

## Equation Summary

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### Numerical aperture and $f/\#$ :

$$NA = n' \sin u' \qquad f/\# = \frac{f}{EPD}$$

### Rayleigh criterion:

$$\Delta X = \frac{0.61\lambda}{NA}$$

### Image height as a function of field angle:

$$h' = f \tan \theta$$

### Transverse ray error:

$$\varepsilon'_y = \frac{1}{n'u'_a} \frac{\partial W}{\partial \rho_y} \qquad \varepsilon'_x = \frac{1}{n'u'_a} \frac{\partial W}{\partial \rho_x}$$

### Strehl ratio:

$$\text{Strehl} \cong (1 - 2\pi^2\omega^2) \qquad \omega = RMS_{OPD}$$

### Wavefront aberration polynomial:

$$W_{IJK} \Rightarrow H^I \rho^J \cos^K \theta$$

$$W(H, \rho, \theta) = W_{020}\rho^2 + W_{111}H\rho \cos \theta + W_{040}\rho^4 + W_{131}H\rho^3 \cos \theta \\ + W_{222}H^2\rho^2 \cos^2 \theta + W_{220}H^2\rho^2 + W_{311}H^3\rho \cos \theta + O(6)$$

### Contrast:

$$\text{Contrast} = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

## Equation Summary

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### Focal lengths of any two thin lens system:

$$f_a = \frac{d f}{f - BFL} \quad f_b = \frac{d BFL}{f - BFL - d}$$

### Zero-Petzval solution for two thin lenses:

$$f_a = -f_b = f - BFL \quad d = \frac{(f - BFL)^2}{f}$$

### Two-mirror solution:

$$c_1 = \frac{BFL - f}{2d f} \quad c_2 = \frac{BFL + d - f}{2d BFL}$$

### Schwarzschild solution:

$$d = 2f \quad c_1 = (\sqrt{5} - 1)f \quad c_2 = (\sqrt{5} + 1)f$$

### Aplanatic condition:

$$i = -u'$$

### Bending and shape factors:

$$\beta = \frac{c_1 + c_2}{c_1 - c_2} \quad C = \frac{u_a + u'_a}{u_a - u'_a}$$

### Thin lens bending for minimum spherical:

$$\frac{c_2}{c_1} = \frac{2n^2 - n - 4}{n(2n + 1)}$$

## Equation Summary

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### Thin lens bending for minimum coma:

$$\frac{c_2}{c_1} = \frac{(n^2 - n - 1)}{n^2}$$

### Achromatic doublet:

$$\Phi = \phi_1 + \phi_2 \quad \phi_1 = \Phi \frac{V_1}{V_1 - V_2} \quad \phi_2 = -\Phi \frac{V_2}{V_1 - V_2}$$

### Petzval sum:

$$\sum_j \frac{\phi_j}{n_j}$$

### Thick lens power:

$$\phi = \phi_1 + \phi_2 - \frac{t}{n} (\phi_1 \phi_2)$$

### Minimum clear aperture for no vignetting:

$$CA_{\min} = |y_a| + |y_b|$$

### Aspheric sag equation:

$$sag = z(r) = \frac{cr^2}{1 + \sqrt{1 - (\kappa + 1)(cr)^2}} + dr^4 + er^6 + fr^8 + gr^{10} + \dots$$

### Gradient index profiles:

$$n(r) = N_{00} + N_{10}r^2 + N_{20}r^4 + \dots$$

$$n(z) = N_{00} + N_{01}z + N_{02}z^2 + \dots$$

## Equation Summary

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**Merit function:**

$$\phi = \sum_{i=1}^m w_i^2 (c_i - t_i)^2$$

**Athermalization condition:**

$$\frac{df_{Lens}}{dT} = CTE_1 d_1 - CTE_2 d_2$$

**Bireflectance scattering distribution function:**

$$BSDF(\theta_i, \phi_i; \theta_o, \phi_o) = \left(\frac{L}{E}\right) sr^{-1}$$

**Sellmeier dispersion:**

$$n(\lambda) = \sqrt{1 + \frac{c_1 \lambda^2}{\lambda^2 - c_4} + \frac{c_2 \lambda^2}{\lambda^2 - c_5} + \frac{c_3 \lambda^2}{\lambda^2 - c_6}}$$

**Schott dispersion:**

$$n(\lambda) = \sqrt{c_1 + c_2 \lambda^2 + \frac{c_3}{\lambda^2} + \frac{c_4}{\lambda^4} + \frac{c_5}{\lambda^6} + \frac{c_6}{\lambda^8}}$$

**Snell's law:**

$$n \sin \theta = n' \sin \theta'$$

**Paraxial ray tracing:**

$$\begin{aligned} n' u' &= nu - y\phi \\ y' &= y + n' u' \left(\frac{d}{n'}\right) \\ \phi &= c(n' - n) \end{aligned}$$

## Equation Summary

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### Lens maker's equation and linear magnification:

$$\frac{1}{s'} = \frac{1}{f} + \frac{1}{s} \qquad m = \frac{h'}{h} = \frac{f}{s+f}$$

### Thin lens power:

$$\Phi = \frac{1}{f} = (c_1 - c_2)(n - 1)$$

### Diffraction gratings:

$$m\lambda = d[\sin(\theta_m) - \sin(\theta_i)] \qquad \lambda_{blaze} = 2d \sin \alpha$$

### Sampling ratio:

$$Q = \frac{\lambda(f/\#)}{\text{pixel pitch}}$$

### Lagrange invariant and étendue:

$$H = n \bar{u} y - n u \bar{y} \qquad n^2 A \Omega = \pi^2 H^2$$

$$Etendue = \iint_{\text{surface}} dA a \Omega$$

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