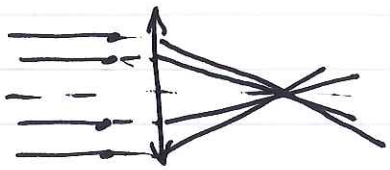
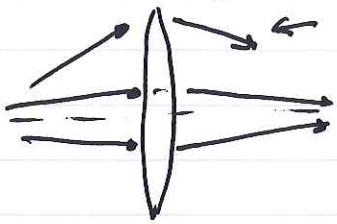
Ideal lens vs Real lens



Ideal lens changes the beam direction without any displacements independently on where the beam hits the lens.

Thin lens — thickness is negligible

Paraxial approximation: the beams travel close to the optical axis, the angles involved are small



← non-paraxial beams.

paraxial beams

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ Snell's law

Paraxial approximation $\sin\theta \approx \theta$ (rad)

In reality $\sin\theta \approx \theta - \frac{\theta^3}{6} + \frac{\theta^5}{5!} - \dots$

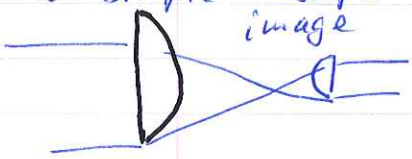
Larger angle — more ~~imperfe~~ deviation from an ideal thin lens.

from observations: what is wrong with a simple telescope

Flat surface looks spherical

Color distortions

Only the center is in focus.



Distortions — lens aberrations

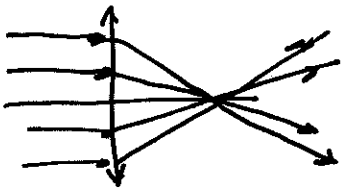
monochromatic (for each color)

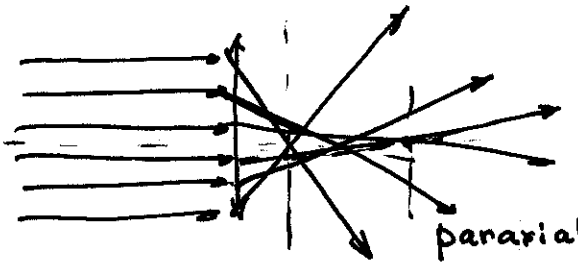
chromatic (different behavior for different colors)

clarity of an image

distortions → spherical curvature barrel / pincushion distortions

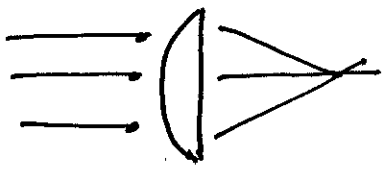
1. Spherical aberration



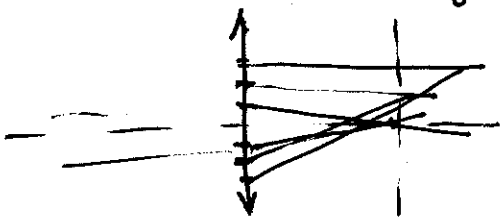


The larger is the distance b/w F_P and F_M, the larger is spherical aberration.

Life tip: for a plano-convex lens put a curves surface toward flat wavefront

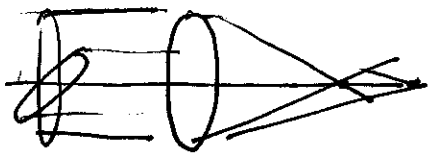


2. Coma - different sections of a lens focus at different height



♀

3. Astigmatism



Dispersion: refractive index of a material depends on light & wavelength (frequency)

Refraction law: air - glass $\sin\theta_1 = n_g(\lambda) \sin\theta_2(\lambda)$

Different wavelengths are focussed differently, distorting the colors

How to avoid these problems?

1. Restrict the size of the lens (better paraxial approximation), but dimmer images) — helps with some monochromatic aberrations

2. Use multiple lens compounds instead of a single lens (the parameters of the lenses can be optimized to minimize aberrations)

3. Use achromatic doublets — a pair of positive and negative lenses made out of different type of glass with different dispersion to correct chromatic aberrations

4. Use aspherical lens — specially designed lens shape to minimize aberrations.