of light at the boundary of the two medium.

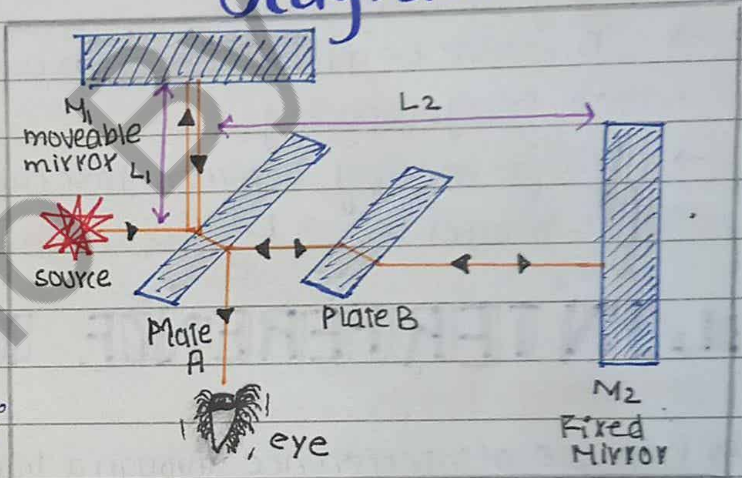
Construction

→ Two plane mirrors; M1 (moveable) & M_2 (fixed).

→ Two glass plates A and B

→ A source of monochromatic light

'Diagram'



Working

→ As light beam falls on Plate A its splits into two parts, 1st part is reflected and moved to M1 whereas second part transmits through A crossing B and moves to M_2.

→ Part 1 is reflected by M1, transmitted through A and enters the eye.

→ Part 2 is reflected by M_2, transmitted through plate B and again reflected by A to enter the eye.

→ Constructive interference will occur if the path difference between the two parts of light is either zero or integral multiple of λ and brightness will be seen $d = m\lambda$

→ Destructive interference will occur if the path difference between the parts is odd integral multiple of half wavelength. darkness will be seen. $d = (m + \frac{1}{2})\lambda$

→ If M_1 is moved λ/4 backward dark fringe will be seen. If it's further moved λ/4 bright fringe will be seen by repeating alternating dark and bright fringes will appear.

Wavelength of light

→ To find 'λ' of light used, use this formula $\lambda = 2P/m$

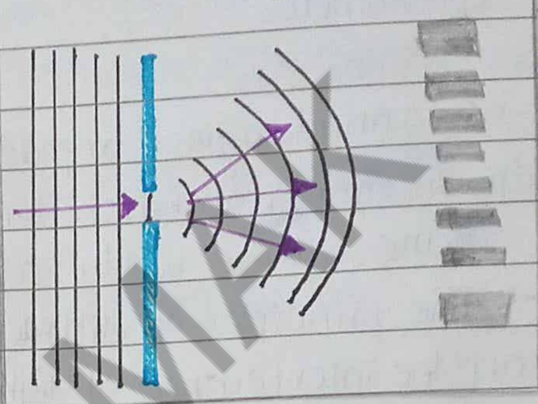
→ Where P is total distance moved by M1 and 'm' is integral multiple.

1, DIFFRACTION OF LIGHT:-

Definition

"The spreading of light waves round the edges of a narrow opening or the spreading of light in to the region behind an obstacle is called diffraction"

'Diagram'



Main Points

→ Diffraction is most prominent when the gap is approximately the same size as the wavelength of the wave.

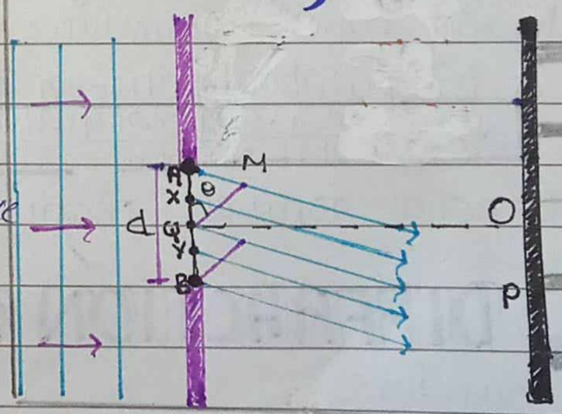
→ Diffraction of light waves from slit C in young's double slit experiment illuminates the next two slits, without diffraction their illumination won't be possible.

1, DIFFRATION AT A SINGLE SLIT:-

Fraunhofer diffraction — definition

"The diffraction of light produced by a narrow slit when plane light waves are incident normally on the slit and light waves emerging from the slit are also plane, is called Fraunhofer diffraction."

'Diagram'

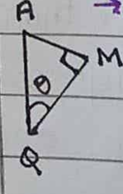


Main Points

→ When there's no path difference between waves coming from point A and B as well as from X and Y, bright fringe will be observed at O due to constructive interference

→ Path difference between the points A and Q is approximately $\lambda/2$ similarly the path difference for point X and Y and Q and B is also $\lambda/2$ hence wavelets reaching at point P will interfere destructively and dark fringe will be observed

→ $m\lambda$ order minima is given by $\boxed{\sin\theta_m = \frac{m\lambda}{d}}$



→ $\sin\theta = \frac{P}{H}$

$= \frac{AM}{AQ}$

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

$d\sin\theta = \lambda$

→ If narrow slit's used then angle θ increases This means that a broder central maximum is obtained but the intensity of all bright fringes decreases as less light passes through the slit.

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1, DIFFRACTION GRATING

Definition

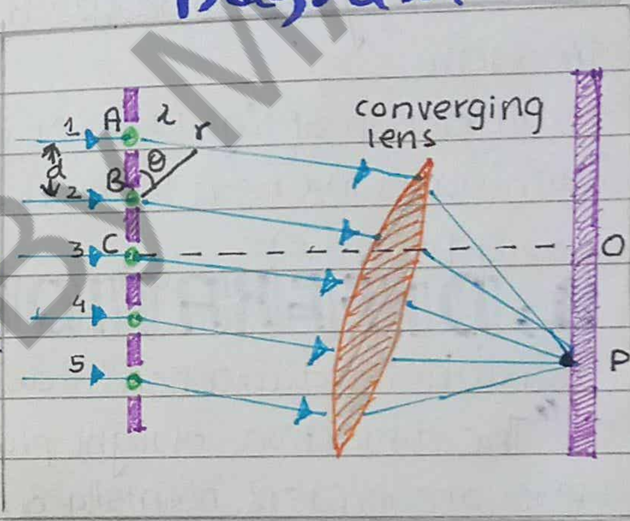
"A technique used to calculate wavelength of light using a grating spectrometer."

Main Points

→ Grating is a glass or plastic plate 2 to 3 cm in length and 2 to 3 mm in thickness on which large number of parallel, equally spaced slits of the same width are ruled. Each scratch plays the role of a slit.

→ The principles of diffraction grating is based on the interference of light waves

'Diagram'



Working

→ A parallel beam of monochromatic light falling on the grating sends out waves from each slit which are brought to a focus at point P by a lens.

→ The parallel rays after diffraction through the grating make an angle θ with the normal at the point of incidence

→ If the waves from any two consecutive slits differ in path by λ they will interfere constructively and bright fringe will be observed at P.

→ In ray 1 and 2, path difference is $AR = \lambda$ hence $d\sin\theta = \lambda$

→ 'd' is separation between two slits its value can be obtained by

$$d = \frac{\text{Unit length of grating}}{\text{Total No. of lines ruled}}$$

unit, d is also called grating element.

→ General form of grating equation is $d\sin\theta = m\lambda$

1, DIFFRACTION OF X-RAYS BY CRYSTAL:-

Main Points

→ X-rays are electromagnetic waves of very short wavelength of order 10^{-10} m

→ The can't be diffracted using Young's double slit or by thin film method. since the slits are larger than their wavelength.

→ In crystals the layers of atoms are less than 1nm apart thus they can diffract x-rays and in return the structure of crystals can be studied.

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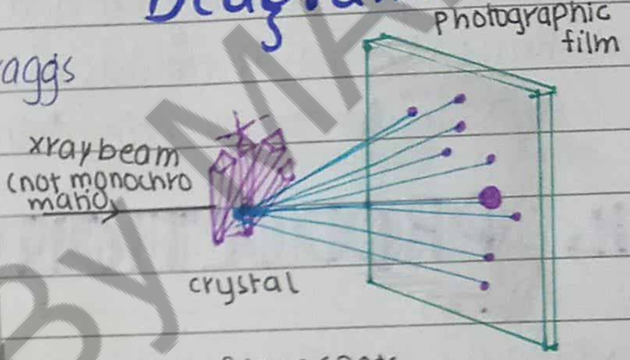
Experiment

→ A narrow beam of x-rays is collimated through a slit and allowed to fall on NaCl crystal

→ The transmitted beams enter detector and laue photograph is obtained which shows central spot surrounded by many other spots arranged in defined pattern. These spots are called laue spots.

→ Laue spots are different for different crystals. This 'laue type experiment' shows us that atoms are arranged in their three dimensional lattices.

'Diagram'



Δ Illustration of laue spots

Bragg's law

→ To find wavelength of x-ray beam we use braggs law.

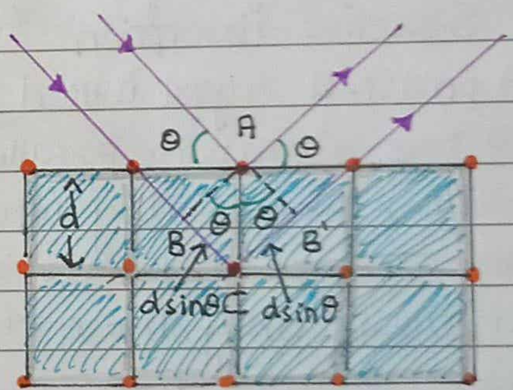
→ Two parallel rays are incident at the first and second layer of crystal

→ Separation between two layers is 'd' and θ is the angle complementary to the angle of incidence.

→ Path difference b/w two rays is $BC + C'B' = m\lambda$

and we know from the diagram $BC + CB' = d\sin\theta$

→ General equation; $2d\sin\theta = m\lambda$ is called the Bragg's law.



▲ Bragg's law illustration

I, POLARIZATION OF LIGHT

Definition

" Polarization is the process by which the electric and magnetic variations of light waves are restricted to a single plane of vibration "

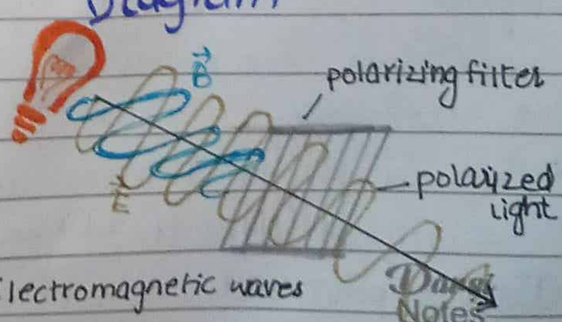
Main Points

→ Interference and diffraction are best ways to prove wave nature of light but only polarization gives evidence of light being transverse in nature as well.

→ Polarization is the property exhibited by transverse waves only. It doesn't occur for sound waves

→ To study that only transverse waves exhibit polarization property take two wooden boards having slots. 'A' has horizontal while 'B' has vertical slots. Take a string through the slots of both

'Diagram'



Electromagnetic waves

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and set it in wave motion. The wooden board having slots parallel to the wave motion will allow the wave to pass but the other slot having horizontal slot wont allow the wave to pass as slots will be ~~parallel~~ perpendicular to wavemotion.

→ If a compressional wave is made to pass through the slots, it will pass through both i.e sound wave.

Ordinary light

→ Ordinary light being emitted from sources like candles, bulbs is not polarized.

→ Reason is that it consists of light waves emitted from atoms whose electrons are experiencing transitions in all planes.

1, PRODUCTION OF POLARIZED LIGHT:-

Ways

→ Selective absorption → Reflection from surface

→ Refraction through crystals → scattering by tiny particle.

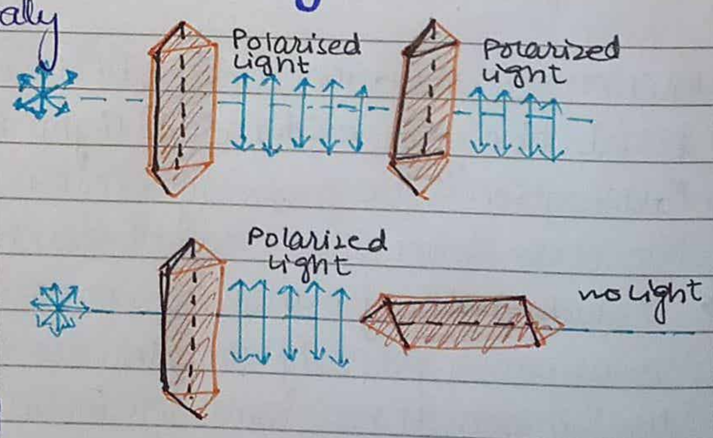
Selective absorption

→ A polaroid crystal is used, such a crystal has property to trans~~port~~mit all the vibrations parallel to its crystallographic axis while absorbs all the remaining vibrations

The internal molecular structure of the crystal is such that

→ it allows only those electric and magnetic vibrations which are parallel to its crystallographic axis and absorbs all remaining vibrations.

Diagram



→ when two crystals are placed verticaly then polarized light will transmit through them but if the second crystal is rotated to a horizontal position, no light will be able to transmit.

→ second crystal is also called as analyzer. since it tells wether incoming light is polarized or not.

Polarization by reflection

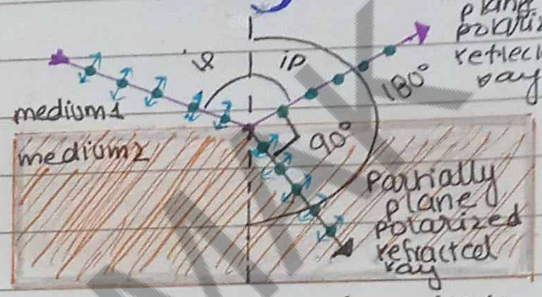
→ When unpolarized light falls on glass water etc at an angle called polarizing angle, the light is completely polarized.

→ At this angle reflected and refracted ray in transmitted medium are found to be at right angle to each other.

→ By applying snell's law we have $n_1 \sin i_p = n_2 \sin r$ where $r = 90° - i_p$ Thus after putting value we get

$$\frac{n_2}{n_1} = \tan i_p$$ — Brewester law

Diagram



Polarization of light after reflection

Applications of Polarized Light

(i) Reducing Glare

→ Polaroid discs, suitably oriented are used in sunglasses to reduce glares caused by reflected sun light.

→ Polaroid discs are also used in front of camera lens.

(ii) Optical acitivity

→ Polarimeter is used to meausure the concentration of given solutions based upon the optical activity of the light made to enter the solution.

(iii) Curtainless windows

→ Windows containing two polarized sheets are used instead of curtains

(iv) Control of headlight glare

→ During night driving is possible if each car is having polarized head lights & polaried light viewer.

(v) Stress analysis

→ Photoelasticity is used to analyze stresses in plastic model of various structures.

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