Vision



By Anette Smith Burgess, Opthamological Illustrator (Student of Max Broedel, John's Hopkins)

Straight Photography



Image Formation in a Single Lens



What is Light?

- Some useful ways to think of light:
 - Rays of light
 - Waves of light
 - Electromagnetic radiation that has both wavelike and particle-like properties, containing quanta of light: photons

What can happen to light?

- Refraction
- Reflection
- Diffraction
- Scattering
- Absorption

Image Formation in the Eye





Refractive Index map



Anatomy of the Eye



Phototransduction



Bipolar Cells



SEM of rods and cones



The Optic Nerves



Photographic Camera





Camera objectives contain many different lenses that act together as a single next-to-perfect lens

This is necessary to correct for optical aberrations

The Stereo Image



Optical Aberrations

 Aberrations deteriorate image quality. Lens systems are designed to mimic a single, ideal, infinitely thin lens.



Refraction in a single Lens



Fermat's Principle

Light travels between two points along the path that requires the least time, as compared to other nearby paths



(Fermat = French mathematician, 1600s)

Law of Reflection $\theta_1 = \theta_2$



Snell's Law (Refraction) $n_1 \sin \theta_1 = n_2 \sin \theta_2$



Total Internal Reflection

$n_1 \sin \theta_c = n_2$ Critical Angle

Geometrical Ray Optics

Three Principal Rays:



"4f system"



Magnification



M = f / (f - v)













Magnifying glass and loupe





IT'S BREAK TIME



Lens-Maker's Equation

$$\frac{1}{F} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

- F = focal length (1/2 C)
- n = refractive index
- R = radius of curvature



Positive (Converging) Lens

- R_1 positive
- R_2^- negative
- F positive



Negative (Diverging) Lens

- R_1 negative
- R_2 positive
- F negative

Spherical Aberration



Spherical Aberration



Aspherical Lenses



Earliest preserved optical quality lenses (~10th century Visby, Sweden)

Spherical mirror



Caustic Curve



Spherical aberration in a cup of tea

Parabolic Reflector





Parabolic Reflector

The Fresnel Lens





Fresnel Lenses



John Ford using a 24" Fresnel lens shooting John Wayne

Fresnel lens in lighthouse

Refraction in a Prism



Visible Light Wavelength Spectrum



Refractive index ~ wavelength



Chromatic Aberration



Achromatic Doublet



First lens: Crown glass Second lens: Flint glass



Field Curvature



Coma



Correcting Coma



Simple Lenses



Single Element Spherical Lenses

Depth of Field/Focus

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Large depth of field

Small depth of field

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Circle of Confusion



Small aperture = more DOF



Large aperture = less DOF



Did I use a small or large aperture here?



Monarch butterfly (Danaus plexippus) on its favorite food, the milkweed plant

"Bokeh" 暈け



Say's Phoebe (*Sayornis saya* named after the American naturalist Thomas Say) in Moore Creek Preserve shot at F# 2.8

Extremely small aperture



GROUP

(ANSEL EASTON ADAMS IMOGEN CUNNINGHAM JOHN PAUL EDWARDS SONYA NOSKOWIAK HENRY SWIFT WILLARD VAN DYKE EDWARD WESTON)

ANNOUNCES AN EXHIBITION OF PHOTOGRAPHS AT THE M.H. DEYOUNG MEMORIAL MUSEUM FROM NOVEMBER FIFTEENTH THROUGH DECEMBER THIRTY-FIRST, NINETEEN THIRTY-TWO

Ansel Adams shooting in the High Sierra

F#("F-number") = f/D

Determined by ratio of lens focal length f and lens aperture Diameter D



$$f/1 = f/(\sqrt{2})^0$$
, $f/1.4 = f/(\sqrt{2})^1$, $f/2 = f/(\sqrt{2})^2$, $f/2.8 = f/(\sqrt{2})^3$..

Again.

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F# also affects resolution (we will talk about this next time)

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High resolution

Low resolution

Next time, we will also talk about two-lens imaging systems

- Modern microscopes use this layout
- Possible to control both field and aperture stop

First Homework is due Thursday!

- Homework is due at the beginning of class
- If you cannot attend class on Thursday, please email me the homework (same deadline)



(Straight photography vegetables, shot by Edward Weston, F64 group)