Chapter - 10
WAVE OPTICS

Q.1 What is wave front ?
Q.2. write the statement of Huygen's wave theory.
Imp Q.3. write principle of Huygen's secondary wave length Theory.
Q.4. By using Huygen's wave theory verify the law of reflection and law of refraction.

Wave :- The disturbance of the particle of any medium is called wave.

Ans. 1) The locus of all particles which vibrating with the same phase or same amplitude.

Wave front have three types:-

i) spherical wave front
ii) Plane wave front
iii) cylinderical wave front
iv) circular wave front.

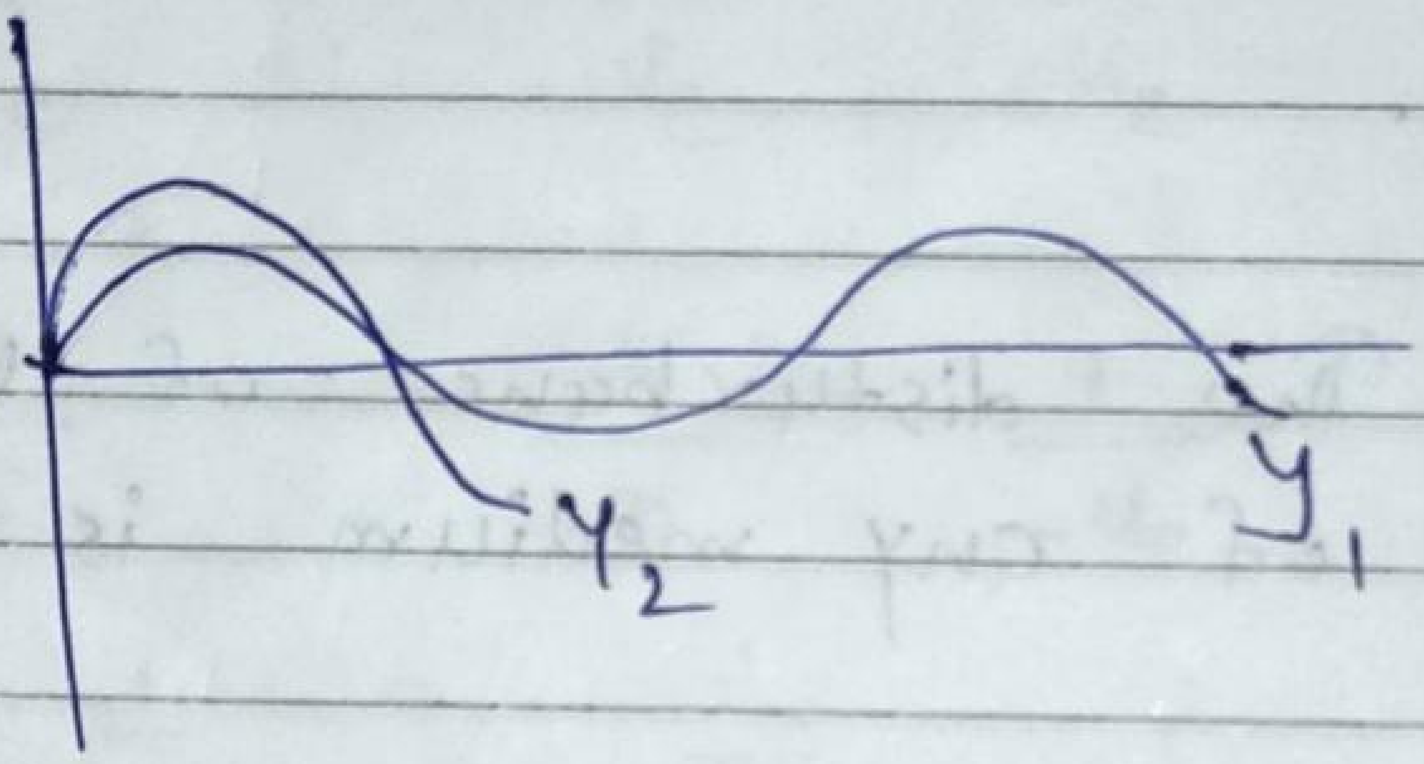
Q.5 write the principle of superposition.
Q.6. Explain the phenomenan of light of interference
Q.7. write the condition for the constructive and distructive interference.

Ans. 5) Two or more than two waves are propagating at any medium at the

Same time then after the superimpose the resultant displacement is vector sum of individual displacement of the waves.

$$y = a \sin \omega t$$

where, $y \to$ displacement
$a \to$ amplitude.
$\omega \to$ Angular frequency.



$$y = \vec{y_1} + \vec{y_2}$$

for n waves

$$\Rightarrow \quad y = \vec{y_1} + \vec{y_2} + \dots + \vec{y_n}$$

Ans.6) **Interference :-** Two waves with same frequency but approximate amplitude is propagating in same medium at same time then after the principle of superposition the intensity is changed, this phenomena is called Interference.

Two waves with same frequency but approximate amplitude is propagating in same medium at same time then after the principle of superposition, intensity is increases this phenomena is called constructive intructive interference but after the principle of superposition intensity decreases ~~the~~ this phenomena is called distructive interference.

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23/09/21

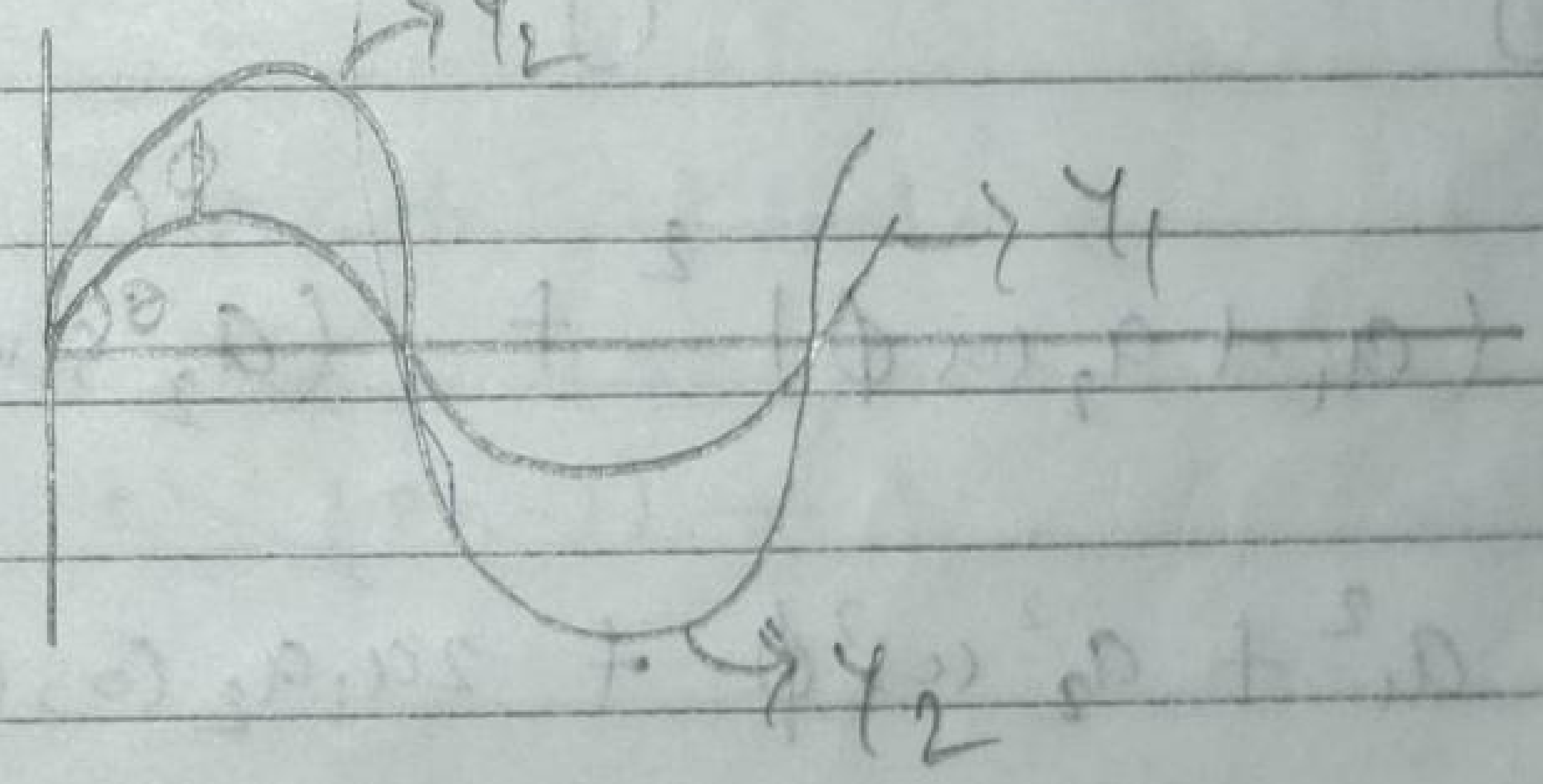
Condition :-

source must be cohrence.

Intensity $\propto$ (Amplitude)^2

$$I \propto A^2$$

$$\boxed{I = KA^2}$$



$$y = a \sin \omega t$$
$$y_1 = a_1 \sin \omega t$$
$$y_2 = a_2 \sin(\omega t + \phi)$$

Principle of superposition,

$\Rightarrow y = \vec{y}_1 + \vec{y}_2$, where $y \rightarrow$ Resultant displacement

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

$\Rightarrow y = a_1 \sin \omega t + a_2 \left[\sin \omega t \cos\phi + \sin\phi \cos \omega t \right]$

$\Rightarrow y = a_1 \sin\omega t + a_2 \sin\omega t \cos\phi + a_2 \cos\omega t \sin\phi$

$\Rightarrow y = (a_1 + a_2 \cos\phi)\sin\omega t + a_2 \sin\phi \cos\omega t$

$\Rightarrow y = A\cos\theta \sin\omega t + A\sin\theta \cos\omega t$

where, $A\cos\theta = a_1 + a_2 \cos\phi \rightarrow (1)$

$A\sin\theta = a_2 \sin\phi \rightarrow (2)$

$\Rightarrow y = A(\cos\theta \sin\omega t + \sin\theta \cos\omega t)$

$\Rightarrow \boxed{y = A\sin(\omega t + \theta)}$

squarring and adding eqn (1) & (2).

$\Rightarrow A^2 = (a_1 + a_2\cos\phi)^2 + (a_2 \sin\phi)^2$

$\Rightarrow A^2 = a_1^2 + a_2^2\cos^2\phi + 2a_1a_2\cos\phi + a_2^2\sin^2\phi$

$\Rightarrow A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\phi$

$\Rightarrow \boxed{A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}}$

where, $A \rightarrow$ Resultant Amplitude

Case I) $\cos\phi = 1$

$\boxed{A = a_1 + a_2}$

This is constructive interference and also condition.

Case II) $\cos\phi = -1$

$$\boxed{A = a_1 - a_2}$$

This is distructive interference and also condition.

Ans 7

Condition for constructive interferience :-

$$\cos\phi = +1$$

$$\phi = (2n)\pi \quad ; \quad n = 0, 1, 2, 3 \dots$$

even multiple of π

Condition for distructive interference :-

$$\cos\phi = -1$$

$$\phi = \pi, 3\pi, 5\pi, \dots$$

$$\phi = (2n-1)\pi \quad , \quad n = 1, 2, 3 \dots$$

odd multiple of π

Path difference :- $\Delta = \frac{\lambda}{2\pi} \times \phi$

for constructive :-

$$\Delta = \frac{\lambda}{2\pi} \times 2n\pi$$

$$\Delta = (2n)\frac{\lambda}{2}$$

Even multiple of $\lambda/2$.

for distructive :-

$$\Delta = \frac{\lambda}{2\pi}(2n-1)\pi$$

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

odd multiple of $\lambda/2$.

Q.8. write the condition for interference.

Q.9 what is the meaning of ~~coher~~ coherent source?

Q.10. Explain young's double ~~sweet~~ slit experiment.

Q.11 If the ratio of the intensity of two sources is 1:4 then find out the ratio of minimum and maximum intensity.

Ans.11) $\because I \propto A^2$

$$I = KA^2$$

Given,

$$\frac{I_1}{I_2} = \frac{1}{4}$$

$$\Rightarrow \frac{KA_1^2}{KA_2^2} = \frac{1}{4}$$

$$\Rightarrow \frac{A_1}{A_2} = \frac{1}{2}$$

$\Rightarrow A_1 = 1$ and $A_2 = 2$

$$A_{max} = A_1 + A_2 = 1+2 = 3$$

Width of fringe:- This is the difference b/w two consecutive bright or dark fringe. represented by β.

$$A_{min} = A_1 - A_2 = 1 - 2 = -1$$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{K A_{max}^2}{K A_{min}^2}$$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{(3)^2}{(-1)^2}$$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{9}{1}$$

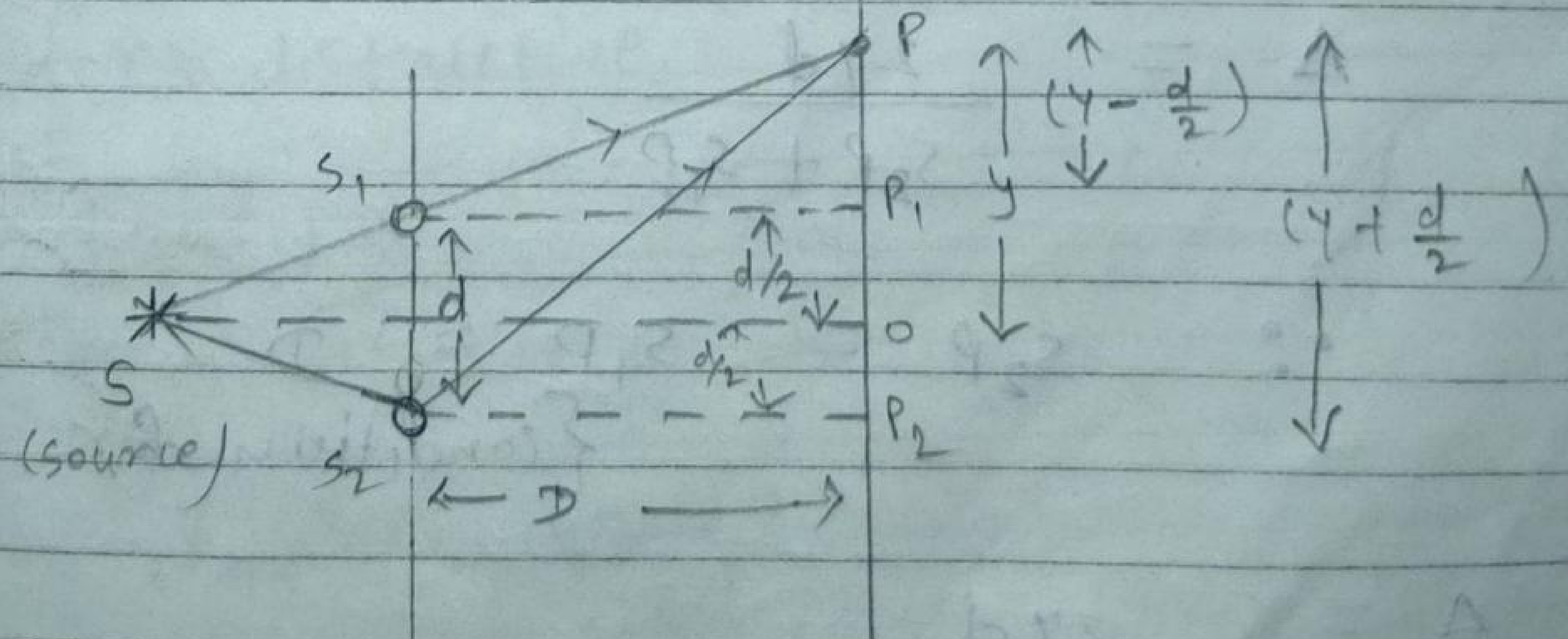
$$= 9 : 1$$

Q.12) Why clear sky seen a blueish colour?

Ans. By the scattering, The scattering power of blue colour is 10 times greater than other colours causes of this clear sky seen bluish.

Q.13 Derive an expression for width of fringe by young's double slit experiment.

Ans. 13)



Width of fringe (β) ;- This is the diff. b/w two consecutive bright and dark fringe.

$$\beta = y_{n+1} - y_n$$

$\Rightarrow$ Path diff. $(\Delta) = S_2P - S_1P \rightarrow (1)$

In $\Delta S_1 P_1 P$

$\Rightarrow (S_1P)^2 = (S_1P_1)^2 + (PP_1)^2$

$\Rightarrow (S_1P)^2 = D^2 + \left(y - \frac{d}{2}\right)^2 \rightarrow (2)$

In $\Delta S_2 P_2 P$

$\Rightarrow (S_2P)^2 = (S_2P_2)^2 + (PP_2)^2$

$\Rightarrow (S_2P)^2 = D^2 + \left(y + \frac{d}{2}\right)^2 \rightarrow (3)$

Eq^n (3) $-$ (2)

$\Rightarrow (S_2P)^2 - (S_1P)^2 = \left(y + \frac{d}{2}\right)^2 - \left(y - \frac{d}{2}\right)^2$

$\Rightarrow (S_2P + S_1P)(S_2P - S_1P) = (2y * d)$

$\Rightarrow S_2P - S_1P = \frac{2yd}{S_2P + S_1P}$

$\Rightarrow \Delta = \frac{2yd}{S_2P + S_1P}$

$\because S_2P = S_1P = D$
{condition for youn's condition}

$\Rightarrow \Delta = \frac{2yd}{D + D}$

$\Rightarrow \boxed{\Delta = \frac{yd}{D}}$

for constructive,

$$\Rightarrow n\lambda = \frac{yd}{D}$$

$$\Rightarrow y = \frac{n\lambda D}{d}$$

$$\Rightarrow \boxed{y_n = \frac{n\lambda D}{d}} \text{ and } y_{n+1} = \frac{(n+1)\lambda D}{d}.$$

According to width of fringe :-
(light fringe)

$$\Rightarrow \beta = y_{n+1} - y_n$$

$$\Rightarrow \beta = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d}$$

$$\Rightarrow \beta = \frac{\lambda D}{d}(n+1-n)$$

$$\Rightarrow \boxed{\beta = \frac{\lambda D}{d}}$$

for distructive,

$$\Rightarrow (2n-1)\frac{\lambda}{2} = \frac{yd}{D}$$

$$\Rightarrow y_n = \frac{(2n-1)\lambda D}{2d}$$

and

$$y_{n+1} = \frac{\{2(n+1)-1\}\lambda D}{2d}$$

$$y_{n+1} = \frac{(2n+1)\lambda D}{2d}$$

According to Width of fringe,
(Dark fringe)

$$\beta = y_{n+1} - y_n$$

$$\beta = \frac{(2n+1)\lambda D}{2d} - \frac{(2n-1)\lambda D}{2d}$$

$$\boxed{\beta = \frac{\lambda D}{d}}$$

It means the gape b/w dark and light fringe is same.

Q.14 what ~~is~~ ~~defraction~~ diffraction ?

Q.15 write the difference b/w fresnal diffraction and franhaifer diffraction. (franhoifer)

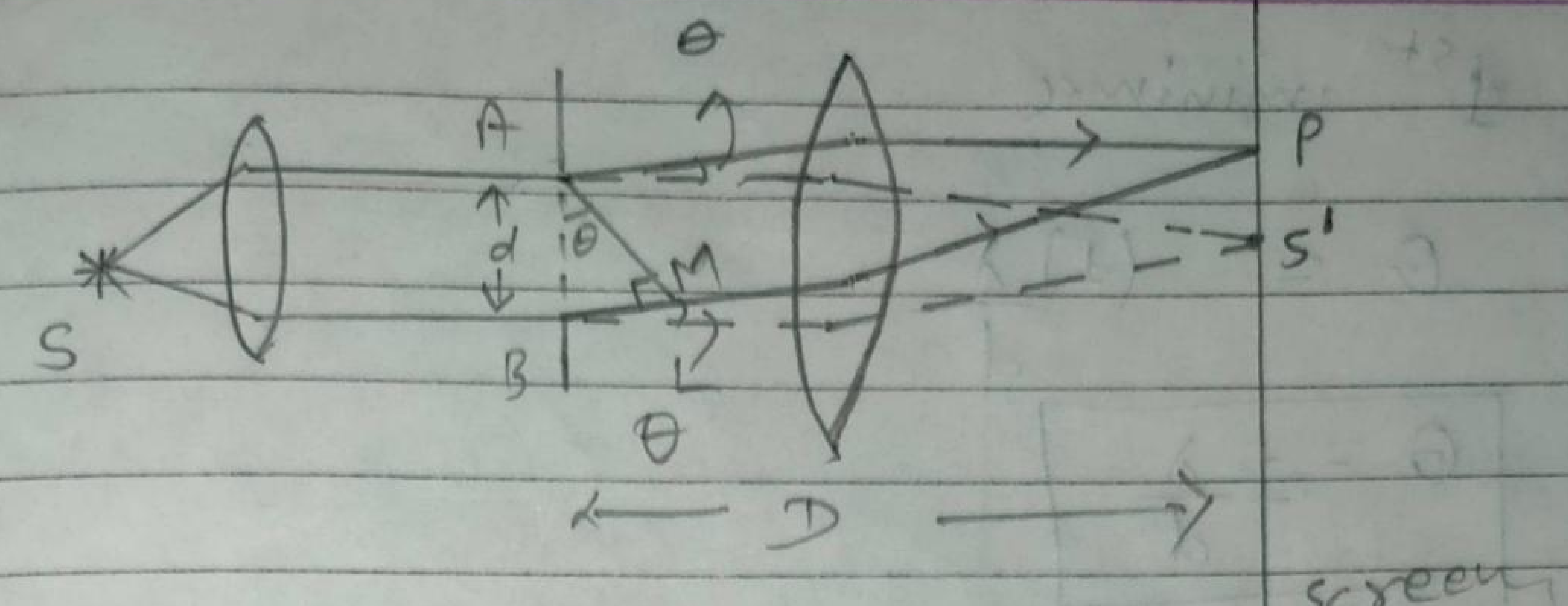
Q.16. Explain single slit experiment. on the basis of this experiment derive an expression for width of fringe.

Ans.14) <u>Diffraction</u> :- The bending property of light from the sharp corner obstacle is known as diffraction.

Diffraction is of 2 types

i) fresnel diffraction
ii) Franhoifer diffraction

Ans.16)



Here,

$$MP = AP$$

and path difference $(\Delta) = BP - AP$

$$= (BM + MP) - AP$$

$$= BM + AP - AP$$

$$\boxed{\Delta = BM} \rightarrow (1)$$

In Δ BMA,

$$\Rightarrow \sin\theta = \frac{MB}{AB}$$

$$\Rightarrow BM = d\sin\theta \rightarrow (2)$$

from (1) & (2)

$$\Rightarrow \Delta = d\sin\theta$$

for minima,

$$\Rightarrow \Delta = n\lambda$$

$$\Rightarrow n\lambda = d\sin\theta$$

$$\Rightarrow \sin\theta = \frac{n\lambda}{d}$$

$$\Rightarrow \theta = \frac{n\lambda}{d} \quad \{\sin\theta \approx \theta\}$$

1^{st} minima

$$\theta = (1)\frac{\lambda}{d}$$

$$\boxed{\theta = \pm\frac{\lambda}{d}}$$

for Maxima,

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

$$\Rightarrow (2n-1)\frac{\lambda}{2} = \cancel{\frac{n\lambda}{d}}\ d\sin\theta$$

$$\Rightarrow \sin\theta = (2n-1)\frac{\lambda}{2d} \Rightarrow \boxed{\theta = (2n-1)\frac{\lambda}{2d}}$$

1^{st} maxima,

$$\Rightarrow \theta\ \cancel{\sin\theta} = (2(1)-1)\frac{\lambda}{2d}$$

$$\Rightarrow \boxed{\theta = \frac{\lambda}{2d}}$$

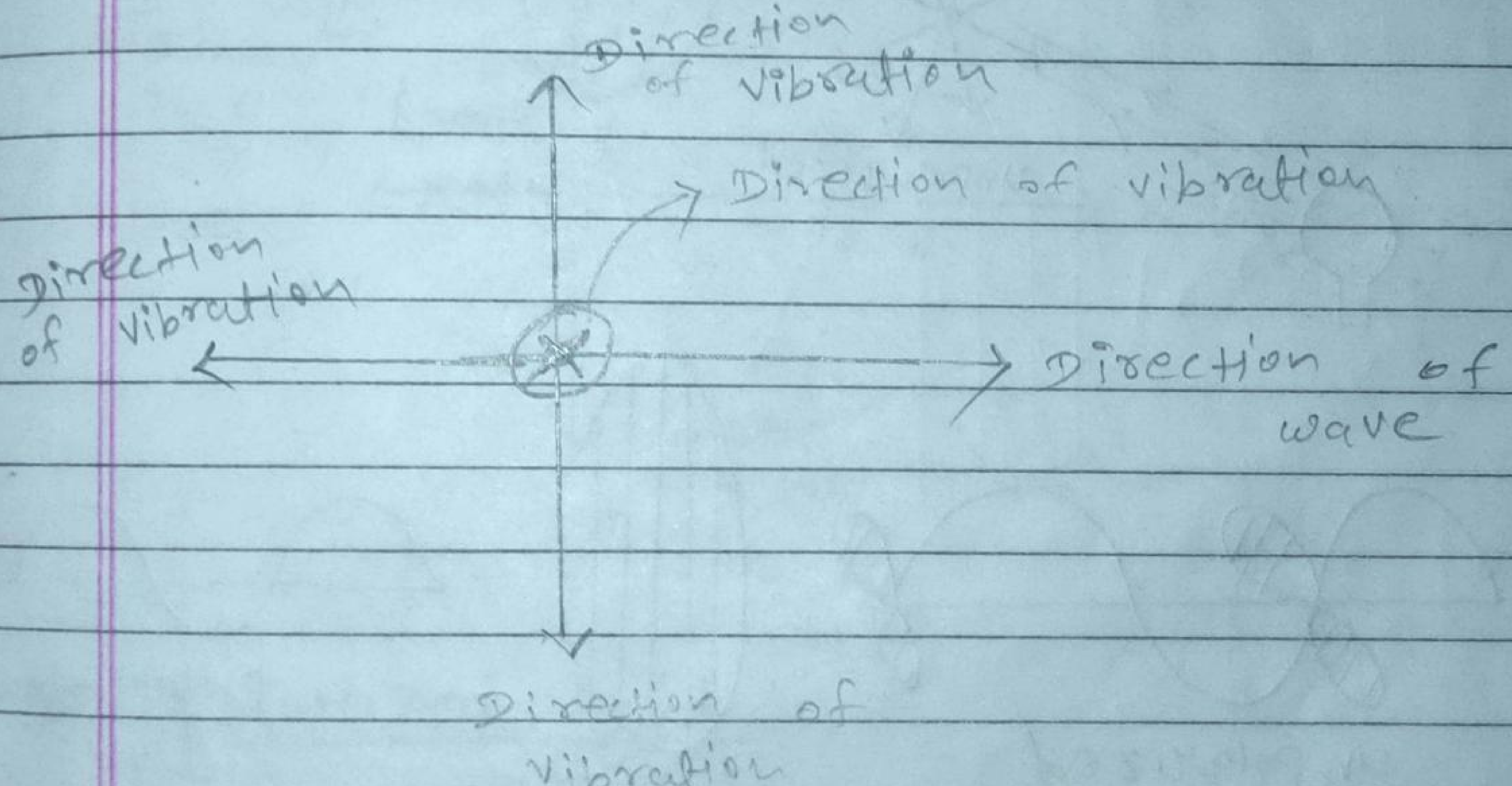
~~Q.17~~ Polarization :-

i) In Huygen's wave theory of light, it was assume that light waves are longitudinal in nature Just like the sound waves

ii) But the phenomena of polarization proves that light waves are transverse in nature.

iii) Polarization occurs only in transverse wave.

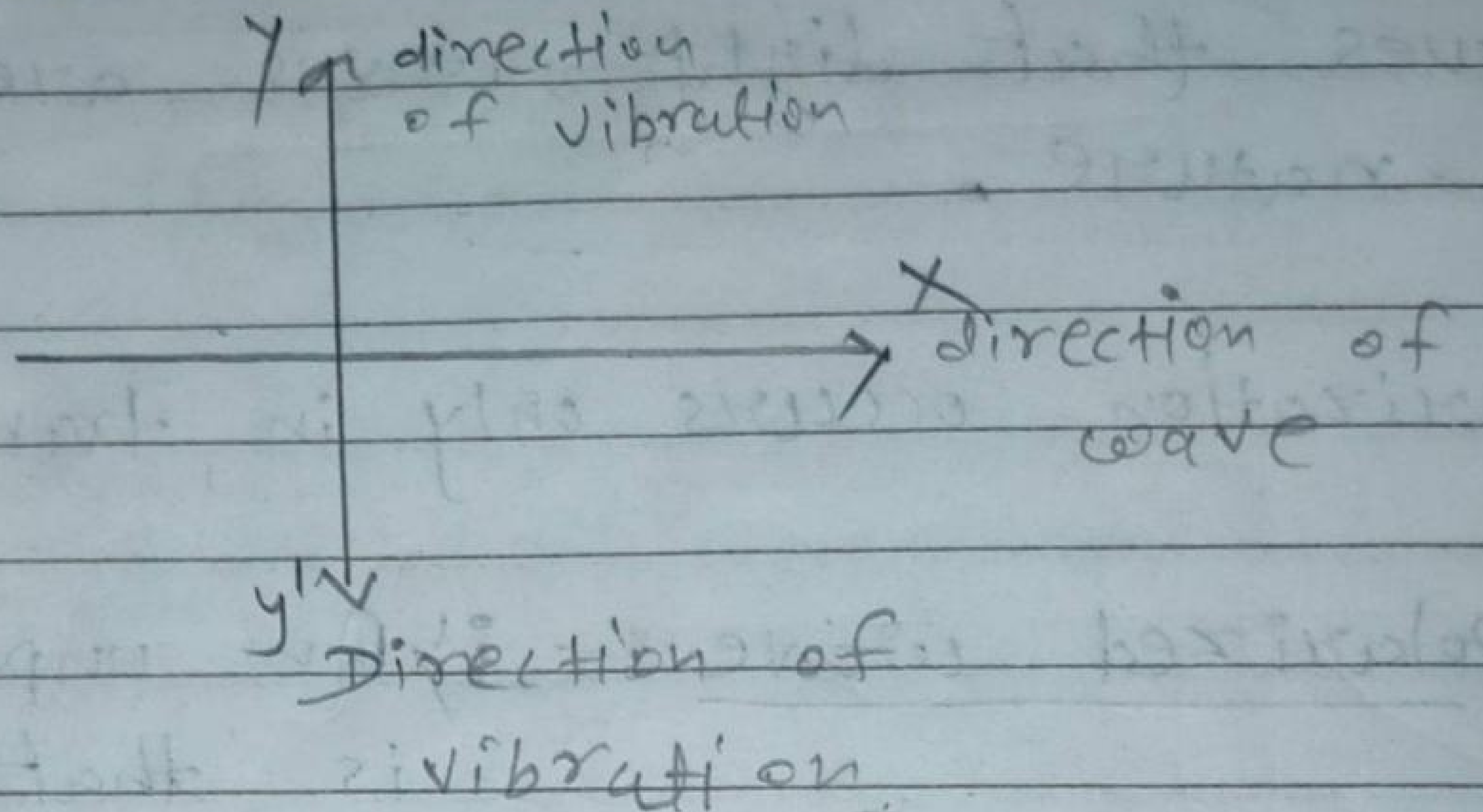
Unpolarized wave :- i) An unpolarized wave is that wave in which all the plane of vibrations are present in it, perpendicular to the direction of wave

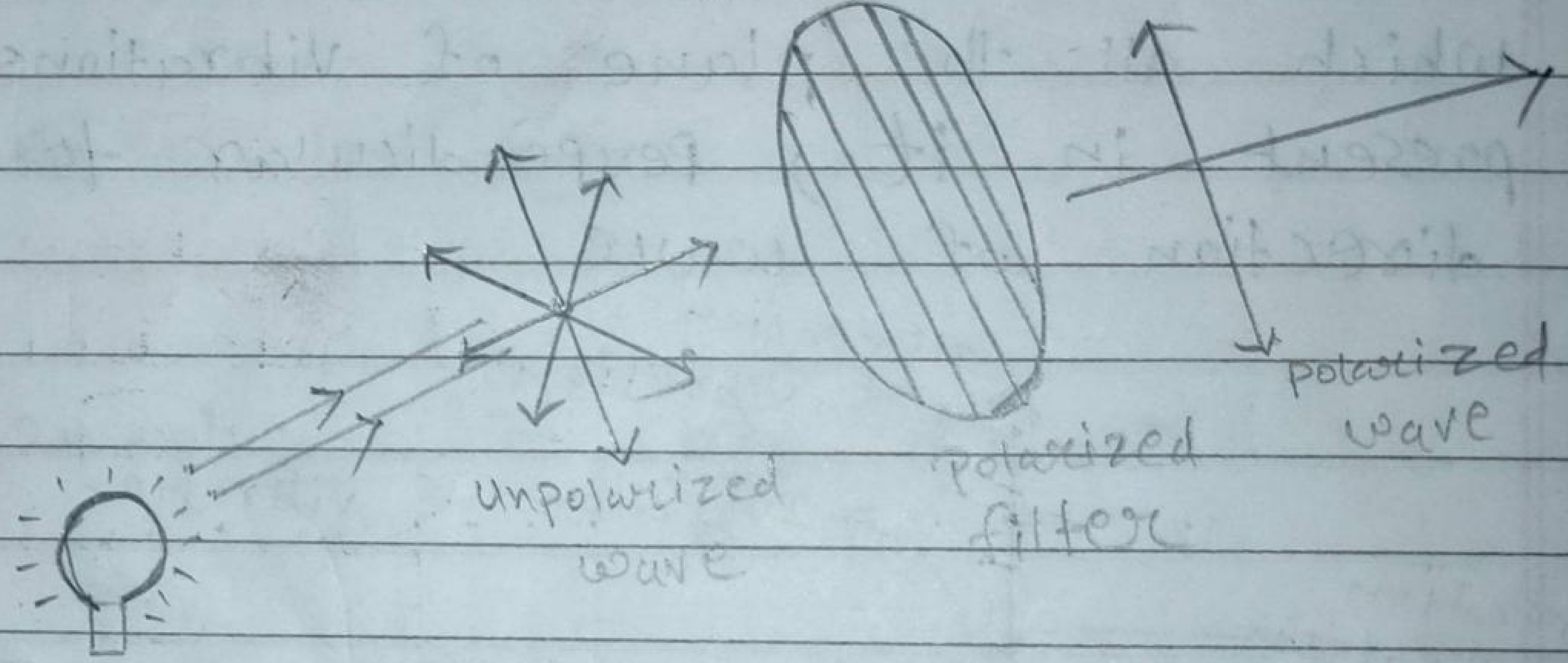


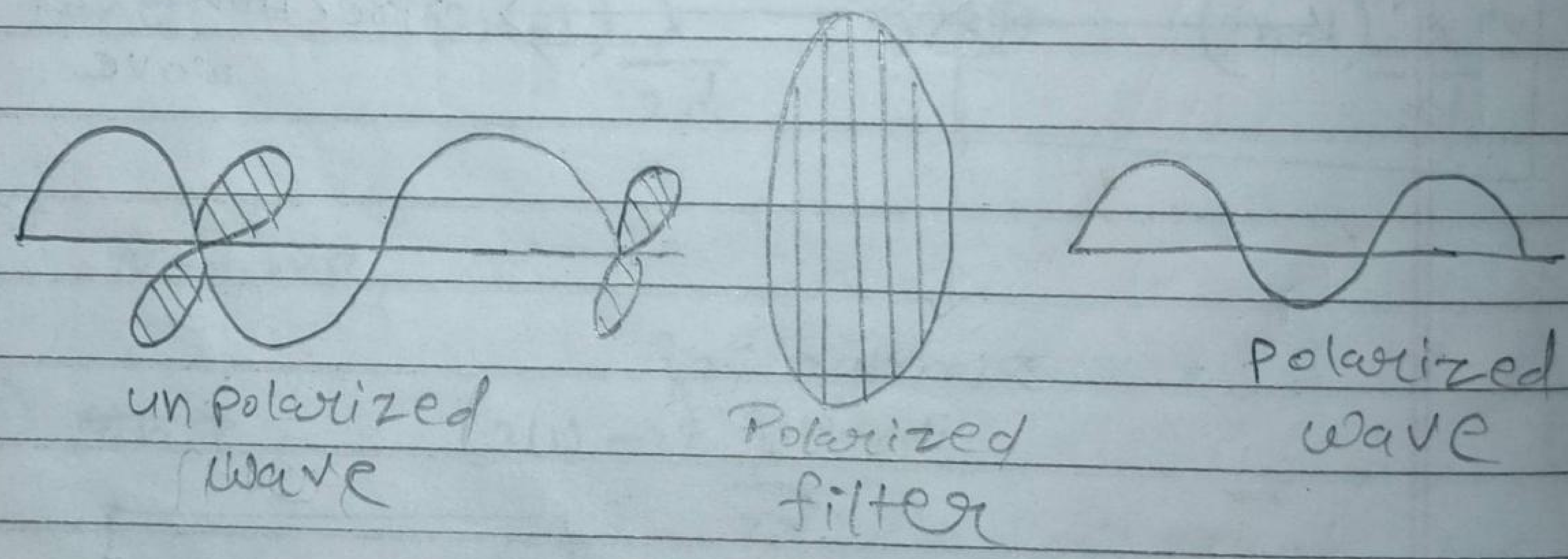
ii) If a wave is propogating along X direction then it's vibrations are distributed in all directions in YZ plane

Polarized wave :- i) The waves are said to be polarized wave whose vibrations are in a plane perpendicular to the direction of propogation of the wave and are restricted in a

particular direction.







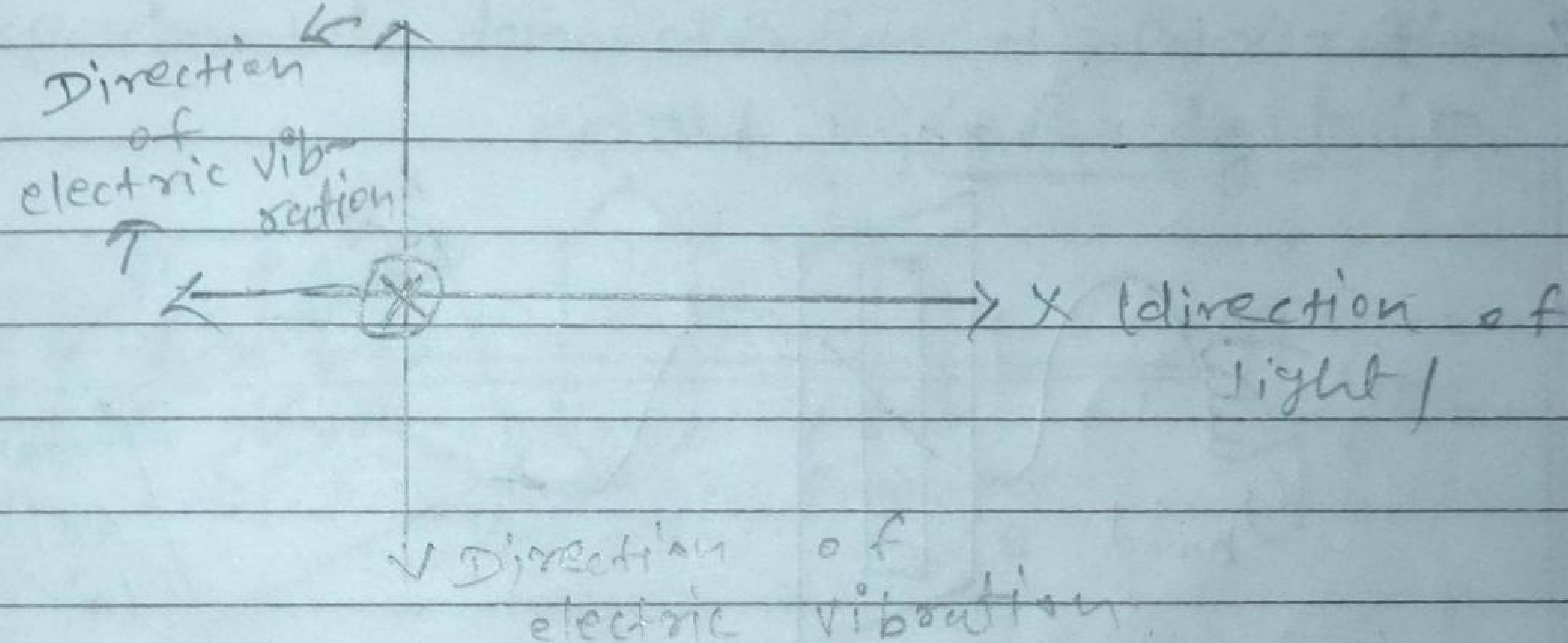
i) According to maxwell, light wave is a Electromagnetic wave which is made up of ~~ocsi~~ oscillations of Electric vector and magnetic vector.

ii) In the light wave the electric and magnetic vector vibrate perpendicular to the direction of propogation of wave.

iii) The optical Effect of light is due to electric vectors only.

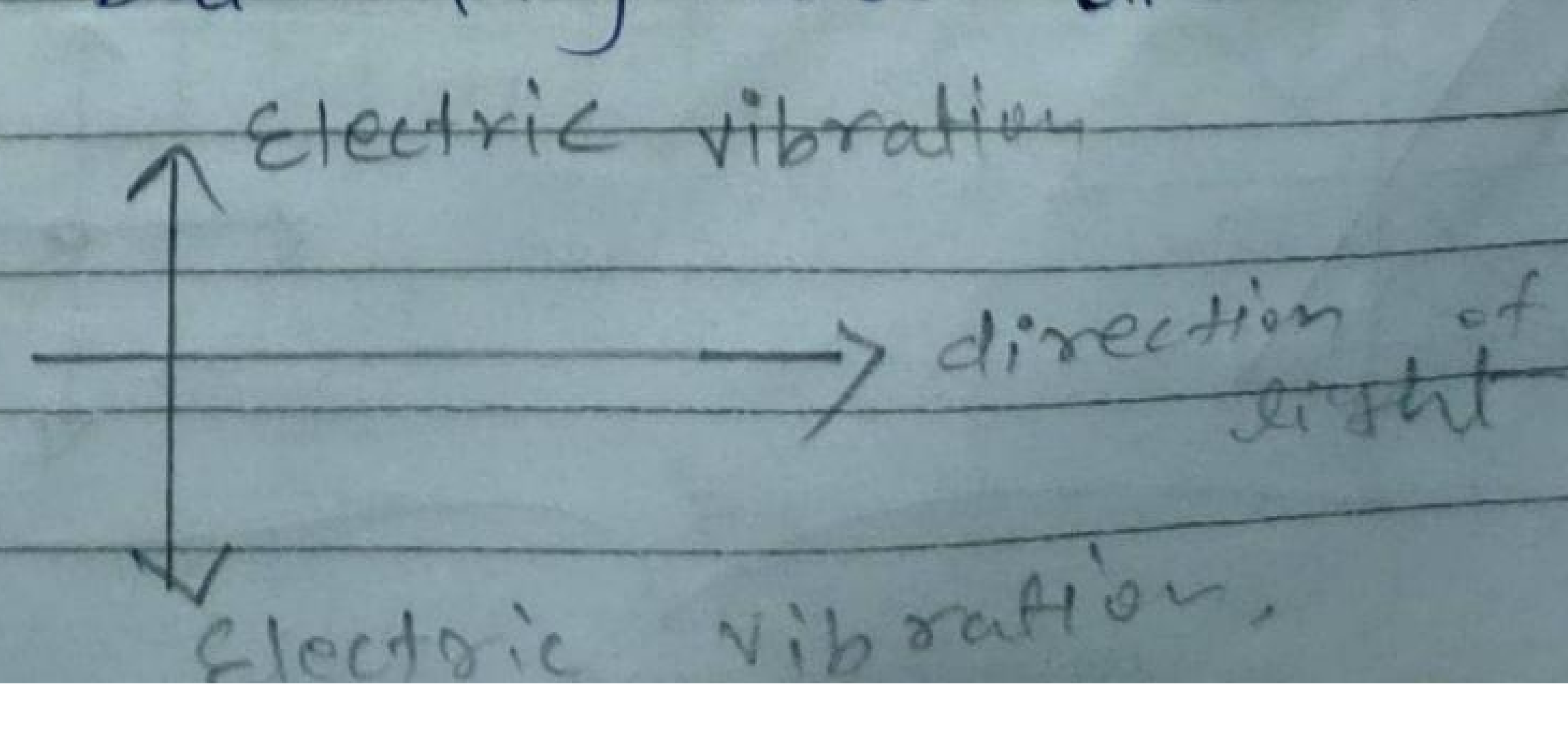
Unpolarized light :-

If the vibrations of electrical vectors symmetrically in all possible directions in a plane perpendicular to the direction of propogation then the light is said to be unpolarized.

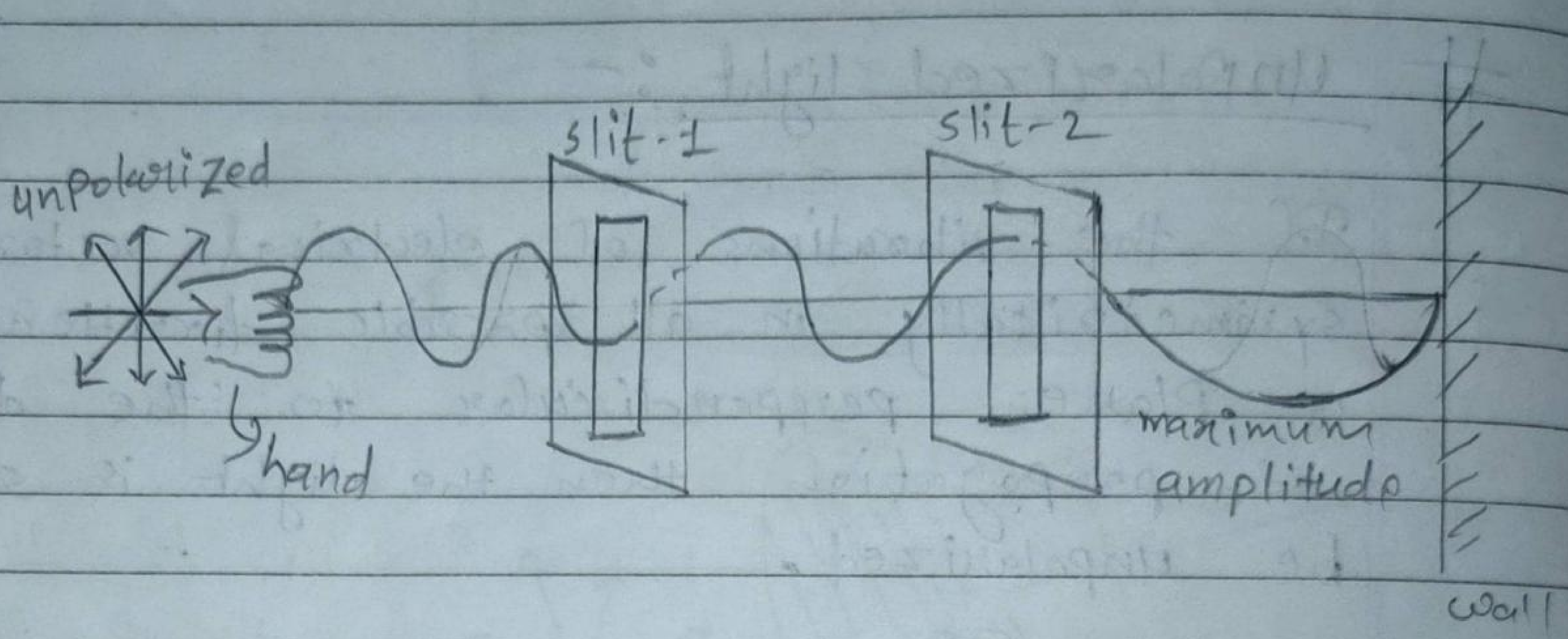


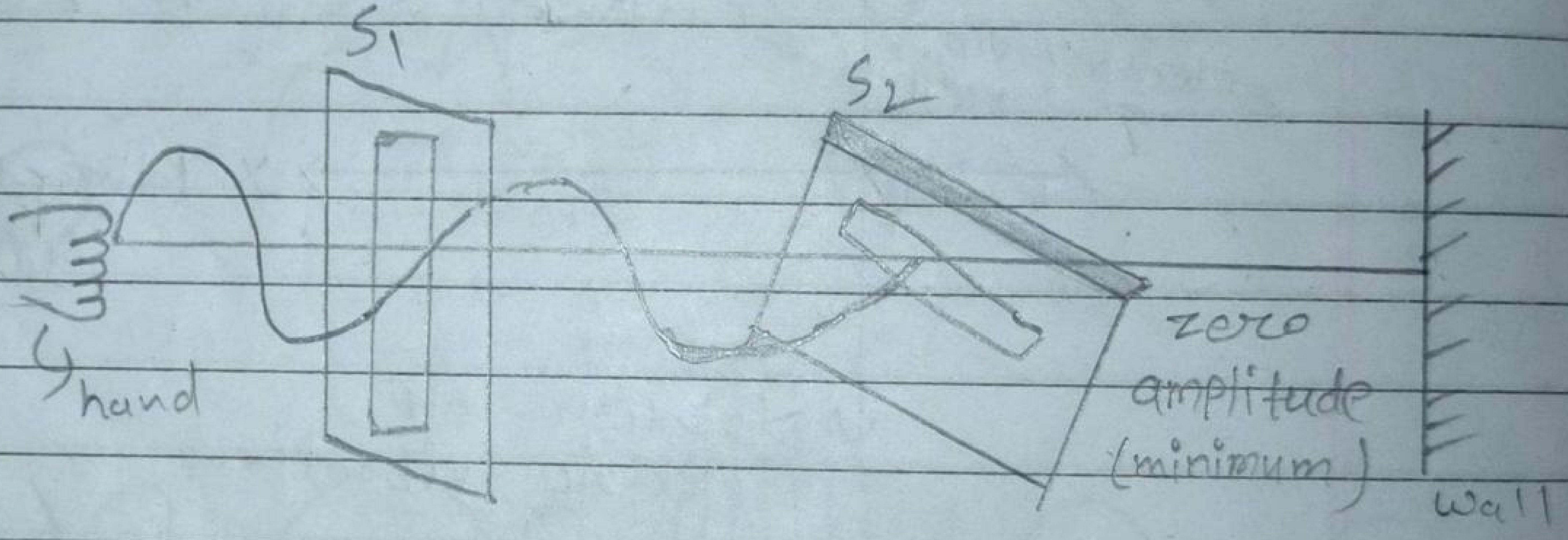
polarized light :-

If the vibration of electric vectors occurs in a plane perpendicular to the direction of propogation of light then the light gets polarized. They do not vibrate symmetrically in all possible direction but they are ~~lies~~ lie in a single direction.



Demonstration of Polarization of Mechanical wave :-

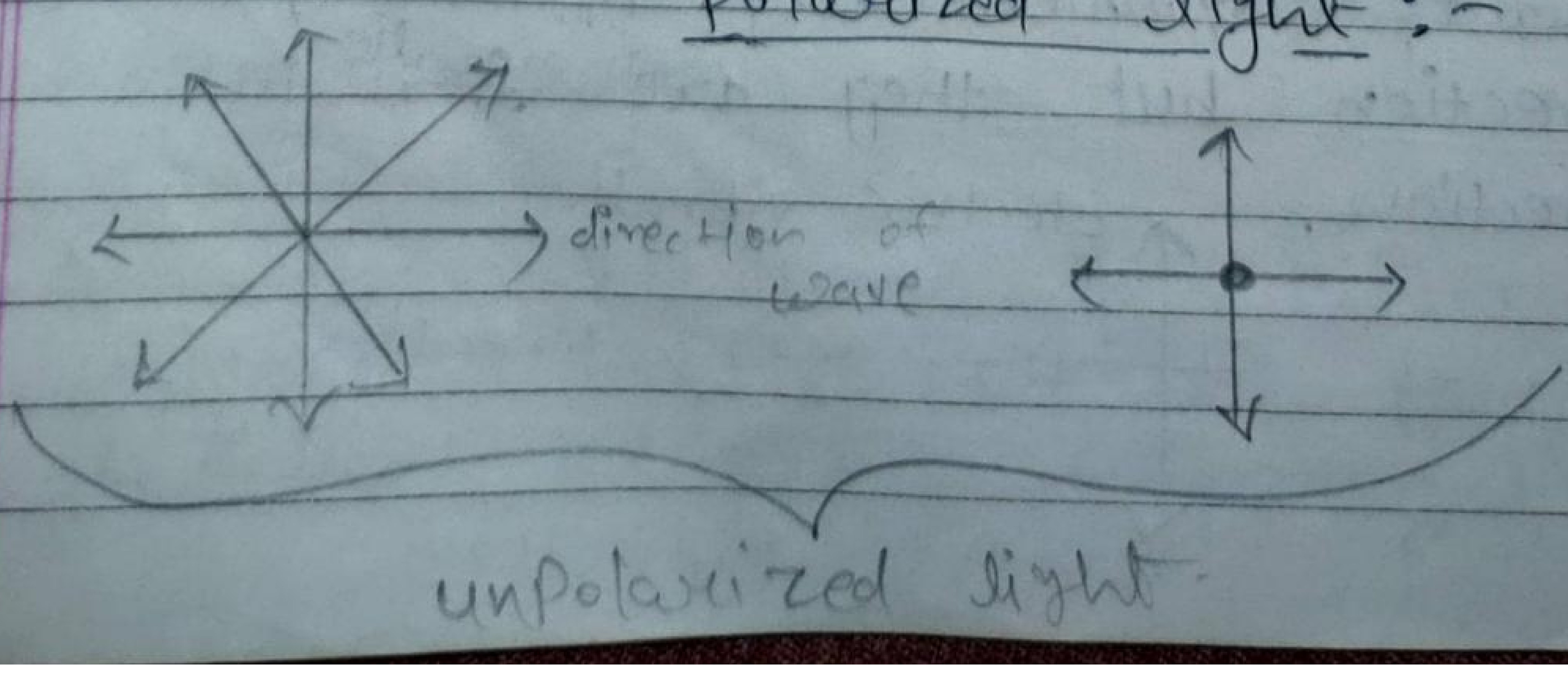


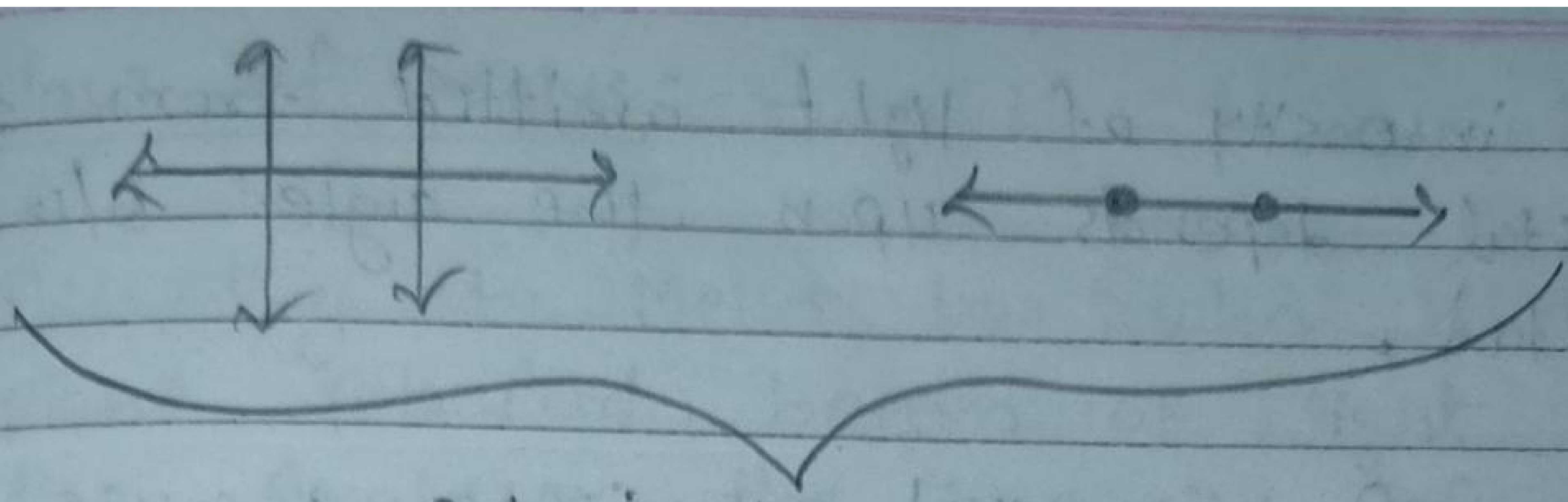


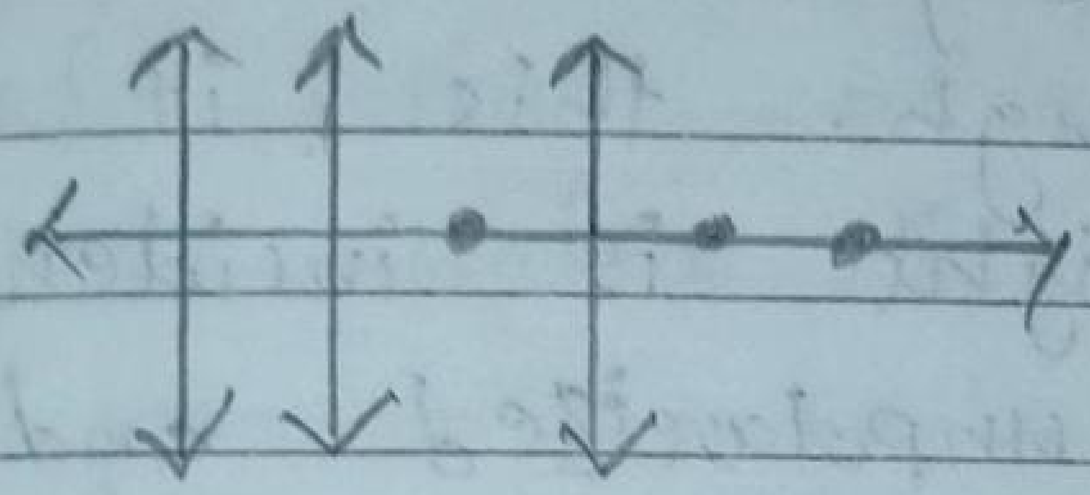
i) wave coming out from S_1 will be plane polarized wave therefore S_1 is called polarizer.
S_2 is called Analyser because it decides the amplitude of wave

Representation of Unpolarized light & Polarized light :-

a)



B) 

c) 

Experimental demonstration of polarization of light :-

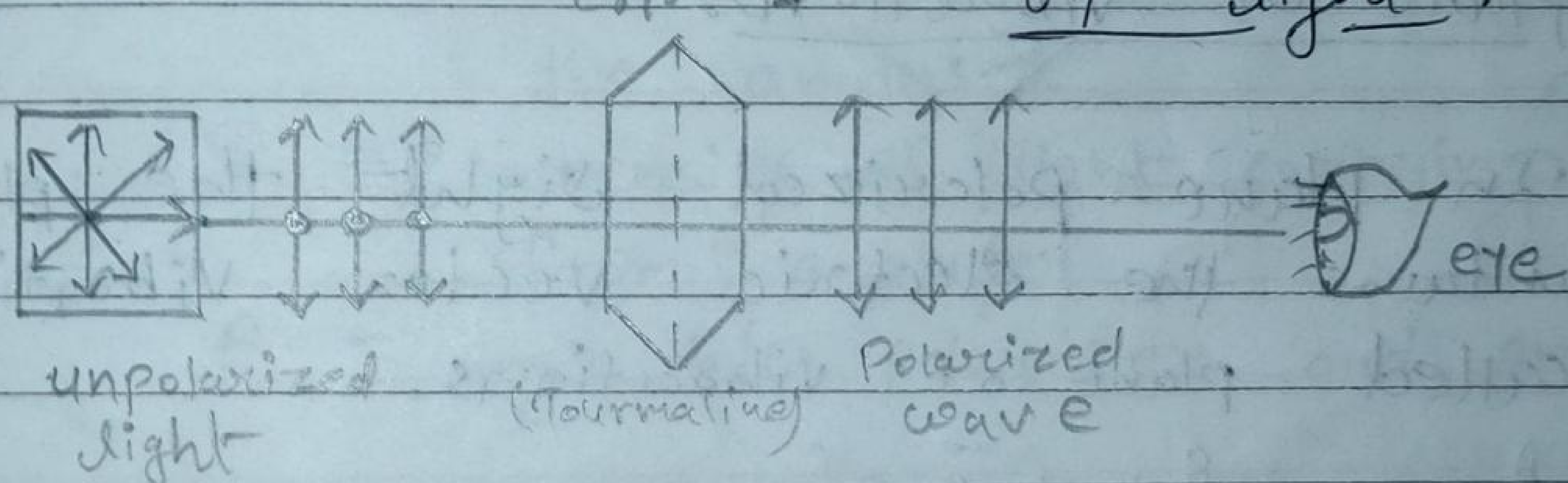


fig. a

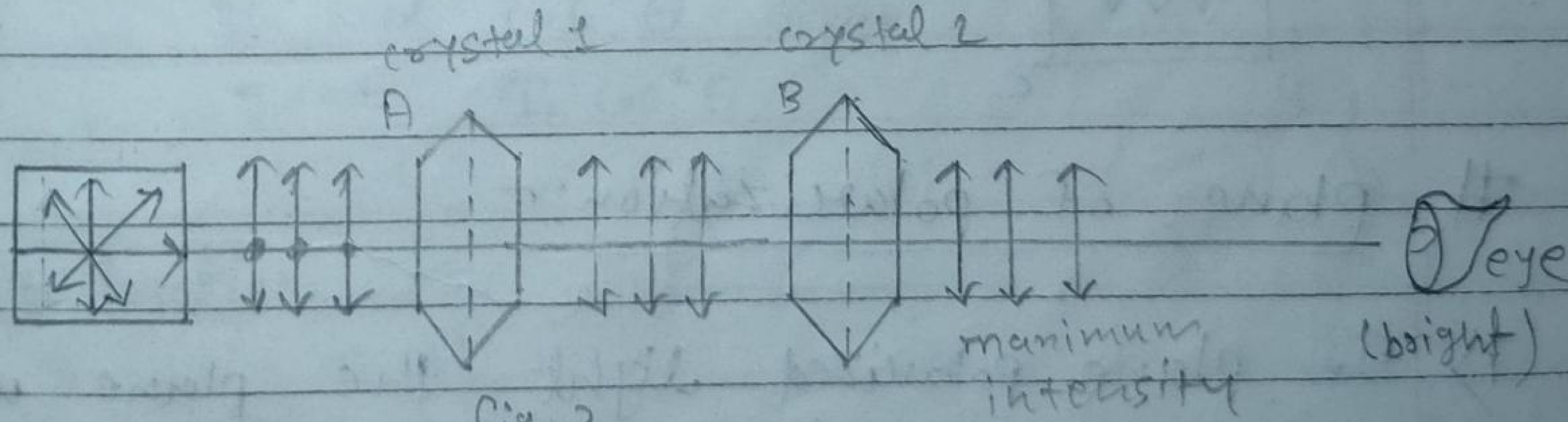
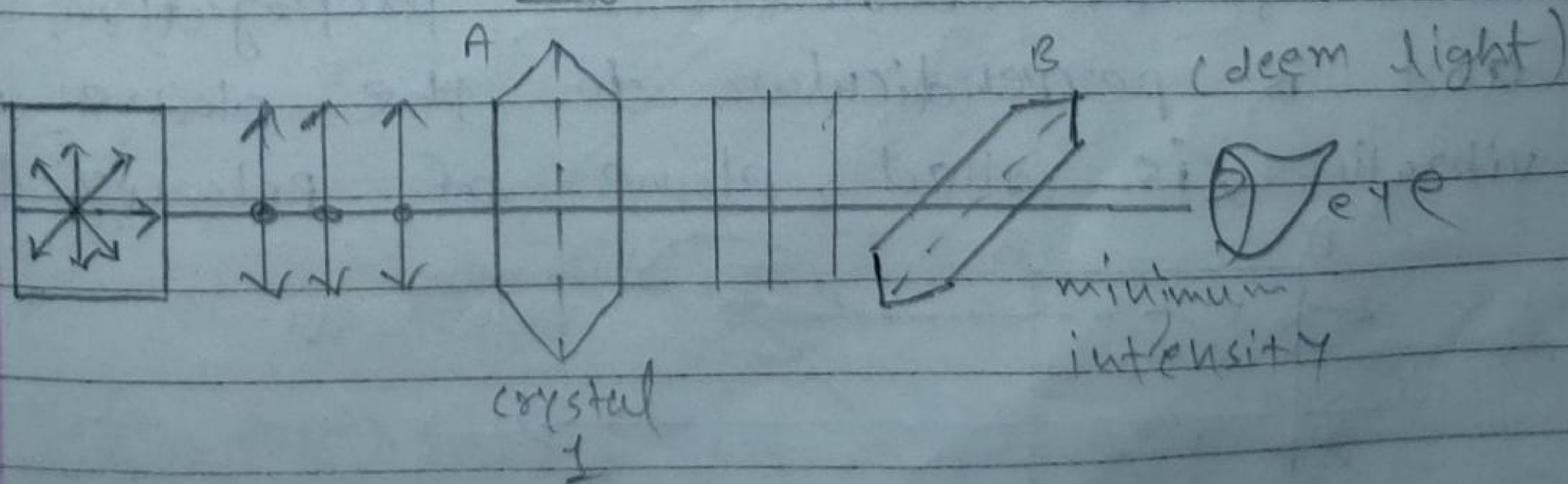


fig. 2.

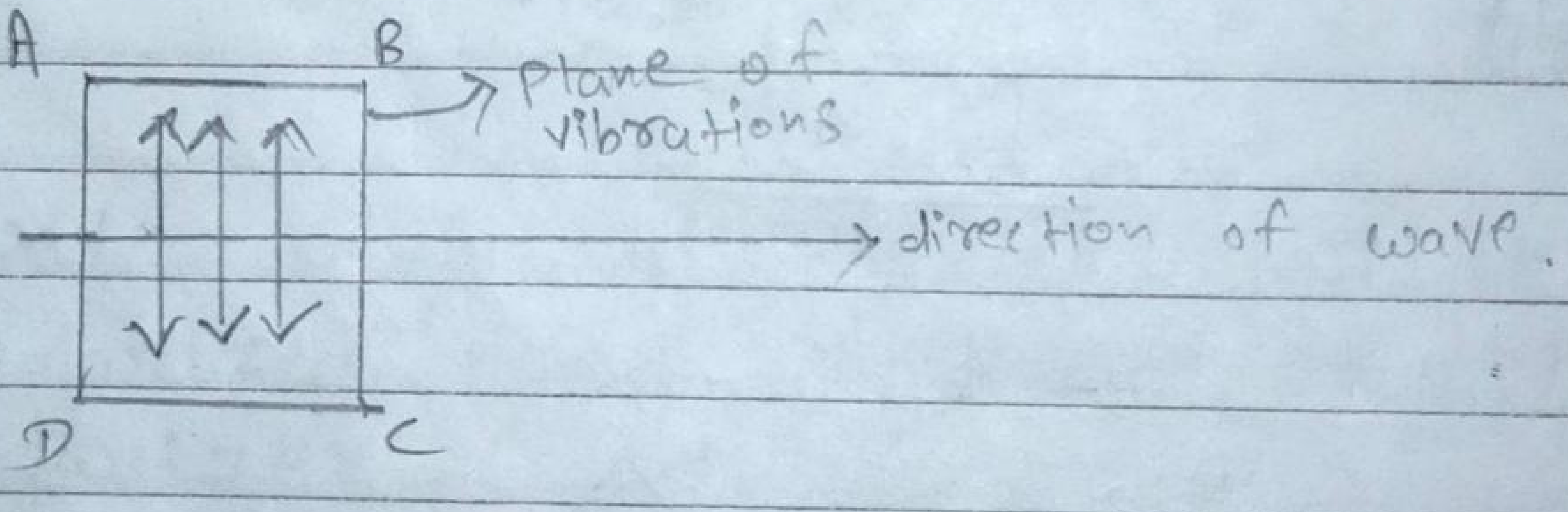


i) The intensity of light amitted from second crystal depends upon the angle b/w two crystal.

ii) crystal A is called polarizer because it polarizes the light. Crystal B is called Analyser because through this it is detected that the light is incident on it are polarized or unpolarized and adjust the intensity of the light.

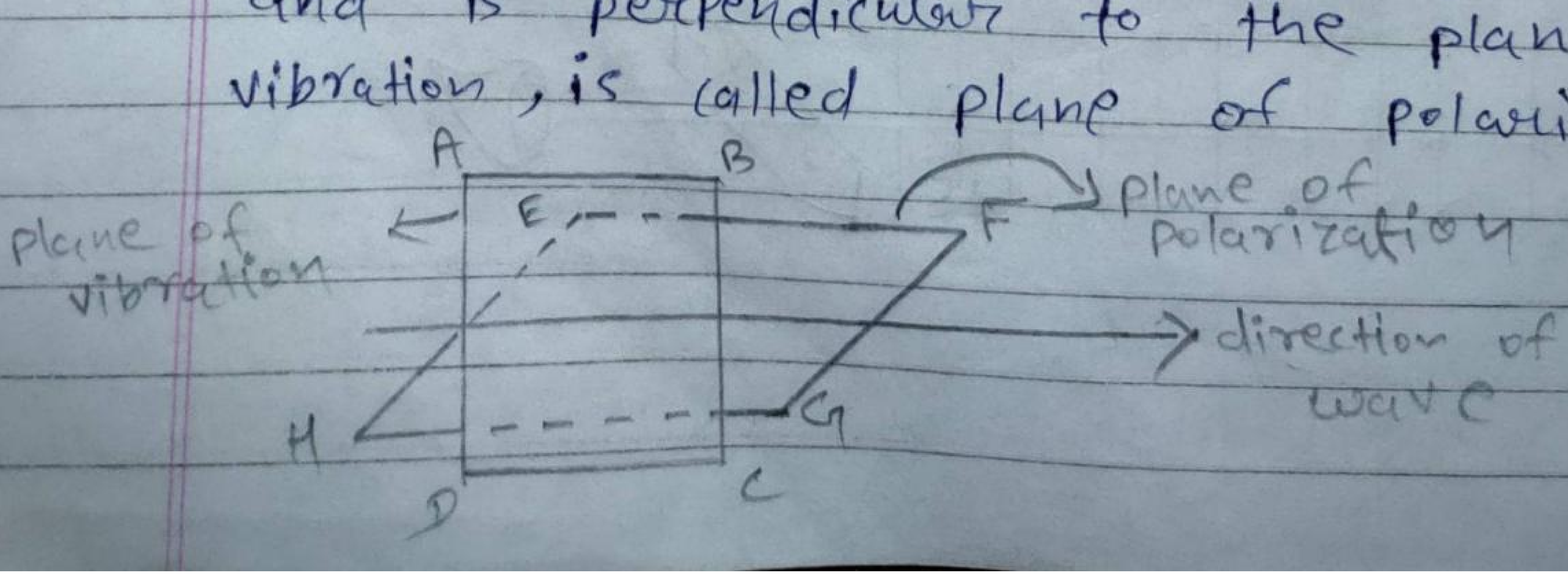
plane of vibrations:-

i) In plane polarized light the plane which contains the electric vector vibrations is called plane of vibrations.



plane of polarization:-

i) In plane polarized light the plane which contains the direction of propogation of wave and is perpendicular to the plane of vibration, is called plane of polarization.



IMP.

Law of Melus :-

i) According to Melus law, when a fully plane polarized beam of light falls on the Analyser the intensity of emergent light is directly proportional to square of cosine of the angle b/w the pass axis of the analyser and Polarizer.

$$\boxed{I = I_0 \cos^2\theta}$$

Let I_0 = Intensity of the light falling on the analyser

I = Intensity of light carrying out from analyser.

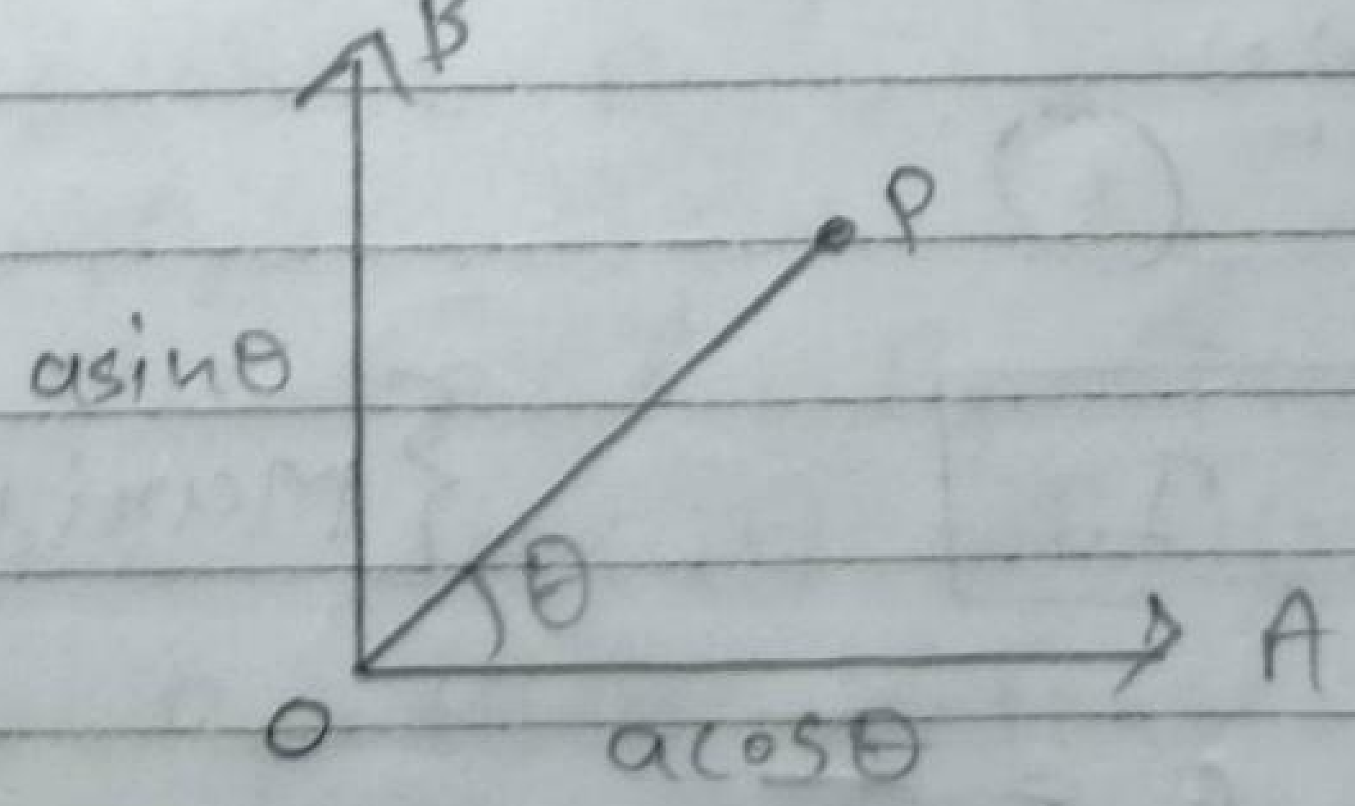
θ = angle b/w polarizer and analyser

Then according to melus law

$$I \propto \cos^2\theta$$

$$I = I_0 \cos^2\theta$$

Derivation :- let



let the angle b/w OP and OA is θ
And 'a' be the amplitude of emergent

light from polarizer along axis op.

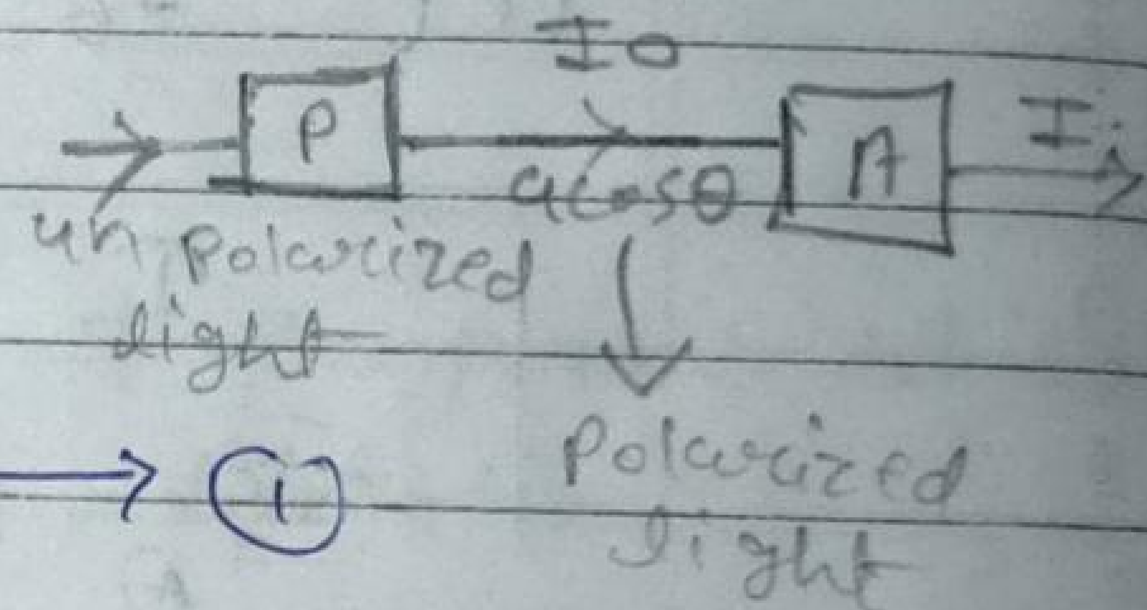
→ Amplitude 'a' can be resolved into two components

i) $a\cos\theta$, along axis of analyser
ii) $a\sin\theta$, along axis of polarizer.

→ $a\cos\theta$ only emerges out of analyzer.

→ Therefore

$$I \propto (a\cos\theta)^2$$
$$I \propto a^2\cos^2\theta$$
$$I = K a^2 \cos^2\theta$$
$$\boxed{I = I_0 \cos^2\theta} \longrightarrow (1)$$



where, $I_0 \to Ka^2$
$K \to$ constant
$I_0 \to$ Intensity of light emerging from polarizer and Analyser.

Case I) if $\theta = 0°$ {Pass axis of polarizer and Analyser are parallel to each other}

from eq^n (1)

$$\boxed{I = I_0}$$ {Maximum}

Case 2) if $\theta = \frac{\pi}{2}$

$$\boxed{I = 0}$$ {minimum}

Special case:- when unpolarized light is passed through polaried then the intensity of emergent light is half the intensity of incident light.

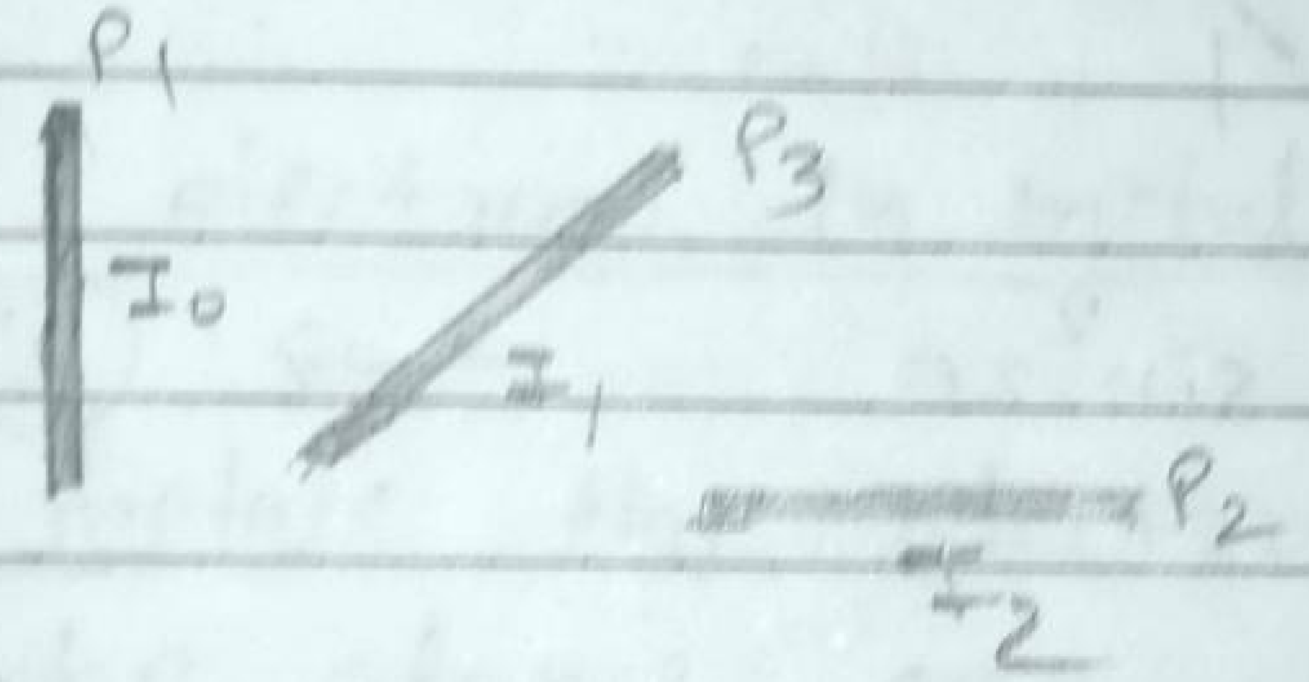
$$\boxed{I = \frac{I_0}{2}}$$

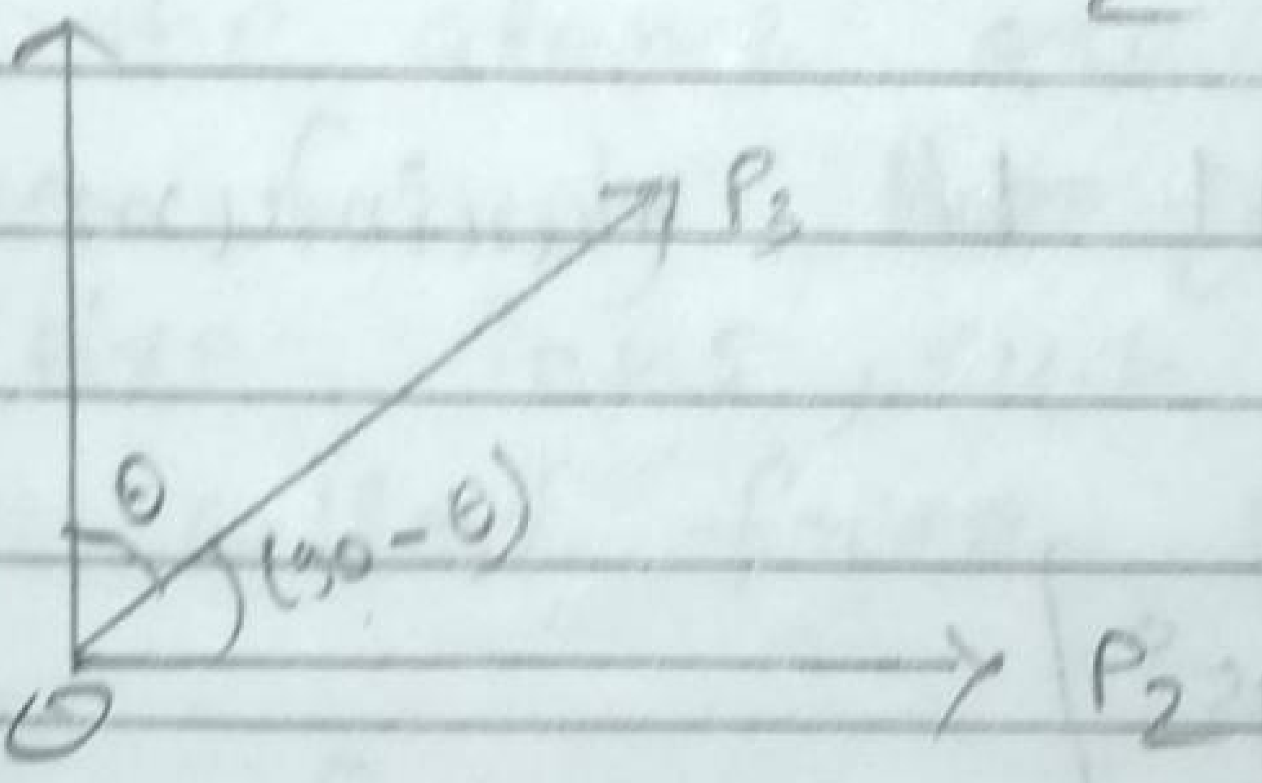
Back Exercise

Question 10.8

Q. Discuss the intensity of transmitted light when a polaried sheet is rotated b/w two crossed polaried.

Sol.





→ let P_1 and P_2 are two crossed polaried

→ Third polaried P_3 is rotated b/w ~~them~~ P_1 and P_2.

→ Angle b/w P_1 & P_3 is θ.

→ I_0 is the intensity of light after passing through P_1 then intensity of light emerging from P_3 is I_1

$$I_1 = I_0 \cos^2\theta \longrightarrow (1)$$

→ Intensity of light emerging from P_2 is I_2.

$\Rightarrow \quad I_2 = I_1 \cos^2(90-\theta)$

$\Rightarrow \quad I_2 = I_1 \sin^2\theta$

from ①,

$\Rightarrow \quad I_2 = I_0 \cos^2\theta \cdot \sin^2\theta$

$\Rightarrow \quad I_2 = \dfrac{I_0 (2\cos\theta \sin\theta)^2}{4}$

$\Rightarrow \quad I_2 = \dfrac{I_0 \sin^2 2\theta}{4}$

$\Rightarrow \quad I_2 = \dfrac{I_0}{4} \sin^2 2\theta \longrightarrow ②.$

Case I > I_2 will be maximum when

$\boxed{\theta = 45^\circ}$

$\boxed{I_2 = \dfrac{I_0}{4}}$ (maximum)

Case II > I_2 will be minimum when

$\boxed{\theta = 0^\circ}$

$\boxed{I_2 = 0}$ (minimum)