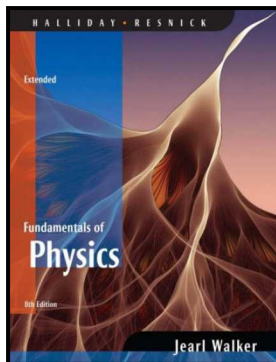


Workshop Physics

1017 - 312

# University Physics II



**Week 10 : Day 2**

# Outline

## □ Polarization

- Plane of polarization
- Polarized light defined
- Intensity of transmitted light
- Polarization by reflection
  - *Brewster's Law*

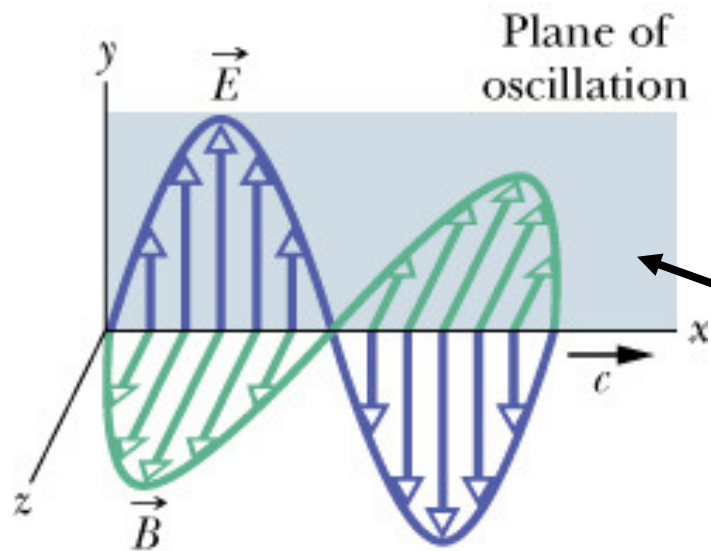
## □ Activity – Polarization

- Demos and hands on: polarizing sheets, materials...

## □ Activity – Polarization Applets

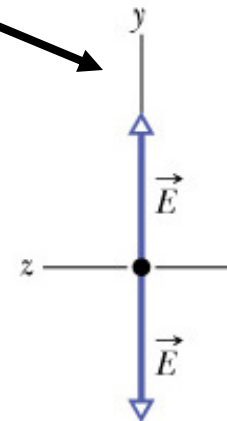
- Simulations of polarization phenomena

# Polarization

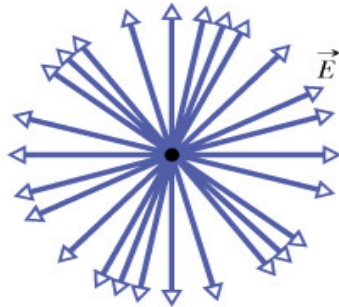


The polarization of light describes how the electric field in the EM wave oscillates.

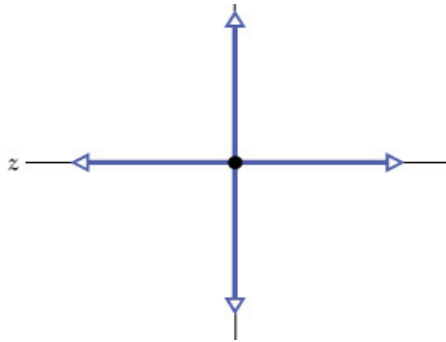
Vertically plane-polarized (or linearly polarized)



# Polarized Light

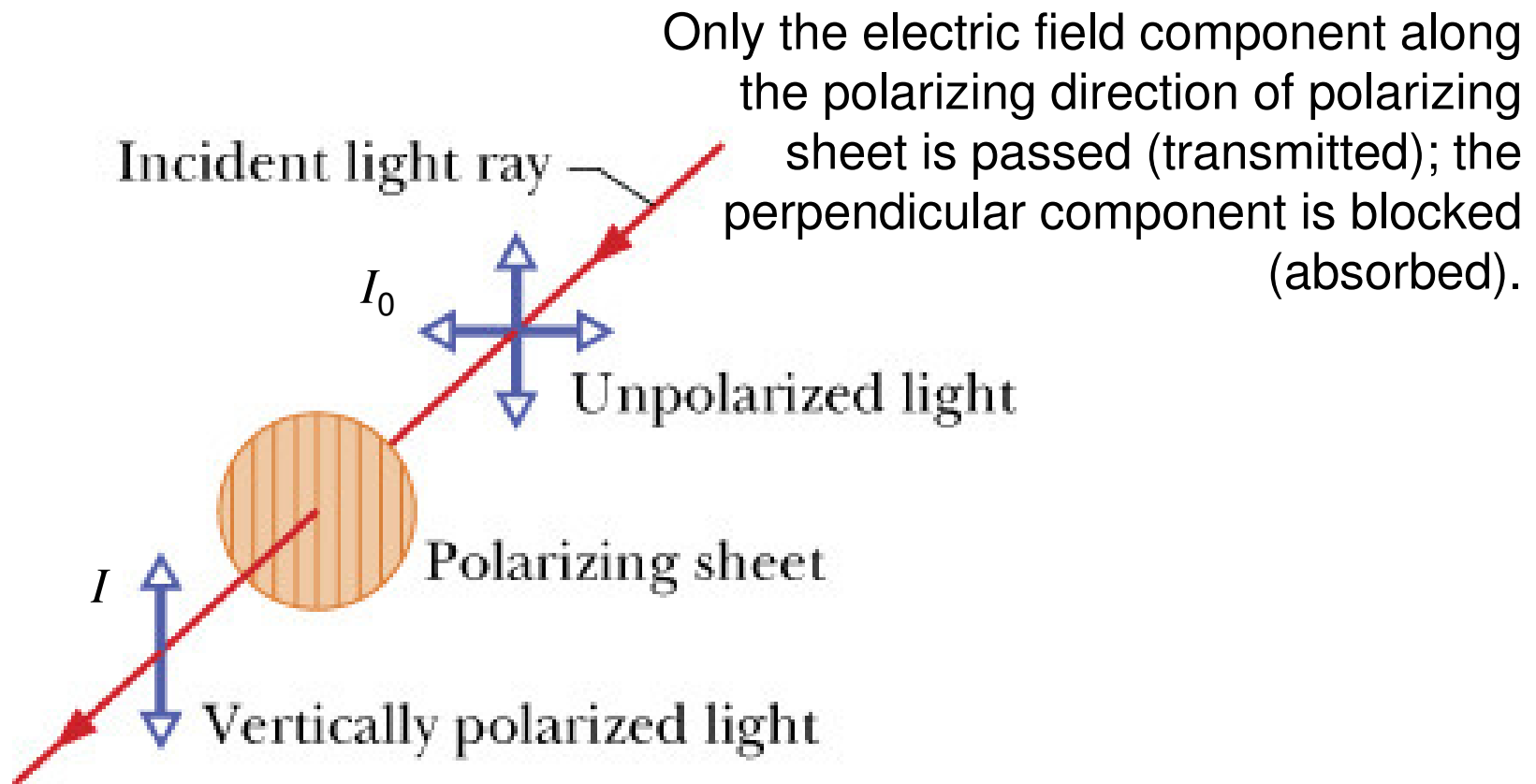


Unpolarized or randomly polarized light has its instantaneous polarization direction vary randomly with time.

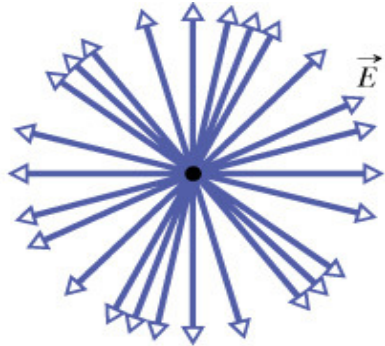


One can produce unpolarized light by the addition (superposition) of two perpendicularly polarized waves with **randomly varying amplitudes**. If the two perpendicularly polarized waves have fixed amplitudes and phases, one can produce different polarizations such as circularly or elliptically polarized light.

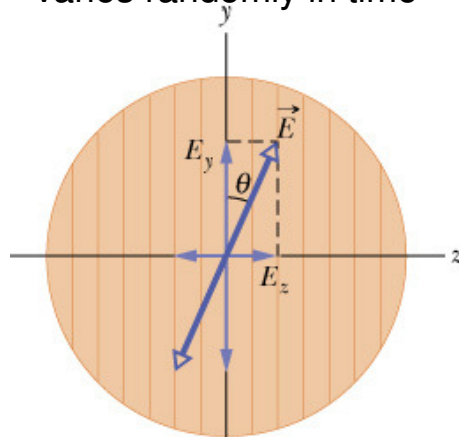
# Polarizing Sheet



## Intensity of Transmitted Polarized Light



For unpolarized light,  $\theta$  varies randomly in time



For polarized light,  $\theta$  is constant in time

Intensity of transmitted light, unpolarized incident light:

$$I = \left( I_0 \cos^2 \theta \right)_{\text{avg}} = I_0 \left( \cos^2 \theta \right)_{\text{avg}} = I_0 \frac{1}{2}$$

Since only the component of the incident electric field  $E$  parallel to the polarizing axis is transmitted.

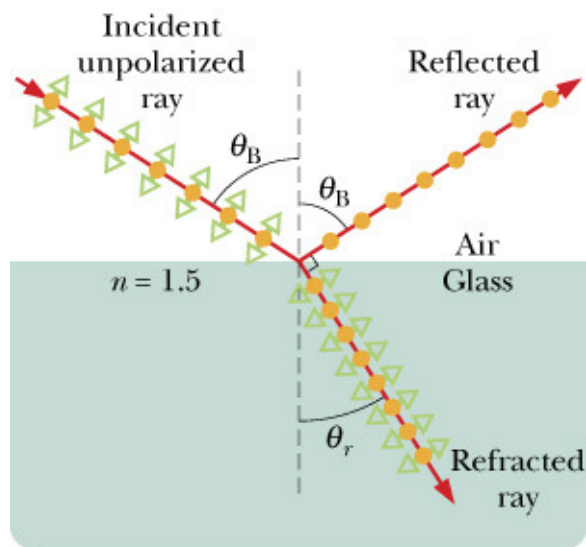
$$E_{\text{transmitted}} = E_y = E \cos \theta$$

Intensity of transmitted light, polarized incident light:

$$I = I_0 \cos^2 \theta \quad \text{Malus' Law}$$

# Polarization by Reflection

When the refracted ray is perpendicular to the reflected ray, the electric field parallel to the page (plane of incidence) in the medium does not produce a reflected ray since there is no component of that field perpendicular to the reflected ray (EM waves are transverse).



● Component perpendicular to page  
 ↔ Component parallel to page

## Applications

1. Perfect window: since parallel polarization is not reflected, **all** of it is transmitted
2. Polarizer: only the perpendicular component is reflected, so one can **select** only this component of the incident polarization

## Brewster's Law

$$\theta_B + \theta_r = 90^\circ$$

$$n_1 \sin \theta_B = n_2 \sin \theta_r$$

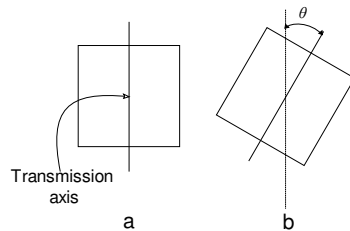
$$n_1 \sin \theta_B = n_2 \sin (90^\circ - \theta_B) = n_2 \cos \theta_B$$

$$\theta_B = \tan^{-1} \frac{n_2}{n_1}$$

# Activity – Polarization

## ☐ Hands on

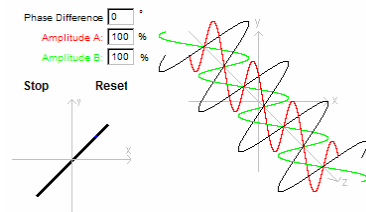
### ➤ Polarizing squares



### ➤ Polarizing materials

## ☐ Applets

### ➤ Simulations



Your Name (Print): \_\_\_\_\_ Date: \_\_\_\_\_  
Group Members: \_\_\_\_\_ Group: \_\_\_\_\_

### Polarization

1. Look through one piece of the polarizer material at the overhead room lights. Describe what happens as you rotate the polarizer through  $360^\circ$ . What can you conclude about the polarization of the light emitted from the ceiling lights?
2. Look through one piece of the polarizer material at the reflections of the overhead room lights on the floor (the bright glare spots on the floor). Include both a glare spot very near to you (viewed at near-normal incidence), as well as a glare spot very far away (viewed at a glancing angle of incidence). Describe what happens when you rotate the polarizer through  $360^\circ$ . What can you conclude about the polarization of the reflected light?  
HINT: The observations are not related to the Law of Reflection!  
<http://www.colorado.edu/physics/PhysicsInitiative/Physics2000/applets/polarized.html> This applet shows the effect of viewing both direct sunlight and sunlight reflected from a surface of water. Notice the orientation of the “sun glasses” in the upper left hand corner.
3. Put two pieces of the polarizer material together so that no light gets through (this is called “crossed polarizers”). Now put a third one between the other two. Describe and explain what happens as you rotate the middle polarizer. Clearly explain the physical basis for each situation. A drawing that shows the polarization of the light through each filter should be included in your explanation.

# Activity – Polarization and Thin Film Problems

## □ Problems

- Recommend #2, #3
- #3 has applet to simulate multiple polarizers...

Your Name (Print): \_\_\_\_\_ Date: \_\_\_\_\_  
 Group Members: \_\_\_\_\_ Group: \_\_\_\_\_

### Polarization and Thin Films Problems

1. (HRW8 35.P.075) The figure on the left shows a lens with a radius of curvature  $R$  lying on a flat glass plate and illuminated from above by light with wavelength  $\lambda$ . The figure on the right is a photograph taken from above the lens and shows that circular interference fringes (called Newton's rings) appear, associated with the variable thickness  $d$  of the air film between the lens and the plate. Find the radius  $r$  of the interference maxima assuming  $\frac{r}{R} \ll 1$ .



2. A flat sheet of silicon (Si,  $n_3 = 3.50$ ) is coated with a transparent thin film of silicon monoxide (SiO,  $n_2 = 1.45$ ) to minimize reflective losses from the surface.
 

Air
SiO $n_2 = 1.45$
Si $n_3 = 3.50$

  - a) Draw the two main reflected rays that undergo interference in the air.
  - b) Determine the minimum film thickness that produces the least reflection at a wavelength of 550 nm for incident light rays in air that are perpendicular to the surface. **SHOW ALL WORK**

3. Unpolarized light of intensity  $100 \text{ W/m}^2$  is incident from the left on a set of two ideal polarizers. The first polarizer (Polarizer A) is oriented with its transmission axis directed  $20.0^\circ$  counterclockwise from the vertical.
  - a) What is the intensity of the light that is transmitted through the set of two polarizers (that is, what is the intensity of the light that emerges from Polarizer B) if the second polarizer is oriented with its transmission axis  $50.0^\circ$  clockwise from the vertical?
  - b) What is the intensity of the light that is transmitted through the set of two polarizers if the second polarizer is oriented with its transmission axis  $\theta_B = 70.0^\circ$  clockwise from the vertical?

<http://lectureonline.cl.msu.edu/~mmp/kap24/polarizers/Polarizer.htm> This applet simulates the transmission of light through any number of linear polarizers (up to three).

### Applet: Polarizers

