OPTICS

PHYS 311

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POLARIZATION

LIGHT POLARIZATION

The direction of E is known as the polarization of the wave.

$$\vec{E} = E_o \sin(kz - \omega t)\,\hat{x}$$

$$\vec{B} = B_o \sin(kz - \omega t)\,\hat{y}$$

$$\vec{S} = \varepsilon_0 c E_0^2 \sin^2(kz - \omega t)\,\hat{z}$$

E is called the **OPTICAL FIELD**

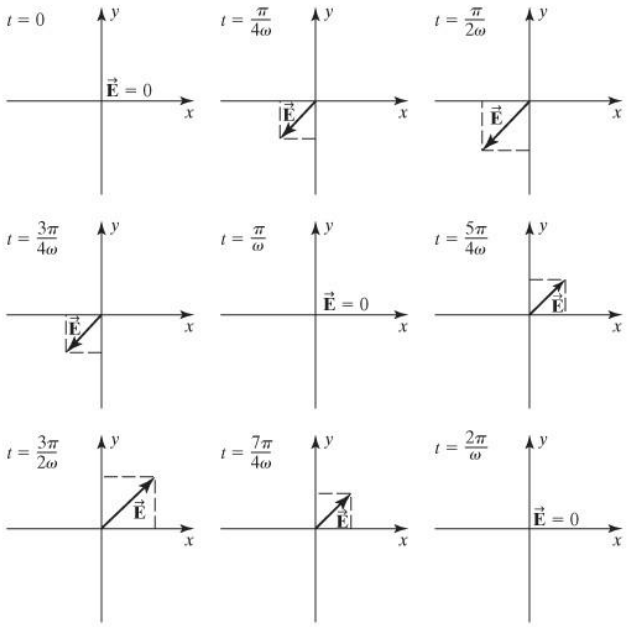
The polaraization of an EM wave determines the direction of the force that the EM wave exerts on a charged particle in the path of the wave.

← **Lorentz force law**

$$\vec{F} = Q(\vec{E} + \vec{v} \times \vec{B})$$

LIGHT POLARIZATION

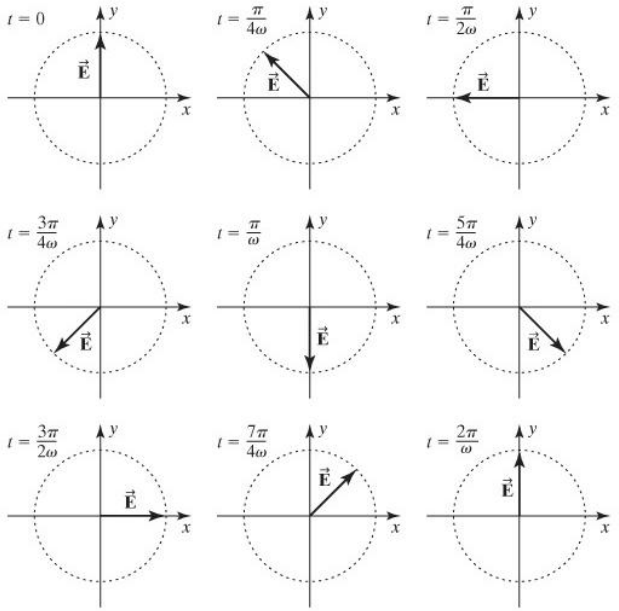
Linear polarization



$\vec{\mathbf{E}} = E_0 \sin(kz - \omega t)\hat{\mathbf{x}} + E_0 \sin(kz - \omega t)\hat{\mathbf{y}}$

(a)

circular polarization



$\vec{\mathbf{E}} = E_0 \sin(kz - \omega t)\hat{\mathbf{x}} + E_0 \cos(kz - \omega t)\hat{\mathbf{y}} = E_0 \sin(kz - \omega t)\hat{\mathbf{x}} + E_0 \sin(kz - \omega t + \pi/2)\hat{\mathbf{y}}$

(b)

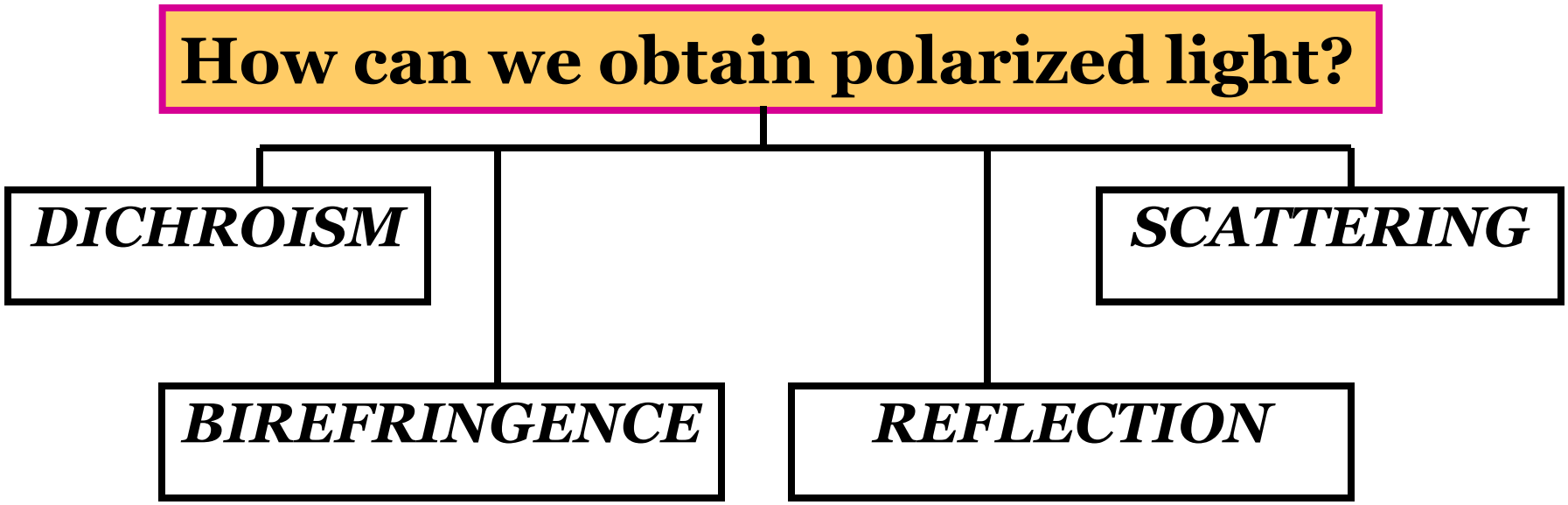
Random polarized, partial polarized light
← How to convert them to polarized light???

POLARIZATION

The polarization of light is a clear evidence of the transverse nature of light waves.

Any interaction of light with matter whose optical properties are asymmetrical along directions traverse to the propagation vector causes polarization.

POLARIZERS


How can we obtain polarized light?
DICHROISM
SCATTERING
BIREFRINGENCE
REFLECTION

DICHROISM: POLARAZATION BY SELECTIVE ABSORPTION

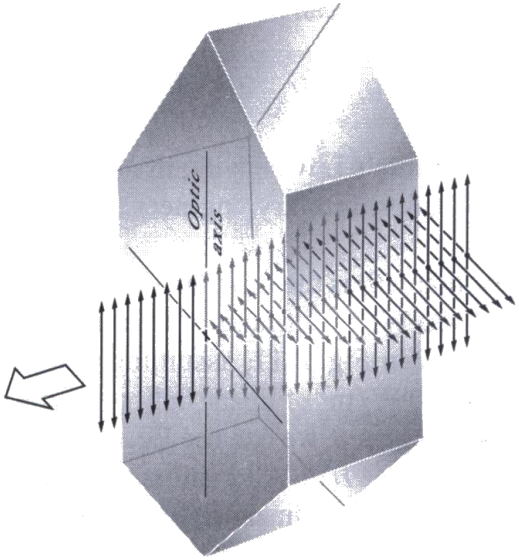
How can we obtain polarized light?

DICHROISM

Dichroism is the selective absorption of light with E-vibration along a unique direction characteristic of the dichroic material.

physically anisotropic

A dichroic polarizer absorbes light in a certain direction and transmit light along a transverse direction orthogonal to the direction of absorption.

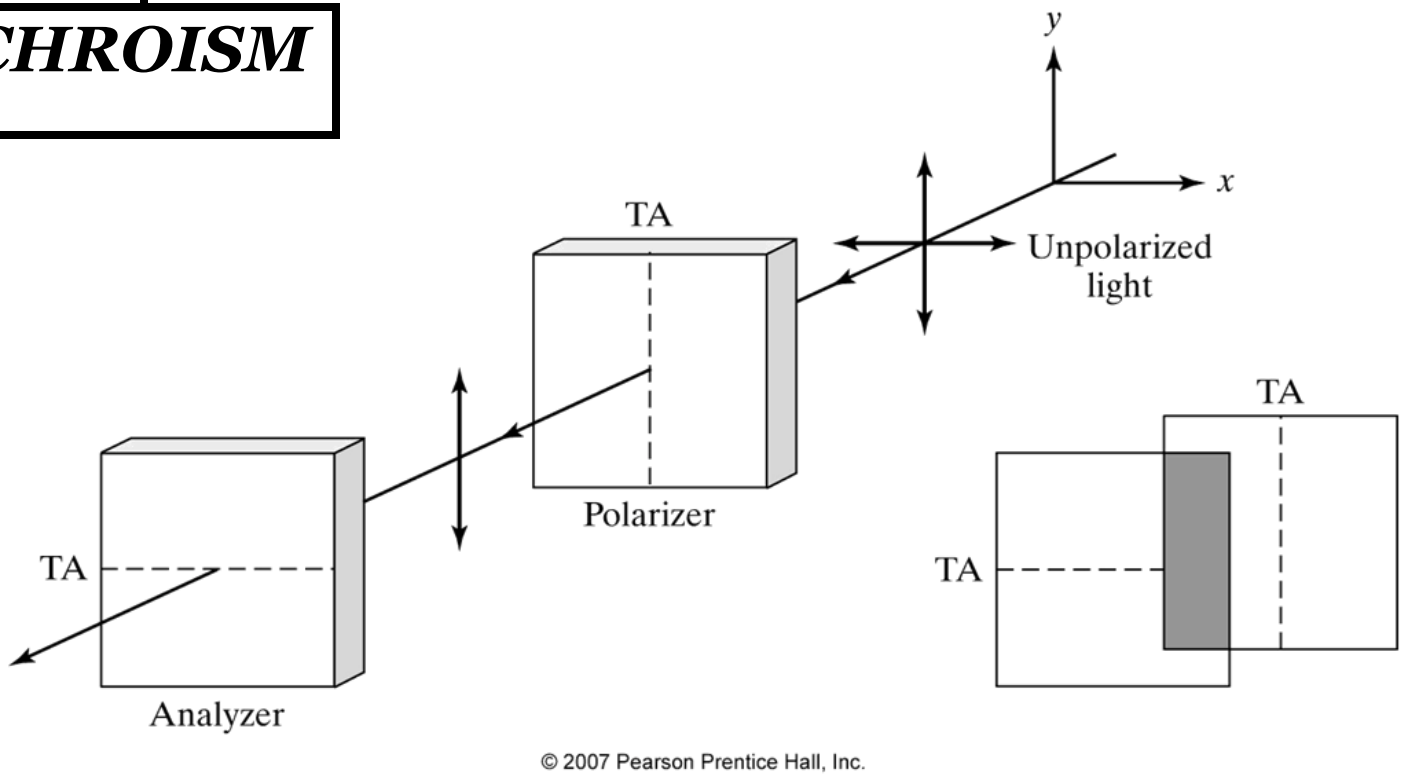


Transmission axis (TA)

DICHROISM: POLARAZATION BY SELECTIVE ABSORPTION

How can we obtain polarized light?

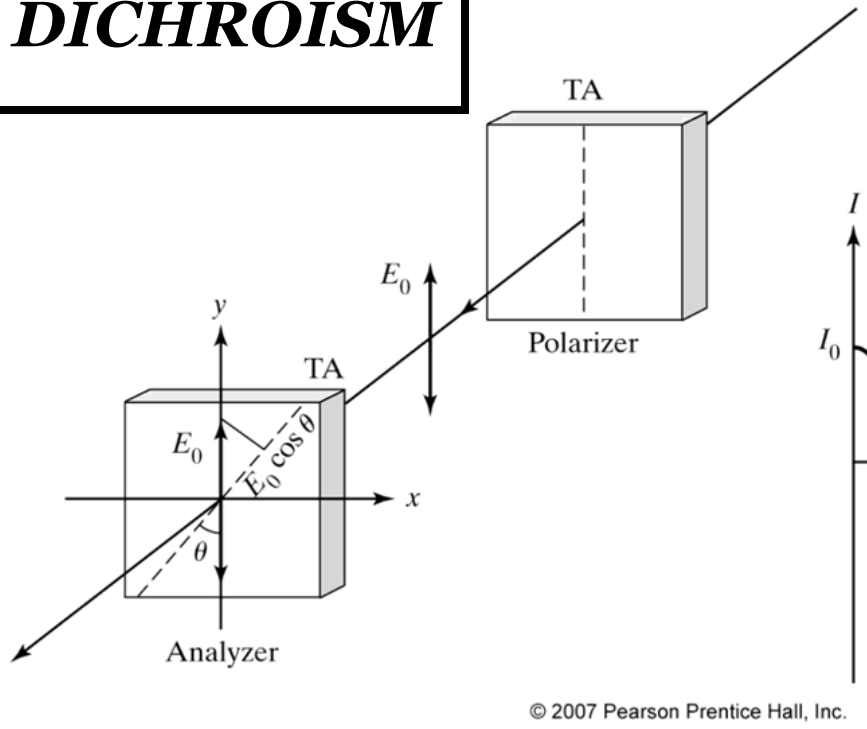
DICHROISM

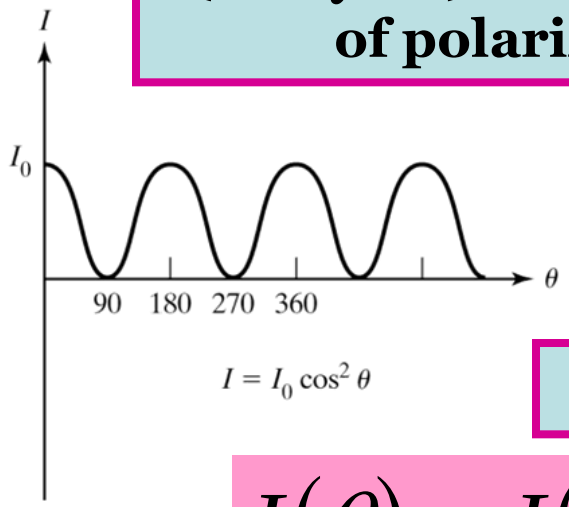


DICHROISM: POLARAZATION BY SELECTIVE ABSORPTION

How can we obtain polarized light?

DICHROISM





We can use a second dichroic polarizer (analyzer) to test the state of polarization.

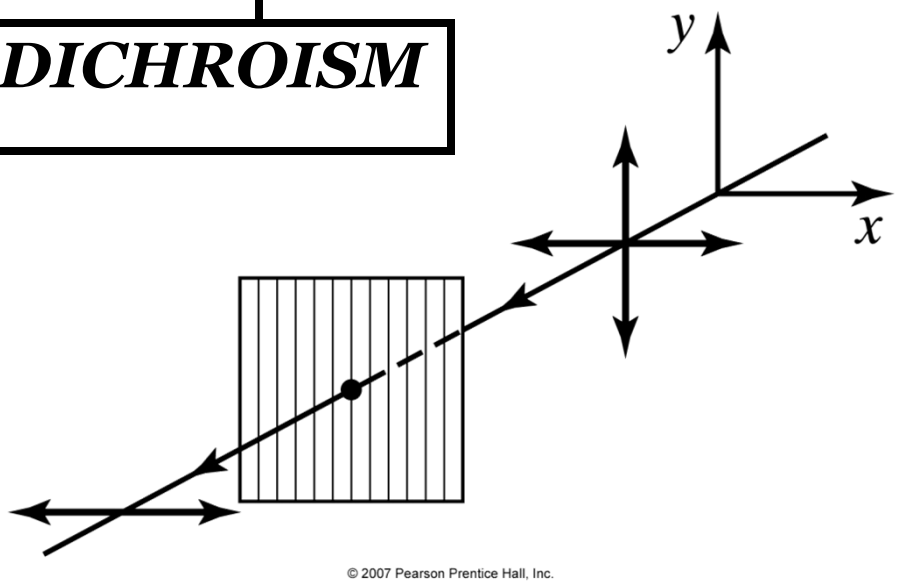
Malus' law

$$I(\theta) = I(0)\cos^2\theta$$

DICHROISM: POLARAZATION BY SELECTIVE ABSORPTION

How can we obtain polarized light?

DICHROISM

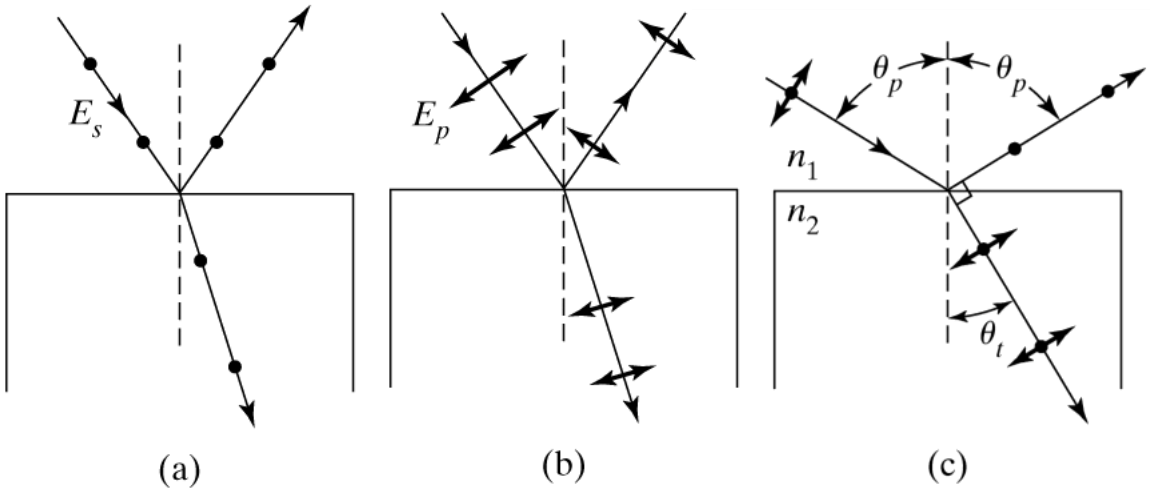


Microwave: Grids
Optical wavelengths: Polaroid

POLARAZATION BY REFLECTION FROM DIELECTRIC SURFACES

How can we obtain polarized light?

REFLECTION



$$n_1 \sin\theta_p = n_2 \sin\theta_t$$

$$\theta_p + \theta_t = 90^o$$

$$n_1 \sin\theta_p = n_2 \cos\theta_p$$

$$\theta_p \equiv \theta_B$$

$$\theta_p = \tan^{-1}(n_2 / n_1)$$

E_s → TE

E_p → TM

Brewster's angle
Polarizing angle

POLARAZATION BY REFLECTION FROM DIELECTRIC SURFACES

How can we obtain polarized light?

REFLECTION

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

Polarizing angle exist for both:
external reflection ($n_2 > n_1$) and internal reflection ($n_2 < n_1$)
In an air-glass interface:
$\theta_p = 56.3^o$ (for external reflection)
$\theta_p = 33.7^o$ (for internal reflection)

POLARAZATION BY SCATTERING

How can we obtain polarized light?

SCATTERING

What is scattering??

Electron bound a nucleus ← dipole oscillator

The alternating electric field oscillates the dipole
The response of the electron to the driving force *depends on* the driving frequency ω and the resonant frequency ω_o

Rayleigh scattering..

Scattering center's size..

$$P = \frac{e^2 \omega^4 r_o^2}{12\pi\varepsilon_o c^3}$$

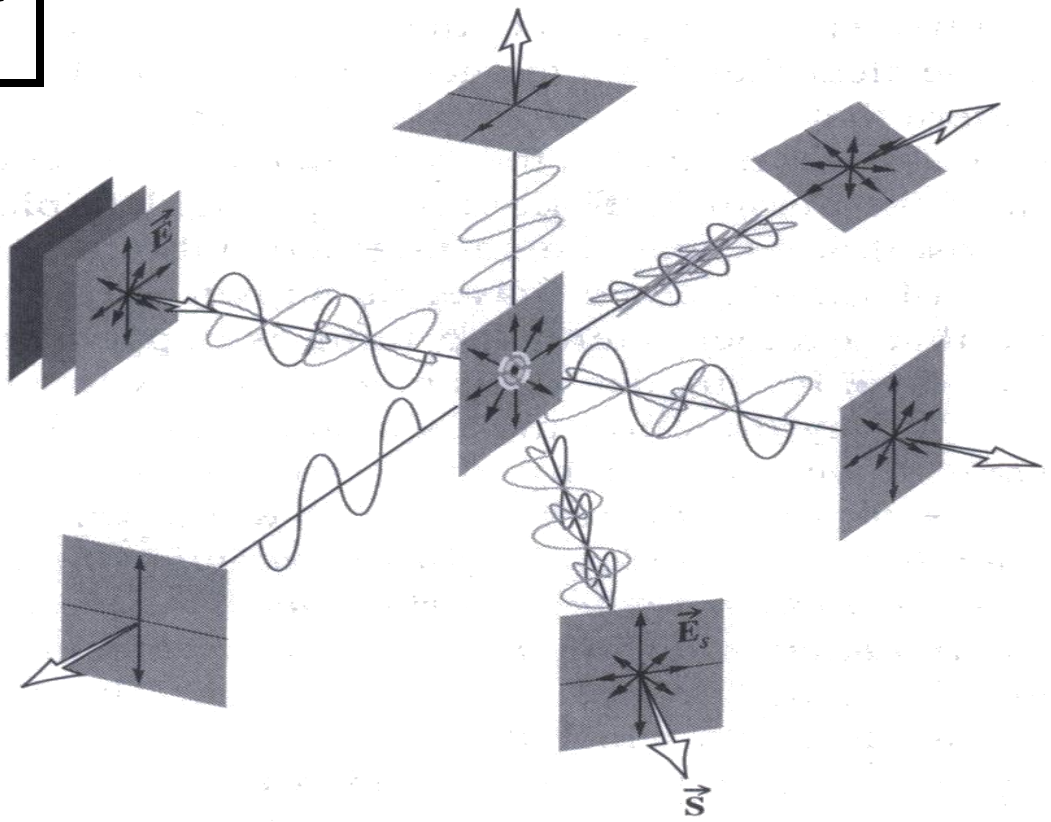
Why the sky is blue??
Why clouds are white??

Incoherent & coherent scattering centers

POLARAZATION BY SCATTERING

How can we obtain polarized light?

SCATTERING



BIREFRINGENCE: POLARIZATION WITH TWO REFRACTIVE INDICIES

How can we obtain polarized light?

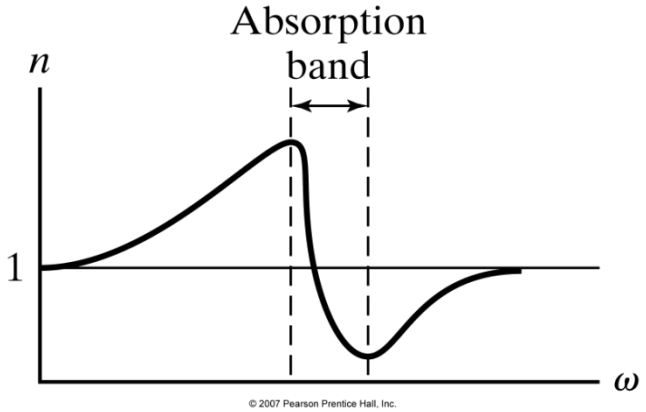
BIREFRINGENCE

Birefringent materials cause double refraction due to the existence of two different indices of refraction for a singel material.

BIREFRINGENCE: POLARIZATION WITH TWO REFRACTIVE INDICIES

How can we obtain polarized light?

BIREFRINGENCE



→ Anisotropy in the binding forces affecting electrons.
→ Anisotropy in the amplitude of electron's oscillations in response to a stimulating EM wave.
→ Anisotropy in absorption.

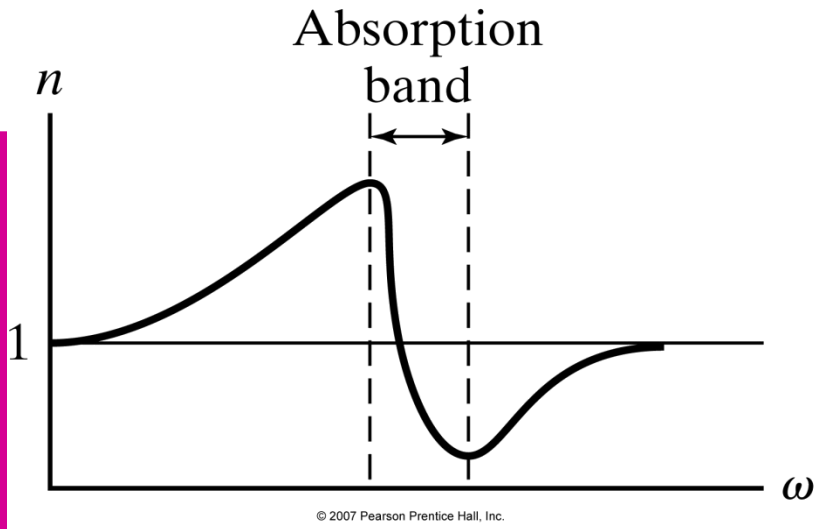
Stimulating frequencies fall within the absorption band of the material.

BIREFRINGENCE: POLARIZATION WITH TWO REFRACTIVE INDICIES

How can we obtain polarized light?

BIREFRINGENCE

The slope of the dispersion curve, dn/dω, is (-) over a certain frequency interval.
← *The absorption band in the material*



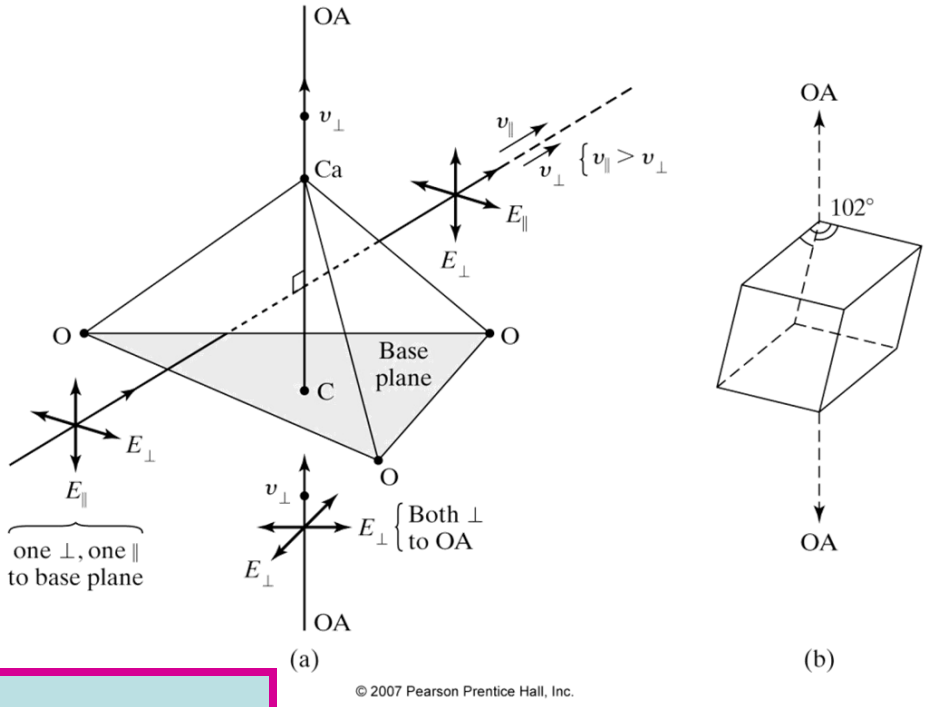
For light propagating in the z-direction, anisotropic binding forces along the x- & y-direction gives different dispersion curves. ← n_x & n_y

BIREFRINGENCE: POLARIZATION WITH TWO REFRACTIVE INDICIES

How can we obtain polarized light?

BIREFRINGENCE

The complex refractive index
$\tilde{n} = n + ik$
← (k is the extinction coefficient)



$n_x = n_y$ & $kx \neq ky$ ← *ideal dichoric*
$nx \neq ny$ & $kx = ky$ ← *ideal birefringent*

BIREFRINGENCE: POLARIZATION WITH TWO REFRACTIVE INDICIES

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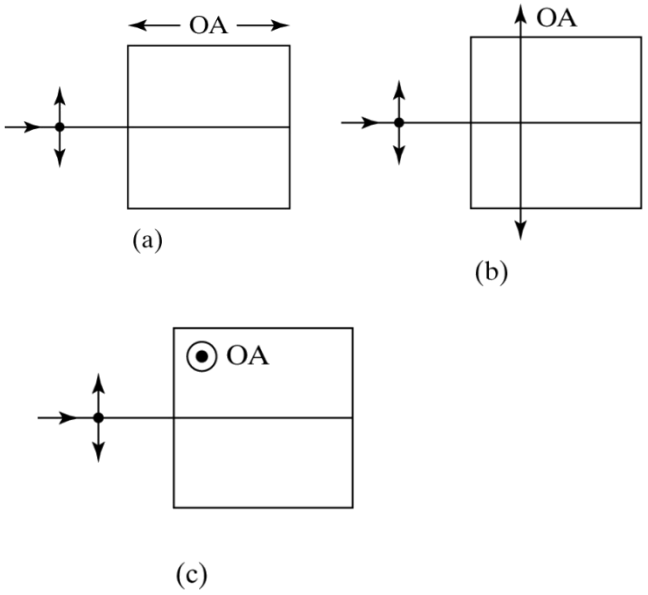
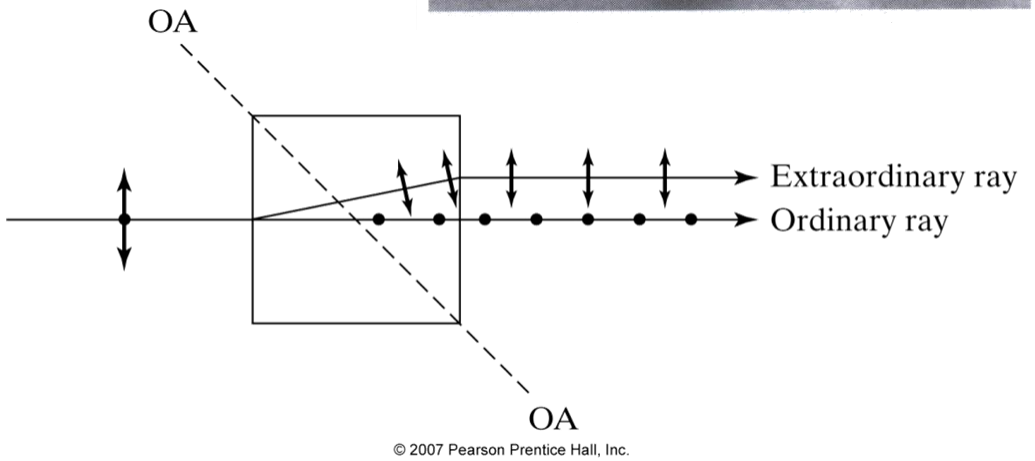
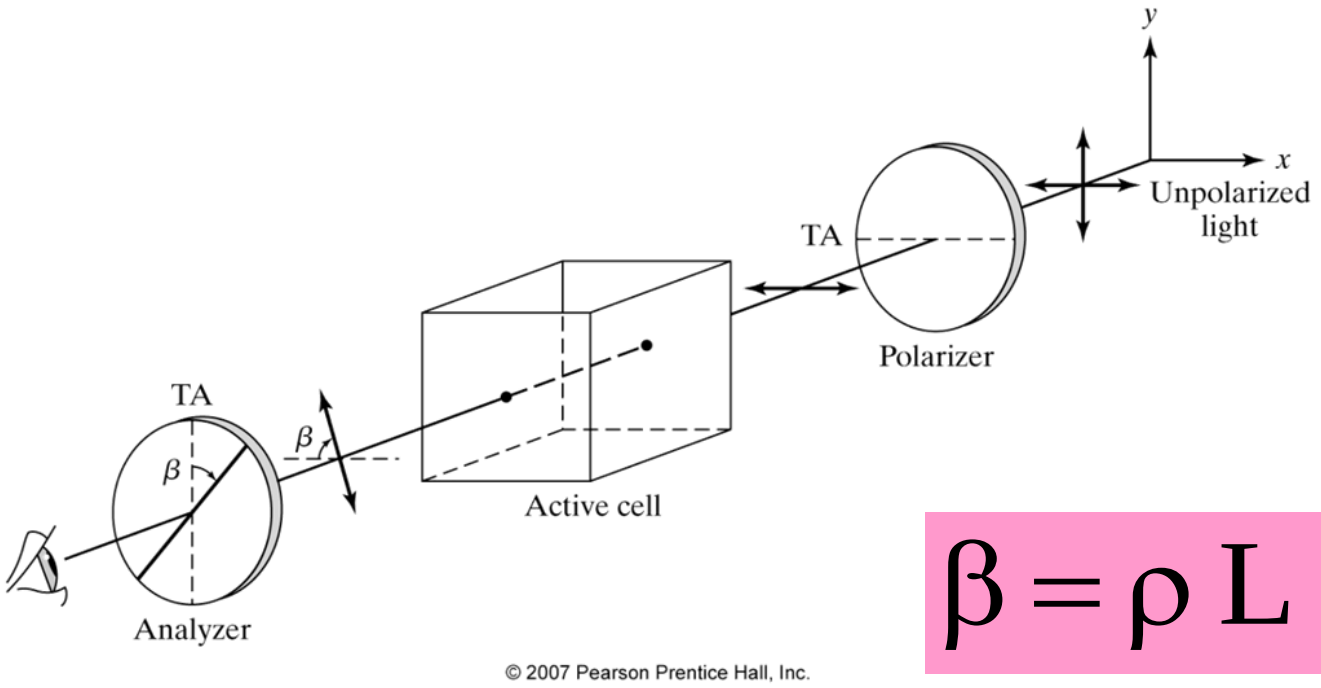
BIREFRINGENCE





OPTICAL ACTIVITY



$$\beta = \rho\, L\, d$$

ρ : specific rotation
β: angle of rotation
L: light path
d: concentration

http://www.youtube.com/watch?v=2-stCNB8jT8&feature=related

http://www.youtube.com/watch?v=O3aITfU_UvE&feature=related