PHYS 262

George Mason University

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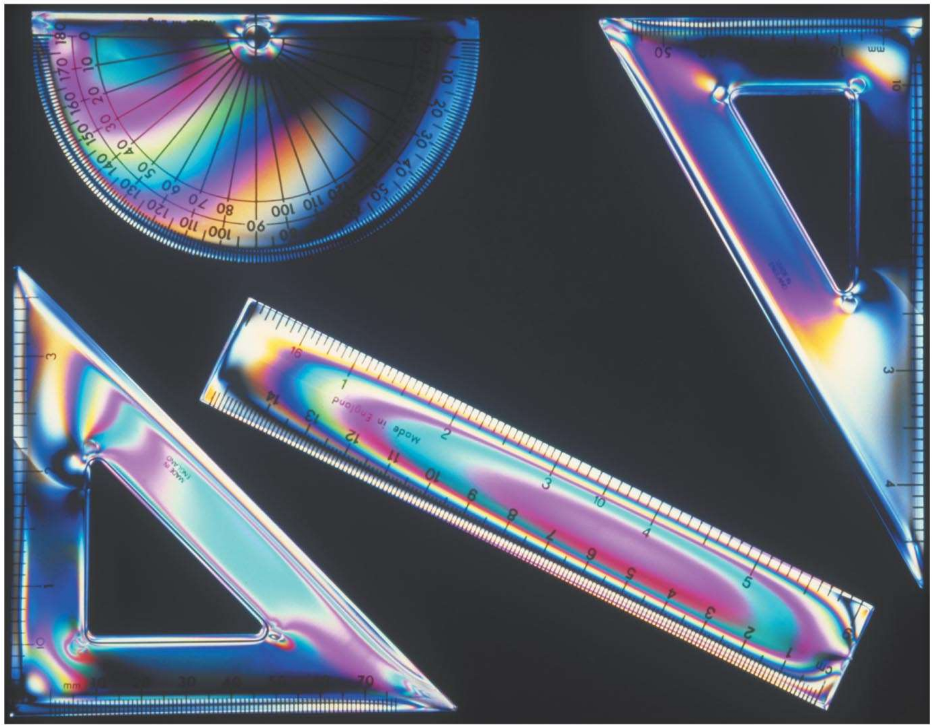
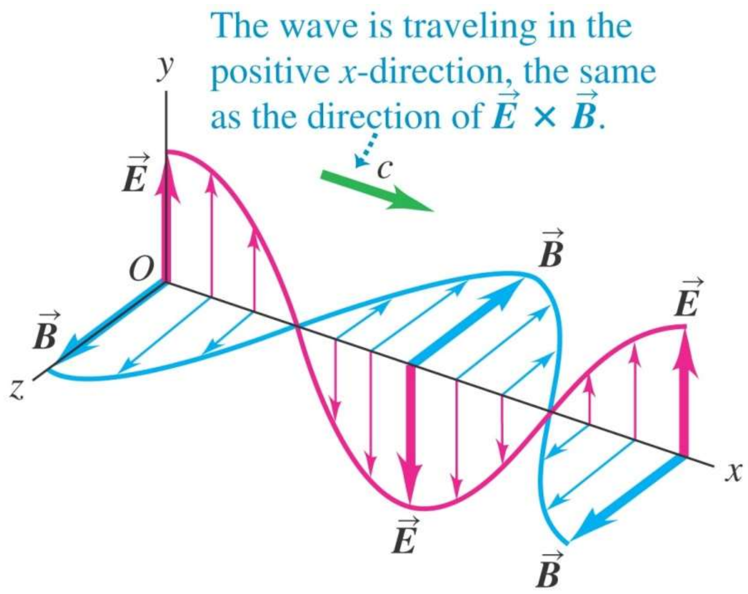
Chapter 33: The Nature and Propagation of Light

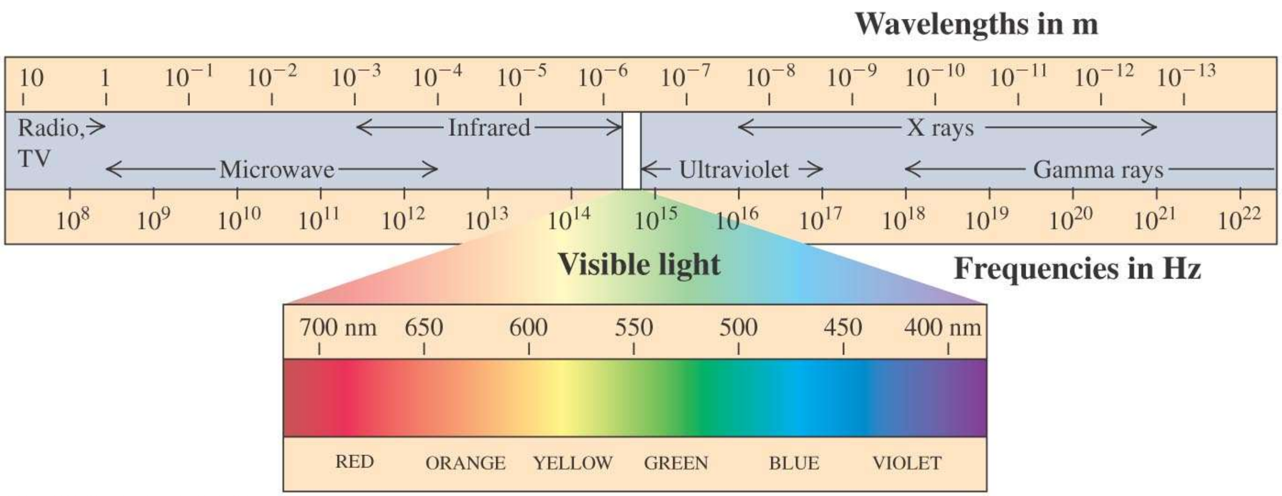
- The nature of light
- Reflection and Refraction
- Total internal reflection
- Dispersion
- Polarization
- Huygens' principle



The Nature of Light

Light is a propagating **electromagnetic** ***waves***



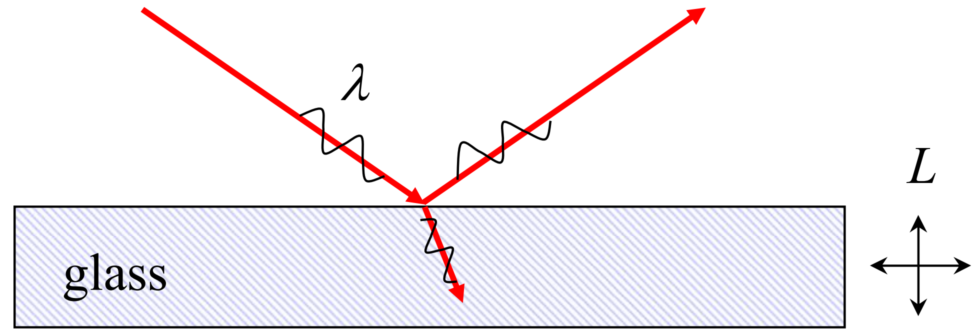


The Study of Light: Optics

- Geometric (Rays) Optics:

$$L >> \lambda$$

Relevant system size >> wavelength



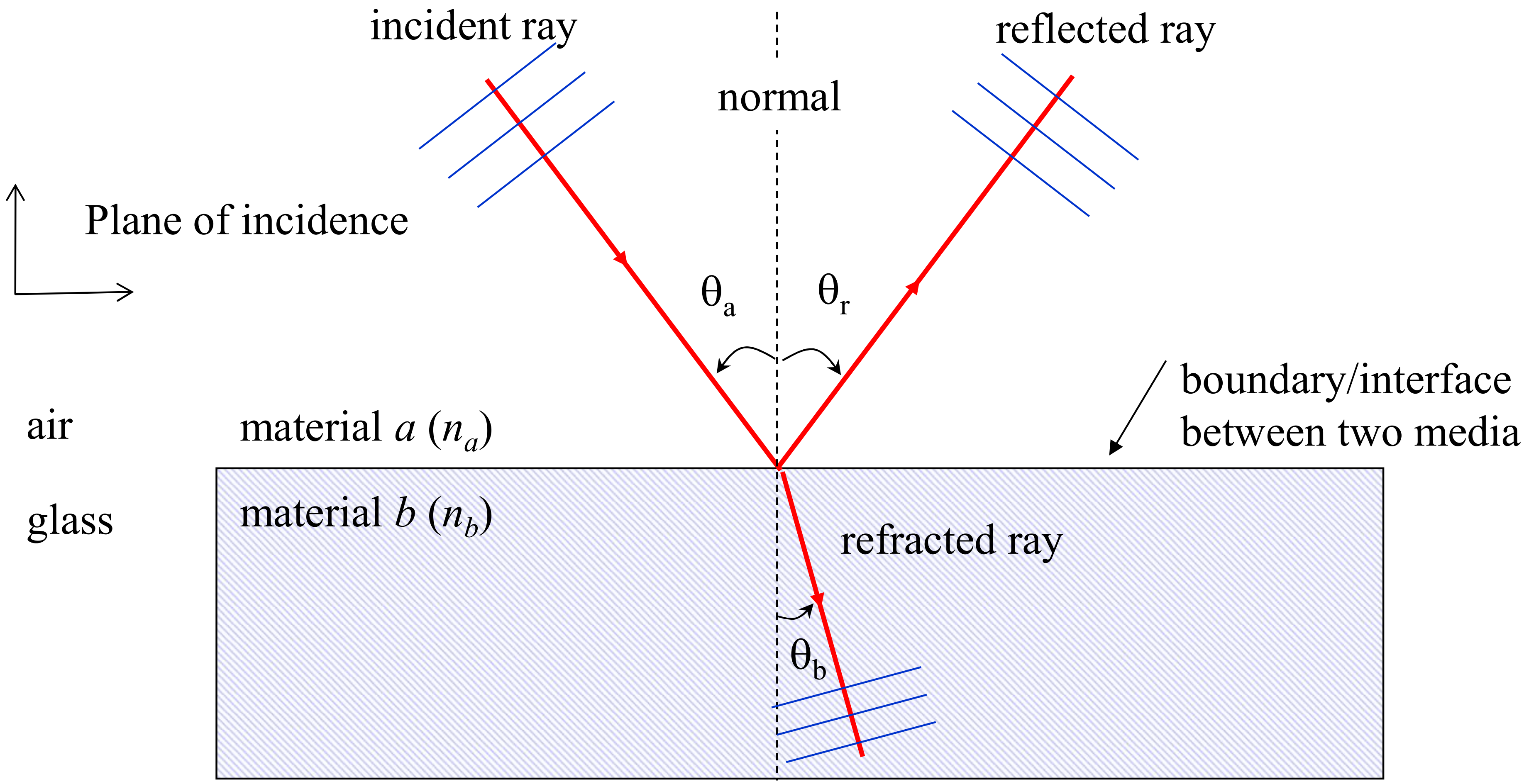
In this approximation, wave characteristic of light is not important and rays model of light gives accurate predictions.

(Visible light: $\lambda \sim 500$ nm $<< L$ → Rays Optics works well with typical optical instruments: mirror, lens, cameras, telescopes,…)

- Physical (Wave) Optics (Ch.35-36):

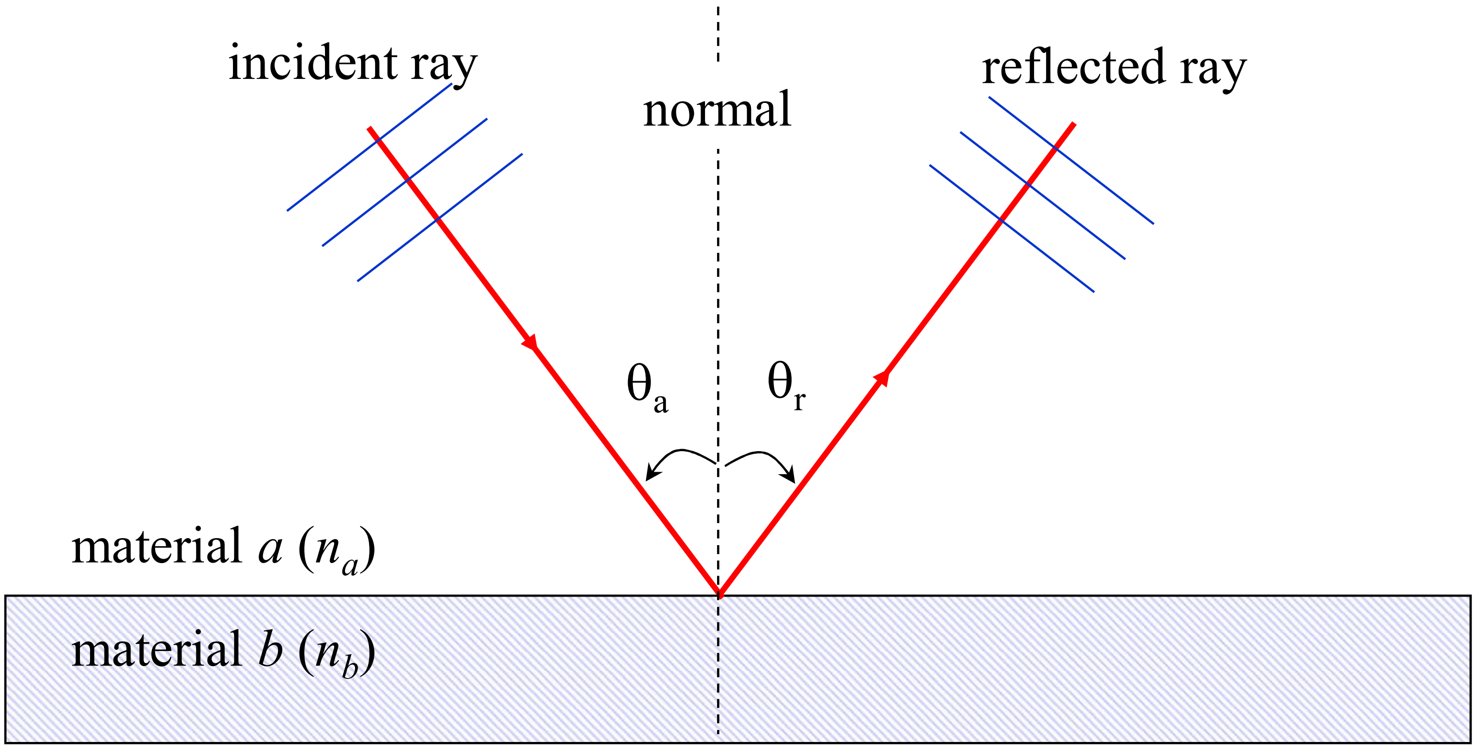
  The study of light when wave properties of light are important (diffraction and interference). $L \approx \lambda$

Reflection and Refraction



When light hits a *boundary*, typically a part of it will be *reflected* & a part of it will be *refracted*.

Law of Reflection



$$\theta_r \text{ (angle of reflection)} = \theta_a \text{ (angle of incidence)}$$

Index of Refraction *n*:

- In materials, light interacts with atoms/molecules and travels *slower* than it can in vacuum, e.g.,

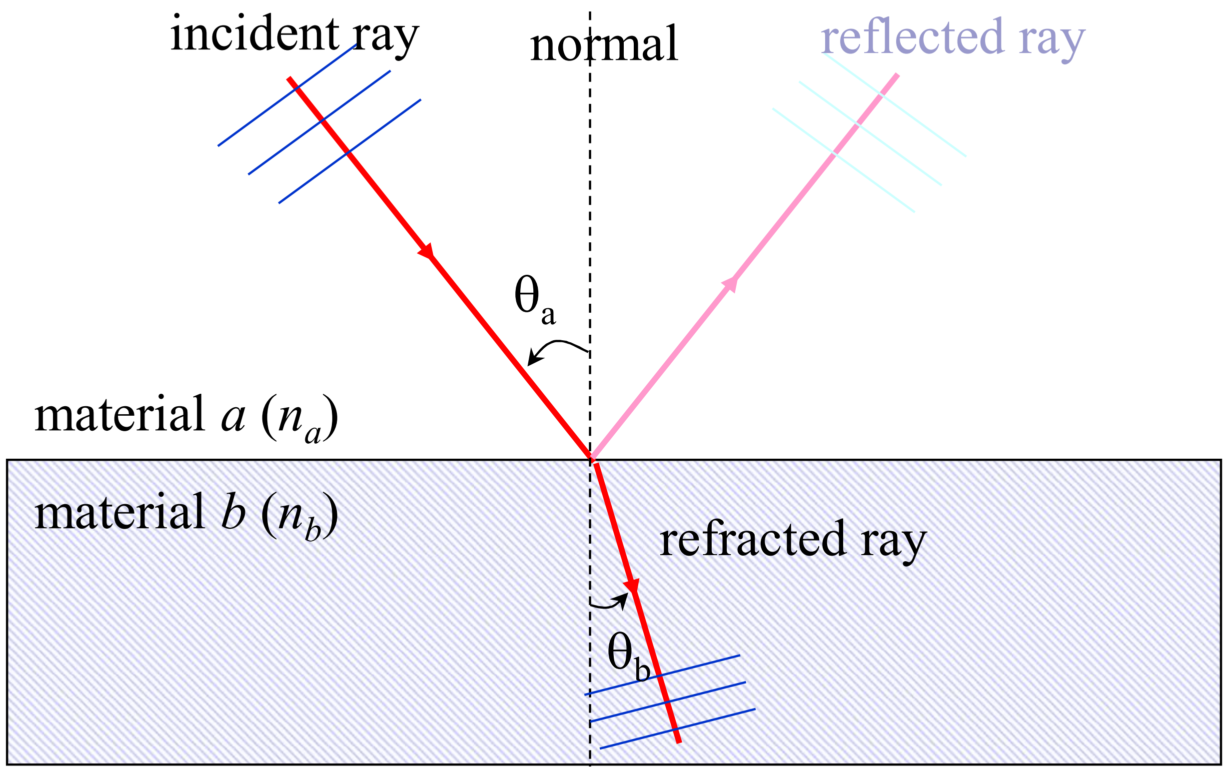
$$v_{water} \cong \frac{3}{4}c$$

- The optical property of transparent materials is called the **Index of Refraction**:

$$\boxed{n \equiv \frac{c}{v_{material}}} \qquad \text{(Table 33.1)}$$

- Since $v_{\text{material}} < c$ always, $n > 1$!

Law of Refraction (Snell's Law)



$$n_a \sin\theta_a = n_b \sin\theta_b$$

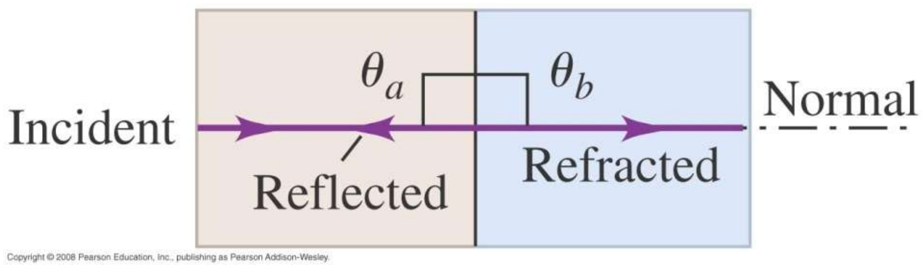
Snell's Law (3 cases)

$$n_a \sin\theta_a = n_b \sin\theta_b$$

Recall

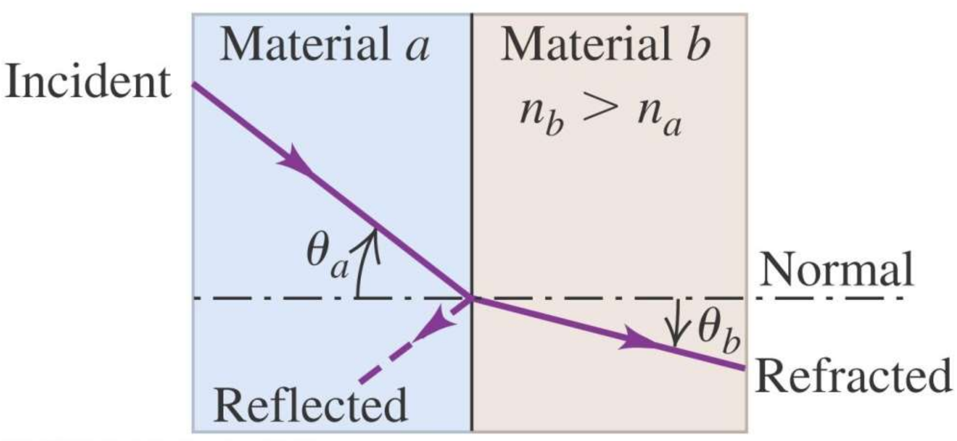
$$n = c / v$$

A ray oriented along the normal does not bend, regardless of the materials.

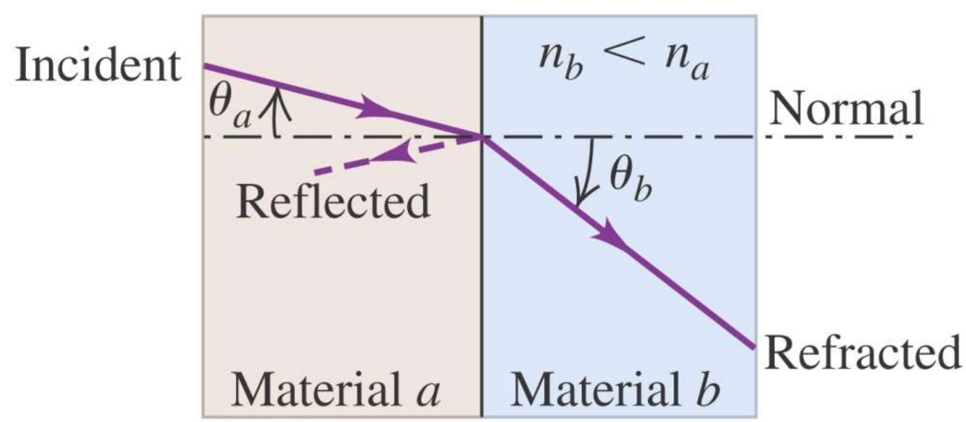


D_{pyrex_oil}

A ray entering a material of *larger* index of refraction bends *toward* the normal.

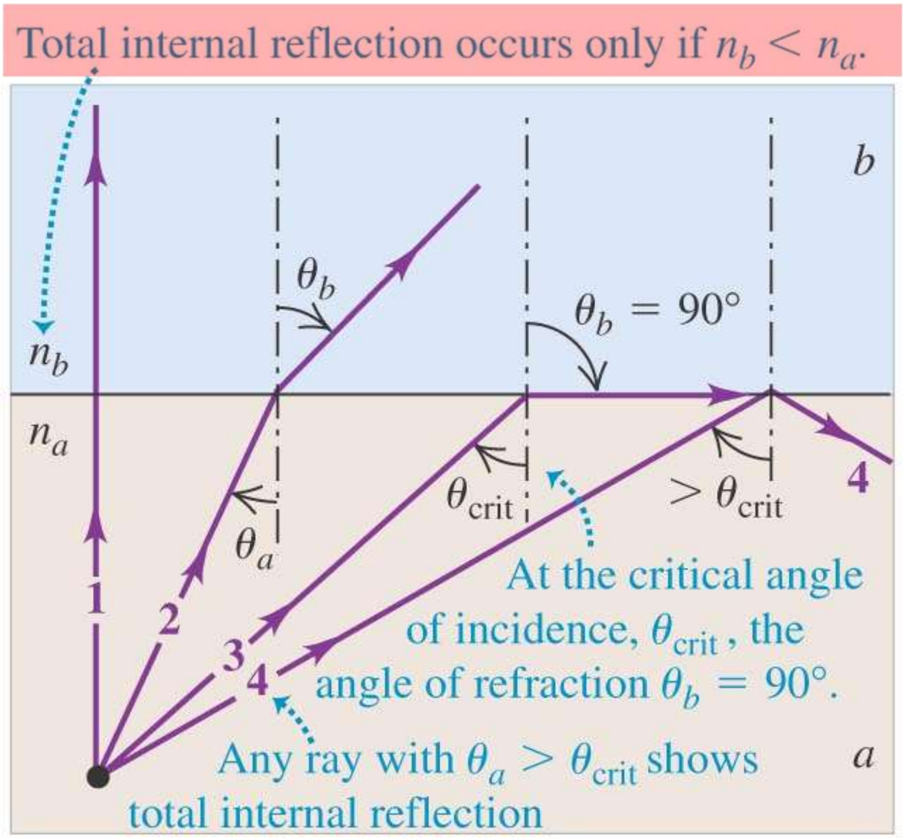


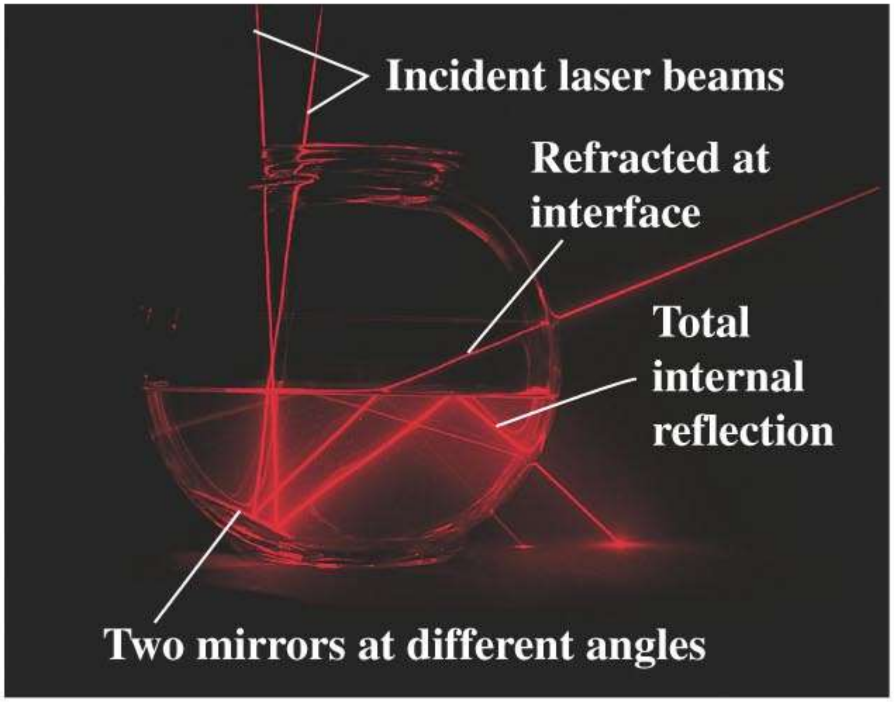
A ray entering a material of *smaller* index of refraction bends *away from* the normal.



Total Internal Reflection

- Light moves from a medium with a *larger n* to one with a *smaller n.*
- As the angle of incidence becomes more and more acute, the light ceases to be transmitted, only reflected.





Total Internal Reflection

- Critical Angle θ_{crit} is determined by the borderline case (ray 3).

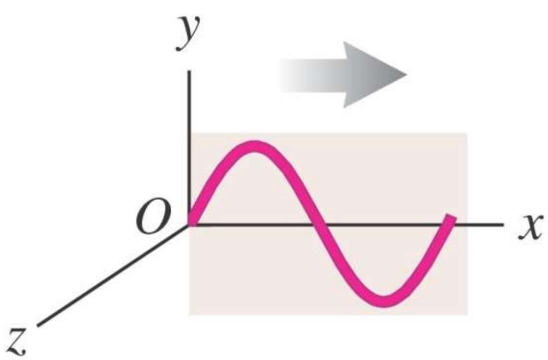
$$n_a \sin\theta_{crit} = n_b \sin 90^\circ$$ (from Snell's Law)

$$\boxed{\sin\theta_{crit} = \frac{n_b}{n_a}}$$ (only valid for $n_a > n_b$)

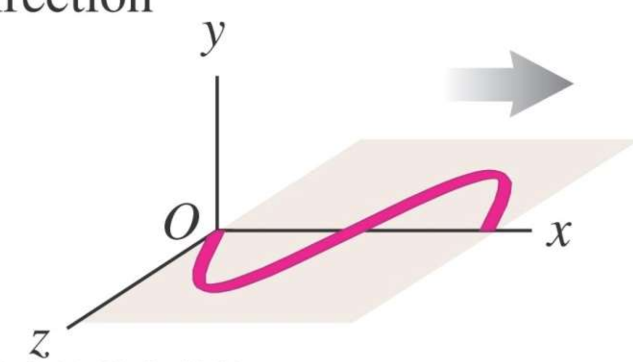
Polarization

For a transverse wave on a string, the direction of the wave's *displacement* gives the **polarization** of the wave.

(a) Transverse wave linearly polarized in the y-direction



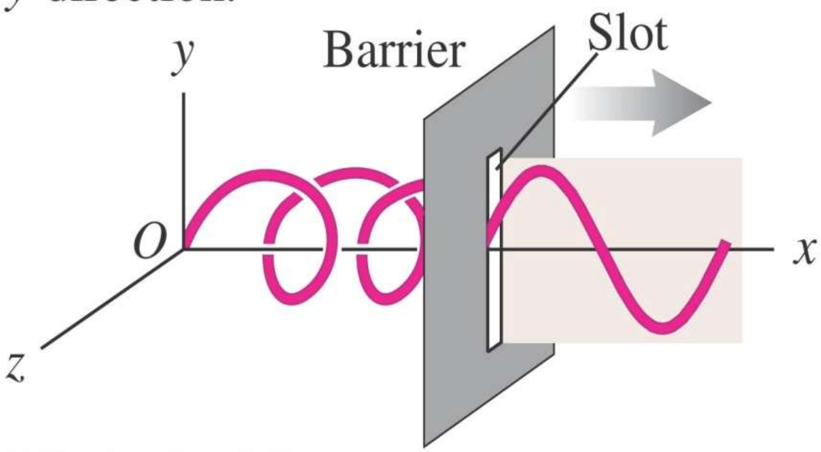
(b) Transverse wave linearly polarized in the z-direction



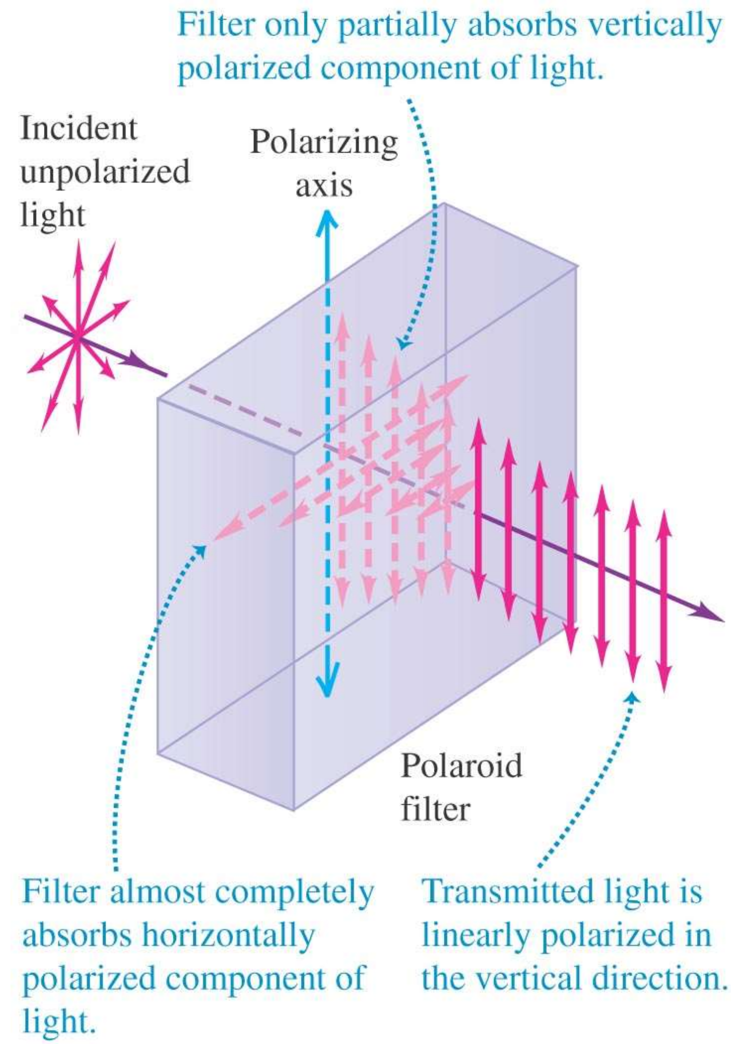
Polarization by Filters

A *non*-linearly polarized wave on a string can be polarized by a slot barrier.

The slot functions as a polarizing filter, passing only components polarized in the y-direction.

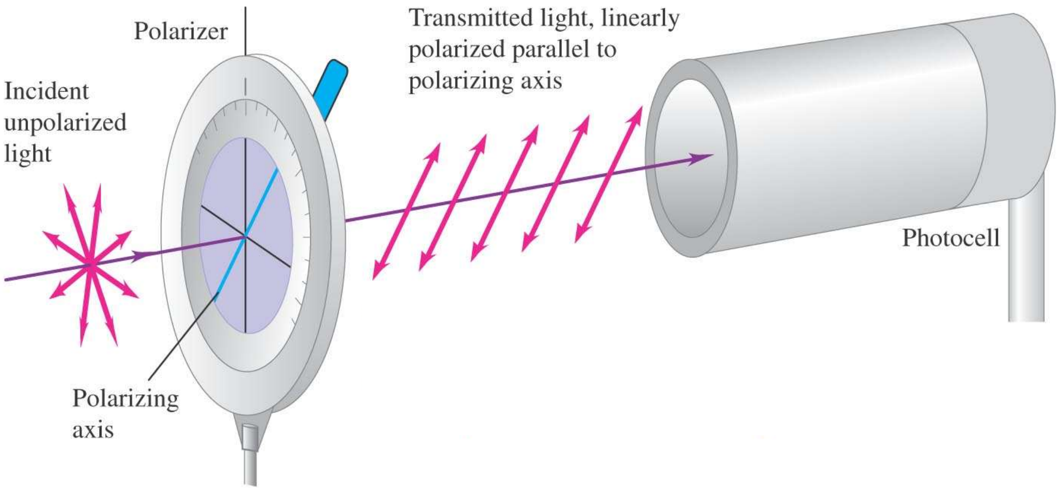


Polaroid Filter for an EM Wave



The Action of a Polarizing Filter

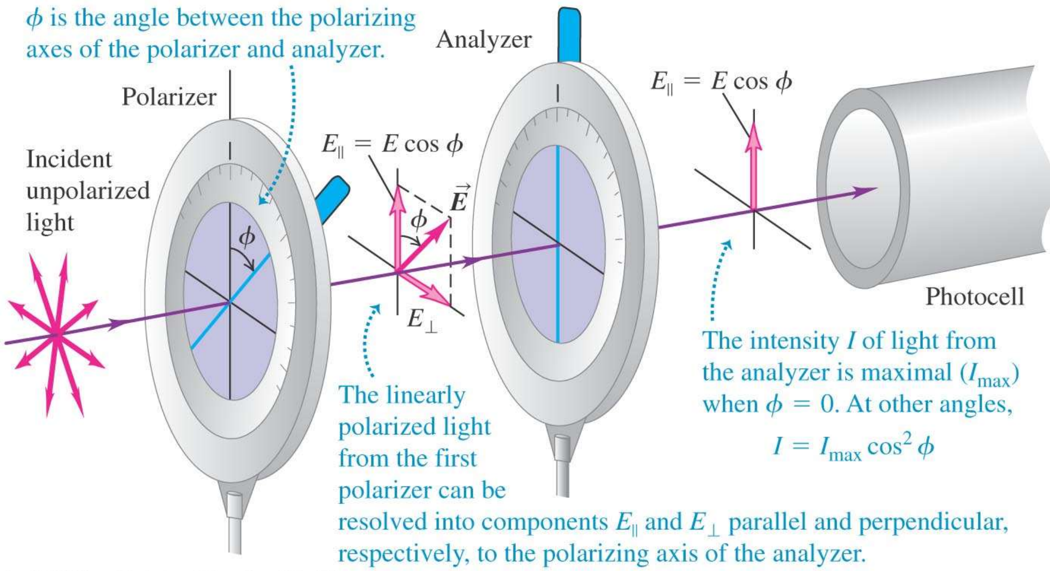
Unpolarized incident light will be linearly polarized parallel to the polarizing axis after transmission.



We can analyze the intensity of the transmitted light passing thru the *second* polarizer (an analyzer):

Only $E_{||}$ will be transmitted,

$$E_{trans} = E_{||} = E\cos\phi$$



The Action of a Polarizing Filter

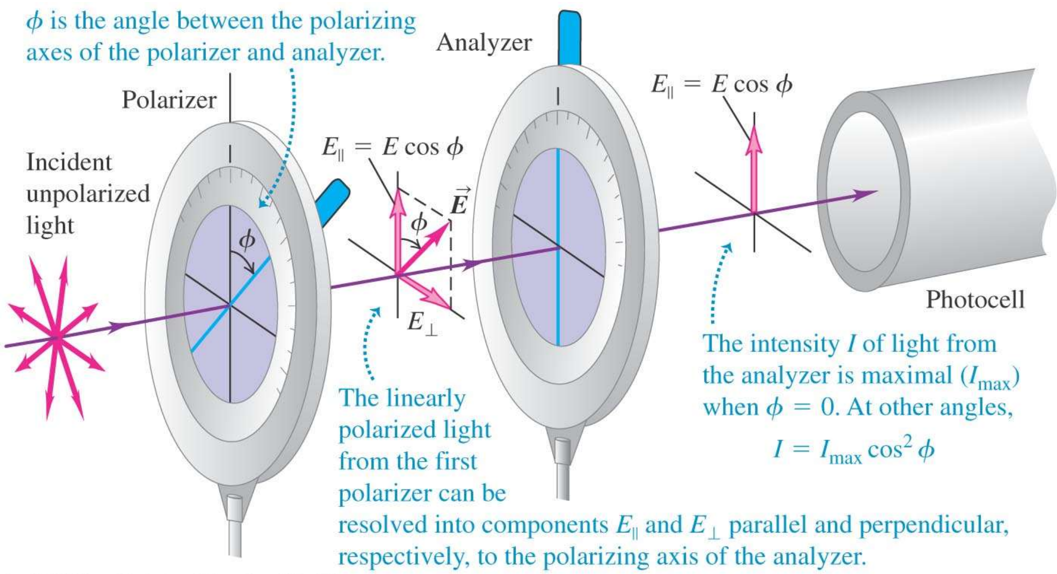
Since intensity (I) is proportional to E^2,

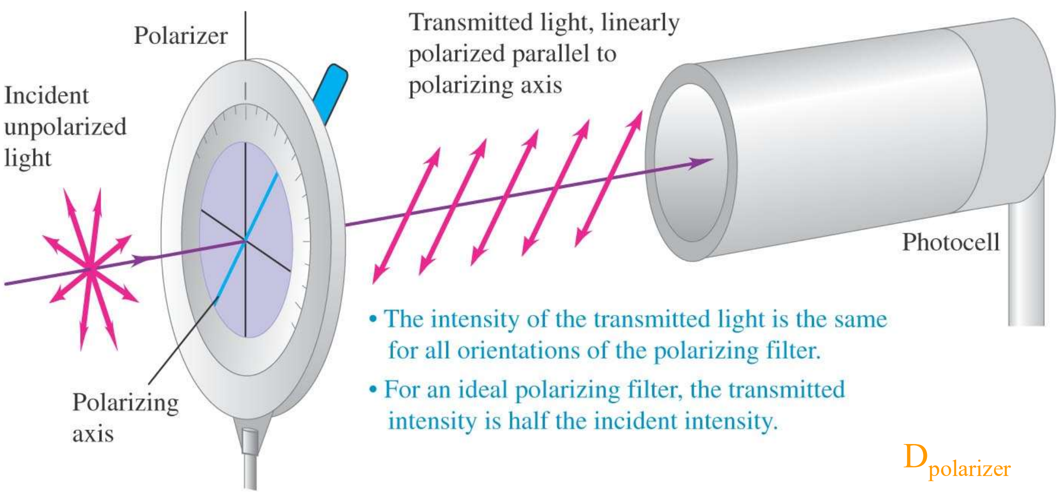
$$I_{trans} = I_{\max} \cos^2 \phi$$

(Malus's Law)
Transmitted intensity of
linearly polarized light
through a polarizer

For an *upolarized* light, $\vec{\mathbf{E}}$ is in all directions,

$$I_{trans} = I_{\max} \int_0^{2\pi} \cos^2 \phi = \frac{1}{2} I_{\max}$$





$D_{polarizer}$