32B – Electromagnetic Waves and Polarization Background

From the text and lecture you now know that an oscillating electric field produces a magnetic field perpendicular to the electric field (Maxwell-Ampere Law), and an oscillating magnetic field produces an electric field (Faraday's Law). This mutual induced-field effect gives rise to travelling electromagnetic waves that are useful for transferring information and energy. An electric field wave of frequency $f = \omega/2\pi$, wavelength λ, and speed $c = \lambda f$ can be written as: $\vec{E} = \overrightarrow{E_o} \cos(\overrightarrow{k} \cdot \vec{r} \pm \omega t + \phi)$. The wave amplitude is E_o and the wave travels in the direction given by $\vec{k}$.

33A - Polarization Observations

Equipment: 3 pieces of linear polarizer material, unpolarized light sources

1) View an incandescent or fluorescent light through one of the polarizers. Rotate the polarizer.
   a) Does the brightness that you see depend on the orientation of the polarizer? no

   b) What can you conclude about your ability to distinguish between polarizations of light with your eye alone?

      we can't see how light is polarized

2) View the incandescent or fluorescent light through a pair of polarizers. Rotate the first one about the propagation axis of the light and observe the brightness as a function of relative angle. Rotate the second and observe the brightness.
   a) Describe your observations.

      two aligned have the same effect as one, perpendicular becomes (near) opaque, and angles inbetween are inbetween

   b) How many minima (or maxima) do you observe for a rotation of 360 degrees?

      two minima, two maxima. 0 and 180 are max, 90 and 270 are min

   c) How are the polarizers oriented to yield a minimum in intensity?

      perpendicular

3) Work as a team to observe the transmitted intensity for three polarizers. Arrange the first and third to minimize transmission through these two. Then add the second between them.
   a) Rotate the second and observe the angles for minima and maxima. Describe what you are seeing.

      max at 45,135, 225, 315 deg, min at 0, 90, 180, 270 deg

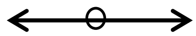
   b) How many maxima do you observe for a rotation of 360 degrees?

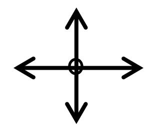
      4

4) Observe the intensity of light reflected at an angle of incidence of about 45 degrees from a shiny surface (like the hallway floor or a wall or tabletop). Then view it through a polarizer while rotating the polarizer. What can you conclude about the polarization of light reflected from a surface?

the light reflected is polarized

Polarized Waves

Consider a wave that has an electric field that oscillates in the *X*-direction. Viewed end-on, the field in a ray of light looks like this  . The magnetic field is perpendicular to the electric field. A wave in which the direction of the electric field does not change with time or position is called a linearly polarized wave. Maxwell's equations (plus the Lorentz force equation) determine how an electromagnetic wave travels through space and materials, and therefore the behavior of a wave incident on a molecule or a surface depends on the polarization direction of the wave. All light waves can be thought of as being made up of two polarizations, perpendicular to one another. (We usually choose "horizontal" and "vertical".) Unpolarized light is emitted by most natural sources has equal amounts of horizontally and vertically polarized waves. An end on view of unpolarized light is shown to the right. If one polarization has a larger amplitude than the other, then the wave is partially polarized.



The reflection coefficient for light from a surface depends on the polarization of the incident light. The absorption of light by polymer molecules depends on the polarization of light with respect to the polymer chain. The scattering of light from atoms in the atmosphere depends on polarization.

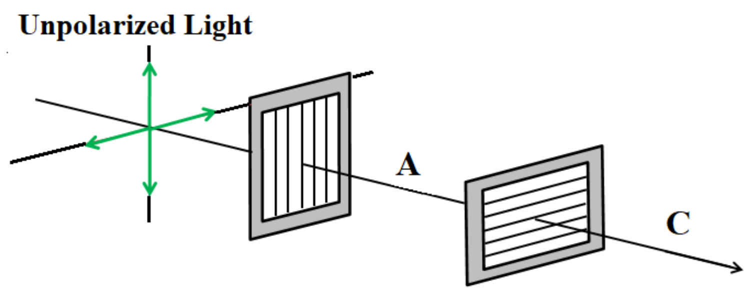
Polarized sunglasses work by absorbing light with polarization along a particular direction, and allowing polarization perpendicular to that to pass through. For linearly polarized light, $E_{transmitted} = E_{incident} \cos\theta$, where θ is the angle between the incident E field and the transmitted polarization direction for the polarizer material. Malus' Law ($I_{transmitted} = I_{incident} \cos^2\theta$) follows from the electric field.

1) The fraction of unpolarized light intensity that passes through a linear polarizer is given by $I_T = I_{inc}\frac{1}{2\pi}\int_0^{2\pi}\cos^2\theta \, d\theta$. What fraction of unpolarized incident light intensity passes through a linear polarizer? Explain your answer.

.5 I_inc

it blocks one component and not the other, which averages out to half of the light being blocked when the input is oriented randomly

2) Consider a situation with two polarizers set so that unpolarized light of intensity *Io* is normally incident on the first and then the resultant wave passes normally through the second. The first polarizer is oriented vertically, and the second is oriented horizontally.



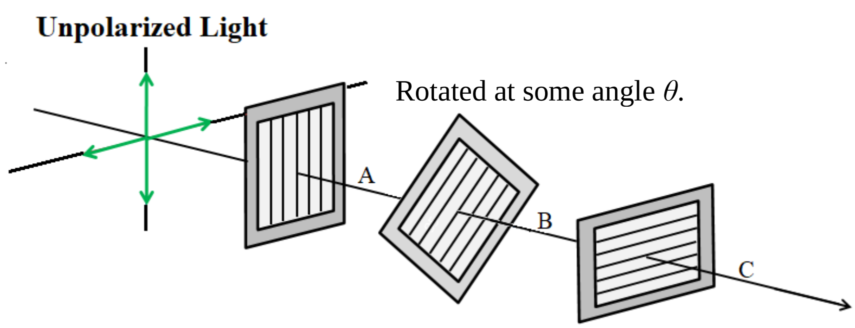
a) What is the intensity at position A between the two polarizers?

.5 I_inc

b) What is the intensity at position C, after both polarizers?

0

3) A third polarizer is added between points A and B and has orientation θ with respect to vertical.



a) What is the intensity at each of the following points?

A .5 I_inc

B .25 I_inc

C .125 I_inc

b) At what angle for the middle polarizer is the intensity at C maximized?

45 deg