Lect. 21, Apr. 20, 2010 ①

Part 5: Electromagnetic Charactor of Light

- # polarization (CH22)
- # Double Refraction (CH22)
- # Maxwell's Equation (CH23)
- # plain waves in a Dielectric (CH 23)
- # Poynting flux (CH23)
- # Reflection and Refraction of EM waves (CH 24)

Polarization (CH22)

The general wave function, also called displacement function, for 1-D (along z axis), plane wave is

$$\psi = a\cos(kz - \omega t + \phi_0)$$

k : wave number

ω : angular frequency

ϕ_0 : initial phase

$(kz - \omega t + \phi_0)$: phase term

$v = \frac{\omega}{k}$: phase velocity

a : amplitude.

* For a plane wave : $a(x,y,z) = \text{const}$
* For multiple waves: interference and diffraction

$a(x,y,z)$ is a function of location

$\Rightarrow$ fringe pattern

* Polarization : $|a(x,y,z)| = \text{const}$, constant amplitude

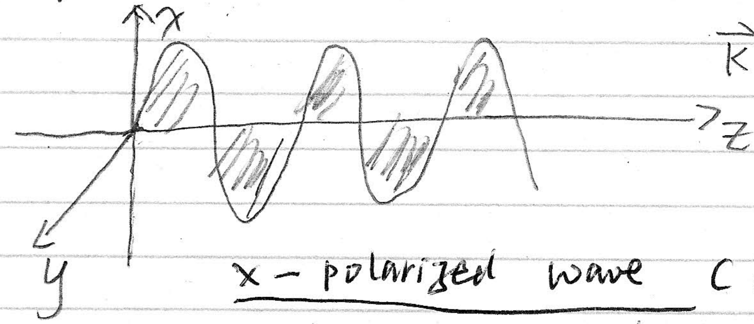
still a plane wave

However, the direction of displacement matters

$$a \rightarrow \vec{a} = \hat{i}a_x + \hat{j}a_y$$

* Polarization (Ch 22) (continued)

* Linearly polarized wave



x - polarized wave (Fig 22.1a)

$$x(z,t) = a\cos(kz - \omega t + \phi_0)$$

$$y(z,t) = 0$$

Linear: oscillation for a given particle at z moves along a straight line

* Also called "plane polarized" wave: oscillation of all particles contain in the same plane

* Y - polarized wave (see Fig 22.1b)

$$x(z,t) = 0$$

$$y(z,t) = a\cos(kz - \omega t + \phi_0)$$

* Circularly - polarized wave (see Fig 22.1c)

the particle moves along a circular path

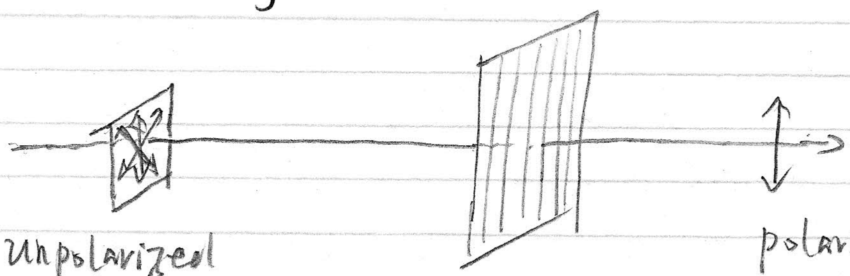
$$x(z,t) = a\cos(kz - \omega t + \phi_0)$$

$$y(z,t) = a\sin(kz - \omega t + \phi_0)$$
$$= a\cos(kz - \omega t + \phi_0 - \frac{\pi}{2})$$

total amplitude $\sqrt{x^2+y^2} = a$: a constant

Polaroid:

only light along the pass axis is transmitted.
other lights are absorbed



(see Fig. 22.6)

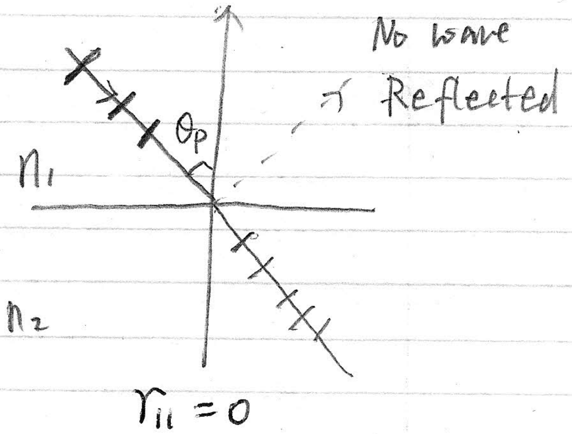
Production of Polarized Light

* wire - Grid polarizer: (see Fig. 22.8)
  Electric field along the direction of wires dissipated
* polaroid: long chain polymer molecules that contain atoms which provide high conductivity along the length of the chain
* Reflection

Incidence angle θ_p

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

polarization angle or Brewster angle:



$\underline{r = 0}$ for the light whose electric vector lies in the plane of incidence

* plane of incidence : incident light k + normal of surface

At $\theta = \theta_p$, reflected light is linearly polarized, whose $\vec{E} \perp$ plane-of-incidence

Malus' Law (CH 22.3)

$$I = I_0 \cos^2\theta \quad \text{(see Fig. 22.15)} \quad \text{--- (10)}$$

θ: the angle between the polarization direction of the incident light and the pass axis of the polaroid.

$\theta = 0°$: complete transimission

$\theta = 90°$, complete blocked

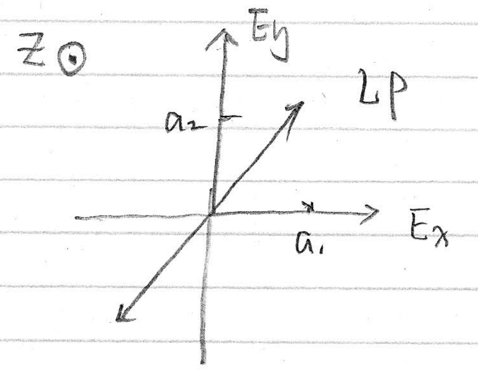
State of polarization and superposition (CH 22.4)

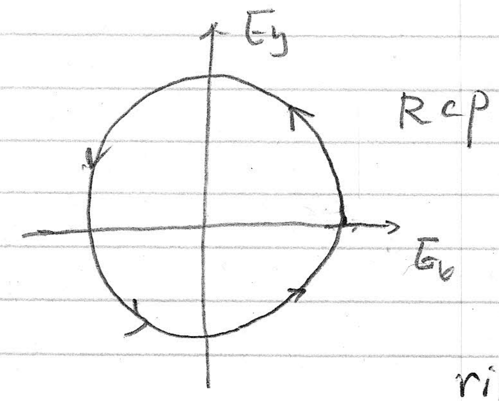
Consider the superposition of two linearly polarized waves both propagate along the z direction

$\vec{E_1} = \hat{x}\, a_1 \cos(kz - \omega t + \theta_1)$: LP (linear polarized)

$\vec{E_2} = \hat{y}\, a_2 \cos(kz - \omega t + \theta_2)$: LP

$\theta = \theta_2 - \theta_1$





$\theta = 0 \Rightarrow$ LP

or $\theta = 2\pi \cdot m$

$$\begin{cases} E_x = a_1 \cos\omega t \\ E_y = a_2 \cos\omega t \end{cases}$$

[without loss of generality:

$z = 0,\ \theta_1 = 0 \Rightarrow E_y = a_2 \cos(\omega t - \theta)$)

$\theta = \frac{\pi}{2} \Rightarrow$ RCP: right circularly polarized

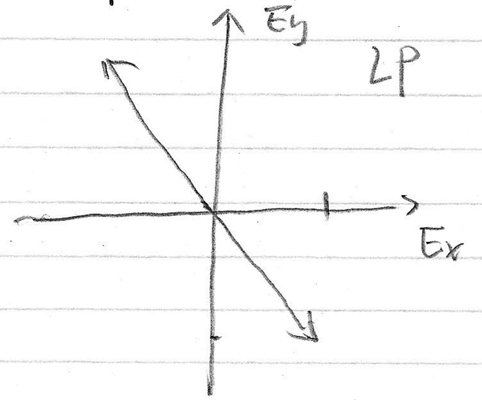
or $\theta = \frac{\pi}{2} + 2\pi \cdot m$

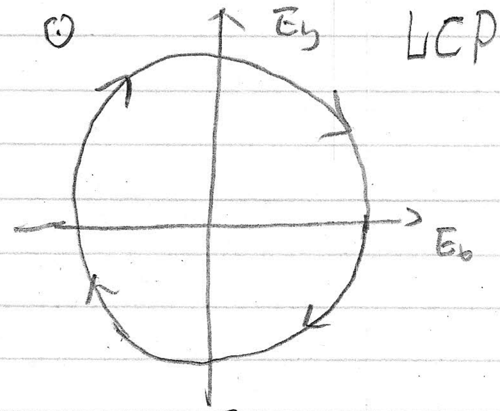
$$\begin{cases} E_x = a_1 \cos\omega t \\ E_y = a_2 \cos(\omega t - \frac{\pi}{2}) = a_2 \sin\omega t \end{cases}$$

$a_1 = a_2$: circular

$a_1 \neq a_2$: elliptical

State of polarization (CH 22.4) (continued)





$\theta = \pi \Rightarrow LP$

$$\begin{cases} E_x = a_1 \cos \omega t \\ E_y = -a_2 \sin \omega t \end{cases}$$

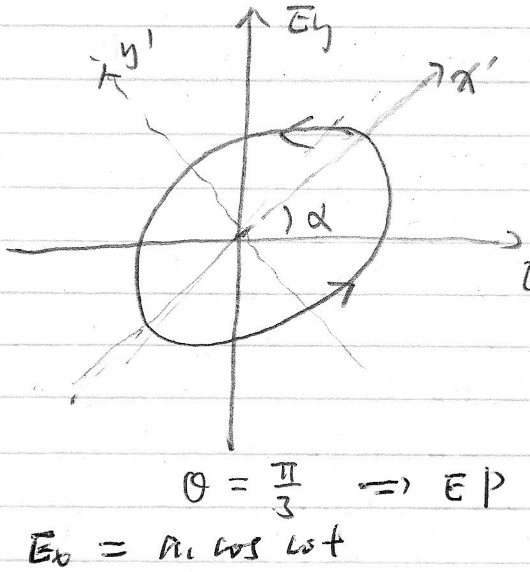
$\theta = \frac{3}{2}\pi \Rightarrow LCP$

$$\begin{cases} E_x = a_1 \cos \omega t \\ E_y = -a_2 \sin \omega t = a_2 \cos(\omega t - \frac{3}{2}\pi) \end{cases}$$

clock-wise rotation

If $\theta \neq 0, \frac{\pi}{2}, \pi, \frac{3}{2}\pi \Rightarrow$ EP (elliptical polarization)

LP, RCP, LP, LCP



EP.
(x', y') new principle axis

$\theta = \frac{\pi}{3} \Rightarrow EP$

$$\begin{cases} E_x = a_1 \cos \omega t \\ E_y = a_2 \cos(\omega t - \frac{\pi}{3}) \end{cases}$$

$$\tan 2\alpha = \frac{2 a_1 a_2 \cos\theta}{a_1^2 - a_2^2}$$

If $a_1 = a_2$, $\tan 2\alpha \to \infty$, $2\alpha = \frac{\pi}{2} \Rightarrow \alpha = \frac{\pi}{4}$