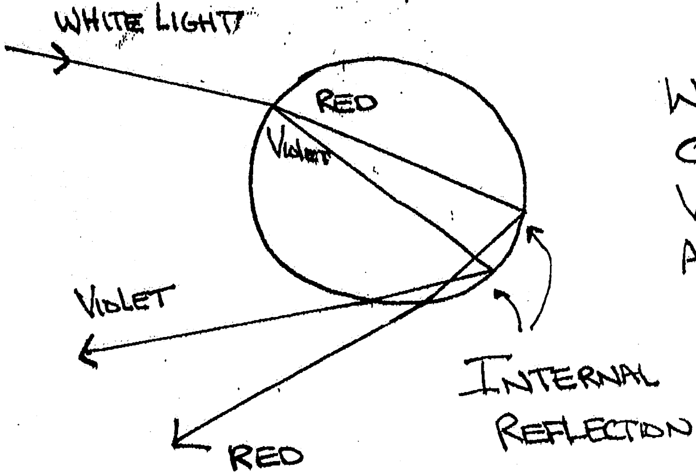
PHYS 262: LIGHT PROPAGATION CONTINUED, CHAPTER 33

DISPERSION – MOST MATERIALS REFRACT DIFFERENT FREQUENCIES BY DIFFERENT ANGLES. INDEX OF REFRACTIONS (AND THEREFORE DIELECTRIC CONSTANTS) ARE DETERMINED BY THE REFRACTION OF YELLOW LIGHT.

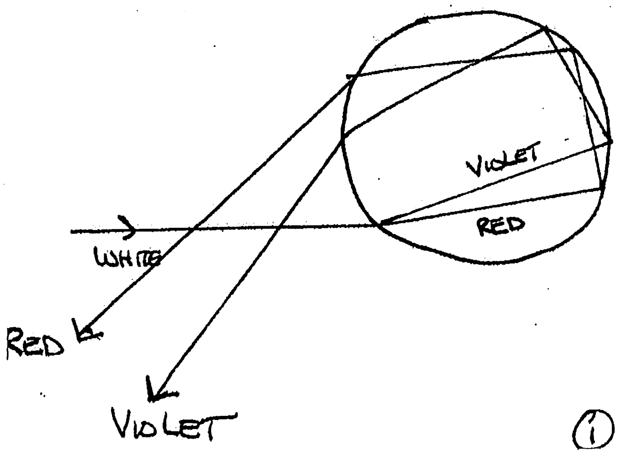
FOR MOST INCIDENT ANGLES, GLASS AND PLASTIC DO NOT DISPERSE LIGHT BY LARGE AMOUNTS WHICH IS WHY THEY ARE USED FOR LENSES. (OBVIOUSLY, A PRISM SHOWS THAT THEY CAN DISPERSE LIGHT.)

WATER DISPERSES LIGHT BY A GREAT AMOUNT AND CREATES RAINBOWS.



WE NEED MANY DROPS OF WATER TO CREATE A VISIBLE RAINBOW SINCE THE VIOLET AND RED GET FARTHER APART AS LIGHT PROPAGATES

LIGHT ENTERING THE BOTTOM OF A WATER DROP CAN REFLECT TWICE AND CREATE THE DOUBLE RAINBOW.



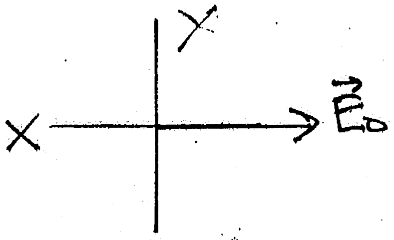
THE SECONDARY RAINBOW IS INVERTED FROM THE FIRST.

USING SNELL'S LAW AND LAW OF REFLECTION, THE RAINBOW ANGLES CAN BE CALCULATED (SEE PAGE 1261)

POLARIZATION - FOR ANY TRANSVERSE WAVE THERE ARE INFINITELY MANY OSCILLATION DIRECTIONS FOR THE SAME PROPAGATION DIRECTION.

FOR LIGHT, WE CHOOSE TO LOOK AT THE DIRECTION OF THE ELECTRIC FIELD. (WE COULD ALSO USE THE MAGNETIC FIELD, BUT WE DON'T.)

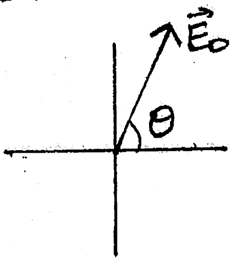
PLANE WAVE - $\vec{E} = \hat{i}\, E_0 \cos(kz - \omega t) = \vec{E}_0 \cos(kz - \omega t)$



WE WOULD CALL THIS WAVE LINEARLY POLARIZED HORIZONTAL LIGHT (OR JUST HORIZONTALLY POLARIZED)

LINEARLY BECAUSE THE $\vec{E}_0$ VECTOR IS NOT CHANGING WITH TIME SO $\vec{E}$ STAYS ALONG A STRAIGHT LINE.

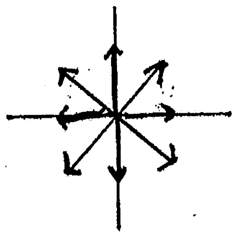
FOR PROPAGATION IN Z-DIRECTION, $\vec{E}_0$ COULD BE ANYWHERE IN THE X-Y PLANE. THIS ALLOWS US TO HAVE LIGHT POLARIZED AT AN ANGLE θ.



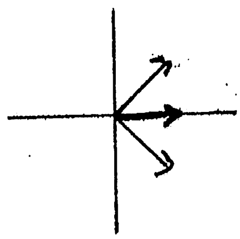
MOST LIGHT IS A MIXTURE OF MANY DIFFERENT WAVES AND SO IS NOT POLARIZED.

UNPOLARIZED LIGHT - EQUAL MIXTURE OF ALL POSSIBLE POLARIZATIONS.

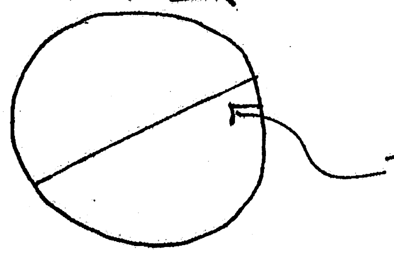
UNPOLARIZED LIGHT:



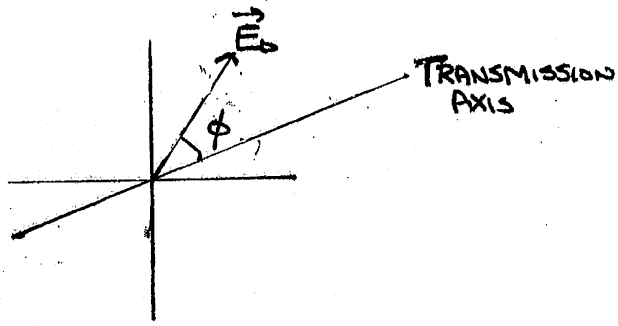
PARTIALLY POLARIZED LIGHT HAS A RANGE OF POSSIBLE ANGLES.



POLARIZER – MATERIAL WHICH SWITCHES AN INCIDENT LIGHT BEAM'S POLARIZATION TO MATCH ITS TRANSMISSION AXIS. (THIS IS HOW POLAROID FIRST MADE ITS MONEY.)



LIGHT OF OTHER POLARIZATION HAS ITS INTENSITY REDUCED WHEN PASSING THROUGH A POLARIZER.



LAW OF MALUS: $$I = I_0 \cos^2\phi$$

I_0 = INTENSITY BEFORE PASSING THROUGH POLARIZER.

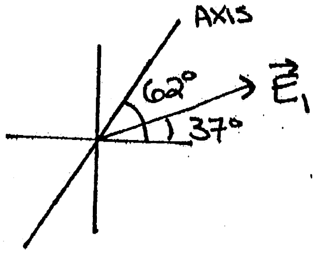
HALF OF UNPOLARIZED LIGHT IS ALLOWED THROUGH

$$\Rightarrow I = \frac{1}{2} I_0$$ UNPOLARIZED LIGHT

A COLLECTION OF TWO OR MORE POLARIZERS IN SERIES IS CALLED AN ANALYZER.

EXAMPLE: TWO POLARIZERS, ONE WITH TRANSMISSION AXIS AT 37°, THE SECOND WITH AXES AT 62° ARE PUT TOGETHER TO MAKE AN ANALYZER. IF UNPOLARIZED LIGHT IS INCIDENT ON THE FIRST POLARIZER, WHAT IS THE OUTGOING LIGHT'S POLARIZATION AND WHAT IS THE RATIO OF THE FINAL INTENSITY TO THE INITIAL?

ASSUME THE INITIAL LIGHT HAS INTENSITY I_0. IT IS UNPOLARIZED, SO AFTER THE FIRST POLARIZER THE LIGHT HAS INTENSITY $I_1 = \frac{1}{2} I_0$ AND IT IS POLARIZED AT 37° $\Rightarrow$ LIGHT OF INTENSITY $\frac{1}{2} I_0$ AND POLARIZATION 37° IS INCIDENT ON POLARIZER TWO.



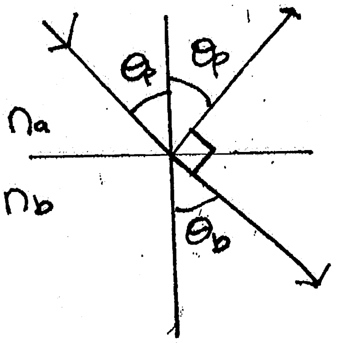
$$I_2 = I_1 \cos^2\phi . \quad I_1 = \tfrac{1}{2} I_0 , \ \phi = 62° - 37° = 25°$$

$$\Rightarrow I_2 = \tfrac{1}{2} I_0 \cos^2 25°$$

$$\Rightarrow \frac{I_2}{I_0} = \frac{\cos^2 25°}{2} = .411$$

THE DIRECTION OF THE FINAL LIGHT WILL BE ALONG THE TRANSMISSION AXIS OF POLARIZER TWO $\Rightarrow$ 62°.

<u>BREWSTER'S ANGLE</u> – UPON REFLECTION LIGHT BECOMES PARTIALLY POLARIZED. THE DIRECTION OF THE POLARIZATION IS PERP. TO INCIDENT PLANE* WHEN $\theta_a = \theta_p$, BREWSTER'S ANGLE, THE LIGHT BECOMES COMPLETELY POLARIZED. DAVID BREWSTER FOUND THAT (1812) THIS OCCURS WHEN THE REFLECTED AND REFRACTED LIGHT ARE PERPENDICULAR. (* p.1266)



$$n_a \sin\theta_p = n_b \sin\theta_b$$

$$\theta_p + 90° + \theta_b = 180°$$

$$\Rightarrow \theta_b = 90° - \theta_p$$

$$n_a \sin\theta = n_b \sin(90° - \theta_p)$$

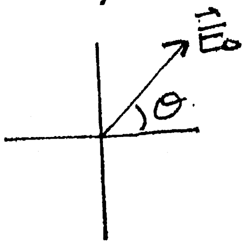
$$\Rightarrow n_a \sin\theta = n_b \cos\theta_p$$

$$\Rightarrow \frac{\sin\theta_p}{\cos\theta_p} = \frac{n_b}{n_a} \quad \Rightarrow \boxed{\tan\theta_p = \frac{n_b}{n_a}}$$

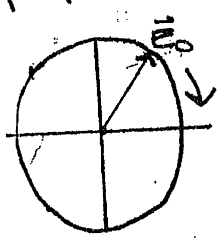
POLARIZATION UPON REFLECTION IS WHY REFLECTED LIGHT HURTS YOUR EYES MORE. WHILE DRIVING, WE OFTEN CALL THIS A GLARE. POLARIZING SUN GLASSES HAVE A TRANSMISSION AXIS WHICH IS AS CLOSE TO 90° TO THE REFLECTED LIGHT'S POLARIZATION AS POSSIBLE.

CIRCULARLY POLARIZED LIGHT – THE ALTERNATE TO LINEARLY POLARIZED LIGHT IS CIRCULARLY OR ELLIPTICALLY POLARIZED LIGHT.

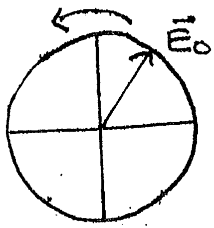
IN LINEARLY POLARIZED LIGHT, THE $\vec{E}_0$ VECTOR IS CONSTANT WITH TIME.



IN CIRCULARLY POLARIZED LIGHT, $\vec{E}_0$ TRACES OUT A CIRCLE AS THE WAVE PROPAGATES. FOR THE PROPAGATION DIRECTION OUT OF THE PAGE:



RIGHT-CIRCULARLY POLARIZED



LEFT-CIRCULARLY POLARIZED.

ELLIPTICALLY POLARIZED LIGHT IS ONE IN WHICH $\vec{E}_0$ TRACES AN ELLIPSE WITH TIME.