5.C.3 Polarizing and Scattering

No Sunglasses — Polarized Sunglasses

1. Introduction

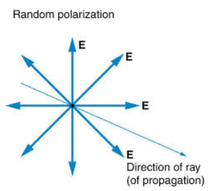
Have you ever wondered why the sky is blue? Write down a possible reason to explain why.

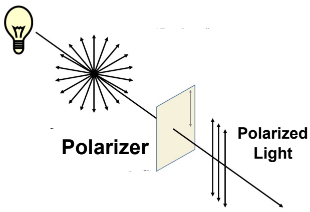
Have you ever worn sunglasses, and noticed that when you turn your head from side to side the characteristic of the daylight changes?

Polarization

Light has electric fields oriented randomly.

Rays are conditioned (called <u>polarization</u>) by absorption <u>or</u> reflection so E-fields are coincident.

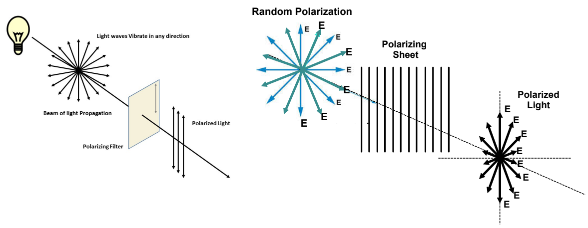




Clarification

Pictorially, polarized light is simplified as a single line of orientation.

There is actually a range of orientations: rays are diminished by the cosine of the polarizer's angle.



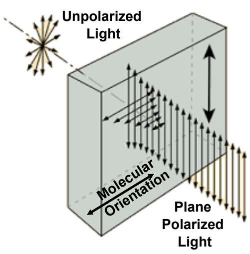
Polarization by Absorption

At certain orientations, <u>dicroic</u> materials preferentially absorb EM energy.

Structure consists of long parallel chains, along which valence electrons move.

Light with E-field parallel to chains is absorbed (energy transferred to electrons (makes heat)); perpendicular aren't.

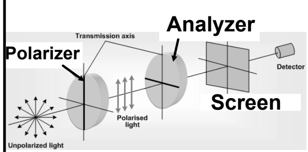
<u>Transmission axis</u> perpendicular to molecular orientation.



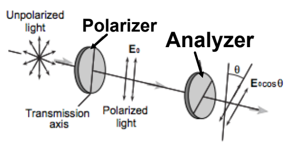
Polarizer Analyzers

Our eyes can't distinguish between polarized and non-polarized light: we use an analyzer.

Light reaching a detector depends on the angle of the polarizer vs. analyzer.



At 90°, no light gets through.



At other angles, more or less light reaches a detector.

AP Phys 2 Unit 5.C.3 Notes - Polarizing & Scattering

Malus' Law

Governs transmission of polarizer/analizers.

Realize: polarizer reduces source intensity by 50%.

Light intensity <u>after analyzer:</u>

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

On Calculator: $I = I_0 \left(\cos\theta\right)^2$

I = Final intensity (W/m²).
I_0 = Intensity <u>after</u> polarizer (W/m²).
θ = Angle between transmission axes of polarizer and analyzer.

Percent Transmission (after analyzer):

$$\%T = \frac{I}{I_0} \bullet 100\%$$

Polarizer/Analyzer Examples

15 W/m² unpolarized light reaches a polarizer/ analyzer pair at an angle of 24.5°.

2. What is the intensity of light after the polarizer?

$$15W/m^2 \bullet 50\% = 7.5W/m^2$$

3. What is the intensity after analyzer?

$$I = I_0 \cos^2 \theta = 7.5W/m^2 \cos^2 24.5^\circ = 6.21W/m^2$$

4. What is the percent transmission through the analyzer? Through the entire system?

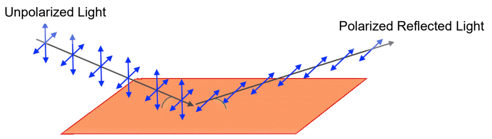
$$\%T = \frac{I}{I_0} \bullet 100\%$$

$$= \frac{6.21W/m^2}{7.5W/m^2} \bullet 100\% = 82.8\%$$

$$= \frac{6.21W/m^2}{15W/m^2} \bullet 100\% = 41.4\%$$

Polarization by Reflection

Reflection also polarizes light: the amount depends on angle of incidence vs. angle of refraction.

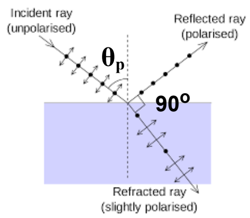


The explanation is complex, and is at the end of the notes.

Brewster Angle

Light is totally polarized at the <u>Brewster angle</u> (θ_p), and depends on the ratio of refraction indices.

Reflected ray is <u>perpendicular</u> to the refracted one.



$$\theta_p = \tan^{-1}\left(\frac{n_2}{n_1}\right)$$

θ_p = Brewster's Angle
n_1 = Index of refraction (material 1)
n_2 = Index of refraction (material 2)

5. Brewster Angle Example

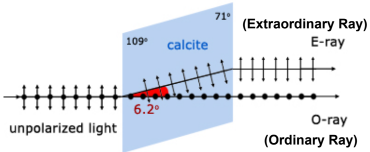
At what angle will light reflecting off an oil patch (n = 1.25) be totally polarized?

$$\theta_p = \tan^{-1}\left(\frac{n_2}{n_1}\right) = \tan^{-1}\left(\frac{1.25}{1.00}\right) = 51.3^\circ$$

Double Refraction

Some materials are <u>birefringent,</u> (called <u>double refraction</u>): two images appear of an object whose image passes through the material. (Calcite Demo. - see through polarizer)

An unpolarized light source splits into two rays, emerging polarized in different locations.

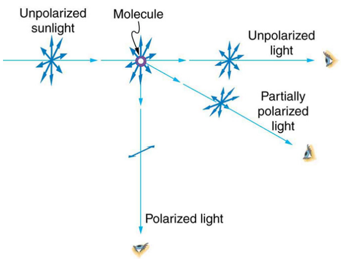


AP Phys 2 Unit 5.C.3 Notes - Polarizing & Scattering

Scattering of Light

When light shines on a suspension of particles, like air molecules, some is absorbed and re-emitted, called scattering.

Two scattering effects:
1. why the sky is blue,
2. why sunrises and sunsets are red.



Why the Sky is Blue

If a kid ever asks you why the sky is blue, just tell them that it's due to Rayleigh Scattering (a relationship between wavelength and scattering), and let it go at that.

This involves resonant frequencies of air molecules: when unpolarized light shines on our atmosphere, the blue-violet region is preferentially absorbed and re-emitted by nitrogen and oxygen.

Blue skylight also has the interesting feature of being polarized. If you've ever looked at the sky with polarized sunglasses and tilted you head, you've seen the sky's intensity change.

Red Sunrise & Sunset

Since blue light scatters more, when the sun's light has the most atmosphere to get through (at sunrise and sunset), blue light has the most time to be filtered out.

Also, dust particles will cause more redness to a sunrise/sunset.

After a volcanic eruption, sunrises and sunsets are much more spectacular.

Reflection Explanation

The physical mechanism for this can be qualitatively understood from the manner in which electric dipoles in the media respond to plane polarized light. One can imagine that light incident on the surface is absorbed, and then re-radiated by oscillating electric dipoles at the interface between the two media. The polarization of freely propagating light is always perpendicular to the direction in which the light is travelling. The dipoles that produce the transmitted (refracted) light oscillate in the polarization direction of that light. These same oscillating dipoles also generate the reflected light. However, dipoles do not radiate any energy in the direction of the dipole moment. If the refracted light is p-polarized and propagates exactly perpendicular to the direction in which the light is predicted to be specularly reflected, the dipoles point along the specular reflection direction and therefore no light can be reflected.

Homework 5.C.3

Problems 5.C.3 in your Booklet
Due: Next Class

Finish Unit 5.C Review Problems
Scan Soon!: