Geometric optics

Erika Balog

Why?

- endoscopy, refractometry
- light microscope
- optics of the eye

How?

Propagation of light

Geometric optics:
if: size of the object >> λ
light ray (light beam)

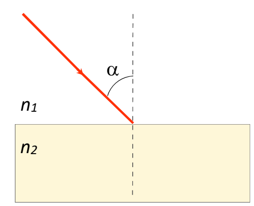
Wave optics:
if: size of the object ~ λ
wave

Geometric optics

light ray (light beam):

c_{vacuum}= 2,9979 x 10^8 m/s

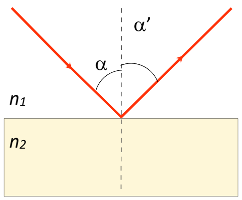
$$n_1 = \frac{c_{vacuum}}{c_1}$$



Fermat's principle – principle of the least time:

light follows the path that can be covered in the least time

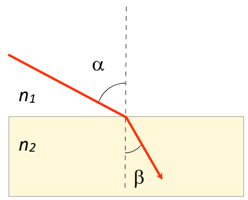
Reflection



- the incident and reflected beams and the axes of incidence are in the same plane.

α=α'

Refraction



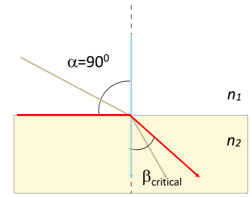
$n_2 > n_1$

- the incident and refracted beams and the axes of incidence are in the same plane.

Snell's law: $\frac{sin\alpha}{sin\beta} = \frac{c_1}{c_2} = \frac{n_2}{n_1} = n_{21}$

Dispersion: the index of refraction depends on the wavelength

Critical angle – total reflection (I)



$n_2 > n_1$

Snell's law:

$$n_1 sin\alpha = n_2 sin\beta$$

$$n_1 sin(90^0) = n_2 sin\beta_{critical}$$

$$sin(90^0) = 1$$

$$n_1 = n_2 sin\beta_{critical}$$

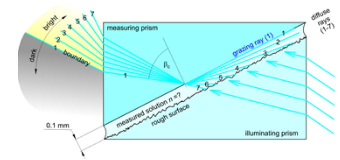
n_2 and $\beta_{critical}$ known ⟶ n_1

Application: refractometry

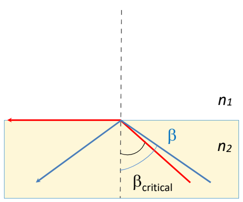
- to determine the concentration of dilute solution

$$n_1 = n_0 + k \cdot c$$

Conditions of applicability:
- dilute solution,
- transparent sample
- refractive index of the sample is smaller than that of the measuring prism.



Critical angle – total reflection (II)



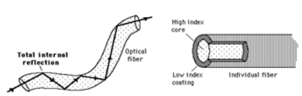
$n_2 > n_1$

Principle of reversibility: the direction of propagation (arrows) may be reversed.

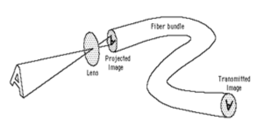
if: $\beta > \beta_{critical}$ ⟶ total reflection

Application: optical fibers

Single fiber



Fiber bundle



- if the arrangement of the fibers is mantained within the bundle, then the image is faithfully transmitted.

Critical angle – total reflection (III)

Medical application: ***endoscopy***

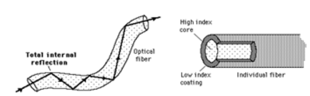
OBJECTIVES

1. Diagnostics: visual inspection, biopsy, contrast agent delivery
2. Therapy: surgery, cauterization, removal of foreign

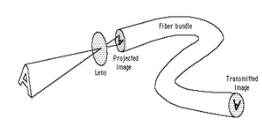
TYPES

Arthroscopy (joints); *Bronchoscopy* (trachea and bronchi); *Colonoscopy* (colon); *Colposcopy* (agina and cervix); *Cystoscopy* (urinary bladder, urethra uterus, prostate via urethra); *ERCP* (endoscopic retrograde cholangio-pancreatography, delivery of X-ray contrast agent into biliary tract and pancreatic duct) ; *EGD* (Esophago-gastroduodenoscopy, upper GI tract); *Laparoscopy* (stomach, liver, female gonads via abdominal wall); *Laryngoscopy* (larynx); *Proctoscopy* (rectum, sigmoidal colon); *Thoracoscopy* (pleura, mediastinum and pericardium via chest wall).

Single fiber

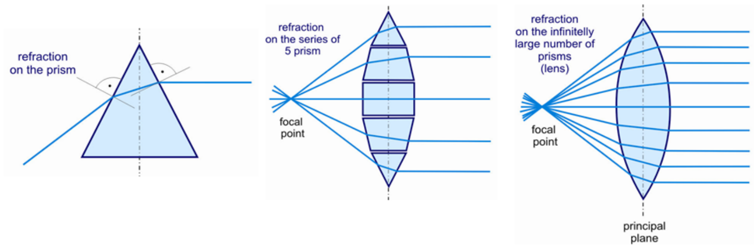


Fiber bundle



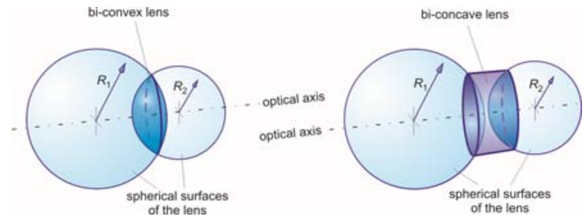
- if the arrangement of the fibers is mantained within the bundle, then the image is faithfully transmitted.

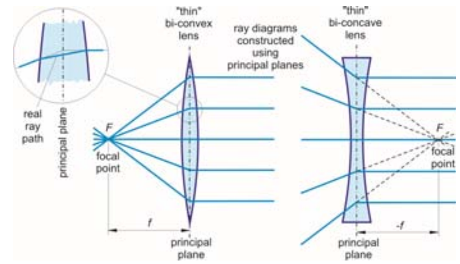
Optical lenses



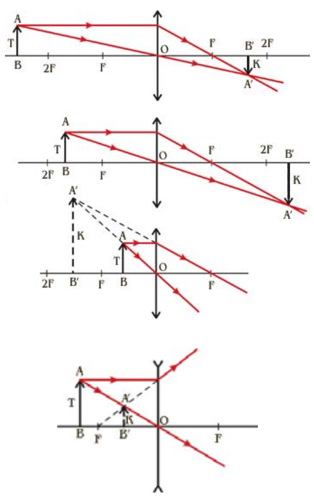
- optical lenses refract light as prisms do. Snell's law can be applied in the same manner.

Optical lenses

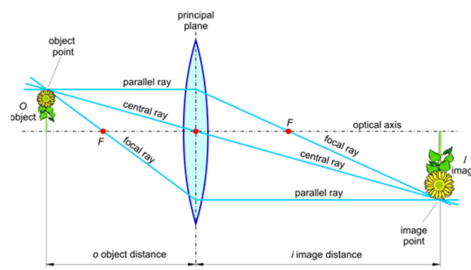




Optical lenses: imaging – principal rays



Optical lenses: imaging – lens equation



The lens equation $\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$

Magnification $M = \frac{I}{O} = \frac{i}{o}$

D – optical power (diopter, m^{-1}) $D = \frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

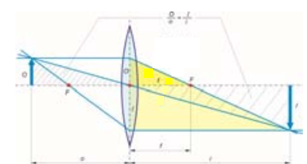
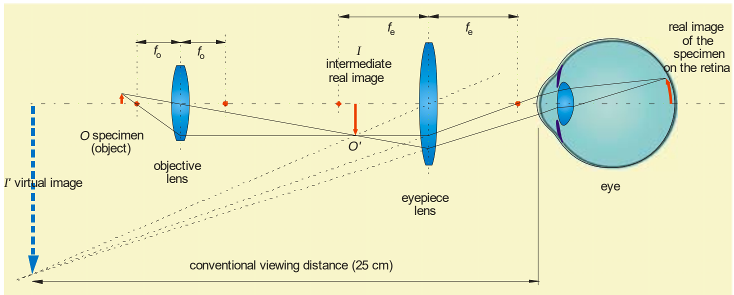
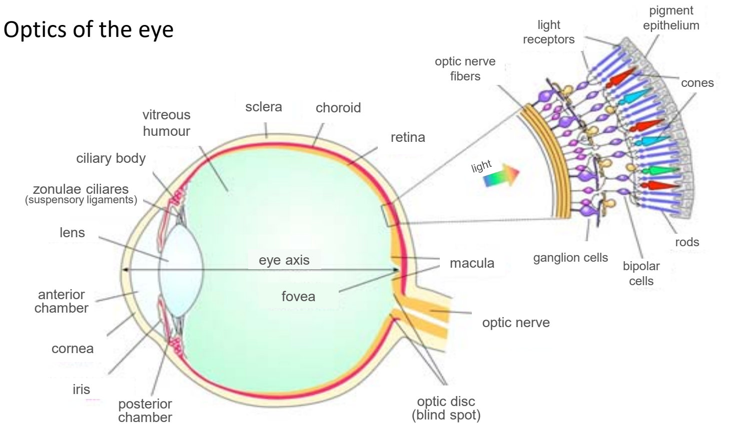


Image formation of the microscope

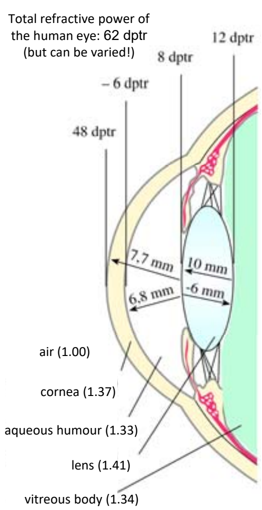


Magnification of the microscope: $M_{micr} = \frac{I'}{O} = \frac{I'}{O'} \cdot \frac{O'}{O} = M_{obj} \cdot M_{eyep}$ (with $\frac{I'}{O'} = M_{eyep}$, $\frac{O'}{O} = M_{obj}$)

Optics of the eye

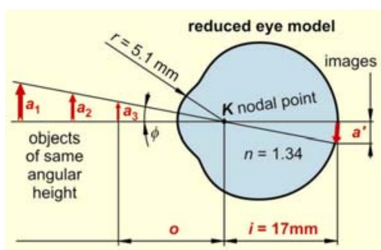


Horizontal section of the human eye



Refractive power of surfaces (D, dptr):

$D = \frac{n - n'}{R}$ — n-n' - refractive index difference of bounding media (air, cornea, etc.). R - radius of curvature of refractive surface.



Inverted, diminished image is formed on the retina.

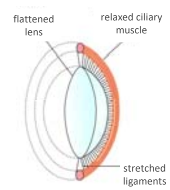
Accommodation: adaptation of the eye's refractive power to the object distance.

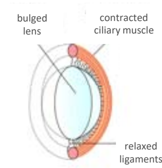
$$D = \frac{1}{o} + \frac{n'}{i}$$

$$D = \frac{1 - n'}{R}$$

Farsight: *o increases* ⟶ *D decreases* ⟶ R increases

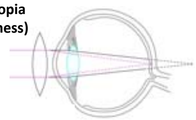
Nearsight: *o decreases* ⟶ *D increases* ⟶ R decreases





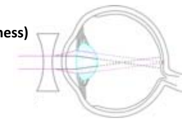
Refraction problems:

Hypermetropia (farsightedness)



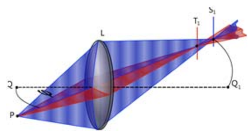
- shortened eyeball.
- correction with convergent lens.

Myopia (nearsightedness)



- elongated eyeball.
- correction with divergent lens.

Astigmatism: focal distance is different in the horizontal and vertical plane.

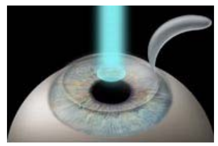


Correction with cylindrical lens.

Presbyopia:

- Accommodation power decreases (R!).
- Manifests with age (>45 years).
- Nearsight worsens.

Permanent correction of refractive problem: LASIK (Laser Assisted In Situ Keratomileusis



The radius of curvature of the cornea is changed (with laser surgery).

Feedback:

http://report.semmelweis.hu/linkreport.php?qr=LAW5VBL3EJU15WLD

PIN code: WEP