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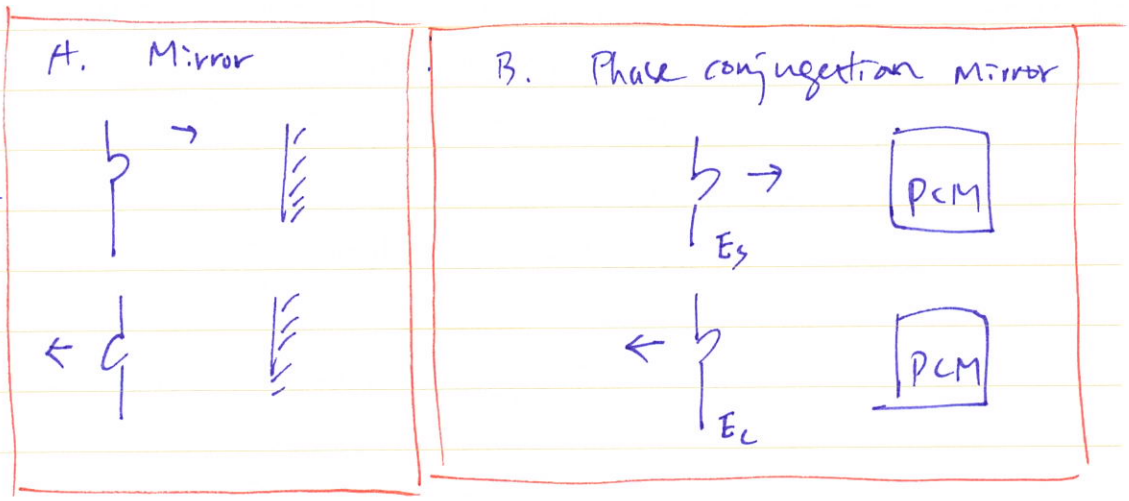
2-3

- Reflection & refraction are reversible in paths.

ex1) Phase conjugation
— time reversed wavefront



$$\tilde{E}_s(r,t) = |\bar{E}_s| e^{-i\omega t} + c.c.$$

$$\tilde{E}_c(r,t) = |\bar{E}_c| e^{-i\omega t} + c.c.$$

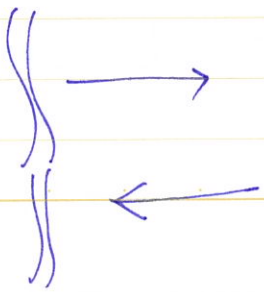
$$\bar{E}_s(r,t) = \hat{\epsilon}_s A_s e^{i\bar{k}_s \cdot \bar{r}}$$

$$\bar{E}_c = r\bar{E}_s^* = r\hat{\epsilon}_s^* A_s^* e^{-i\bar{k}_s \cdot \bar{r}}$$

$$\rightarrow \quad \tilde{E}_c(r,t) = r\tilde{E}_s(r,-t)$$

< time reversability

Application : Aberration correction!



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2-4 Reflection in plane mirrors

- reflection on x-y plane, the unit vector $\hat{r}$

$$\hat{r}_1 = (x, y, z) \rightarrow \hat{r}_2 = (x, y, -z)$$

(reflection)

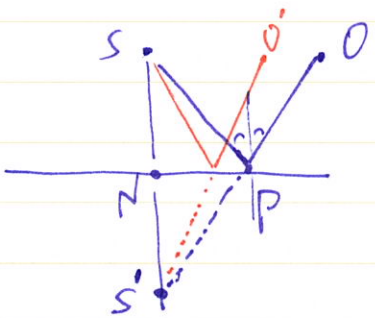
- reflection on all three surfaces (xy, yz, zx planes),
(corner reflection)

$$\hat{r}_1 = (x, y, z) \rightarrow \hat{r}_2 = (-x, -y, -z)$$

; reversed direction

ex) highway reflector.

- Image : for all reflected rays



· $\triangle SNP = \triangle S'NP$

· S : light source / S' : image

· At O, it appears to originate at S' (virtual image)

* the image is located at the point along the surface normal.

* the image point does not depend on the eye.

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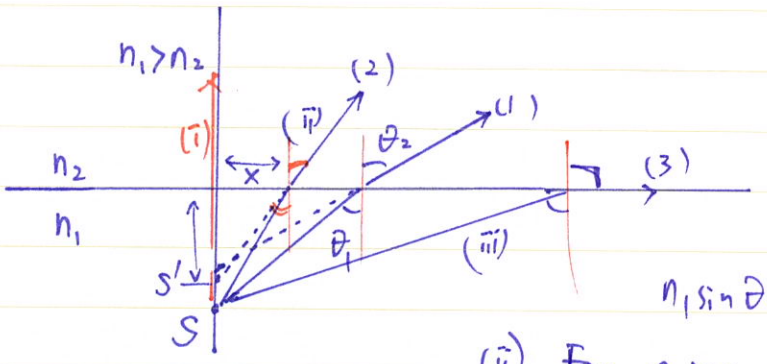
2-5 Refraction through plane surfaces



$n_1 \sin\theta_1 = n_2 \sin\theta_2$

(ii) For $n_1 > n_2$, $\sin\theta_2 > \sin\theta_1$

(i) For normal incidence, $\theta_1 = \theta_2 = 0$

(iii) For $\theta_2 = 90^\circ$, $\sin\theta_1 = \frac{n_2}{n_1} \equiv \sin\theta_c$ (critical angle)

→ rays do not escape!

If $\theta > \theta_c$, total internal reflection.

→ light guiding in an optical fiber

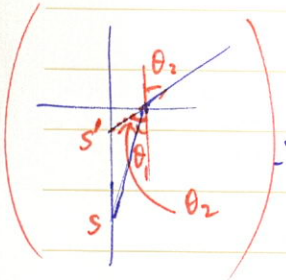
* Image formation varies from angle to angle.

→ for a clear image formation,

$\theta \sim 0$!

→ paraxial rays!

($\sin\theta \checkmark \tan\theta \sim \theta$)



$\therefore n_1 \sin\theta_1 = n_2 \sin\theta_2 \rightarrow n_1 \tan\theta_1 = n_2 \tan\theta_2$

$\rightarrow n_1 \theta_1 = n_2 \theta_1 \rightarrow n_1 \left(\frac{x}{s_1}\right) = n_2 \left(\frac{x}{s'}\right)$

$\therefore s' = \left(\frac{n_2}{n_1}\right) s$ ex) underwater case

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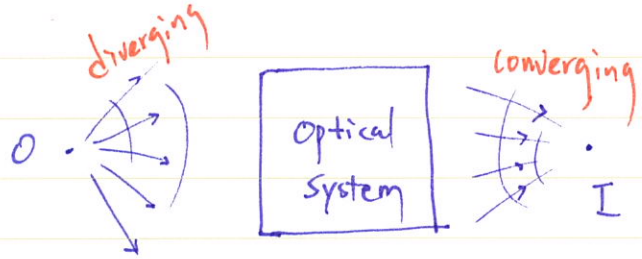
2-6 Imaging by an optical system



- optical system : composed of many reflecting and refracting media,
- Each optical medium : homogeneous and isotropic

A By Fermat's principle,
all rays have the same transit time
for an image at I
→ Isochronous

B. object and image points are reversible.
→ conjugate points for an optical system.

C. In an actual system, the rays are
(i) Scattered
(ii) aberrated
(iii) diffracted
(iv) lost (attenuated)
} results in a deformation.
→ (blurred image)
→ diffraction limited

→ Impossible to set a perfect image!
unless $\lambda \to 0$.
: Wave nature of light!

[2.7 ~ : Ch.18]