Polarization: Lab 2

6.2370 Modern Optics Project Laboratory

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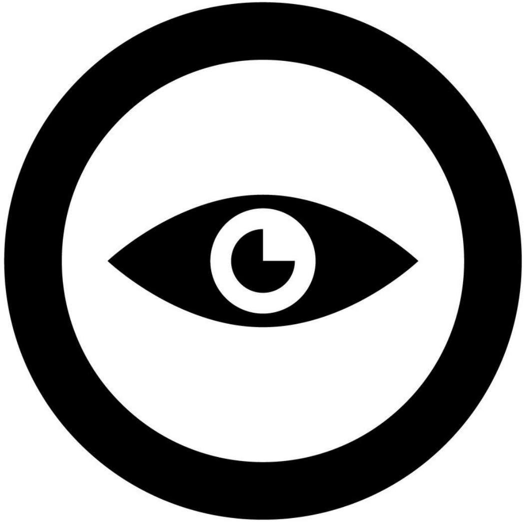
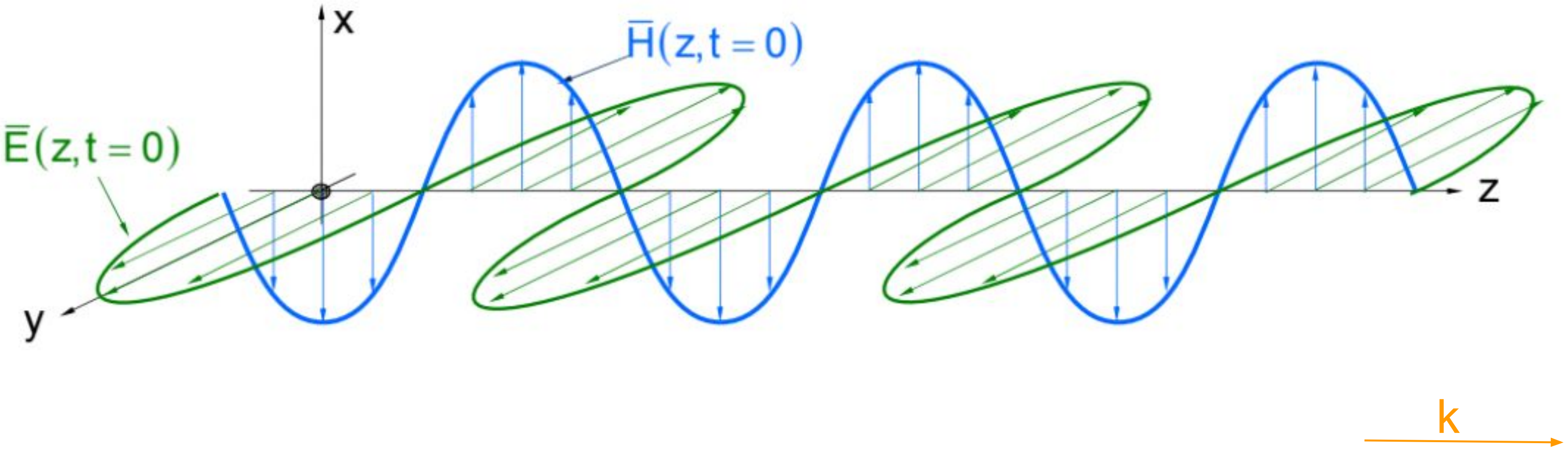
Overview

Essentials

Experiment

Observations





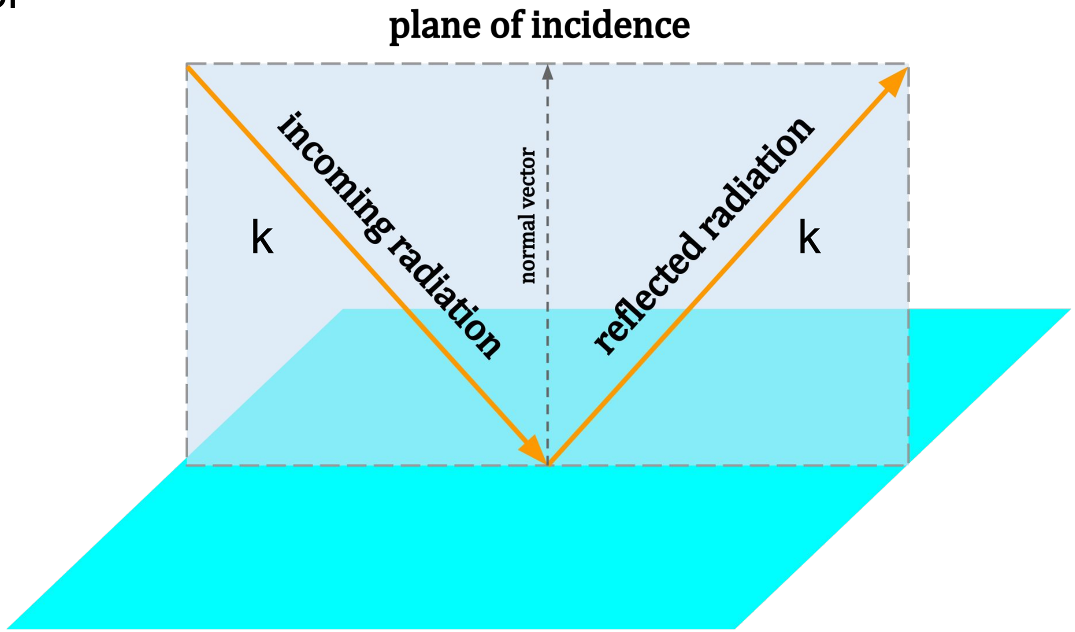
E: Electric Field
H: Magnetic Field

k: Propagation Direction
Right hand Rule: direction(k) = direction(E) x direction(H)

Plane of Incidence

When light strikes a medium

Contains normal vector and k-vector



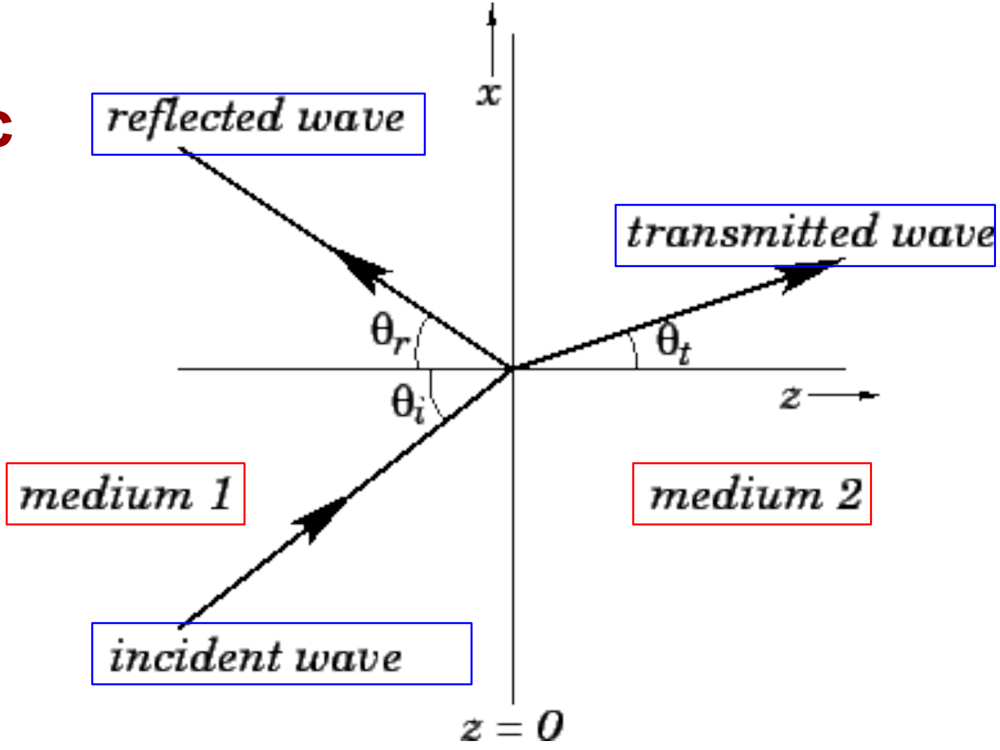
Incidence with a Dielectric

<u>3 components:</u>

- Incident wave
- Reflected wave
- Transmitted wave

<u>n: index of refraction</u>

- Dependent on material properties
- Permittivity (ε)
- Permeability (μ)



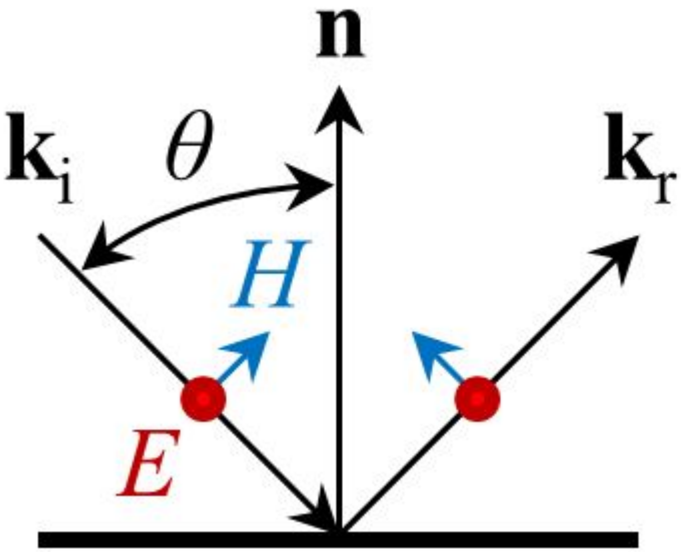
Snell's Law :

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

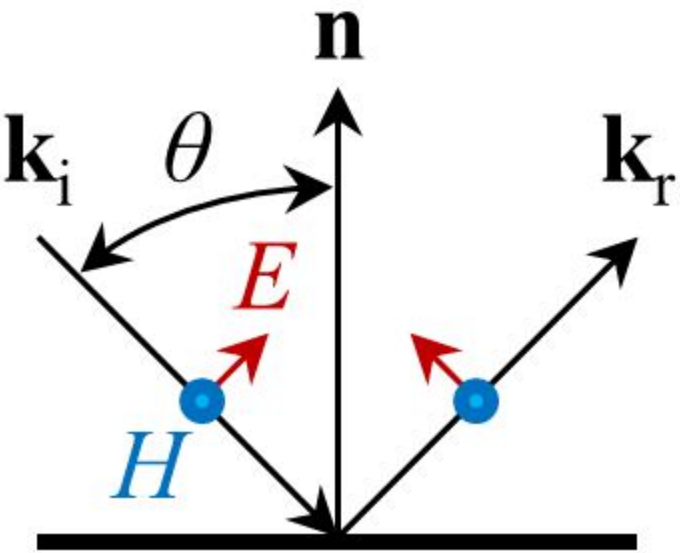
TE and TM Waves

<u>“Transverse” ⇒ Out of Plane of Incidence</u>

TE - Transverse Electric



TM - Transverse Magnetic

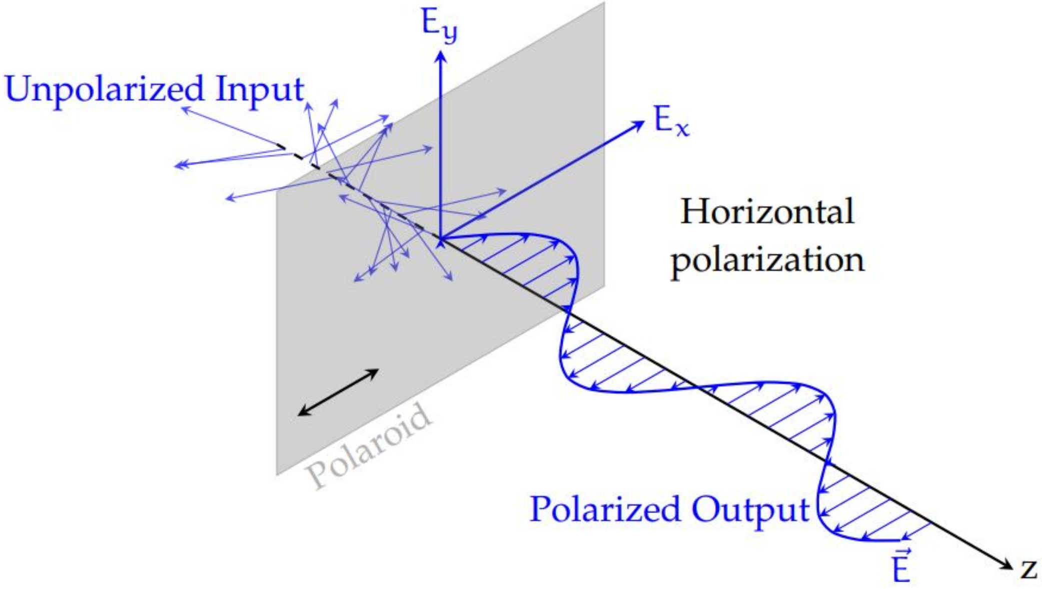


Polarization

Identified with E-field directionality

Polarizer:

- Polarization axis
- Light parallel to axis



Brewster's Angle

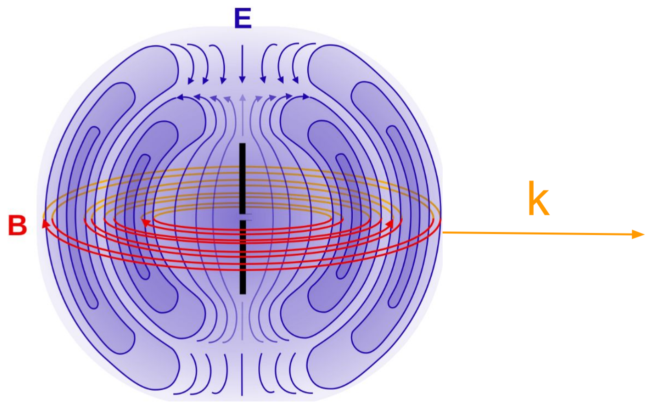
Reflected wave: result of dipole excitation

<u>At the Brewster Angle…</u>
TE: excites dipole
TM: does not excite dipole

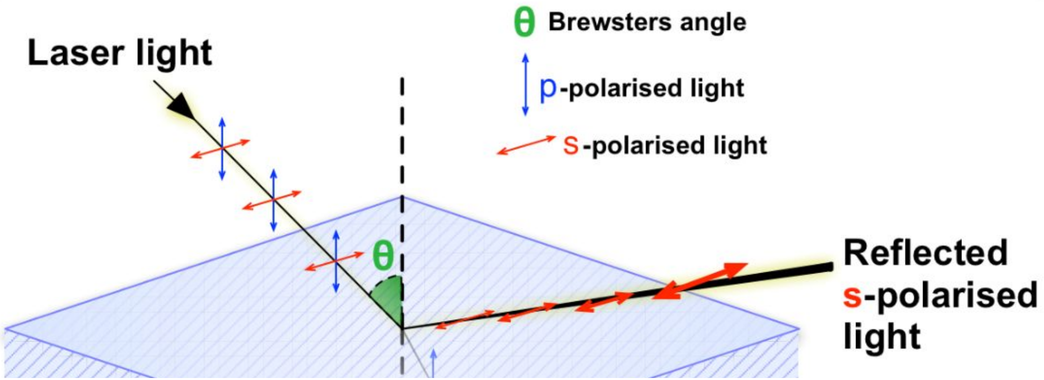
<u>Result:</u>

- TE reflected
- TM disappears

Thus, reflection is TE



dipole

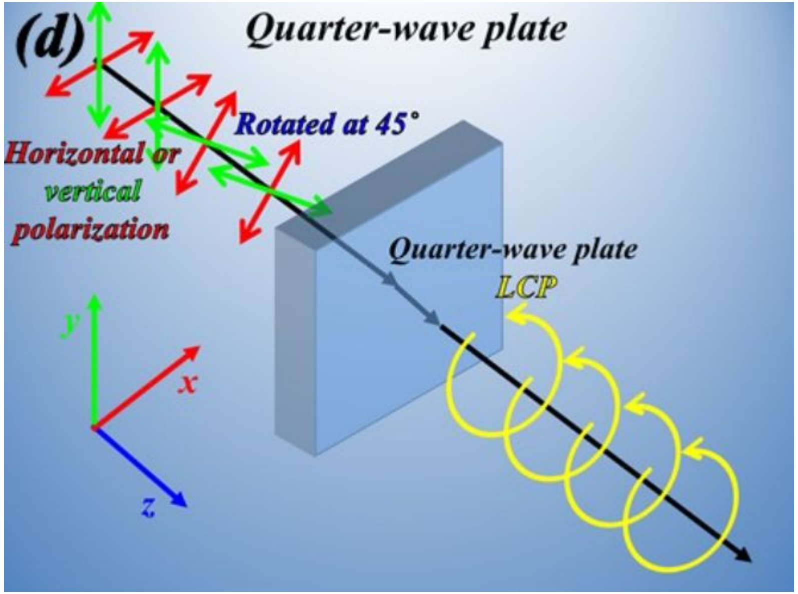


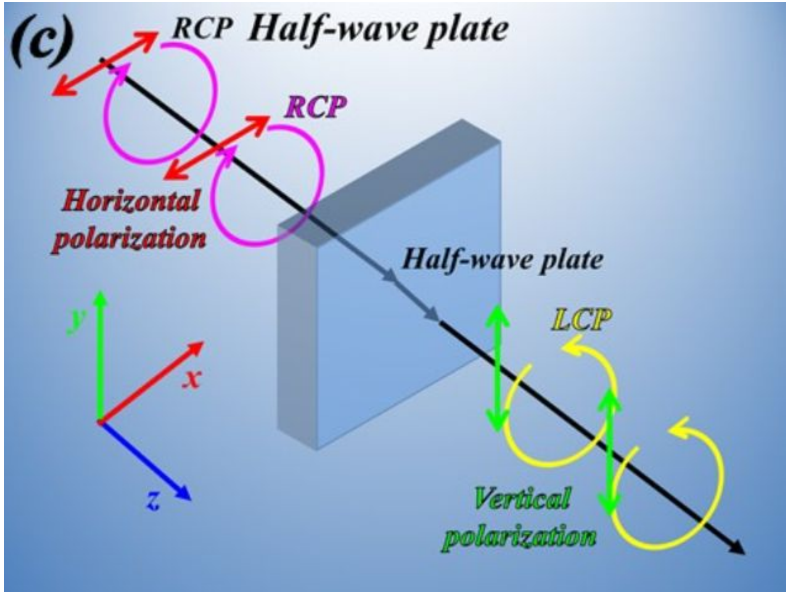
Brewster Angle Diagram

Waveplates

"Fast" and "slow" axis

- "Fast" keeps polarization
- "Slow" gets a phase delay



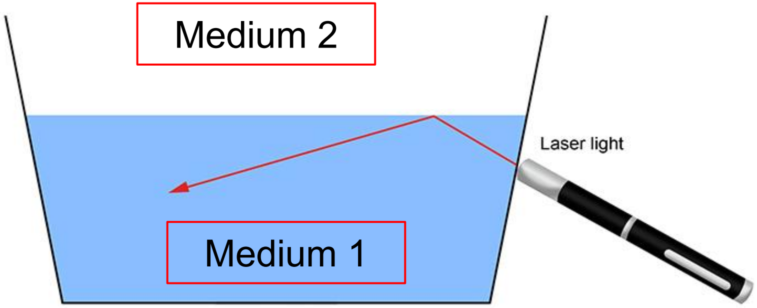


Total Internal Reflection

Light is completely reflected into original medium
No transmission

Snell's Law :
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Set transmitted angle to 90 degrees



Assignment: Axis of Polarizer

<u>Objective:</u>
Figure out polarization axis of a polarizer

<u>Setup:</u>
Floor wax
Polarizer with unknown polarizing axis

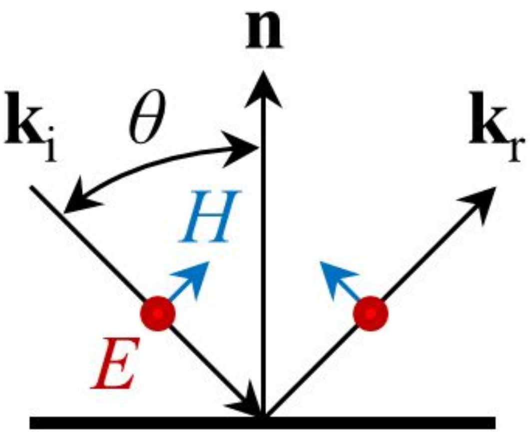
<u>Approach:</u>
"Shiny part" → Brewster's Angle

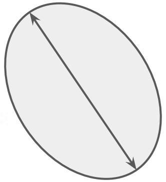
Assignment: Axis of Polarizer

<u>Results:</u>

- Light is TE on plane of incidence
- If TE ⊥ axis, no bright spot

Therefore, axis is where no floor shine is visible through polarizer





Result: No light!

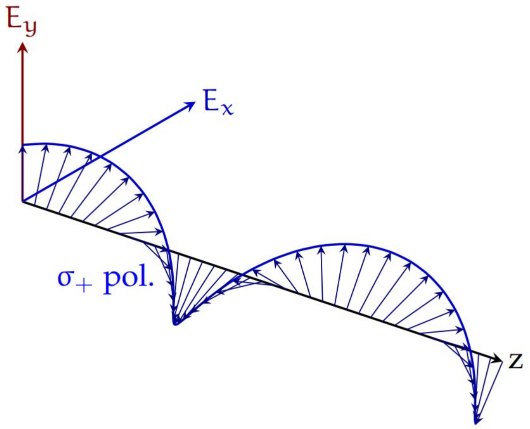
Assignment: Mystery Waveplate

Objective:

- Given a half waveplate (HWP) and quarter waveplate (QWP), identify which is which
- Given “A” and “B” plates

Approach:

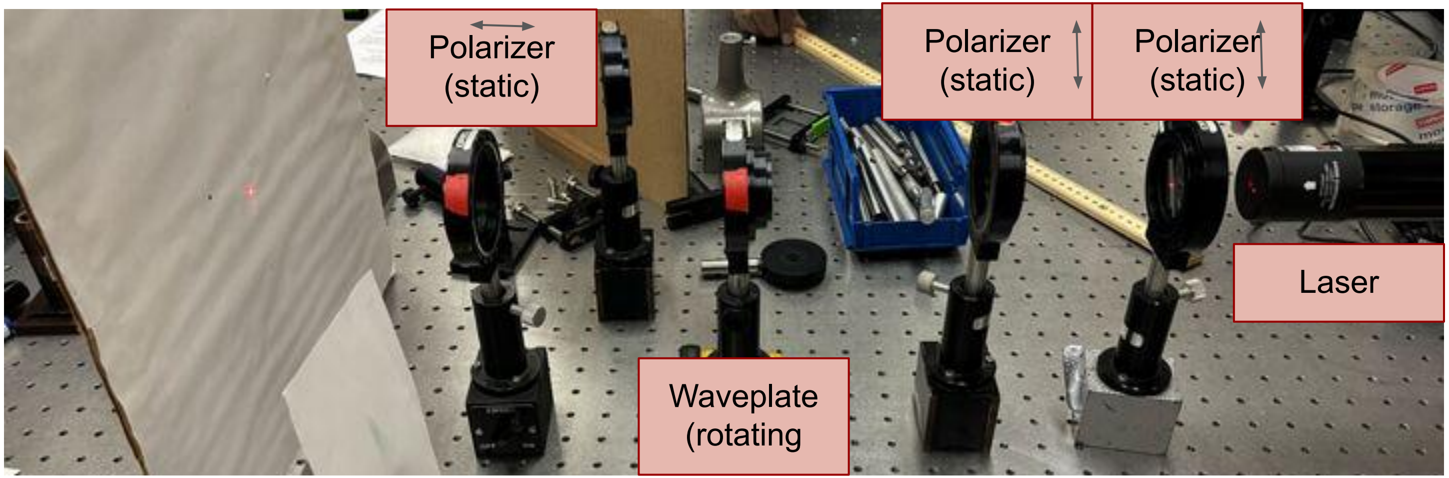
- Circularly polarized light: component in all directions
- Plates have no effect if polarized light does not hit both axes



Circularly-Polarized Light

Assignment: Mystery Waveplate

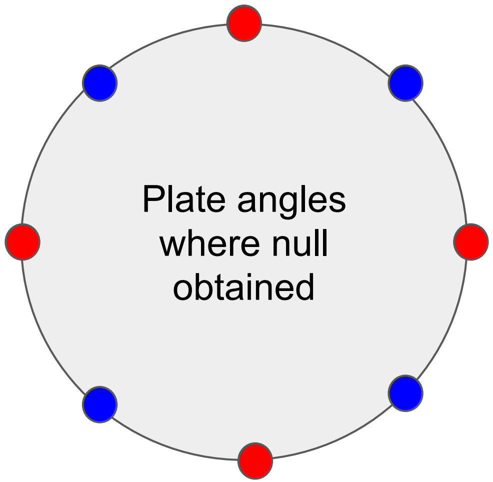
Setup In Lab:



Assignment: Mystery Waveplate

Results:

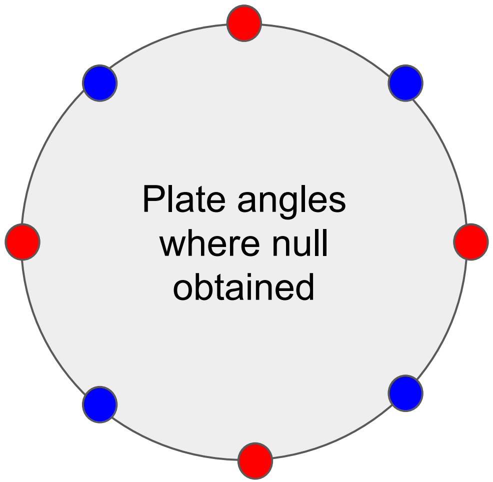
(A) Null Angle	(B) Null Angle
0°	45°
90°	135°
180°	225°
270°	315°



Assignment: Mystery Waveplate

<u>Analysis:</u>
Plates only polarize if two components on axis

Quarter wave: no circular at red
Half wave: no “flip” at blue



Assignment: Brewster Angle with Rotary Table

Setup:

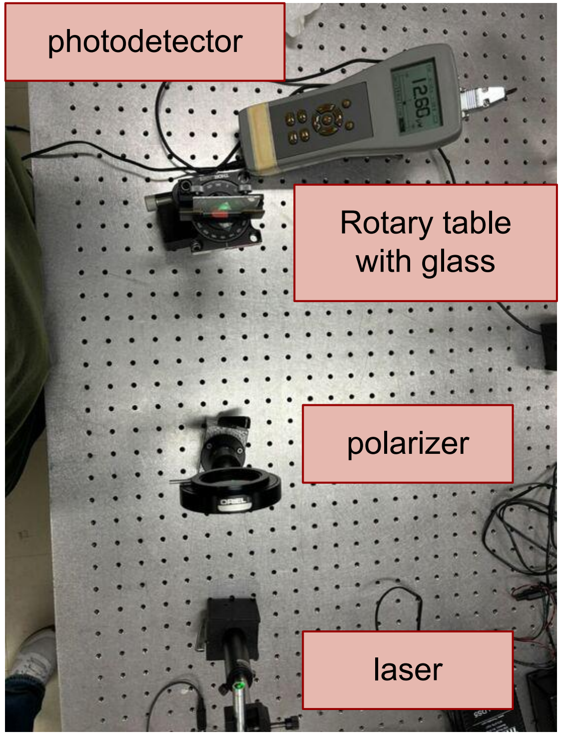
- Light TM polarized
- Light incident with a piece of glass
- Photodetector measuring intensity

Known

- For TM, a certain angle will cause intensity to vanish

Objective

- Find Brewster's Angle



Assignment: Brewster Angle with Rotary Table

Results:

Angle of Incidence (degrees)	Photodetector Reading [μW]
10	23
20	22
30	23
40	19
50	18
60	22
70	38
80	87

Assignment: Brewster Angle with Rotary Table

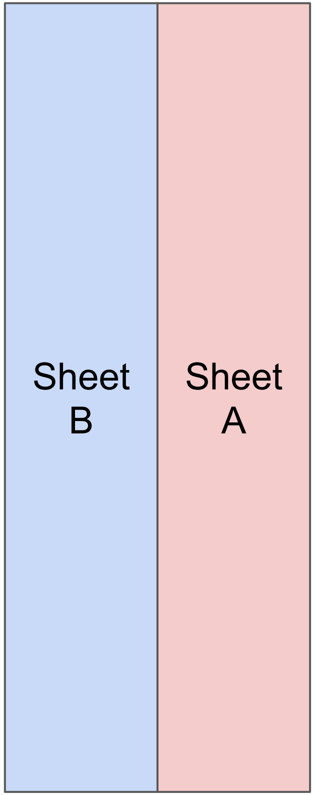
Analysis:

- Lowest Intensity between 50 and 60 degrees
- Brewster angle between these angles
- Consistent with Brewster Angle of glass being 56 degrees

Assignment: Magic Sheet

Setup:
2 polarizers back-to-back

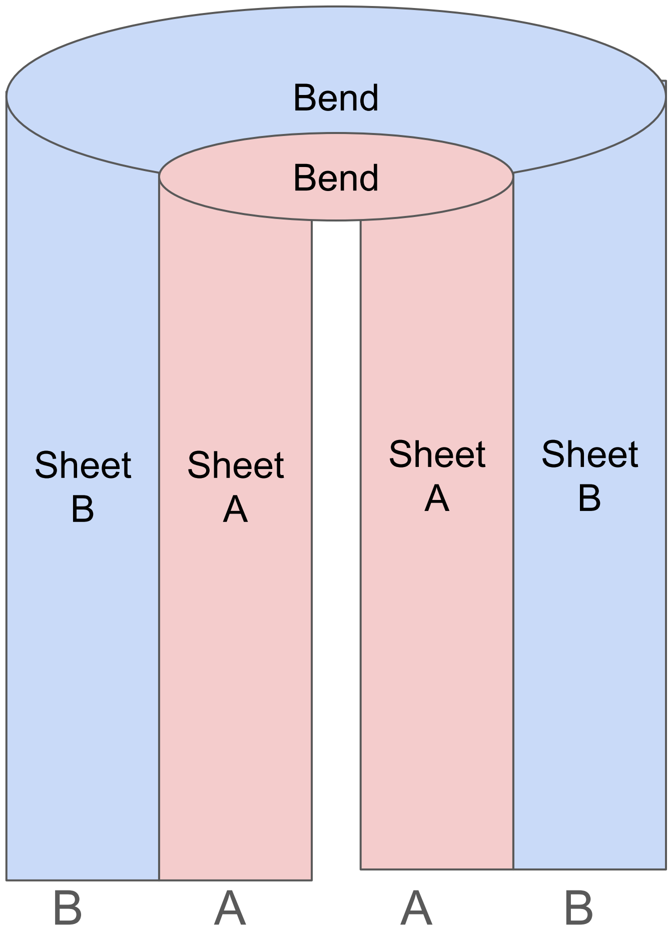
Objective:
Figure out what A and B are



Magic Sheet Approach

<u>Solution:</u>
Bend Sheets
“4 sheets” of polarization

From left to right, 2 cases:
BAAB
ABBA



Magic Sheet: BAAB

BAAB Alone

BAAB with a directional polarizer in between

Observations:

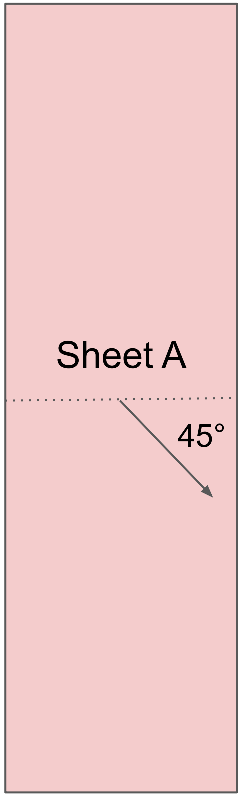
1) No light ever comes through

Implications:

1) A must bend such that:

Axis of bent *orthogonal* to axis of *original*

Magic Sheet: BAAB Conclusion



Conclusion:

1) A's Transmission axis 45 degrees from folding line

Reasoning:
After hitting A: completely polarized in one direction

Bend A: polarization axis orthogonal to original
No light in this direction!

Magic Sheet: ABBA

ABBA

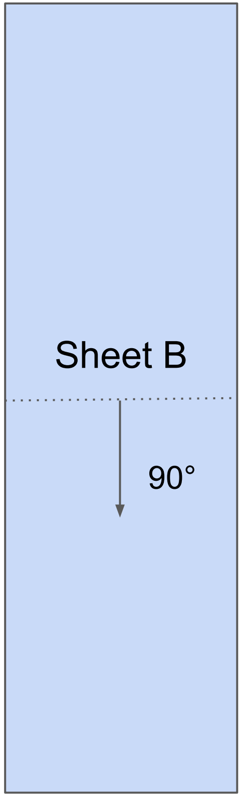
Observations:

1) ~50% less light intensity

Implications:

1) The bend must not extinguish intensity
2) Should not cancel with B's established axes

Magic Sheet: ABBA Conclusion



Conclusion:

1) Transmission axis 90 degrees from folding line

Reasoning:

After hitting B: some intensity lost

Bent B: no change from B

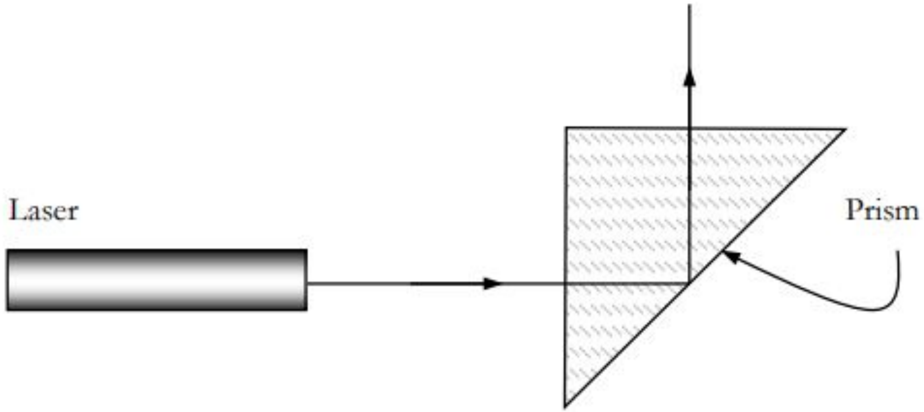
Hitting A: intensity lost, but light still in B's transmission axis

Assignment: Total Internal Reflection

Objective:
- Find the critical angle of glass

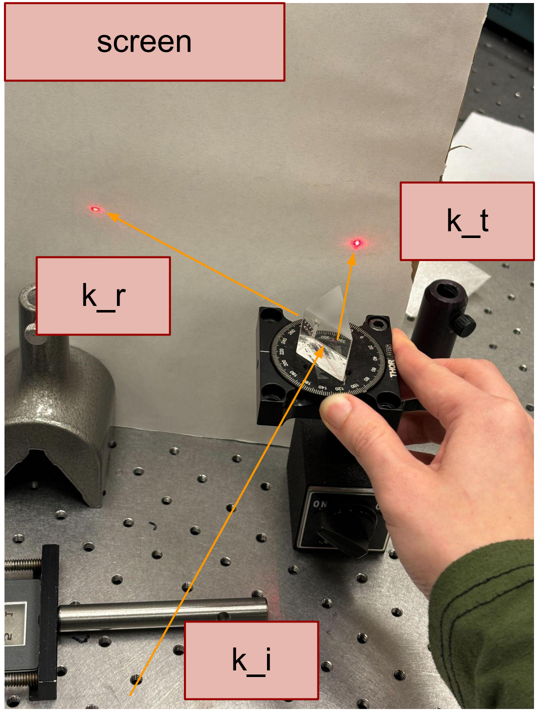
Approach:
- Place glass on rotary table
- Place screen around area
- Rotate glass until only a beam from “transmitted” region is seen

Setup Schematic:

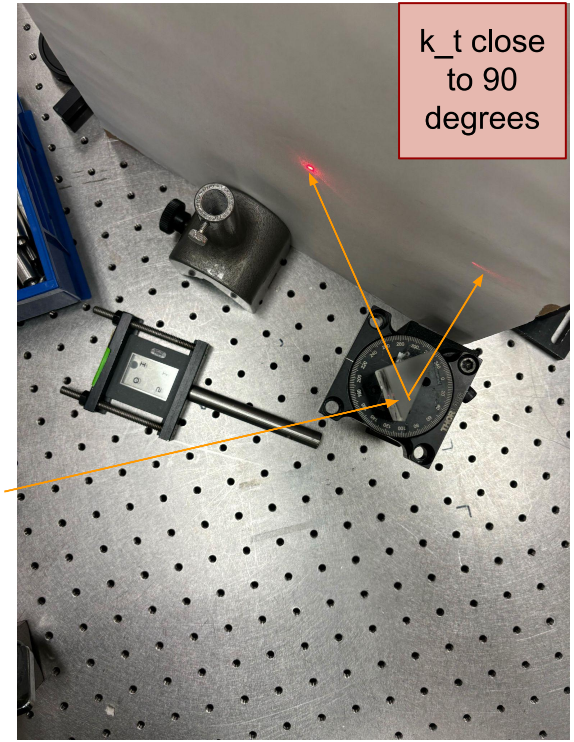


Assignment: Total Internal Reflection

Lab Setup:



Lab Results:



Analysis:

Looking at rotary table, critical angle is about 42 degrees

Consistent with known solution (42 degrees)

Closing Thoughts

Polarization useful for “filtering” light

Light reflection useful for fiber optics

Helpful to limit/expand parameters in lab setups