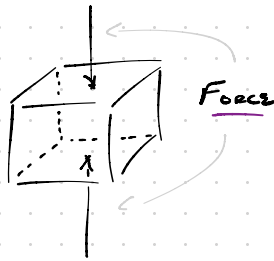


Lecture 28 Questions

Q1 HALF-WAVE PLATES:

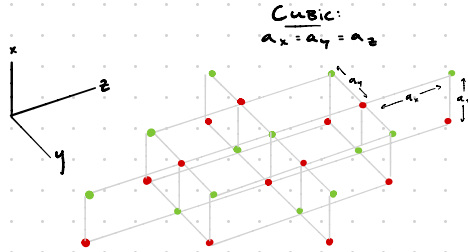
a) WHILE SOME MATERIALS ARE NATURALLY BIREFRINGENT (E.G. QUARTZ, CALCITE), OTHER MATERIALS CAN ACQUIRE BIREFRINGENT BY SOME EXTERNAL INFLUENCE. FOR INSTANCE, STRESS-INDUCED BIREFRINGENCE IS DUE TO PRESSURE APPLIED TO THE FACES OF A MATERIAL:



IF THE DIRECTION OF THE APPLIED FORCE DETERMINES THE C-AXIS OF THE BIREFRINGENCE, WHICH FACES CAN YOU SEND LIGHT INTO SO THAT THE CUBE ABOVE ACTS AS A WAVEPLATE?

b) How ELSE CAN BIREFRINGENCE BE INDUCED?

TAKE, E.G., A ROCK SALT LIKE NaCl:



- Na^+
- Cl^-

THIS CRYSTAL IS "CUBIC" IN THE SENSE THAT IT LOOKS THE SAME VIEWED ALONG THE X, Y, OR Z DIRECTIONS, AND IS THEREFORE ISOTROPIC $[n_x = n_y = n_z]$.

INDICES OF REFRACTION

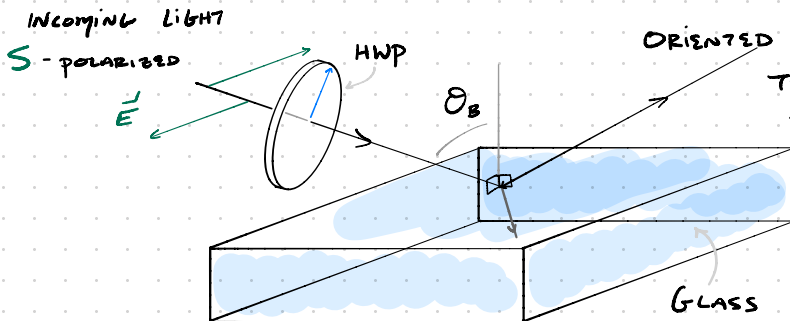
- DOES THE IONIC NATURE OF THIS SOLID SUGGEST A METHOD OF BREAKING THIS 3.D. SYMMETRY?

c) SUPPOSE LIGHT IS INCIDENT ON A GLASS SURFACE

(a) BREWSTER'S ANGLE & THE LIGHT IS S-POLARIZED:

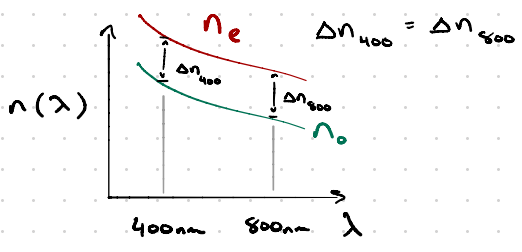
IN THE S-POLARIZATION:

HOW SHOULD THE C-AXIS HALF- OF THE WAVE PLATE BE ORIENTED TO ELIMINATE THE REFLECTION @ THE INTERFACE?



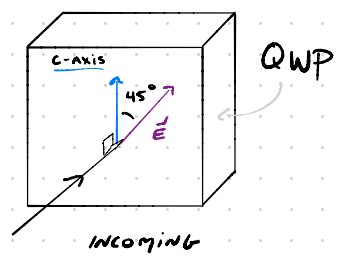
d) A HALF WAVE PLATE IS DESIGNED TO WORK @ 800 nm.
 WHAT WILL THE WAVEPLATE DO TO 400 nm LIGHT, IF THE
 PLATE IS MADE OF A MATERIAL W/ THE SAME

BIREFRINGENCE $\Delta n = n_e - n_o$ @ 400 nm + 800 nm?



Q2 QUARTER WAVE PLATES

a)



LIGHT IS INCIDENT ON A QWP W/ ITS
POLARIZATION @ 45° TO THE C-AXIS AS
 SHOWN.

• ACCORDING TO THE NOTES, THIS WILL PRODUCE A CIRCULARLY
 POLARIZED OUTPUT, BUT WILL IT BE RIGHT- OR LEFT- HANDED?
 ASSUME THAT THE C-AXIS IS THE "FAST" AXIS, I.E. $n_e < n_o$.

• HINT: DO THE A → B → C → D → E ANALYSIS SHOWN IN THE NOTES.

USE $\frac{\Delta n}{\lambda_0} \cdot |dn| = \frac{1}{4}$ FOR QWP.

• HOW SHOULD YOU ORIENT THE WAVEPLATE TO OBTAIN THE OPPOSITE
 HANDEDNESS?

b) DESCRIBE HOW TO MAKE A "CIRCULAR ANALYZER" THAT BLOCKS RIGHT-HANDED LIGHT BUT TRANSMITS LEFT-HANDED. THE MATERIALS @

YOUR DISPOSAL ARE:

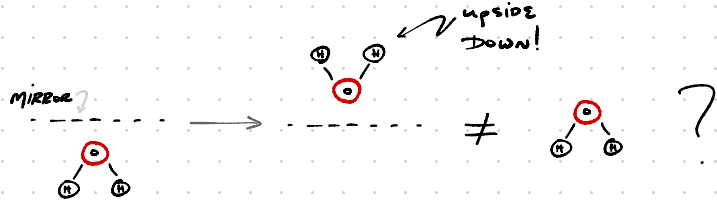
↳ OBAYS
MALUS' LAW

- 1 LINEAR POLARIZER (I.E. POLAROID)
- 1 QUARTER WAVE PLATE.
- DOES YOUR SOLUTION ALSO ACT AS A "CIRCULAR POLARIZER", WHICH TURNS UNPOLARIZED LIGHT INTO CIRCULARLY-POLARIZED LIGHT? WHAT "MODIFICATION" IS NECESSARY?
- CURRENT 3.D. MOVIE TECHNOLOGY ("REAL3D") USES GLASSES WHERE EACH LENS IS A CIRCULAR ANALYZER. ONE LENS TRANSMITS RIGHT-HANDED POLARIZATION, & THE OTHER TRANSMITS LEFTHANDED. THE MOVIE PROJECTOR SENDS OUT TWO VIDEOS OF OPPOSITE CIRCULAR POLARIZATION, SO EACH EYE SEES A DIFFERENT VIDEO. ONE VIDEO IS RECORDED FROM A LOCATION THAT IS DISPLACED FROM THE OTHER BY A DISTANCE ROUGHLY EQUAL TO THE SEPARATION OF YOUR EYES. THIS ACHIEVES A "STEREOSCOPIC" EFFECT, I.E. THE ILLUSION OF DEPTH.
- OLDER TECHNOLOGIES OPERATED ON THE SAME PRINCIPLES BUT USED LINEAR INSTEAD OF CIRCULAR POLARIZED LIGHT. WHAT IS THE PRACTICAL ADVANTAGE OF THE REAL3D TECHNOLOGY?

Q3

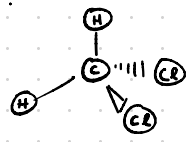
OPTICAL ACTIVITY

a) • EXPLAIN WHY WATER (H_2O) IS "ACHIRAL" (AND THUS NOT OPTICALLY ACTIVE) EVEN THOUGH THERE IS A REFLECTION WHICH DOES NOT MAP THE MOLECULE ONTO ITSELF:

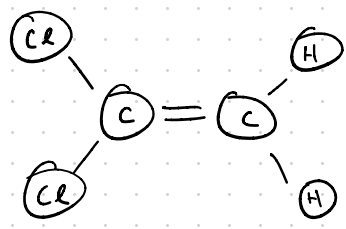


• HOW ARE THE MOLECULES ARRANGED IN THE LIQUID PHASE?

b) • IS DICHLORO METHANE OPTICALLY ACTIVE?



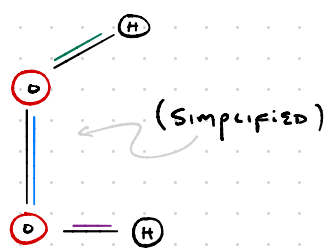
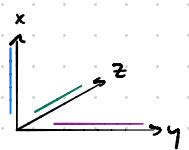
• HOW ABOUT DI-CHLORO ETHYLENE?



• OR THE OTHER ISOMERS?

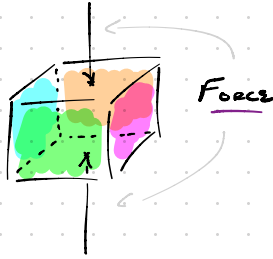
• HOW ABOUT HYDROGEN PEROXIDE (H_2O_2)?

E.G.



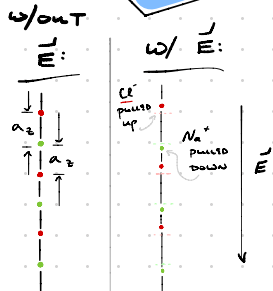
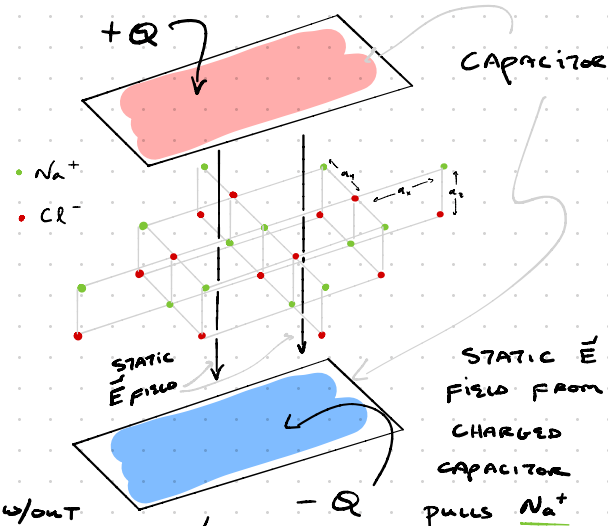
ANSWERS

Q1 a)



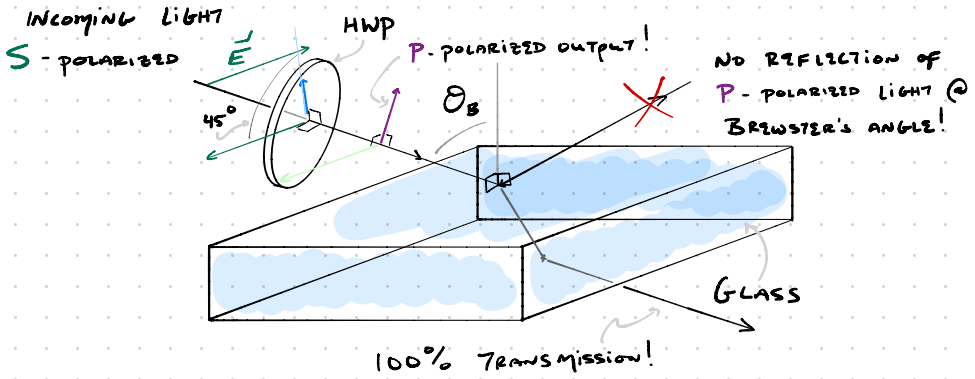
THE MECHANICAL PRESSURE WILL COMPRESS THE BLOCK IN THE DIRECTION \parallel TO THE FORCE, (POSSIBLY EXPANDING THE BLOCK IN THE DIRECTIONS \perp TO THE FORCE). LIGHT WILL THEN ACT DIFFERENTLY IF IT IS POLARIZED \parallel TO THE FORCE, I.E. THE C-AXIS IS \parallel TO THE FORCE. SINCE WAVEPLATES HAVE THEIR C-AXIS \perp TO THE SURFACE NORMAL (I.E. C-AXIS LIES ALONG THE SURFACE), WE WANT TO SEND LIGHT (\odot NORMAL INCIDENCE) INTO ANY OF THE 4 FACES CONTAINING THE C-AXIS IN ORDER TO USE THE SQUEEZED BLOCK AS A WAVEPLATE.

b) WE CAN USE AN ELECTRIC FIELD TO DISTORT THE CRYSTAL:



ions UP, Cl⁻ ions DOWN, BREAKING THE CUBIC SYMMETRY! "KERR EFFECT"
 BIREFRINGENCE INDUCED w) C-AXIS \parallel TO STATIC \vec{E} FIELD!

c)



d)

@ $\lambda_0 = 800 \text{ nm}$:

* OR $-\frac{1}{2}, \pm \frac{3}{2}, \pm \frac{5}{2}, \dots$

$$\frac{\Delta x}{\lambda_0} \times \Delta n = \frac{1}{2}$$

i.e. H.W.P. i.e. 180° shift in || & ⊥ components.

@ $\lambda_0 = 400 \text{ nm}$:

same

same [by assumption]

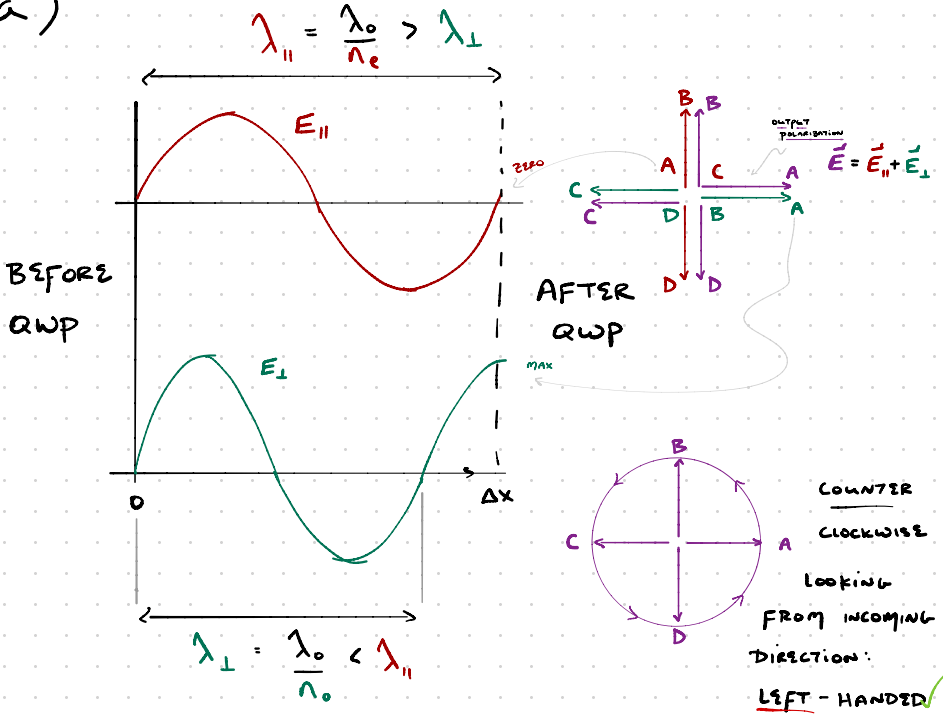
$$\frac{\Delta x}{\lambda_0} \times \Delta n = 2 \times \frac{1}{2} = 1$$

2x SHIFTER

"FULL-WAVE PLATE" i.e. 360° shift → NO EFFECT!

Q2

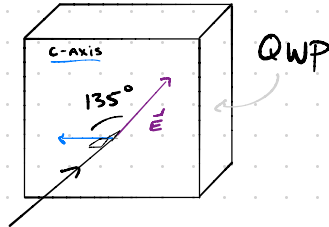
a)

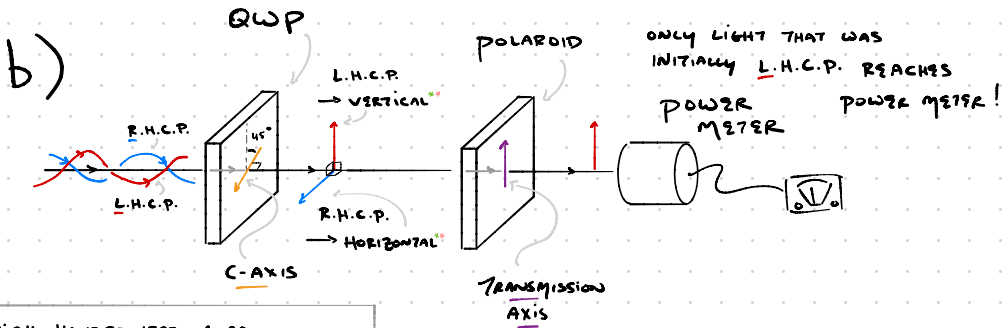


To GET RIGHT-HAND CIRCULAR POLARIZATION,

ROTATE WAVEPLATE 90° :

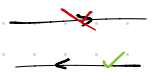
(REDO ABOVE ANALYSIS. \parallel & \perp ROLES ARE SWAPPED.)





* WHICH HANDEDNESS GOES TO VERTICAL & WHICH GOES TO HORIZONTAL DEPENDS ON WHETHER C-AXIS IS "FAST" ($n_e < n_o$) OR "SLOW" ($n_e > n_o$). SEE ANALYSIS IN PART (A).

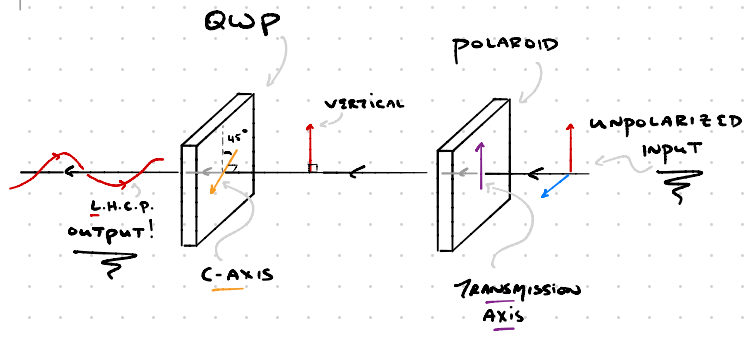
* THE FASTEST WAY TO UNDERSTAND THIS STEP IS TO RUN IT "IN REVERSE", I.E. FLIP THE DIRECTION OF PROPAGATION:



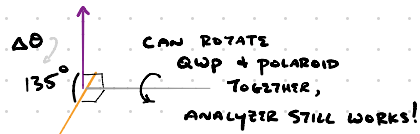
SINCE THE LAST ELEMENT IN OUR CIRCULAR ANALYZER IS A POLAROID, WE WILL NOT GET A CIRCULARLY POLARIZED OUTPUT [WE WILL GET LINEAR]. IF INSTEAD WE SWITCH THE ORDER OF THE ELEMENTS, I.E. POLAROID \rightarrow QWP, WE WILL GET A CIRCULAR POLARIZER.

3D MOVIE GLASSES:

THE USE OF CIRCULAR ANALYZERS HAS THE BENEFIT OF ALLOWING THE VIEWER TO TILT



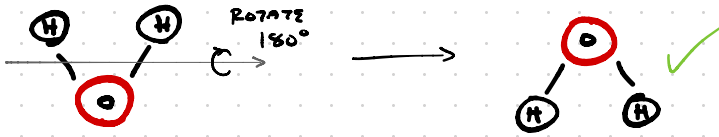
THEIR HEAD: ALL THAT MATTERS IS THE RELATIVE ORIENTATION OF THE QWP C-AXIS + POLAROID TRANSMISSION AXIS, NOT THEIR ABSOLUTE ORIENTATION.



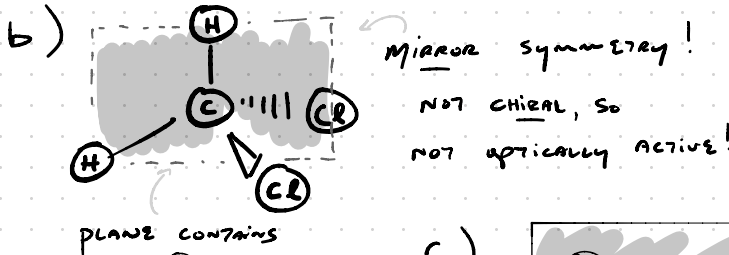
HOWEVER! IF YOU TILT YOUR HEAD TOO MUCH, YOU WILL CONFUSE YOUR BEAM, WHICH IS EXPECTING THE DISPLACEMENT OF THE IMAGES TO TILT AS WELL!

Q3

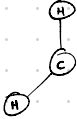
a) THE KEY IS THAT A SUBSEQUENT ROTATION CAN BRING THE MOLECULE BACK TO ITS ORIGINAL ARRANGEMENT:



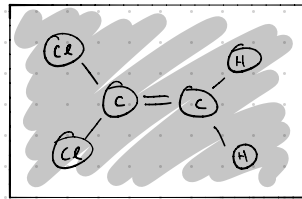
SINCE LIQUID WATER CONTAINS MOLECULES THAT ARE ALL RANDOMLY ORIENTED (I.E. ROTATED), WE DO NOT CHANGE THE LIQUID'S PHYSICAL PROPERTIES BY ROTATING EVERY MOLECULE BY 180° (OR BY ANY ANGLE ABOUT ANY AXIS! NOTE, THOUGH, THAT REFLECTIONS ARE DISTINCT FROM ROTATIONS!)



PLANE CONTAINS



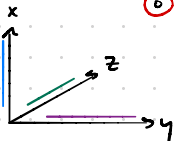
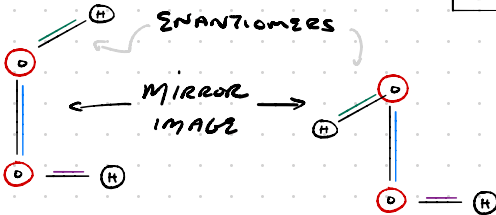
c)



MIRROR SYMMETRY!

EVERY PLANAR MOLECULE IS ACHIRAL AND THUS NOT OPTICALLY ACTIVE.

d)



NO WAY TO ROTATE MIRROR IMAGE TO COINCIDE W/ ORIGINAL!

H_2O_2 IS CHIRAL!

HOWEVER! COLLISIONS BETWEEN MOLECULES RAPIDLY CONVERT ONE ENANTIOMER TO THE OTHER, SO THAT A SAMPLE OF H_2O_2 LIQUID @ STP IS "RACEMIC", I.E. CONTAINING AN EQUAL MIXTURE OF EACH ENANTIOMER, & SO IS NOT OPTICALLY ACTIVE!