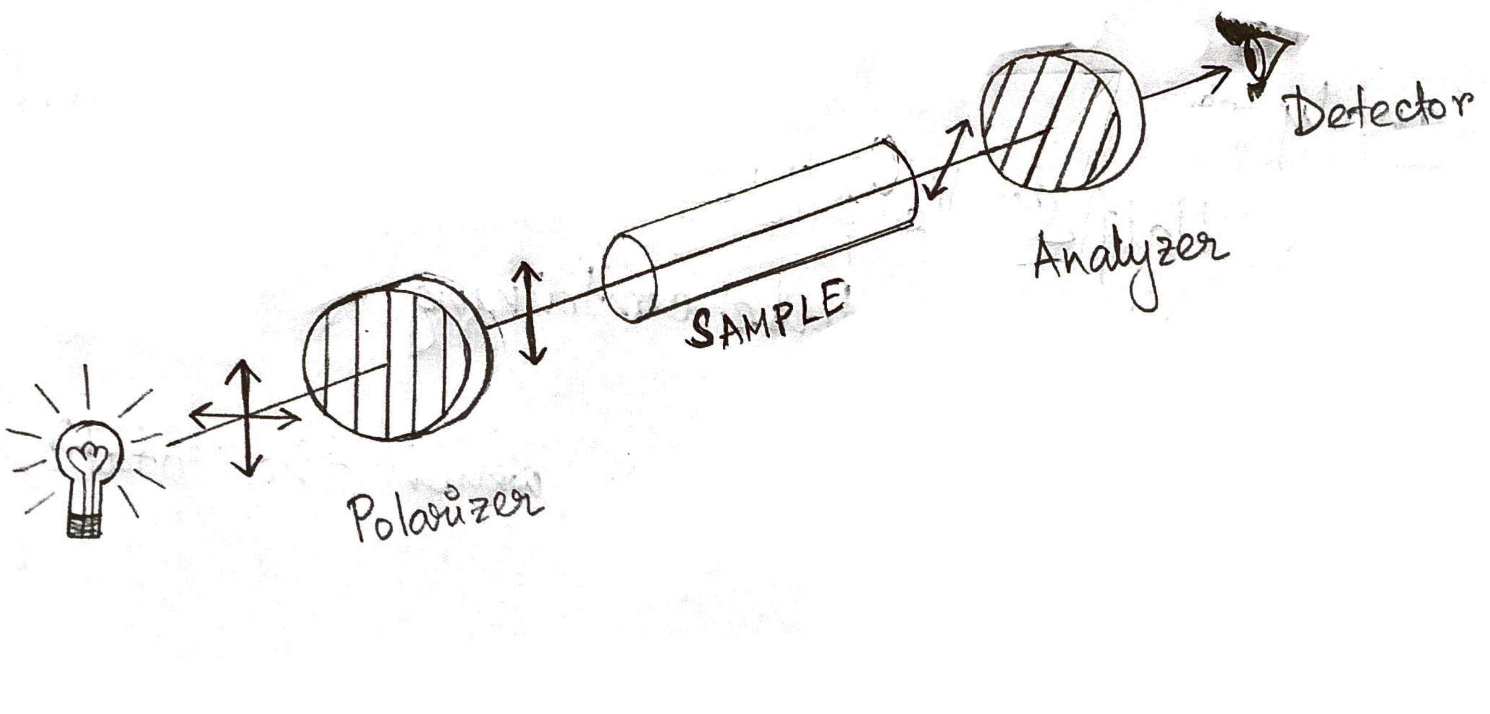
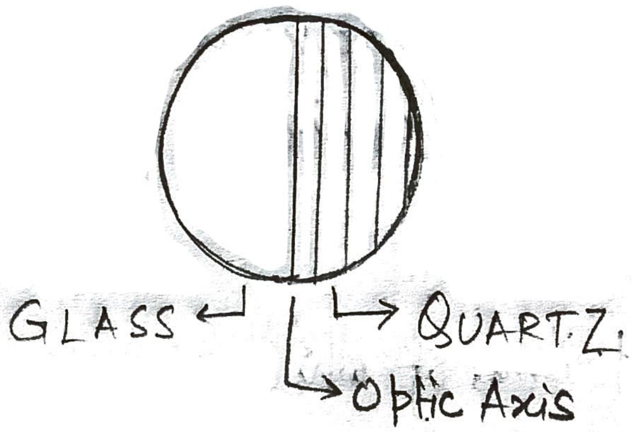
POLARIMETER :

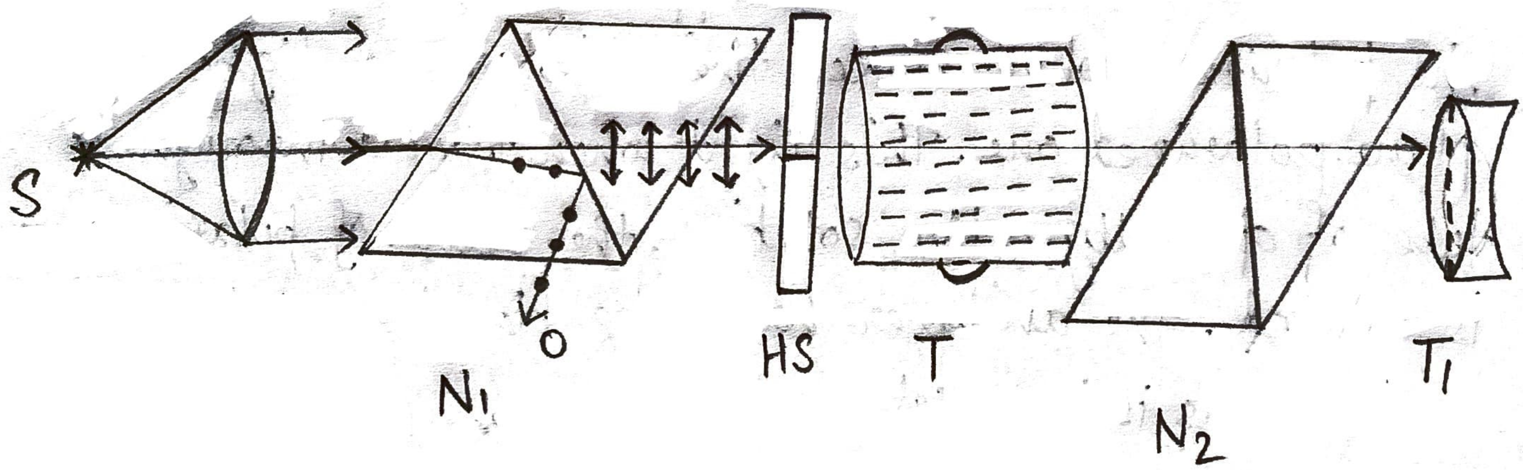
A polarimeter is an instrument used to measure the angle of rotation caused by passing plane polarized light through an optically active substance.

It is made up of two Nicol prisms, of which one acts as the polarizer & the other as the analyzer. The polarizer is fixed & the analyzer can be rotated. The polarizer ~~polariz~~ makes the unpolarized light into plane-polarized one. This light when travels through a tube of optically active solution, the plane of polarization is rotated. The analyzer has to be ~~placed~~ rotated so that the pass axis is parallel to the direction of polarization & the total light gets through.



LAURENT'S HALF-SHADE POLARIMETER:





Consists of two Nicol prisms, N_1 & N_2, where N_1 acts as the polarizer & N_2 acts as the analyzer.

HS → Half Shade plate

T → Polarimeter tube containing an optically active solution.

T_1 → Telescope through which the rotation is observed.

N_2 is fixed on a circular scale on which the angle of rotation b/w N_1 & N_2 are read.

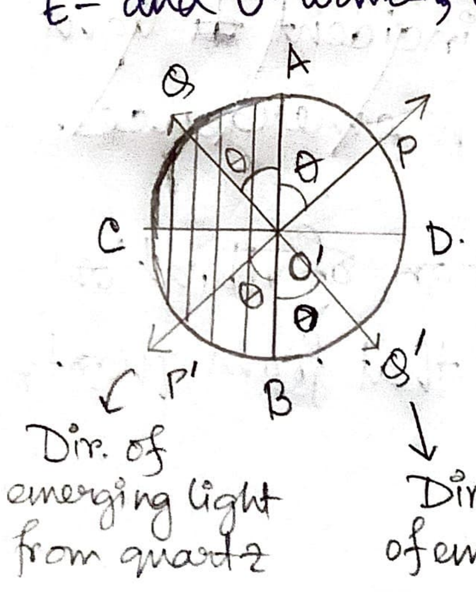
The Half-Shade plate consists of two semicircular ~~half~~ halves, one made up of glass & the other of quartz crystal (+ve).

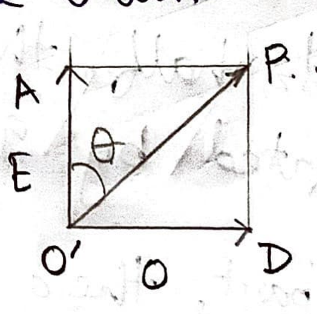
The quartz ~~ππ~~ crystal is a HWP, so the phase diff. b/w the O & E waves while travelling through it will be π & velo. of O wave will be more than that of the E wave.

The thickness of the semi-circular glass plate is so adjusted that the amount of light absorbed in the quartz HWP is equal to the amount absorbed while travelling through the glass plate.

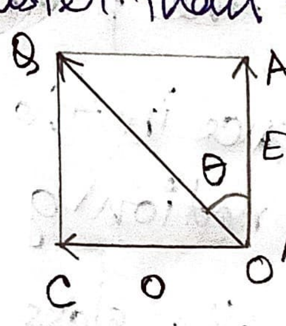
The optic axis of the quartz is parallel to the ~~joining~~ diameter along which the two plates are joined.

The quartz crystal is able to split the incident light into E- and O-waves, where O-wave travels faster than E wave.





Incident Light



Emergent Light

If a plane polarized light vibrating along OQ' is incident on the quartz making an angle θ with $O'A$, it is divided into an E-wave with plane of vibration parallel to the optic axis AB & an O-wave with plane of vibration perpendicular to AB.

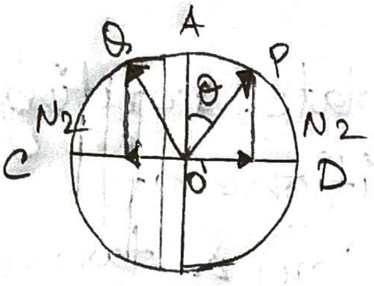
As the quartz part is a HWP, it introduces a π phase diff. b/w O- & E-wave on emergence from the plate.

~~As~~ Since E-wave is always vibrating parallel to the optic axis, upon emergence it does not change its direction; only the direction of the O-wave changes to be along $O'D$ which is also perpendicular to the optic axis, on emergence.

The resultant emergent light is thus vibrating along the direction OP', which also makes an angle θ with AB but in the other half of the plate; i.e., $\angle AO'P = \angle AO'Q = \theta$

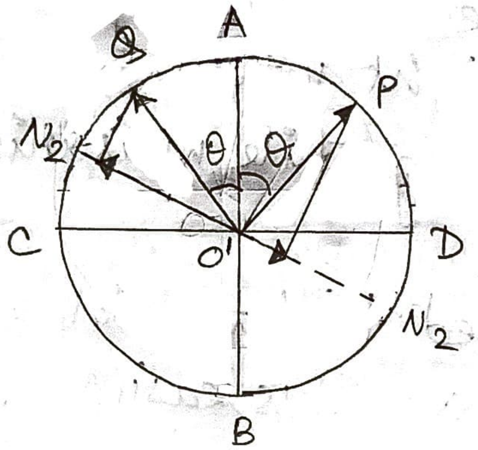
On the glass plate part, the direction of vibration of the emergent light is $O'Q'$ & that from quartz plate is along $O'P'$.

(1)



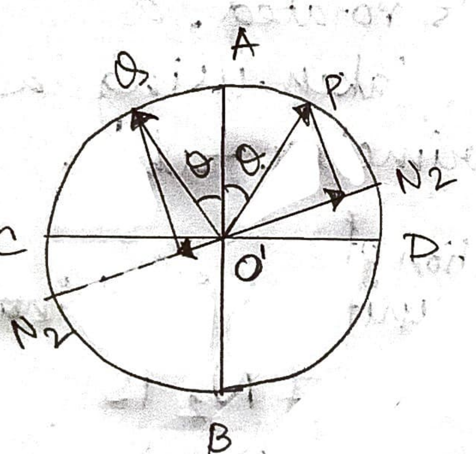
If the principal section of the analyzer N_2 is perpendicular to the optic axis, then intensity of light from both the glass & quartz plates reaching the analyzer are the same & hence we get an uniform illumination when viewed through the telescope, as acc. to Malus' law intensity reaching N_2N_2 is $I(90^\circ-\theta) = I_0 \cos^2(90^\circ-\theta)$

(2)



If the principal section of the analyzer is making an angle like that shown in the left then intensity of light reaching the principal section from the left half is more than that reaching from the right half. Hence the left half is more illuminated than the right half.

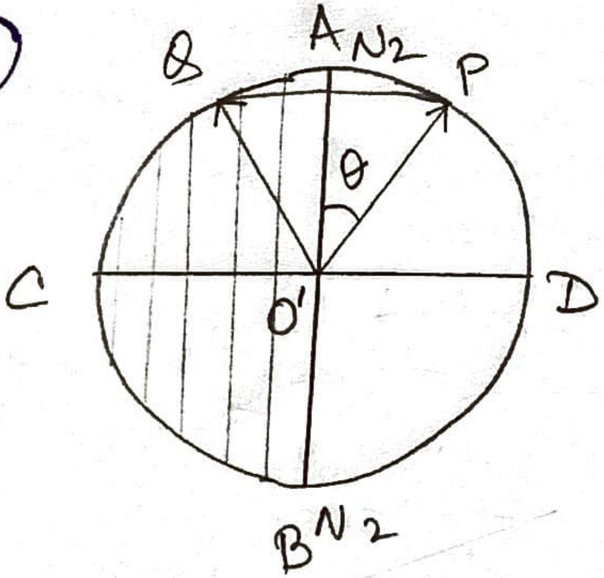
(3)



For the principal section making an angle like that shown in the left, the right half of the plate is more illuminated than the left half.

We have to rotate the analyzer about the direction of the incident light & obtain the position of uniform illumination.

(4)



If the principal section of the analyser be along the optic axis AB, then also vibrations from both the halves are equally inclined with the principal section making angle θ with it.

Acc. to Malus' law, the intensity of light, thus, reaching the analyzer is, $I(\theta) = I_0 \cos^2\theta$ from both the halves. Now in this case,

$\angle AO'P (= \angle AO'Q = \theta) < \angle PO'D$,

so, $\cos(\angle AO'P) > \cos(\angle PO'D)$.

So even though for this position of the analyzer the field of view is uniformly illuminated, the intensity is larger in this case.

While in case where $N_2N_2 \perp AB$, the uniform intensity obtained was much lesser than this case, or we can say when $N_2N_2 \perp AB$ there is uniform darkness in the field of view of the telescope.

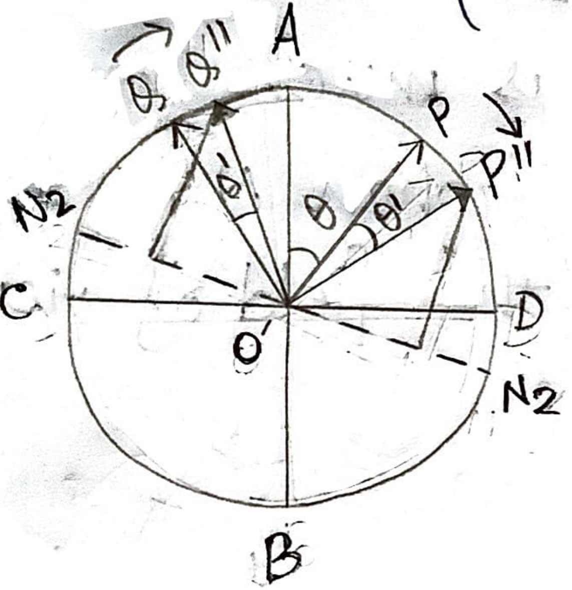
In the absence of the half shade plate, rotating the analyzer would give ~~a~~ two positions of max. ~~in~~ illumination (180° of each other) & two positions at 90° of the max. illumination where the intensity becomes zero (these positions are again 180° separated from each other).

Now the two positions of either max. ~~or~~ intensity or complete darkness are hard to detect as our eyes cannot detect very small changes in ~~in~~ light intensity. This would give erroneous reading while measuring the angle of rotation.

To determine the angle by which the plane of vibration of the incident light gets rotated, a reference circular scale reading is taken using a non-active solution inside the polarimeter tube.

For the reference reading, the position of uniform darkness is obtained when the principal section of N_2 is perpendicular to the optic axis AB. This is because when the intensity of light is low, our eyes can detect a slight change in intensity easily than when the intensity is more.

As the light travels through the optically active solution, the plane of polarization gets rotated for light emerging from both halves equally along the same direction (clockwise or anti-clockwise).



So to get uniform darkness, N_2 has to be rotated accordingly (clockwise or anti-clockwise).

The circular scale reading for a fixed column length of the non-active solution when subtracted from the reading for the active solution, gives the angle of rotation for the active solution.