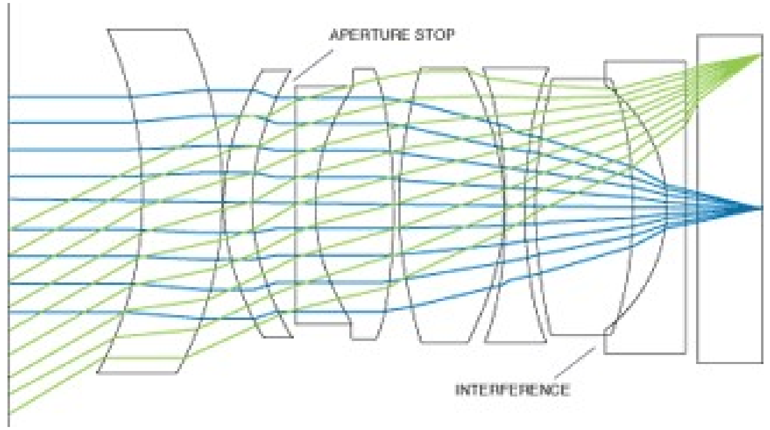
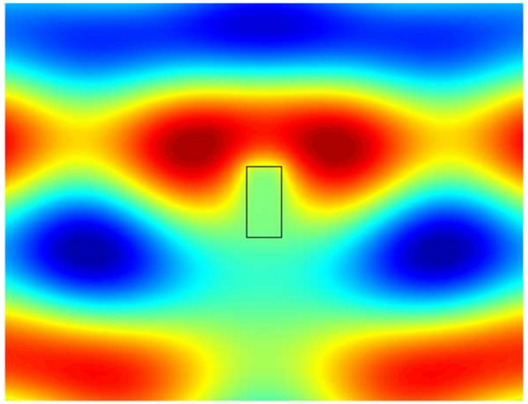
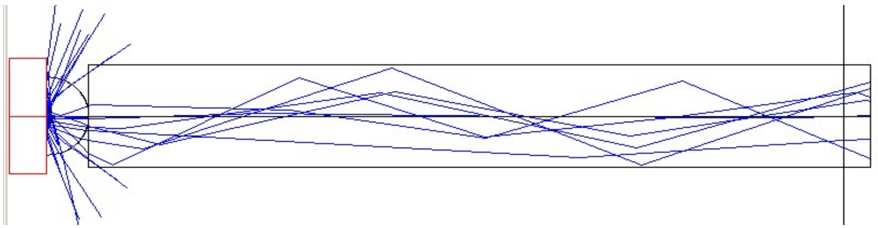
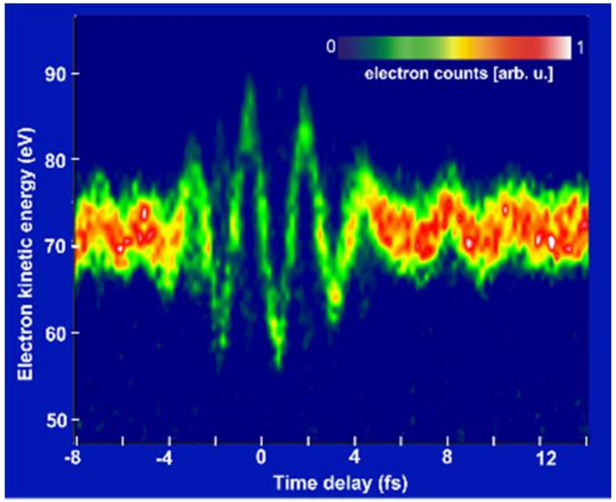
Optics

Investigates phenomena of the creation, detection and propagation of light









Historical light models

Euclide: Optics (BC.280) **Light is emitted by the eye**

Alhazen: (11th century, Bhagdad)

Light emitted by light sources, eye is a detector

Déscartes: (1637 La dioptrique)

Light: particles moving in „ether”

Laws of reflection and refraction (Snell's law, **)**

Huygens (1679) **Light is an elasthic wave of „ether”**

Newton (1704 Opticks)

Light: particles moving like mechanical objects

Dispersion observed, color~ size of particle

Composition of white light

Newton's rings

Fermat: (18th century)

Principle of shortest propagation distance (time)

Young (1802): **Double slit experiment, wave explanation**

Fresnel (1819) **Wave theory of light**

Maxwell: (1862) **EM wave theory of light**

Michelson & Morley: (1881) **There is no „ether”,**

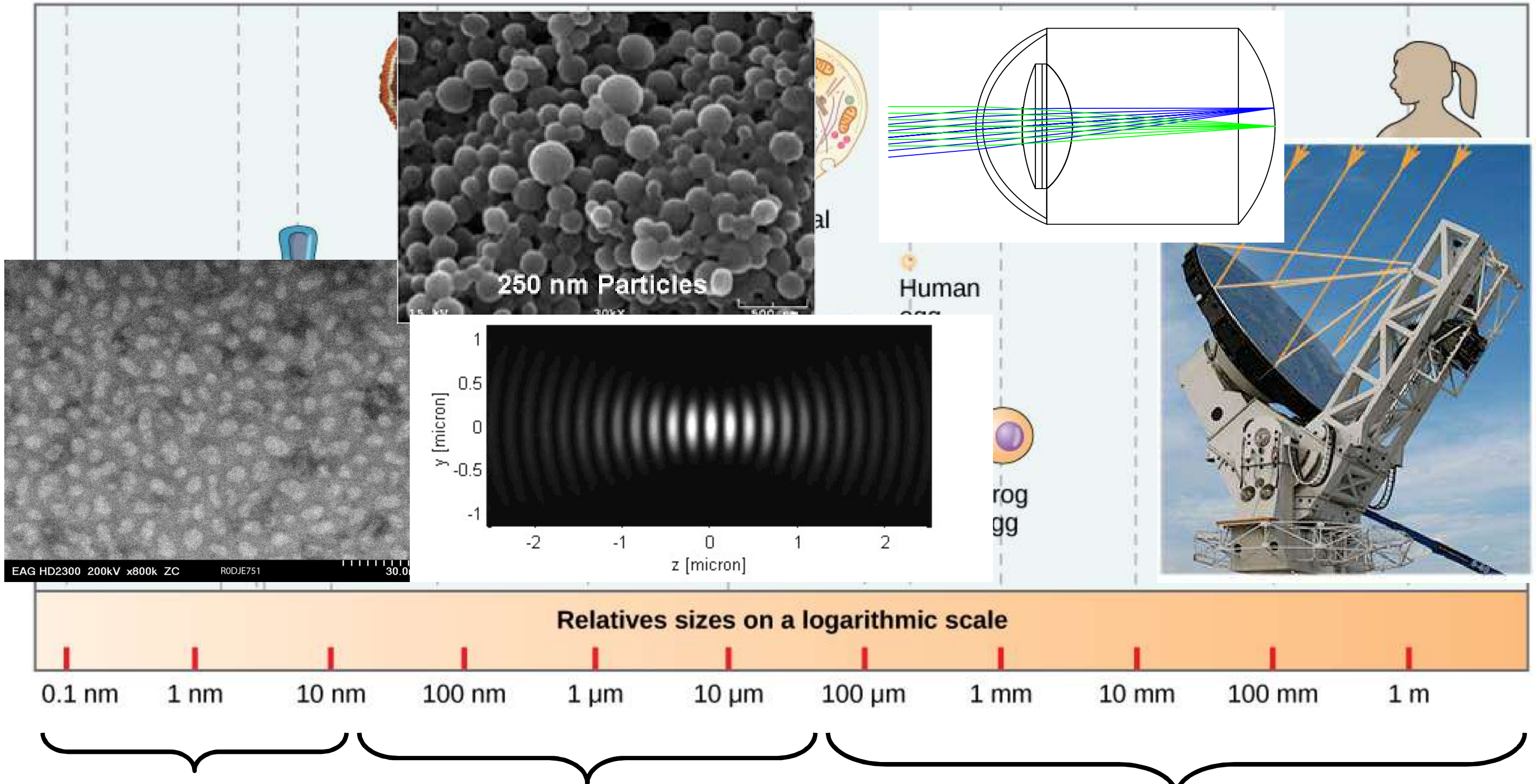
c is independent of coordinatte system

Planck (1900) **Black body radiation, energy quanta**

Einstein (1905) **Photoelectric effect, light particles, photons**

Today: **Dual nature of light (and of matter)**

Modern light models

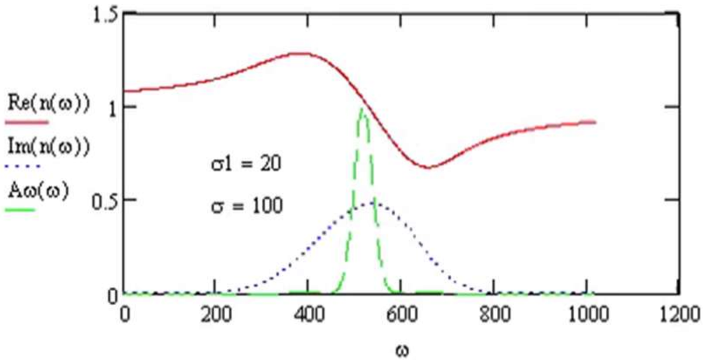


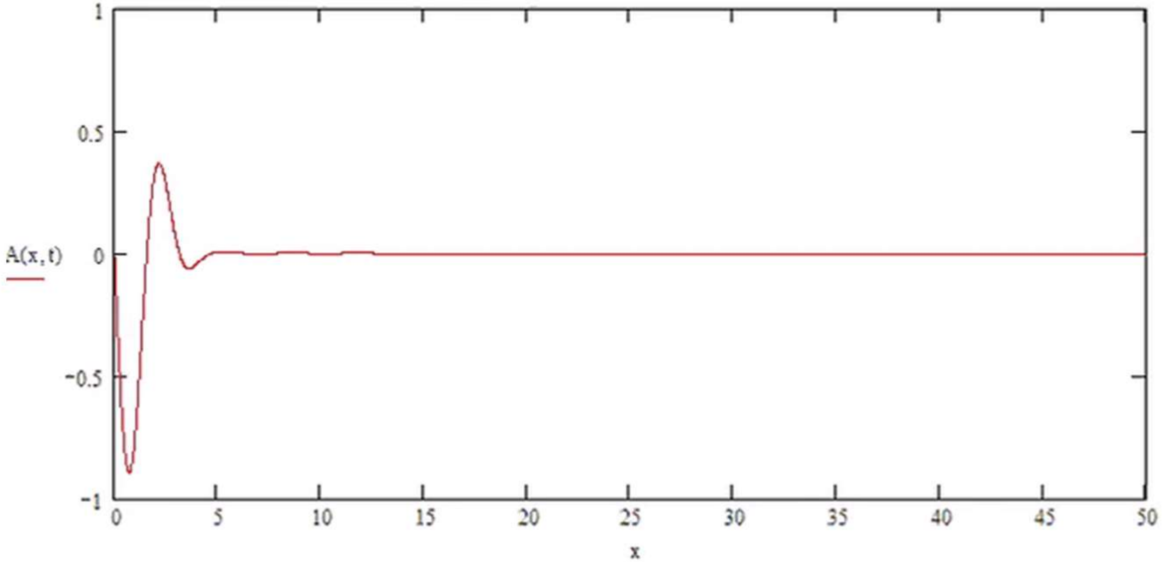
- Quasistatic approximation
- Dipolar (Rayleigh) scattering
- Quantum effects!
- Interactions!

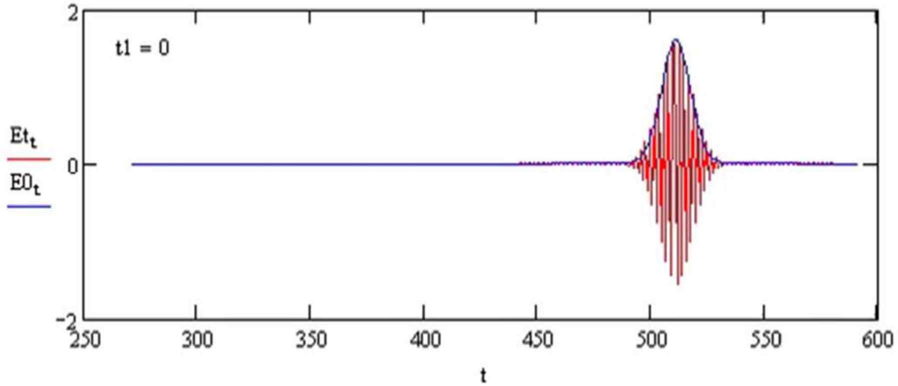
- Rigourous methods (RCWA, FEM, FDTD)
- Right approximations (Born, Green functions…)

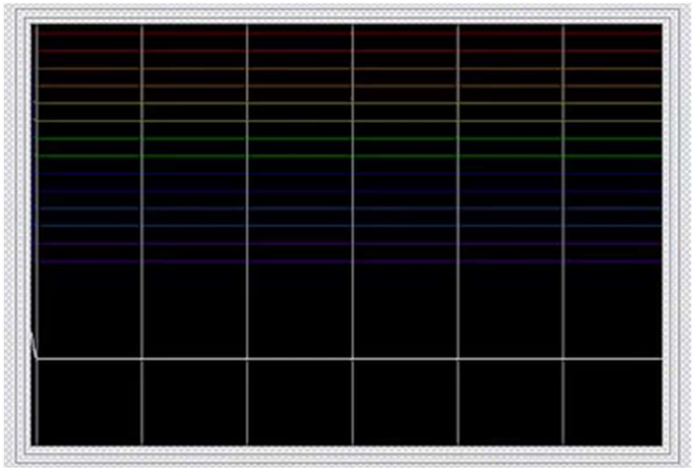
- Ray tracing
- Scalar diffraction

Wave dispersion

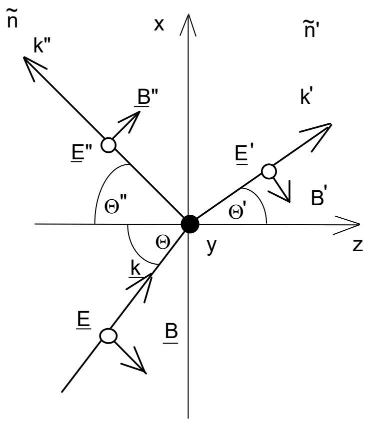




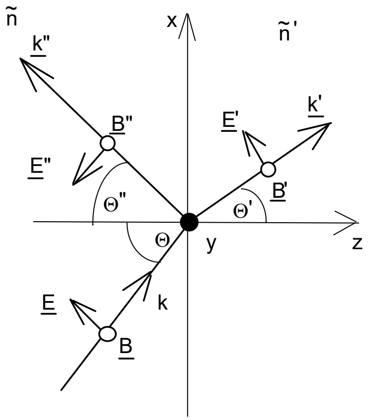




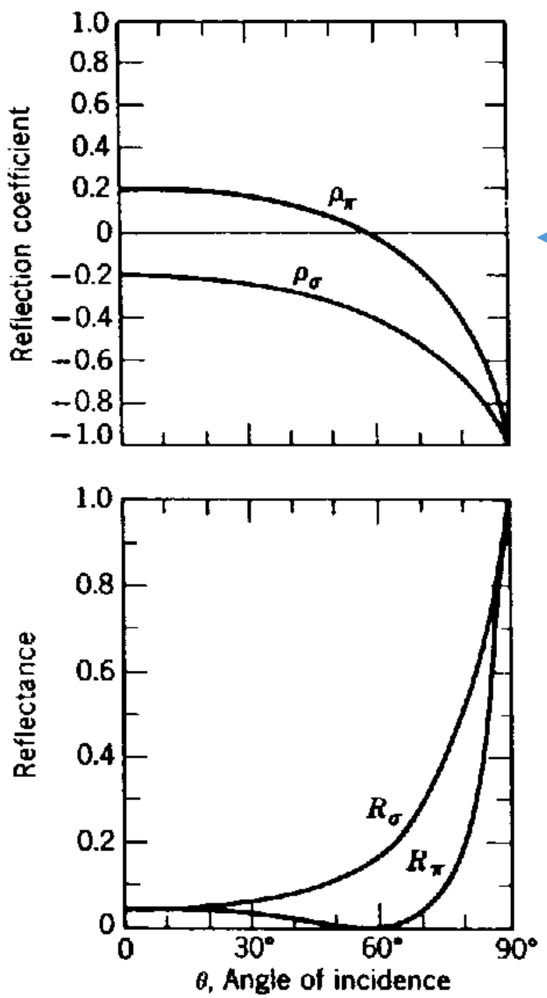
Reflection on a planar interface



S or σ polarization, TE

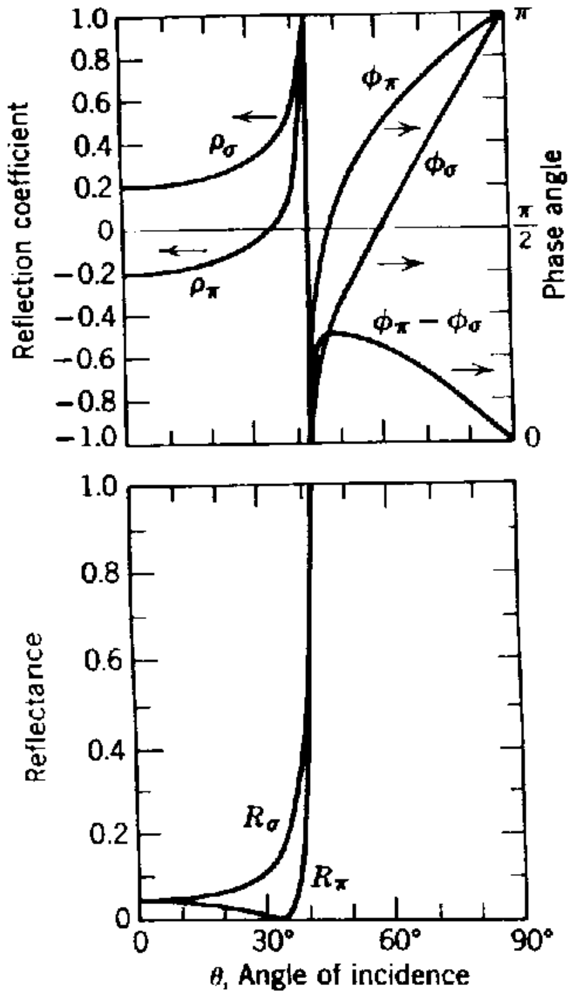


P or π polarization, TM



$n_2 < n_1$

$n_2 > n_1$



Total Internal Reflection

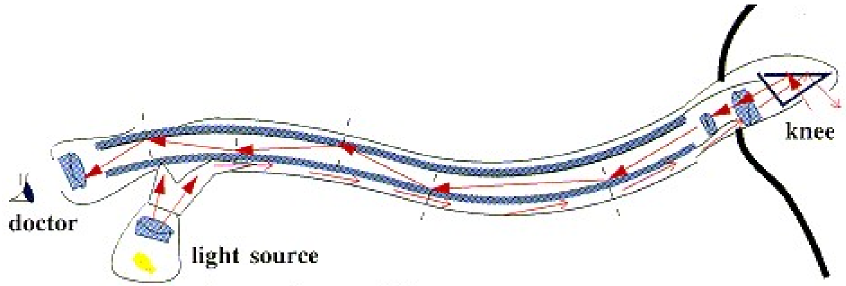
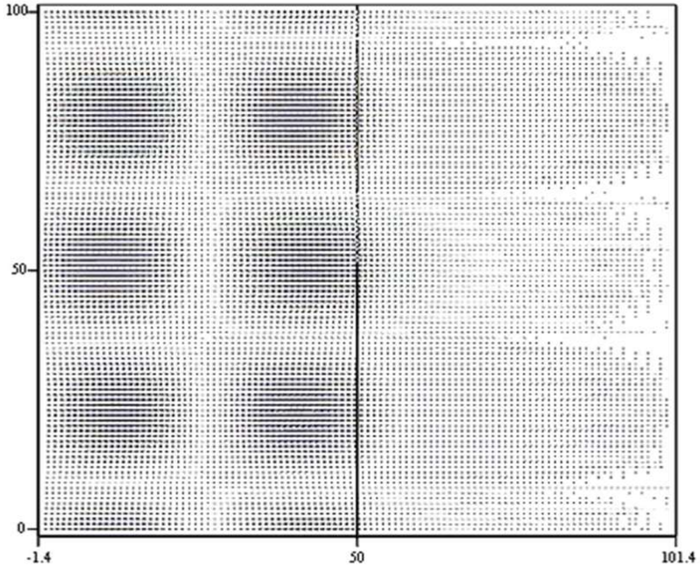
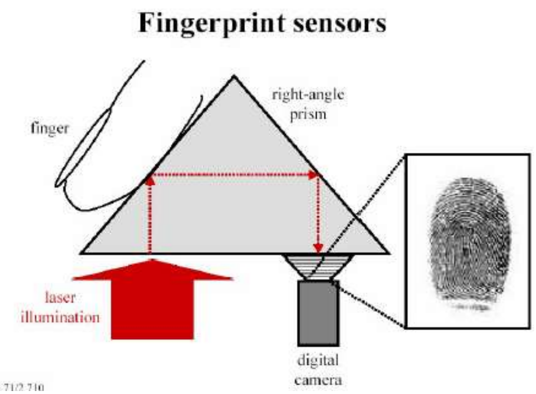
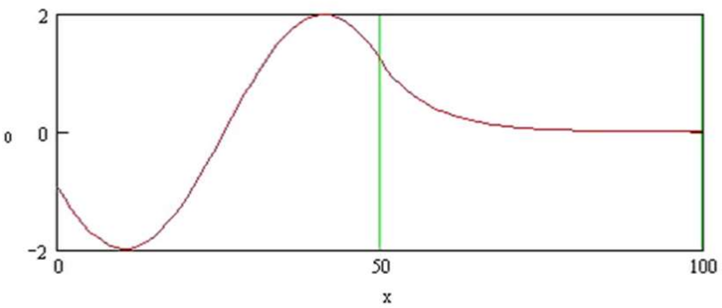
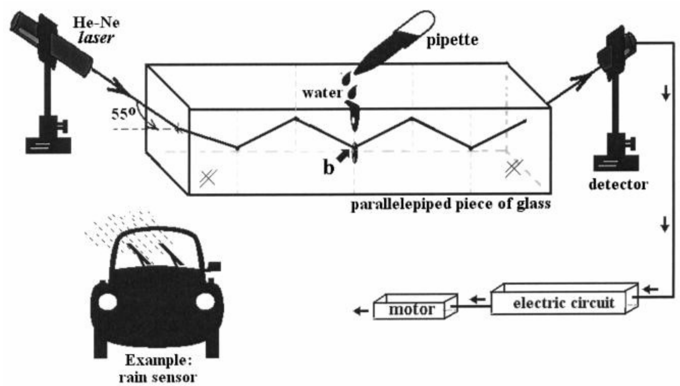


Diagram 7: Medical use of optical fibres

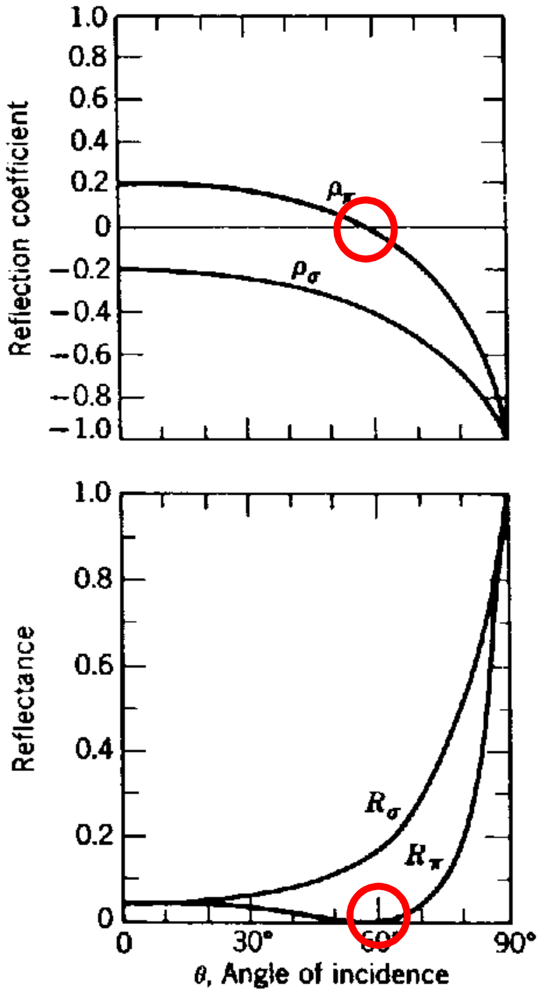








Brewster effect



Polarized sunglasses
Brewster window
Polarizing beam splitter

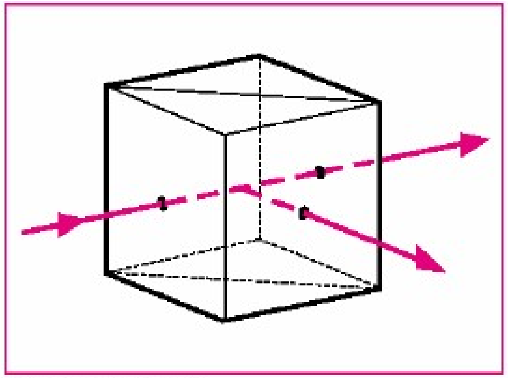
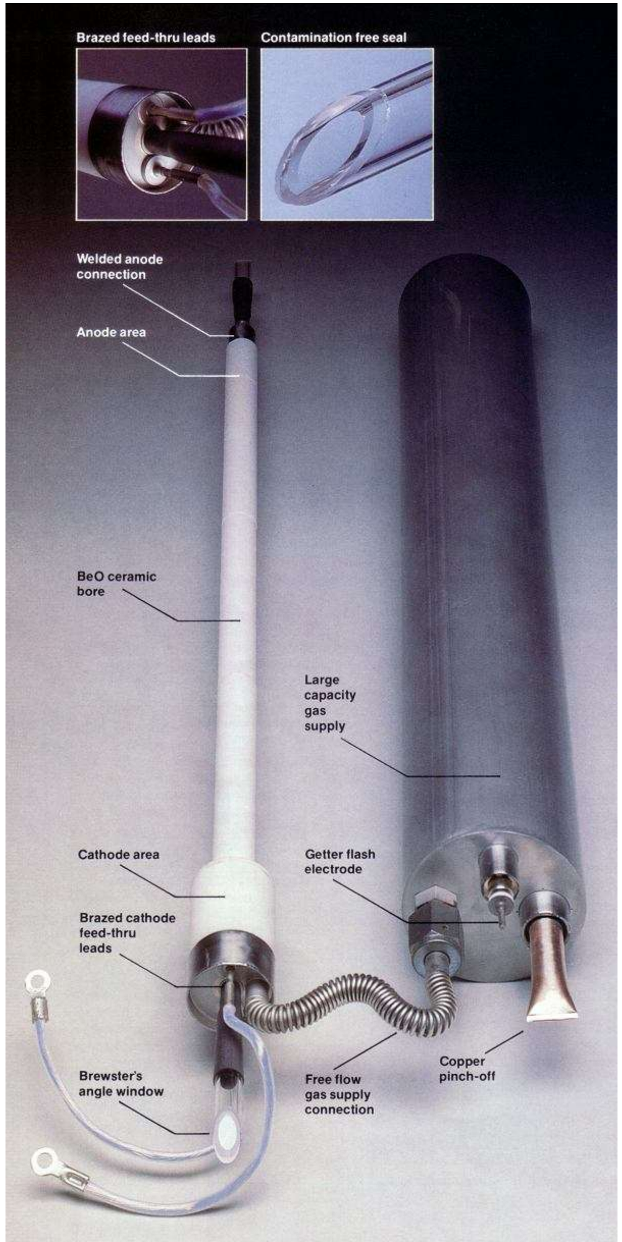
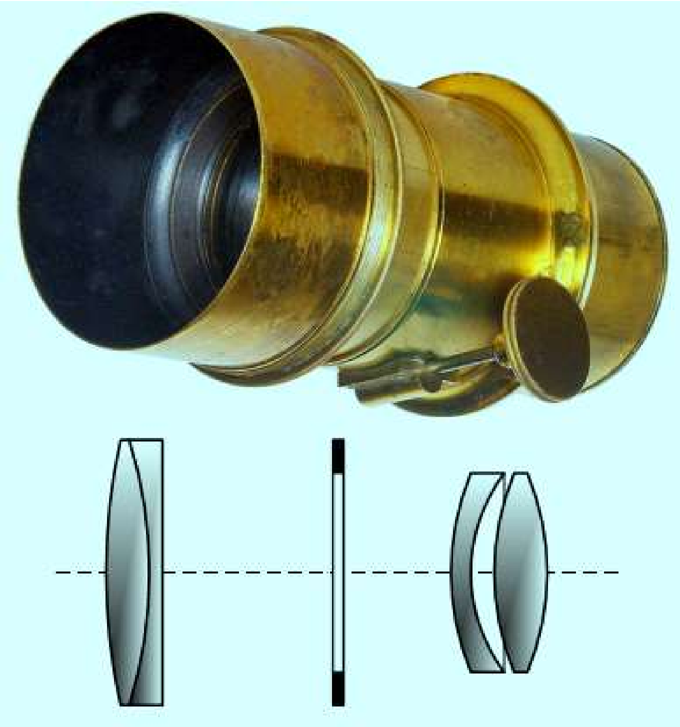


Fig. 1 Beam Splitter Cube.

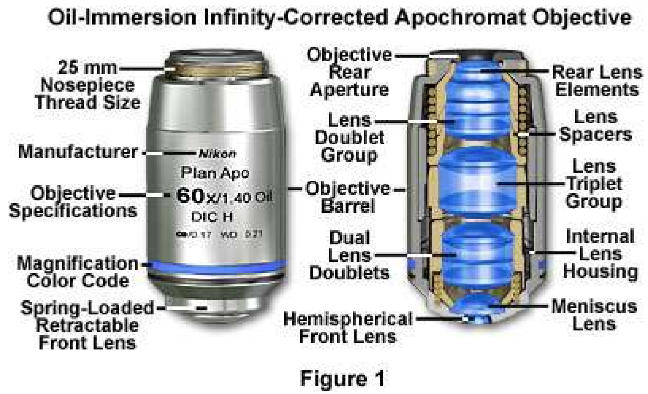


Ray tracing



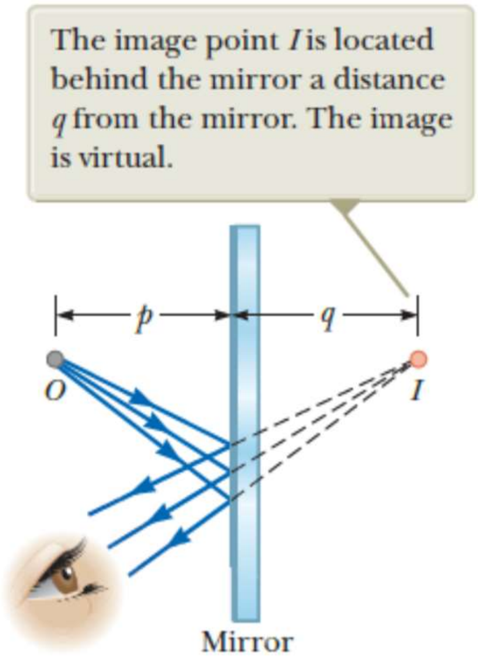
Petzval lens, the first photographic portrait objective lens
Calculated by 8 artillery gunners and 3 corporals using ray tracing. ~ 1 year. Today: ~1 minute of CPU time

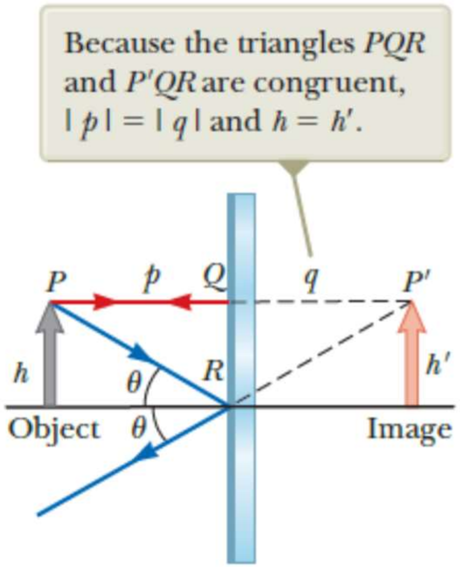
Microscope objective

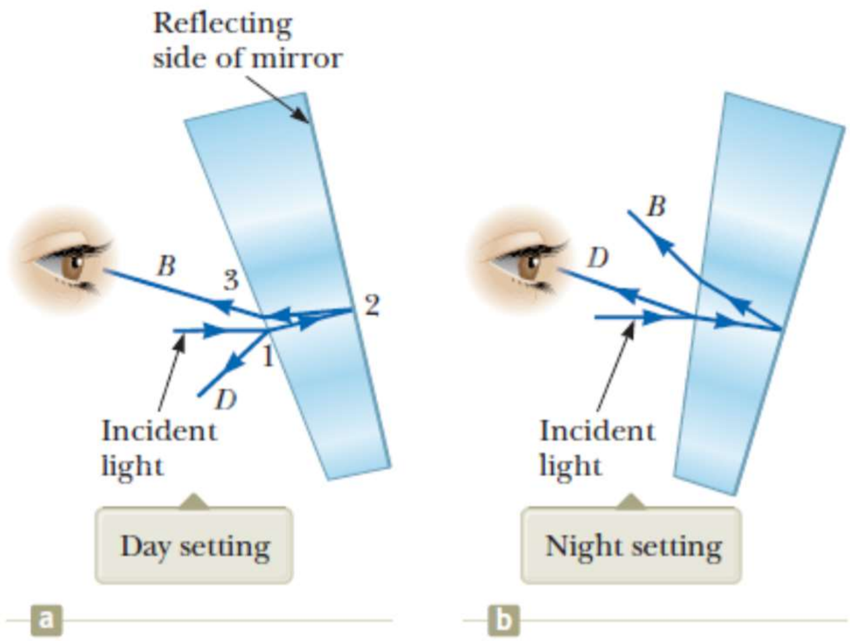


Lithographic system

Image Formation of a plane mirror

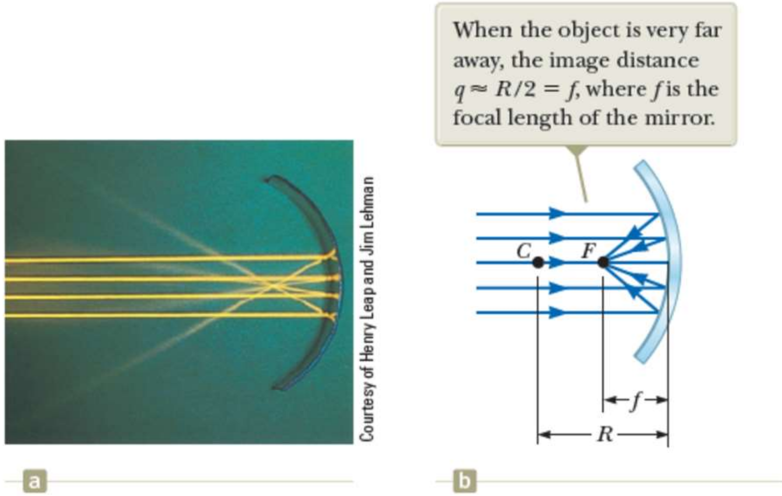


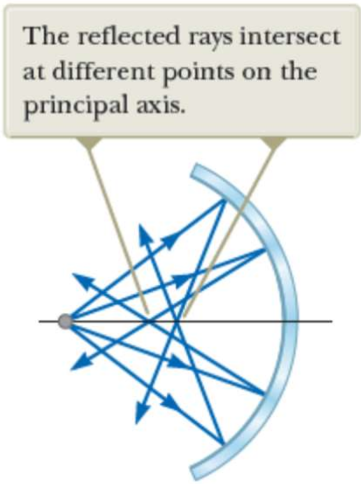




The image in the mirror is reversed front to back, which makes the right hand appear to be a left hand.

Images Formed by Spherical Mirrors





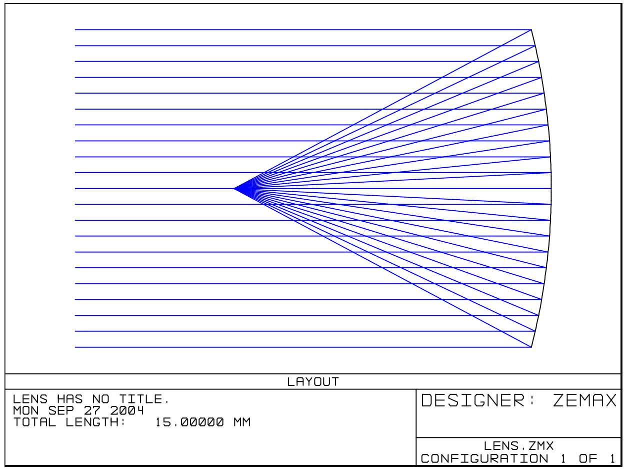
- Spherical aberration
- Coma, Astigmatism etc…
- Chromatic aberrations

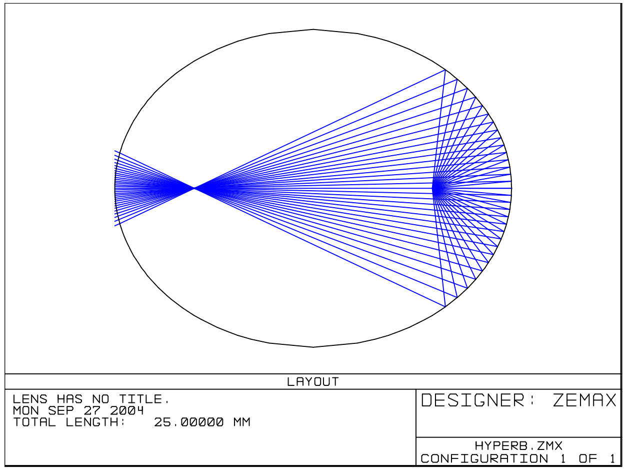
- Paraxial optics

Parabolic surfaces: eliminate spherical aberration

▪ Stigmatism: point-to point Imaging ▪

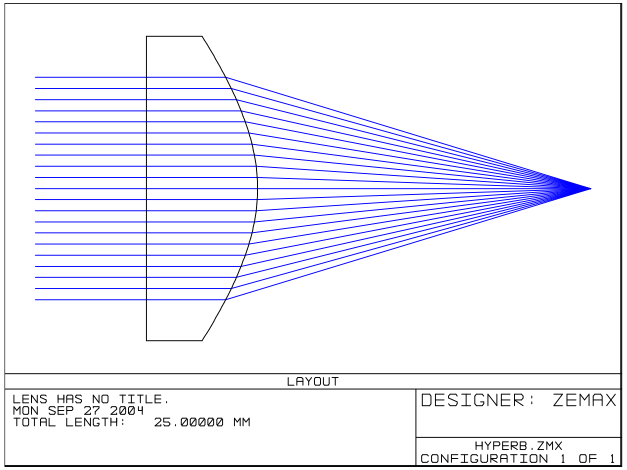
Parabolic mirror

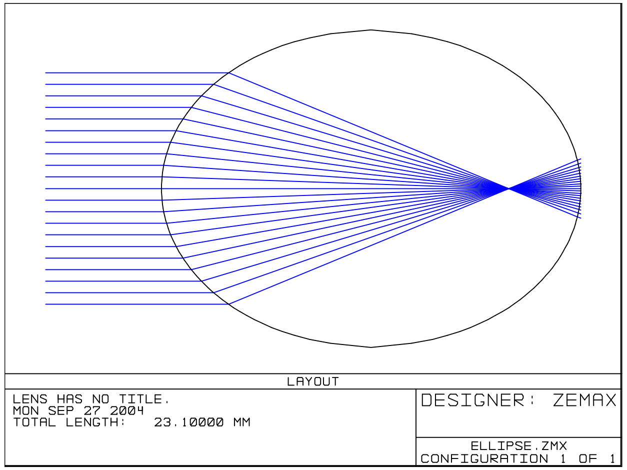




Elliptical mirror

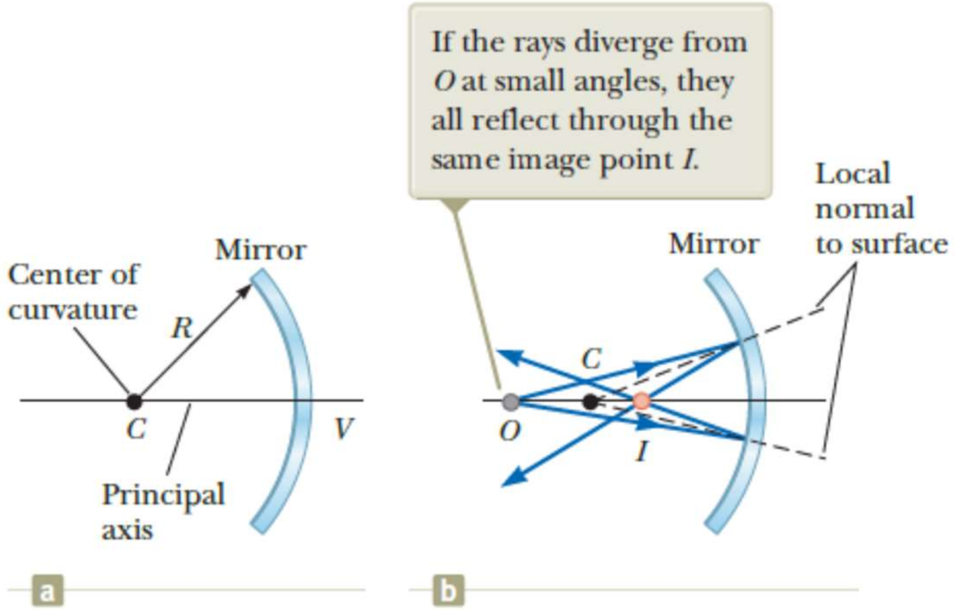
Hiperbolic lens

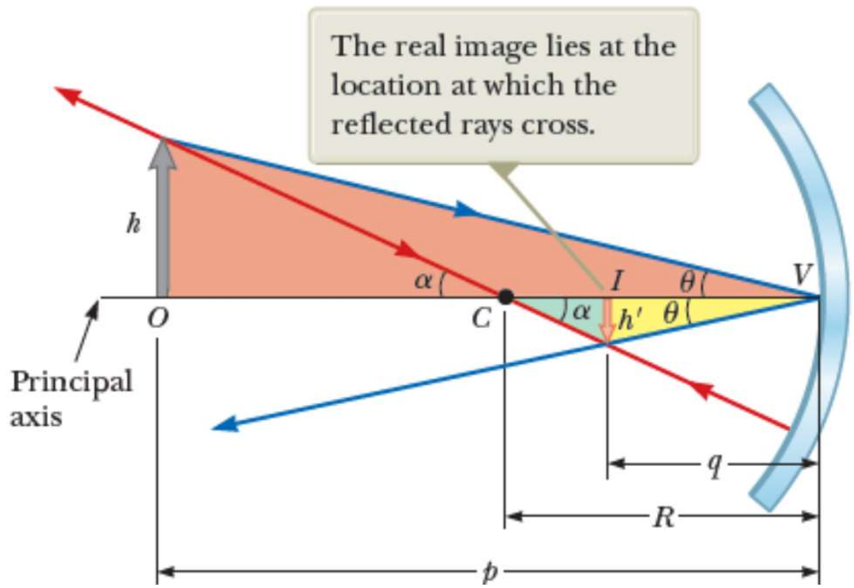




Elliptical lens

Images Formed by Spherical Mirrors 2

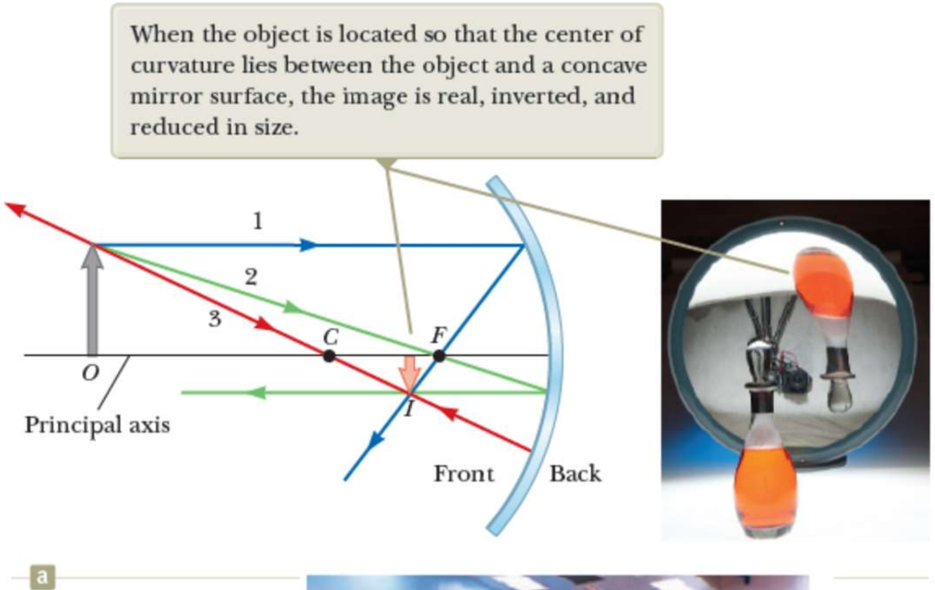


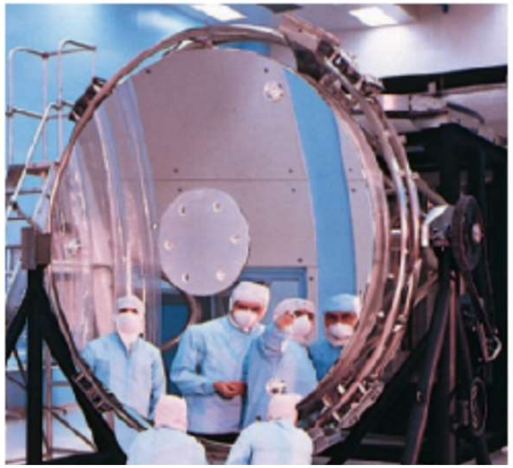


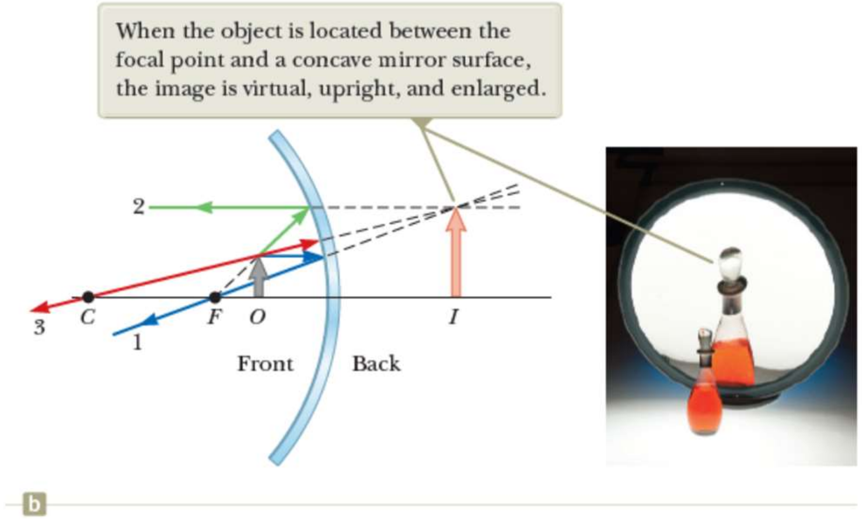
$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

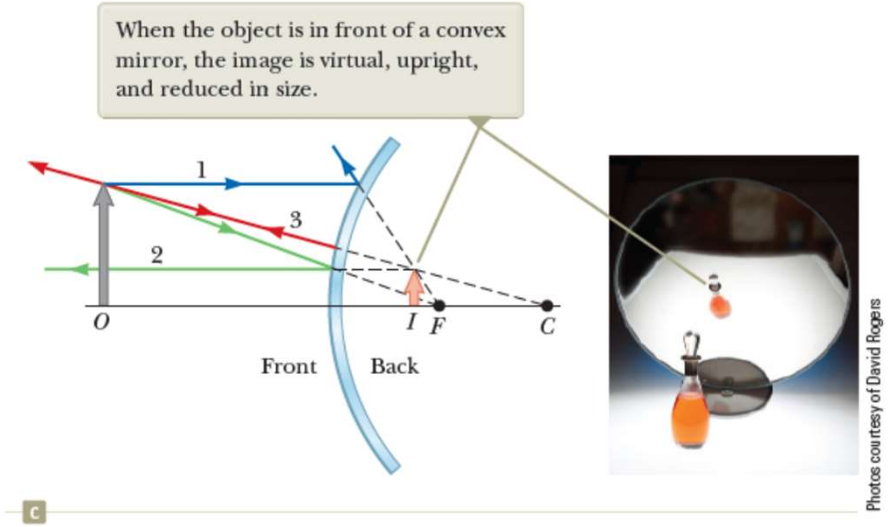
$$M = \frac{h'}{h} = -\frac{q}{p}$$

Images Formed by Spherical Mirrors 3

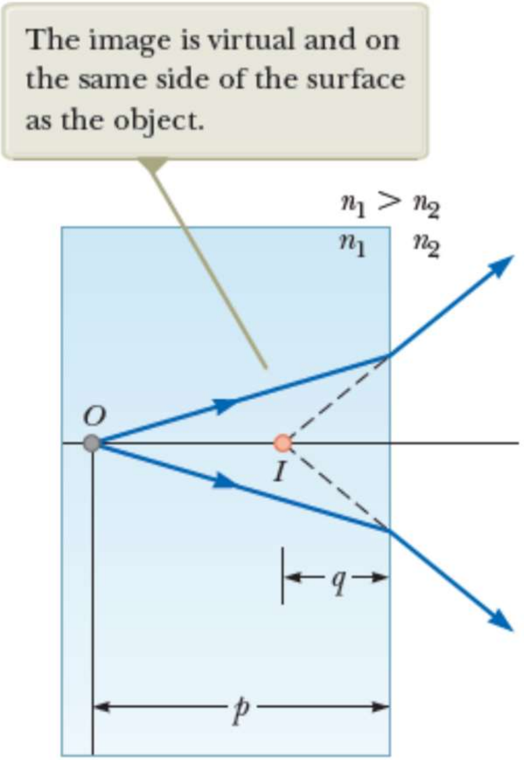


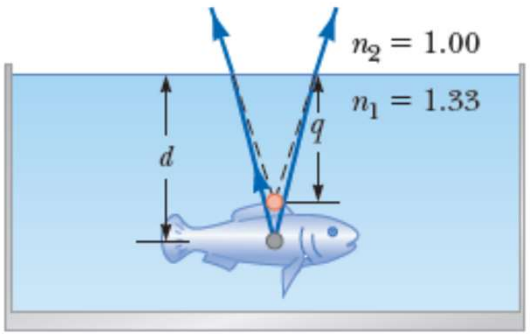


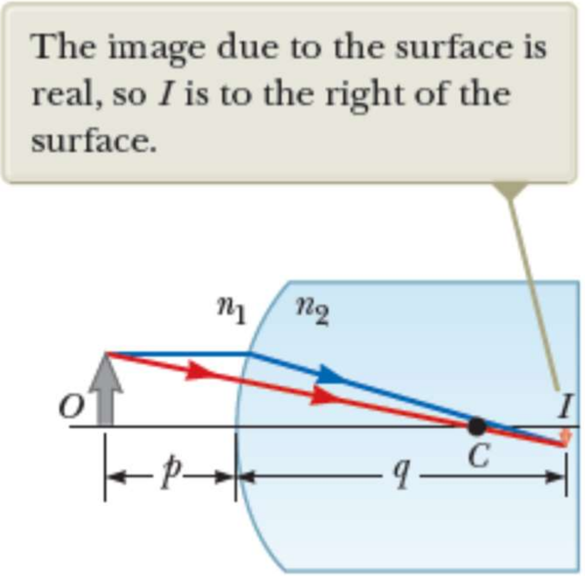


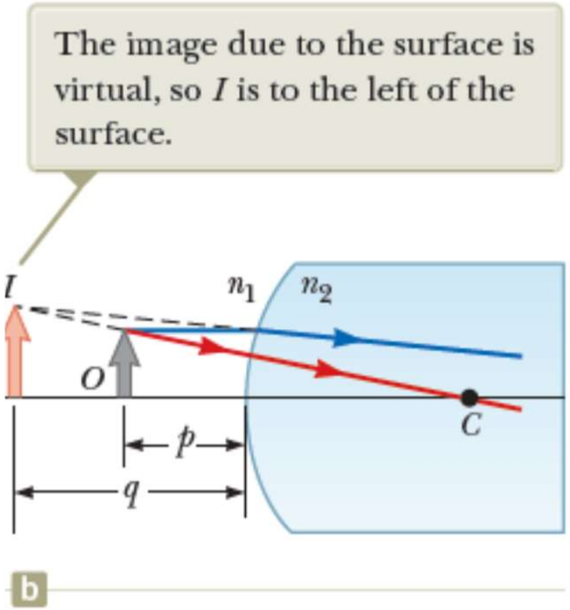


Single refractive surface



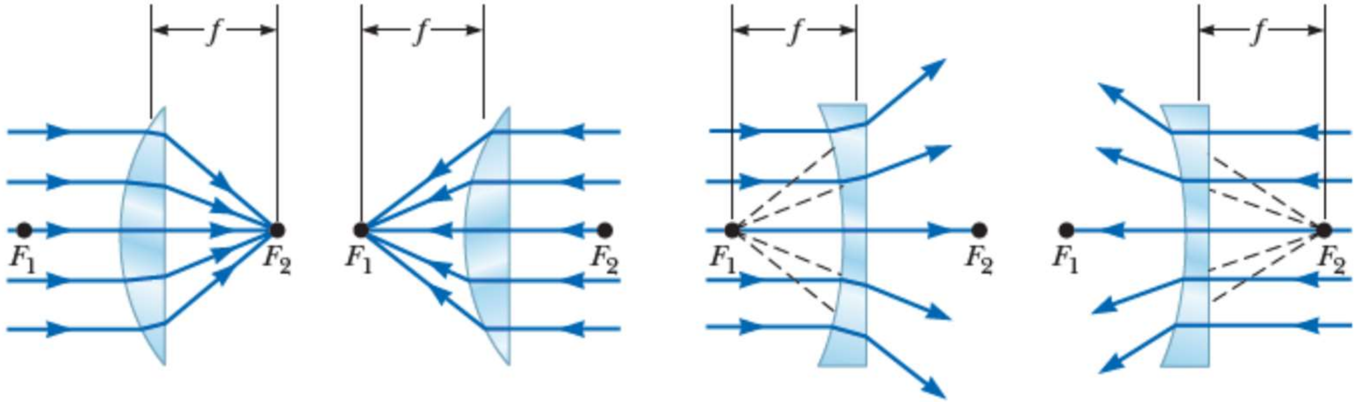


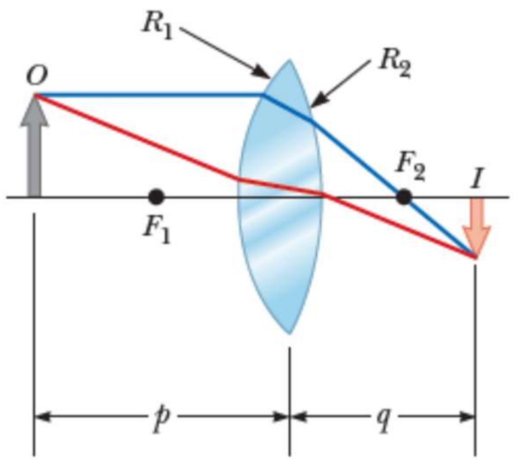




$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

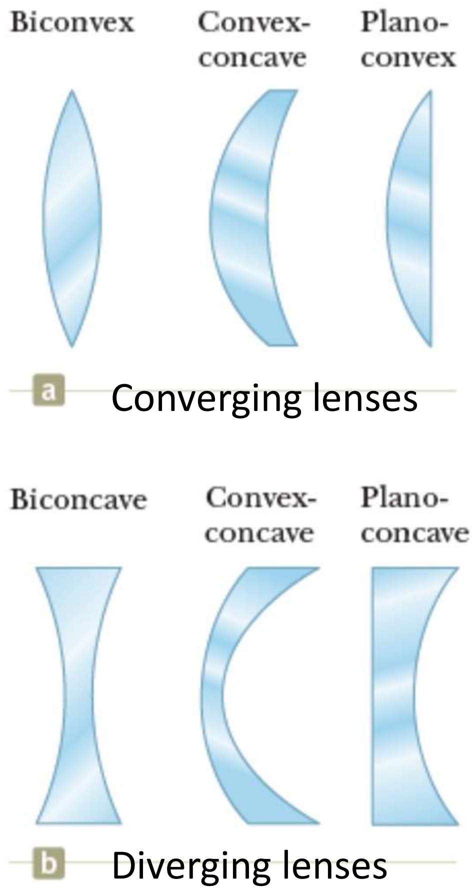
Images Formed by Thin Lenses



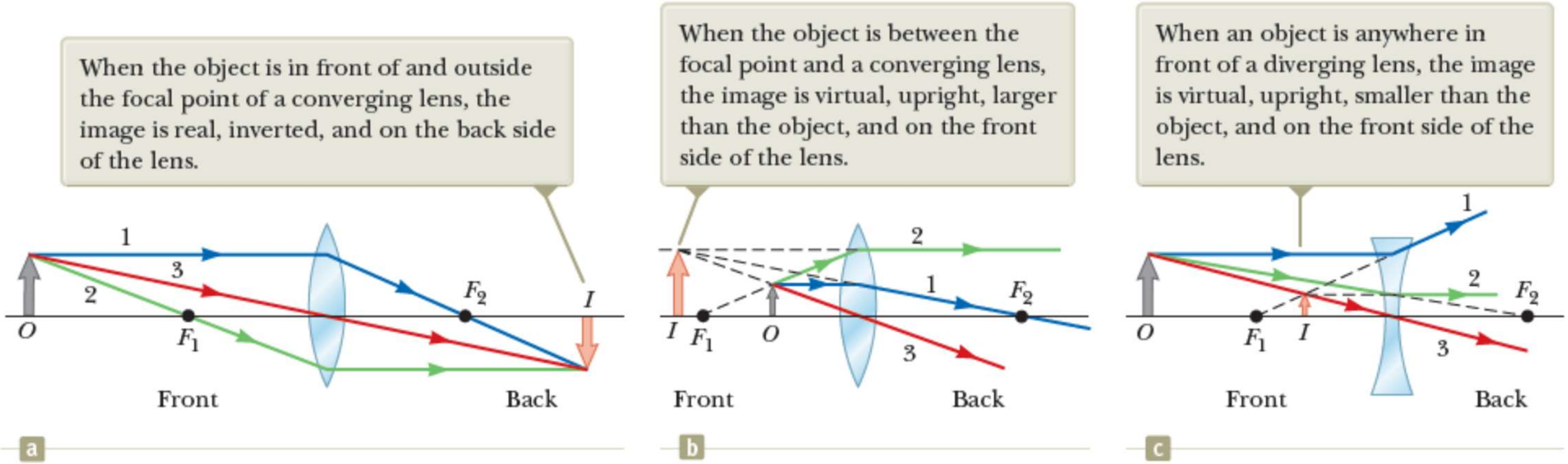


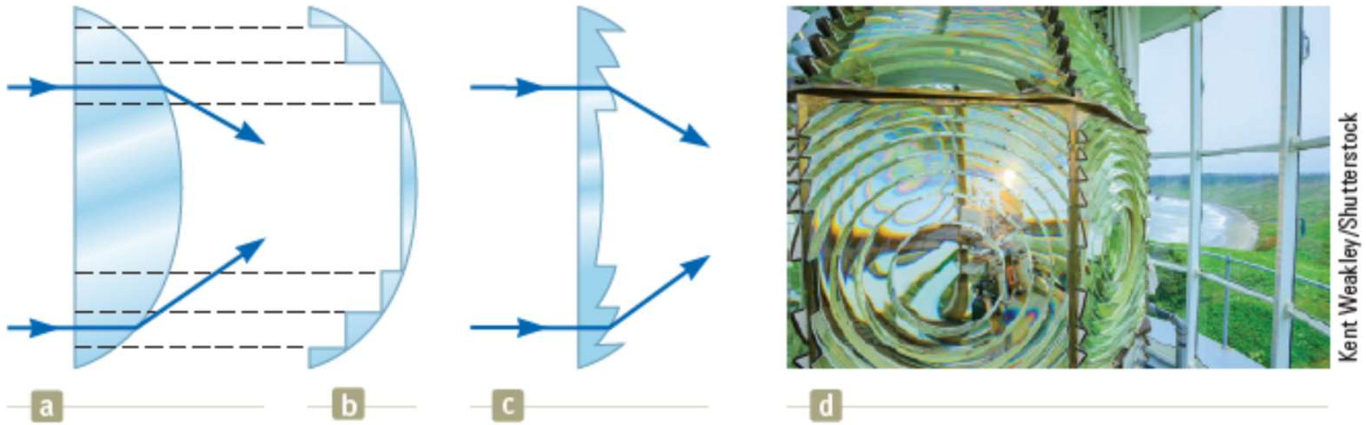
$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{p} + \frac{1}{q} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

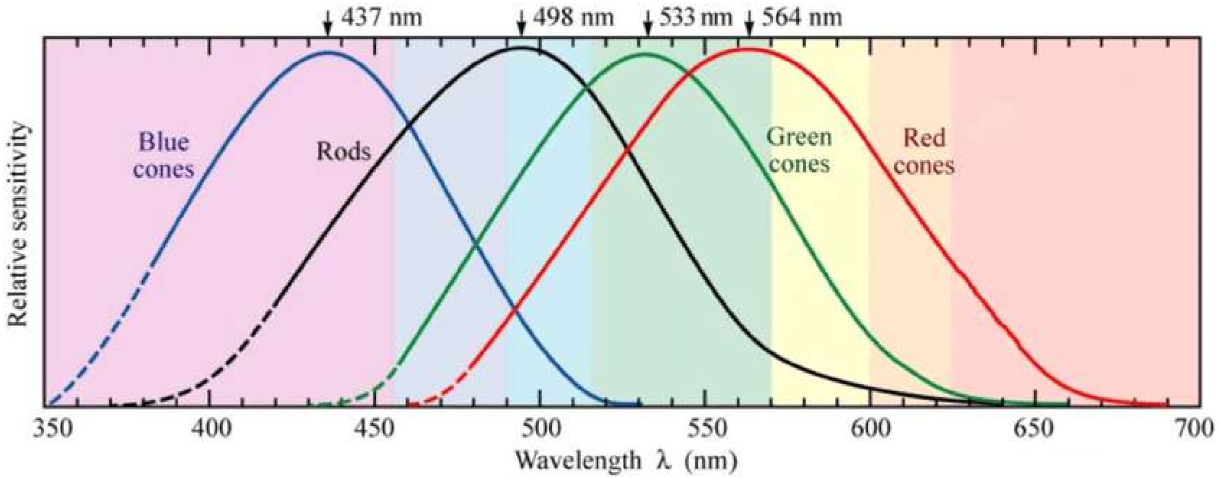


Images Formed by Thin Lenses 2





Optical Instruments: eye



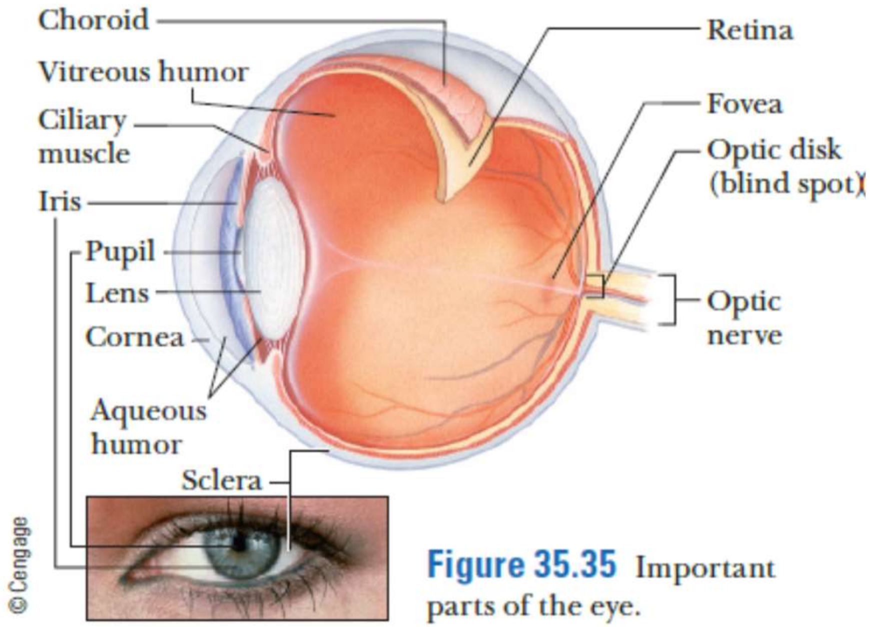
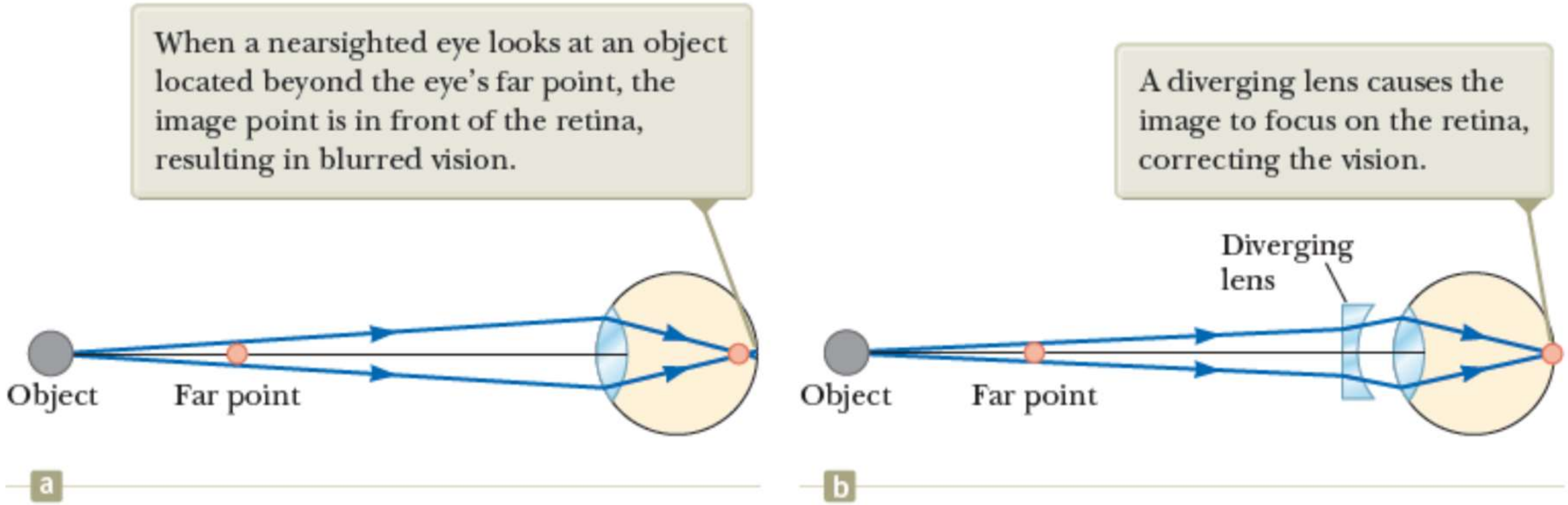
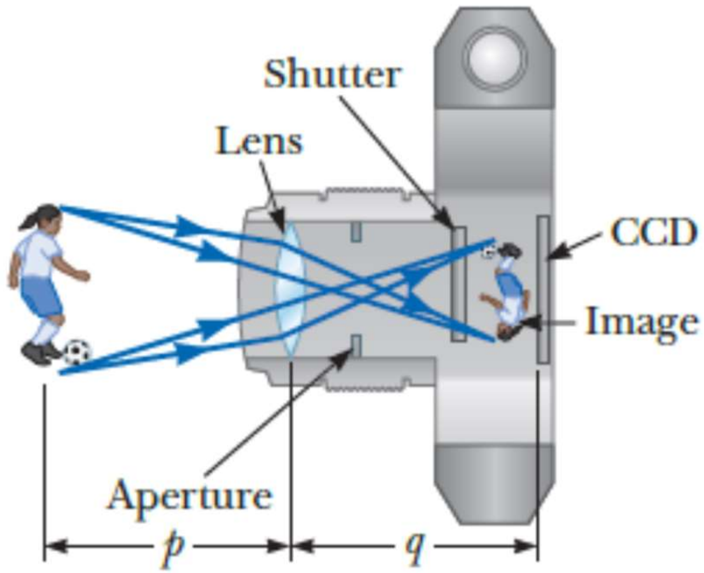


Figure 35.35 Important parts of the eye.

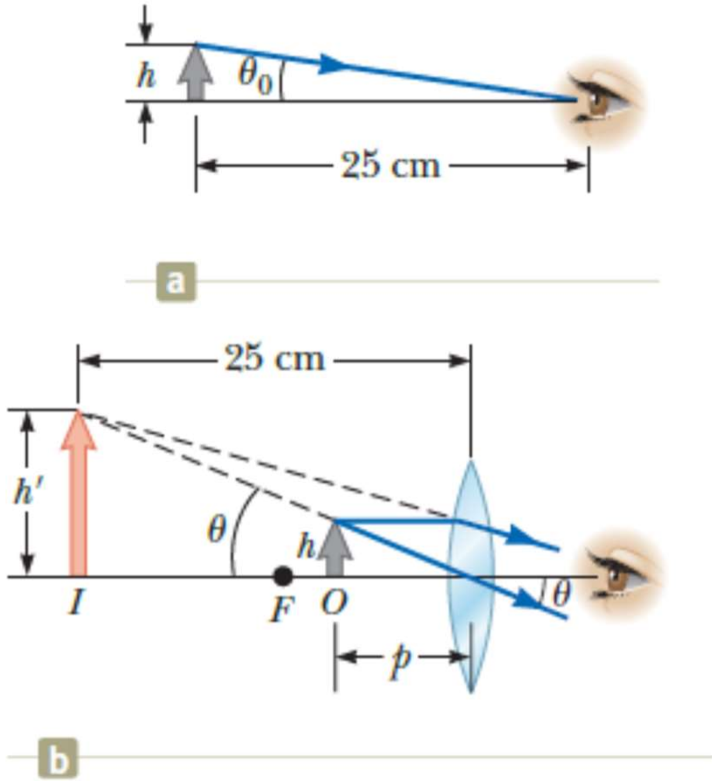


- Accomodation
- Sharp Vision: 5°
- Eye motion
- Vergence
- 3D perception

Simple Imaging Instruments

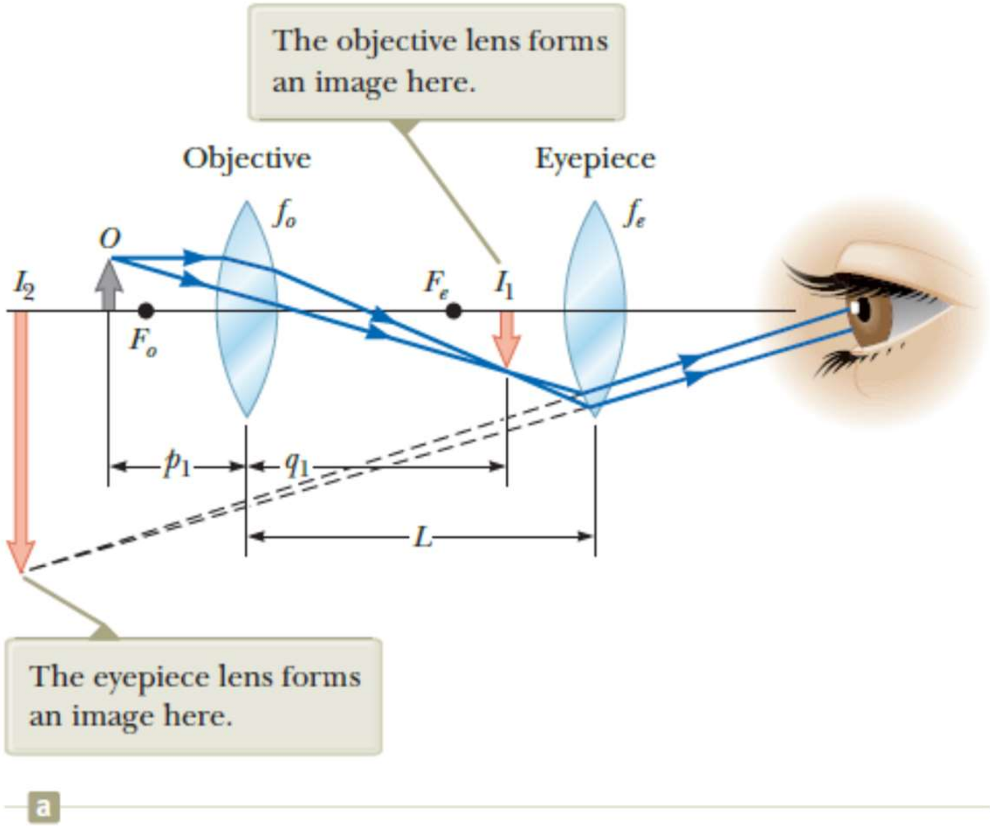


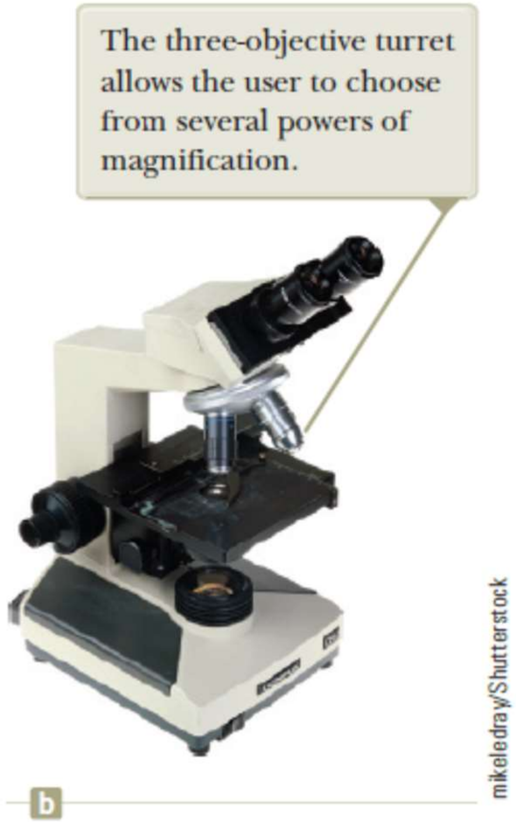
Camera



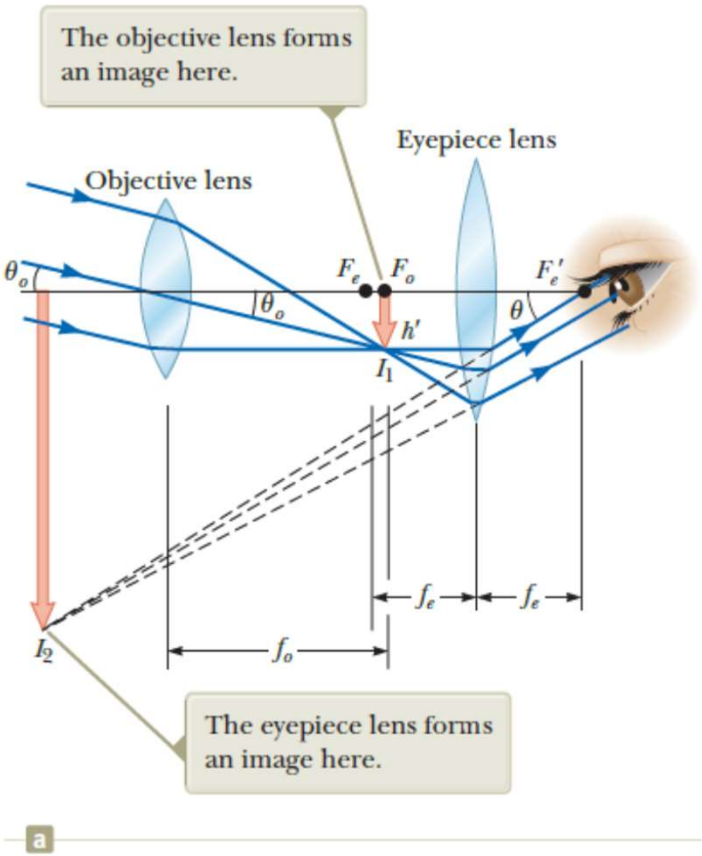
Magnifyer

Composed Imaging Instruments: Microscope

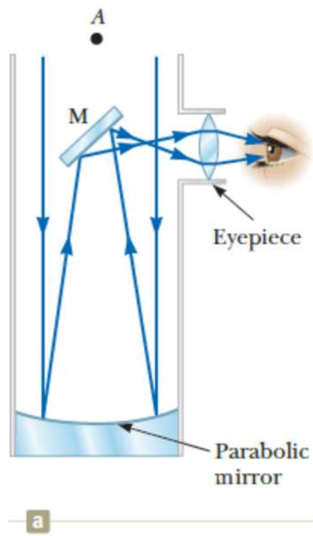




Composed Imaging Instruments: Telescope

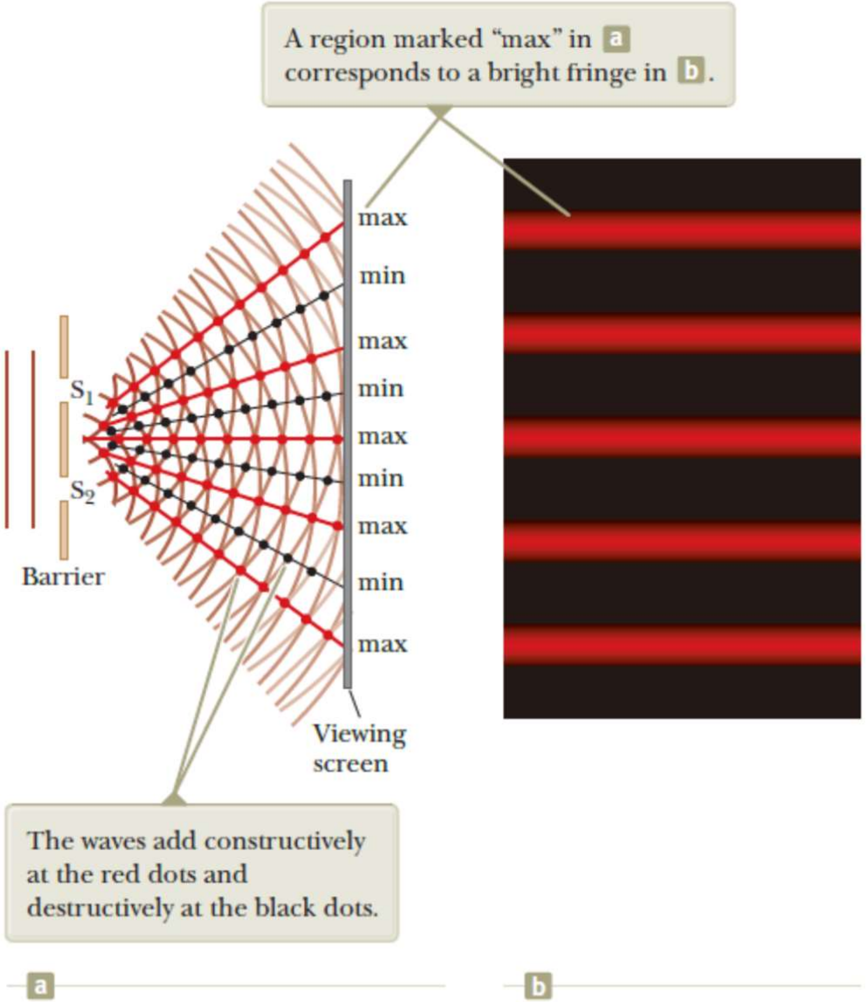


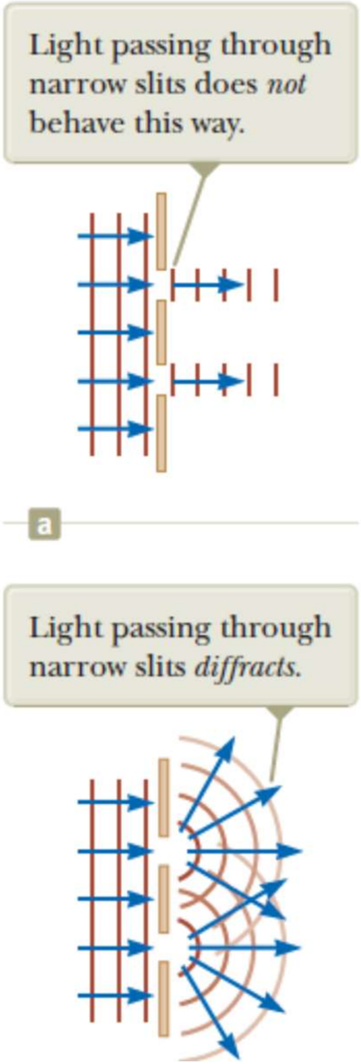
Refractive (Kepler's) telescope



Reflective (Newtonian) telescope

Interference: Young's Double-Slit Experiment

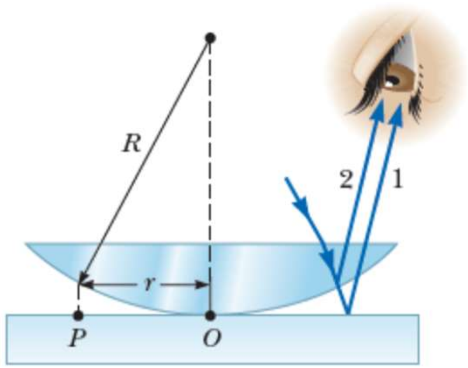




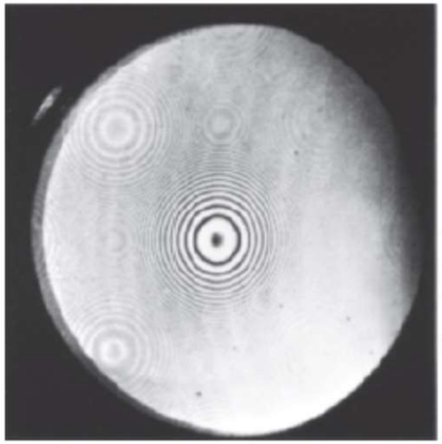
Interference in thin films

Anti-Reflective Coating

Newton's Rings

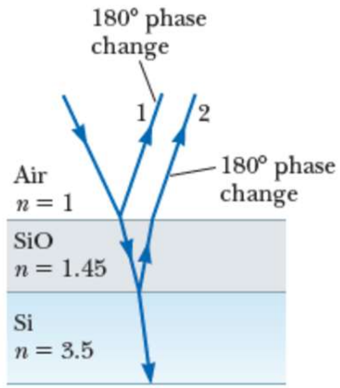


a



Courtesy of Bausch & Lomb

b



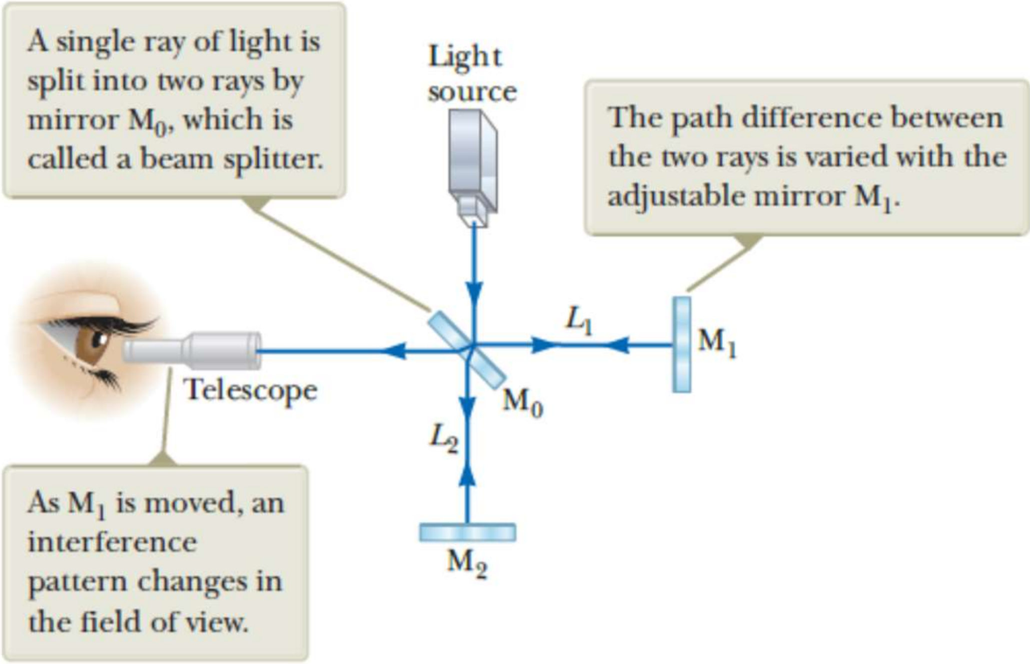
a

Chistoprudov Dmitriy/Shutterstock

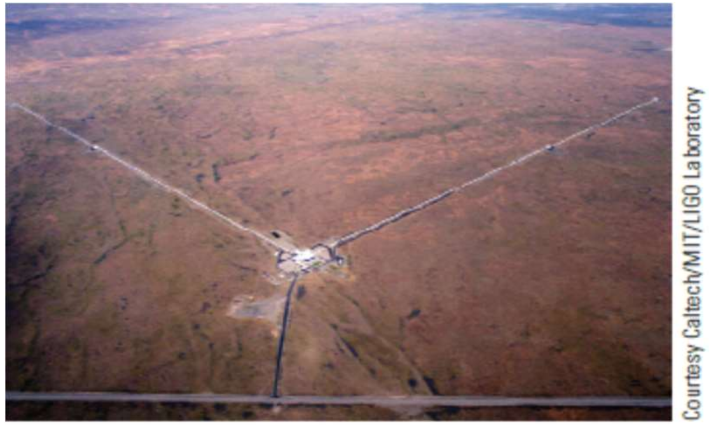
Newton's Rings

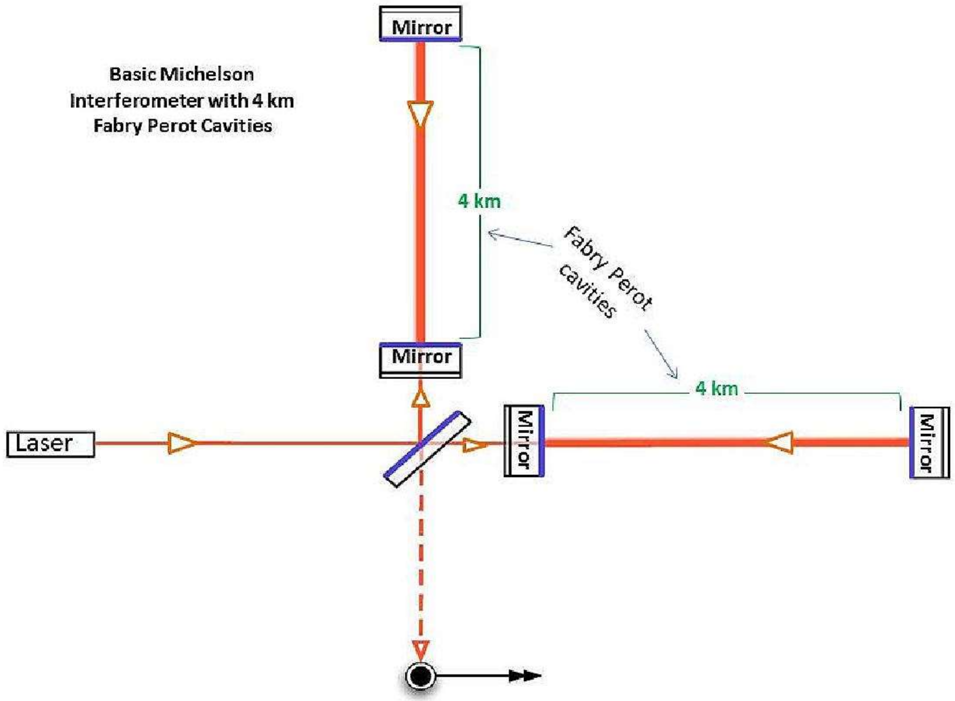
b

Famous Interferometers



Michelson Interferometer





LIGO (Laser Interferometric Gravitational-wave Observatory)