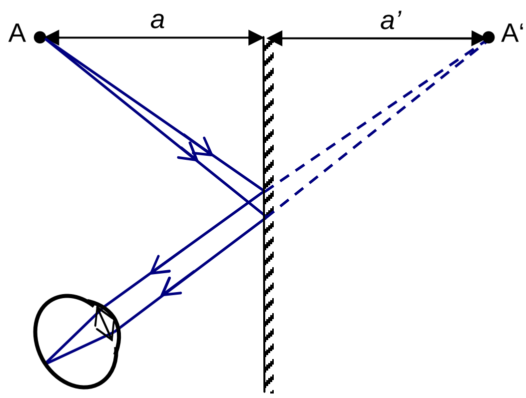
GEOMETRICAL OPTICS

1. Mirrors

- their function is based on the law of reflection
- types : plane
  curved
- reflecting surfaces: „ordinary“ – metal layer covered by glass – protection (corrosion, scratches)
  HQ – special metal layer only – better image

a) plane mirrors



A ... object
A' ... image
a ... object distance
a' ... image distance
$(a' < 0\ virtual, a' > 0\ real)$

describe the image:
real × virtual
magnified × diminished × of the same size
upright (erect) × inverted × laterally inverted

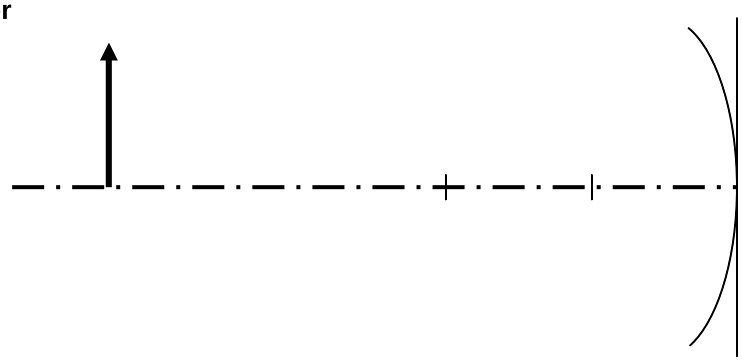
b) curved mirrors

- ***ray diagrams***

C ... centre of curvature
r ... radius of curvature
f ... focal length
P ... pole of the mirror (V)
principal axis

	RAY COMING	IS REFLECTED
1	through C	through C
2	through F	parallel to principal axis
3	parallel to principal axis	through F
4	to P	at the same angle

concave mirror



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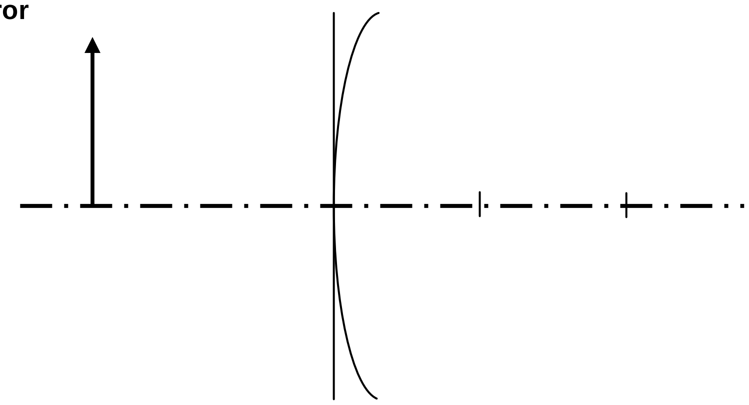
convex mirror

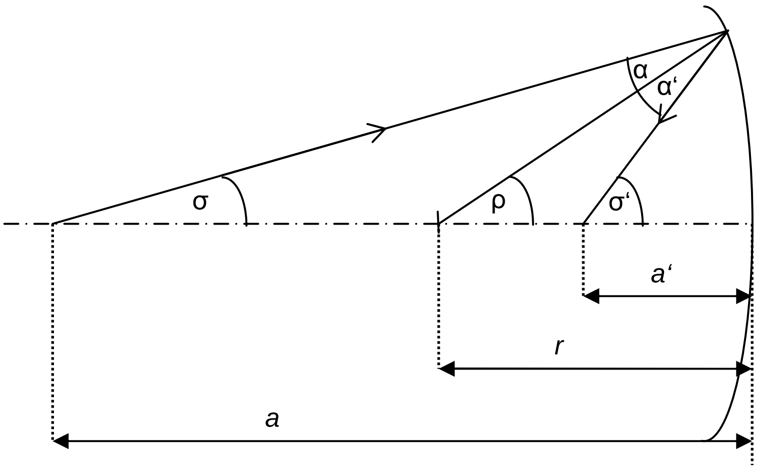


Questions:

Sketch the following situations on an extra sheet of paper and describe the images

1. f = 2.5 cm, a) a = 6 cm, b) a = 5 cm, c) a = 3.5 cm, d) a = 1 cm
2. f = -3 cm, a = 5 cm

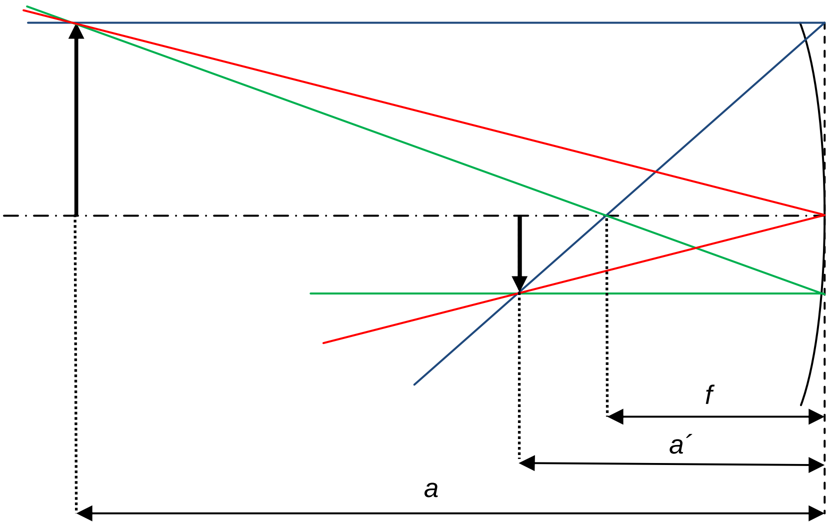
- ***mirror formula***



$$\frac{1}{f}=\frac{1}{a}+\frac{1}{a'}$$

Questions:
3. Prove the precision of your sketches – questions 1 and 2 - using the mirror formula.

- ***magnification formulae***



$$M = \frac{y'}{y} = -\frac{a'}{a} = -\frac{a'-f}{f} = -\frac{f}{a-f}$$

$M > 0$ ... erect (virtual)
$M < 0$ ... inverted (real)
$|M| > 1$ ... magnified
$|M| < 1$ ... diminished

Questions:
4. A concave mirror of focal length 30 cm forms a real image magnified 10 times. Calculate the image and object distance.

L6/ 76-79, 81, 83, 85

2. Thin lenses

- function based on the law of refraction
- different shapes
  CONCAVE – thinner in the middle, $f \langle 0$
  CONVEX, converging – thicker in the middle, $f \rangle 0$
- find and sketch the following shapes of lenses:

biconvex plano-convex convex meniscus

biconcave plano-concave concave meniscus

- lenses have two focuses F and F'
  The focal lengths are equal for thin lenses only!

- $f \neq \frac{r}{2}$ in general – TWO radii of curvature!!!

- power of a lens

absolute refractive index of the medium of the lens

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \varphi$$

POWER OF A LENS

focal length – f

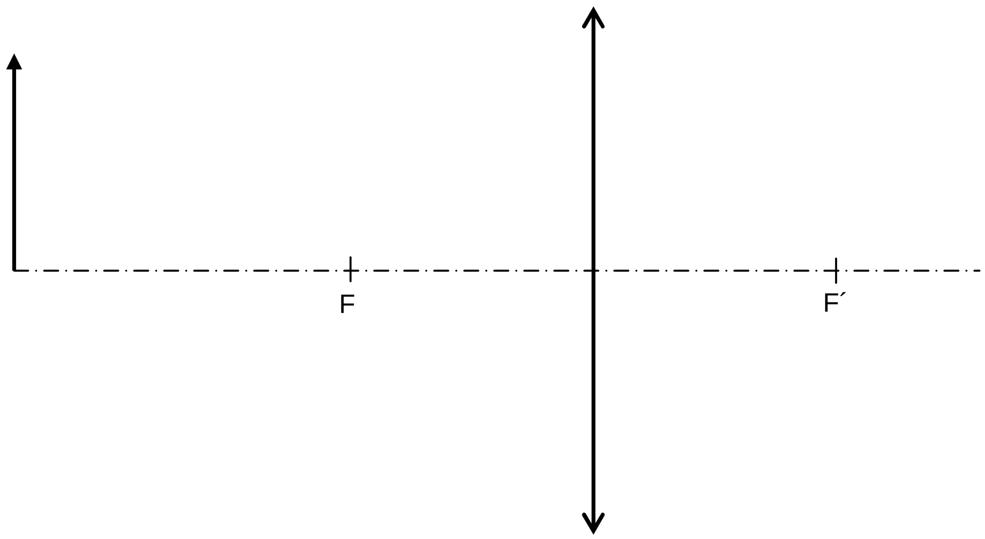
a.r.i. of the medium AROUND the lens – n_1

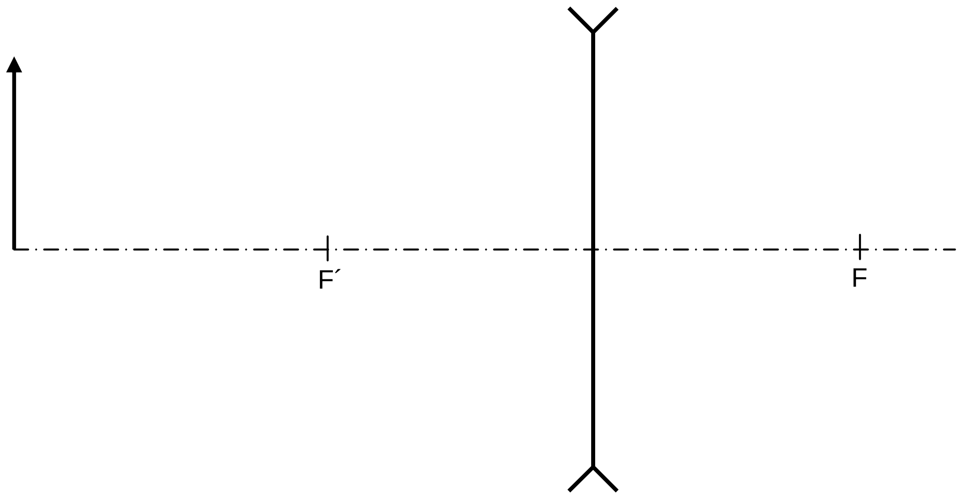
radii of curvature (difficult sign convention – positive result of the bracket for convex lens) – r_1, r_2

$[\varphi] = D$ (dioptre)

- ***ray diagrams***

	RAY COMING	IS REFRACTED
1	through O	through O
2	through F	parallel to principal axis
3	parallel to principal axis	through F’





Questions:

5. Sketch the following situations and describe the images:

1. f = 2 cm, a) a = 4.5 cm, b) a = 4 cm, c) a = 3 cm, d) a = 1 cm
2. f = -4 cm, a) a = *6* cm., b) a = 2 cm

- ***thin lens formula*** ***magnification formulae***

$$\frac{1}{f}=\frac{1}{a}+\frac{1}{a'}$$

$$M=\frac{y'}{y}=-\frac{a'}{a}=-\frac{a'-f}{f}=-\frac{f}{a-f}$$

!!! SIGN CONVENTION for a’

POSITIVE when REAL (the same as for mirrors), but **REAL is BEHIND!!!**
NEGATIVE when VIRTUAL (the same as for mirrors), but **VIRTUAL is IN FRONT OF THE LENS!!!**

Questions:
6. Prove the results of previous sketches using the thin lens formula and magnification formulae.

7. A lens forms a real image magnified 3 times. When the object is moved BY 15 cm towards the lens, the image is 8 times magnified. Calculate the focal length of the lens.

L6/87-91, ×95, 96-102, ×103, 104-106, ×113-115

3. The eye

f = cm (when accommodated to ∞)

near point (NP) = 25 cm

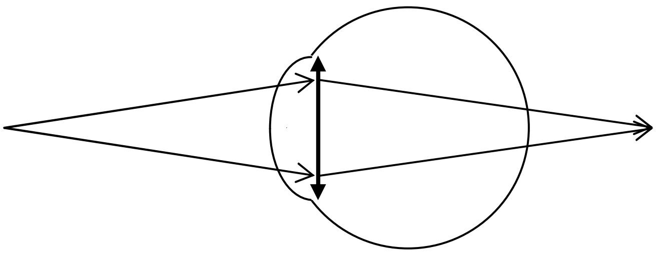
far point (FP) = ∞

distance of most distinct vision *d* = 25 cm

- ***long sight***
  - FP at ∞
  - NP further than 25 cm
  - correction – convex lens

$$\frac{1}{f}=\frac{1}{d}+\frac{1}{NP}$$

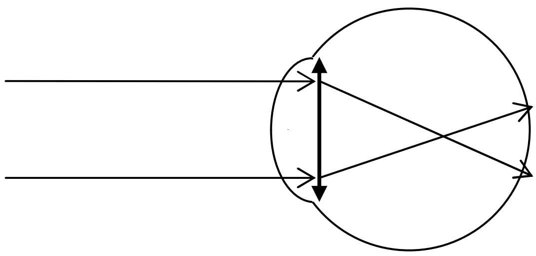
25 cm **object** distance — **virtual image** at NP (**negative** number!!!)



- ***short sight (krátkozrakost)***
  - FP closer than at ∞
  - NP 25 cm (or less)
  - correction – concave lens

$$\varphi=\frac{1}{f}=\frac{1}{\infty}+\frac{1}{FP}=\frac{1}{FP}$$

object at — **virtual image** at FP (negative number!!!)

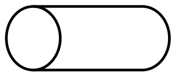


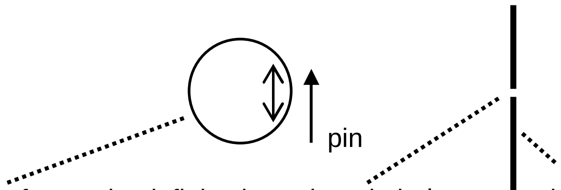
$$\varphi = \frac{1}{f} = \frac{1}{d} + \frac{1}{NP}$$

between –25 cm and 0

Questions:
8. Calculate the power of the human eye
9. Eyes behind „strong“ spectacles seem to be diminished or magnified. Which disease and correction does it correspond with?

10. Calculate the power of the lens a) SS, NP = 10 cm, b) LS, NP = 50 cm, c) SS, FP = 10 m

- ***test your vision***
  - binocular vision  rolled paper
  - blind spot ⊕ ← $6-7\ cm$ → ●
  - inverted image on retina



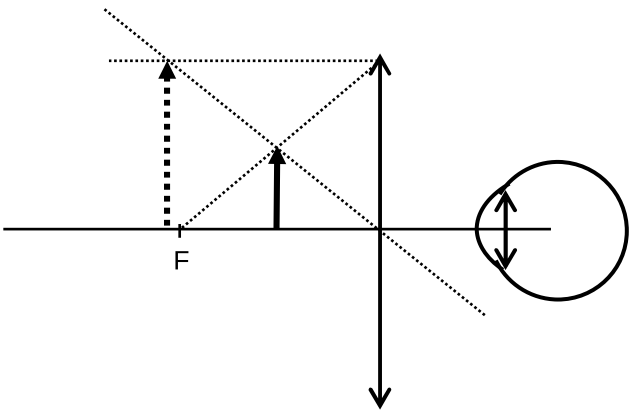
eye focused to infinity through a pin hole   sheet of paper

4. Subjective optical instruments

form **virtual** images, which are **objects for human eye**

angular magnification $\gamma = \frac{\tau'}{\tau}$ — τ' with the device, τ without the device

a) magnifying glass
single converging lens



Find and label τ and τ'

$\gamma \cong \frac{d}{f}$ (British eqn.: $\gamma = \frac{d}{f} + 1$ as it depends on the position of the object and the lens)
max. magnification is about 6, when more – thick lens – distortion of the image

b) compound microscope

consists of two (sets of) convex lenses - **objective** , which forms a real, magnified and inverted image I_1 of an object O (placed just outside its focus F_o). I_1 is just behind the focus F_e of the **eyepiece**, which acts as a magnifying glass and produces a magnified, virtual image I_2. Sketch the optics of the microscope using additional materials or the internet and describe resultant properties of the image I_2 related to the object O.

British convention $\gamma = m_e \times m_o$

magnifications of the eyepiece and the objective

distance between $F_1^{/}$ a F_2

Czech convention $\gamma = \dfrac{\Delta d}{f_1 f_2}$

c) telescopes

consist of an **objective** (convex lens or concave mirror) which forms an image at a focal plane (object is at infinity). The foci of the objective and an **eyepiece** (convex or concave lens) coincide so the final image is formed at infinity too, but as the focal lengths differ, angular magnification is formed.

Kepler's telescope (astronomical) – 2 convex lenses
Newtonian telescope (astronomical) – concave mirror + convex lens
Galilleian telescope – convex + concave lens (shorter)
terrestrial telescope – 2 convex lenses + erecting lens between which does NOT magnify

$$\gamma = \frac{f_o}{f_e}$$

Use additional materials – books, internet ... to sketch the types of telescopes mentioned above, describe the advantages/disadvantages and use of each type.

L6/117-124, 133-135

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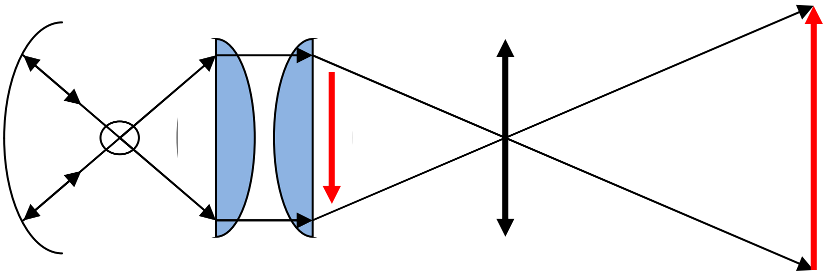
5. Objective optical instruments

form **real** images on screen, sensitive layers of films etc.

a) projector

- projection lens (convex) forms a highly magnified, real and inverted image of a slide (master)
- high power lamp, reflector and condenser make only the intense and uniform illumination of the object
- find all the components on the figure below



b) camera

- objective consists of more lenses (×distortion) and makes a real, diminished and inverted image on the film / CCD sensor, so all of them must work as a **convex/concave** lens (choose one)
- focal length is about the lens-film distance when focused at infinity
- depth of field – connected with the aperture
- sensitivity of the film corresponds with the energy needed for the exposure, which is a product of time and aperture

  long time + small aperture = big depth of field – "everything sharp"
  short time + big aperture = small depth of field – "sharp images of objects having the same object distance"

http://kabinet.fyzika.net/dilna/prezentace/vyukove-prezentace.php

L/117-120, 123-126, ×128-9, 133

Answers:
4. 3.3 m, 0.33 m
7. 72 cm, 32.7 cm
8. 62.5 D (when f = 1.6 cm)
10. -6 D, 0.5 D, -0.1 D