Formulas

$n = \frac{c}{c_0}$ $\lambda = \frac{\lambda_0}{n}$ $k = n k_0$ $\lambda = \frac{c}{f}$

Snell

$\theta_i = \theta_r$

$n_1 \sin\theta_i = n_2 \sin\theta_t$

$n_1 < n_2 \Rightarrow \theta_1 > \theta_2$

$n_1 > n_2 \Rightarrow \theta_1 < \theta_2$

↳ total reflec

$\theta_c = \operatorname{asin}\left(\frac{n_2}{n_1}\right)$

Spherical mirror

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{2}{-R} = \frac{1}{f}$$

$R(+)$ if convex

$R(-)$ if concave

Spherical boundaries

$$\frac{n_1}{z_1} + \frac{n_2}{z_2} \approx \frac{n_2 - n_1}{R}$$

$$y_2 = -y_1 \frac{n_1 z_2}{n_1 z_1}$$

Thin lens

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$$

$$y_2 = -\frac{z_2}{z_1} y_1$$

Matrix optics

$y_2 = A y_1 + B\theta_1$

$\theta_2 = C y_1 + D\theta_1$

$$M = \begin{pmatrix} A & B \\ C & D \end{pmatrix}$$

Cascade:

$\rightarrow \boxed{M_1} \rightarrow \boxed{M_2} \cdots \rightarrow \boxed{M_N} \rightarrow$

$$M = M_N M_{N-1} \cdots M_2 M_1$$

Wave optics

$$\nabla^2 u - \frac{1}{c^2}\frac{\partial^2 u}{\partial t^2} = 0$$

wave function

$U(\bar{r}, t) = U(\bar{r})\, e^{j\omega t}$

$u(\bar{r}, t) = \mathrm{Re}\left[U(\bar{r}, t)\right]$

Intensity : $I(\bar{r}, t) = 2\langle u^2(\bar{r}, t)\rangle$

power : $P(t) = \int_A I(\bar{r}, t)\, dA$

A area

Transparent plate

$t(x, y) = e^{-jk_0 n d}$

phase shift $n k_0 d = 2\pi \frac{d}{\lambda}$

Diffraction grating

$$\sin\theta_q = \sin\theta_i + q\frac{\lambda}{\Lambda}$$

if θ_i small

$\sin\theta_i = \theta_i$

$\sin\theta_q = \theta_q$

Interference

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\varphi$

$I_1 = I_2 = I_0$

$I = 4I_0\cos^2(\varphi/2)$

$\varphi = 0 \rightarrow I = 4I_0$ constructive

$\varphi = \pi \rightarrow I = 0$ destructive

$\varphi = \frac{\pi}{3}, \frac{3}{2}\pi \rightarrow I = 2I_0$

Gaussian Beam

- Plane wave

$u(\bar{r}, t) = |A| \cos\left[\omega t - kz + \arg(A)\right]$

$I(\bar{r}) = |A|^2$

- Spherical wave

$U(\bar{r}) = \frac{A_0}{r} e^{-jkr}$

wavefront $r = q\lambda$

$I(\bar{r}) = \frac{|A_0|^2}{r}$

- Paraboloidal

paraxial approx

$$U(\bar{r}) \simeq \frac{A_0}{r} e^{-jkz} e^{-jk\frac{x^2+y^2}{2z}}$$

condition

$$\frac{N_F \theta_m}{4} \ll 1$$

Lens equation

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

u : objects dist. from the lens

V : Image dist. from the lens

f : focal length

Sign conventions

Right of lens → Positive	Above principal axis → Positive
Left of lens → Negative	Below principal axis → Negative

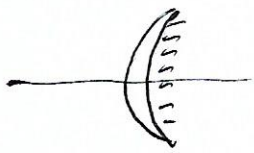
Focal length

Convex lens → Positive

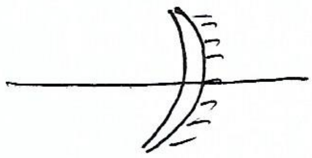
Concave lens → Negative

Mirror equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$



convex



concave