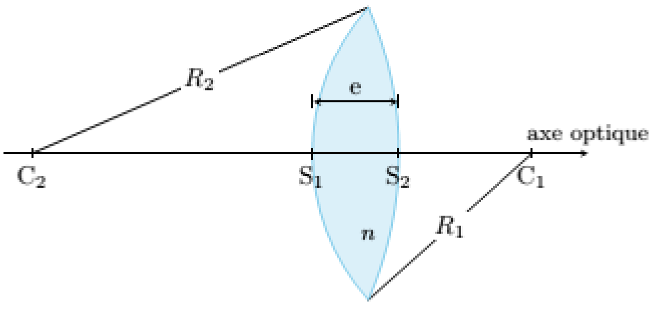
2.2.2.3.Thin Lenses:

Lenses are essential components of optical systems; they have enabled the exploration of the infinitely large universe (telescope) and the infinitely small world (microscope), as well as the improvement of vision (eyeglasses). They are present not only in everyday life (eyeglasses, contact lenses, cameras) but also in the field of scientific research (telescopes, spectrographs, microscopes).

They are found not only in everyday life (glasses, contact lenses, cameras) but also in the field of scientific research (telescopes, spectrometers, microscopes...).

2.2.2.3.1. Description

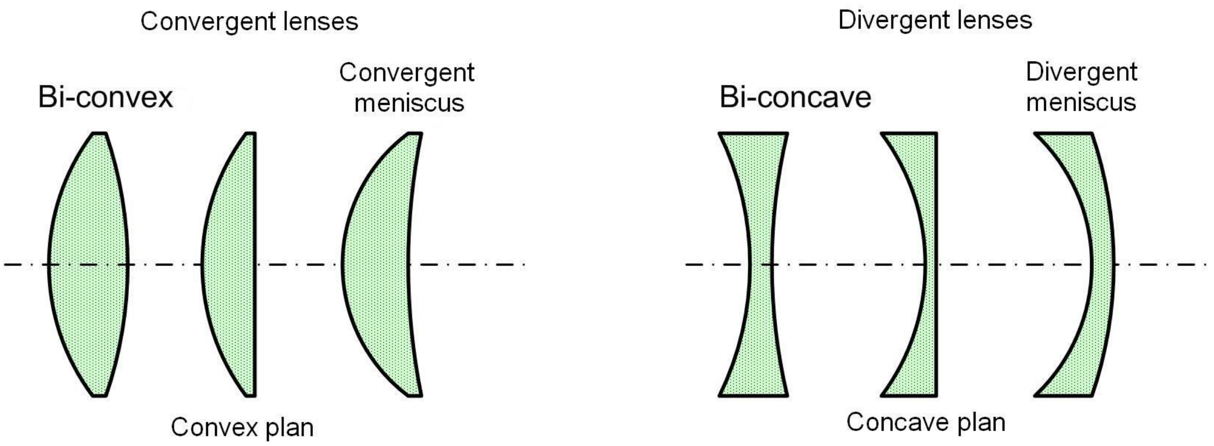
A thin lens is formed by the combination of two spherical diopters, or a spherical diopter and a planar diopter, with large radii of curvature (R1, R2) compared to the thickness of the lens (e).



Lentille optique.

In the thin lens approximation, the vertices S1 and S2 are considered to coincide at a point O called the optical center. Two types of lenses are distinguished:

- Thin-edged lenses which are convergent,
- Thick-edged lenses which are divergent.



Characteristics of thin lenses:

include:

- Lens center (O)
- Two focal points, object F and image F', **symmetric with respect to O.**

$$f = \overline{OF} = -\overline{OF'} = -f'$$ ➡

Pour une lentille convergente, $f < 0$ et $f' > 0$.
Pour une lentille divergente , $f > 0$ et $f' < 0$.

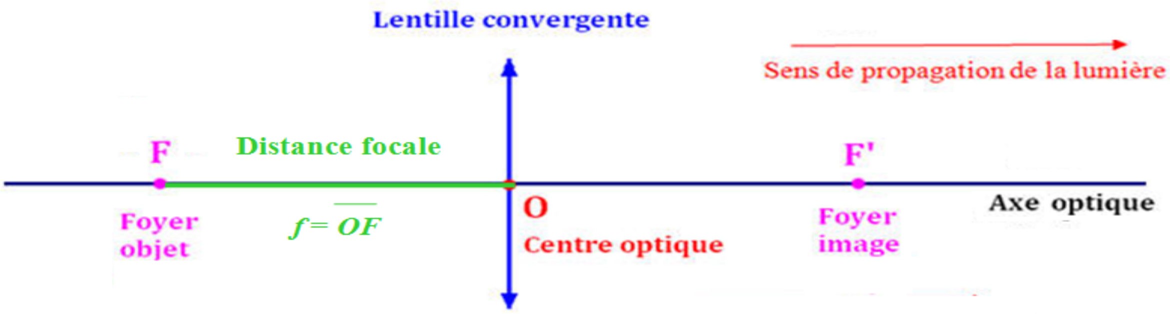
- Vergence V of the lens (the inverse of the image focal distance).

$$V = \frac{1}{f'}$$ ➡

Pour une lentille convergente, $V > 0$.
Pour une lentille divergente $V < 0$.

V: vergence or power of the diopter (unit: Diopter = m-1).

- If V > 0: Converging Lens
- If V < 0: Divergent Lens



5.3. Image Formation

Geometric Construction of the Image:

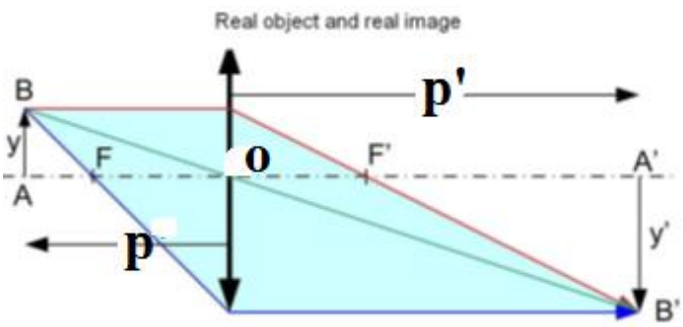
To construct the image of an extended object, follow these principles:

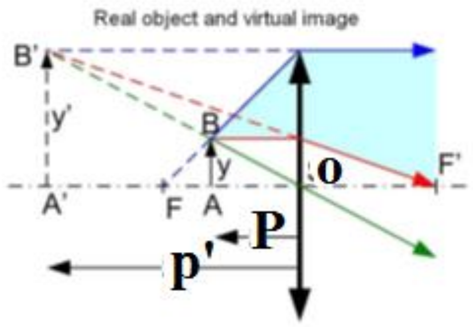
- Operate under the Gaussian approximation: approximate stigmatism and approximate aplanatism are present.
- Position the object: If the object AB is real, it must be to the left of the lens; if the object is virtual, it is located to the right of the lens.
- To determine the image of a point, use rays with known behavior.

1. A horizontal ray reaching a converging lens will converge at F' if it is convergent and diverge as if coming from F' if the lens is divergent.
2. A ray passing through or extending to F will exit horizontally.

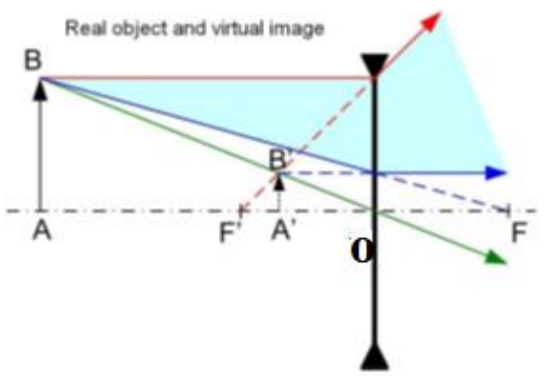
A ray passing through O is not deviated. Once the rays are drawn, we determine whether the image is real or virtual. If the rays originating from B actually intersect at B', then B' is a real image. If the rays originating from B diverge after refraction in a way that they appear to come from B', then B' is a virtual image (visible to the naked eye).

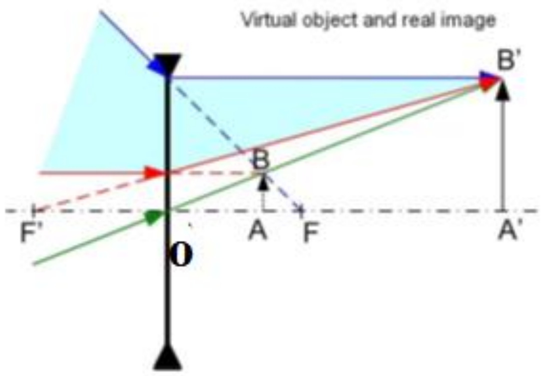
a) Creating images for a converging lens





b) Creating images for a diverging lens





- **Conjugation Formula**

The conjugation formula describes the relationship between the position of the object OA and the position of the image OA'.

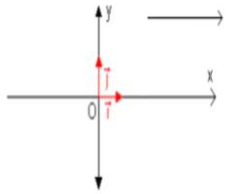
$$\frac{1}{\overline{OA'}} - \frac{1}{\overline{OA}} = \frac{1}{f'} = -\frac{1}{f}$$

Position de l'image A'

Position de l'objet A

Distance focale Image *f'*

Distance focale Objet *f*

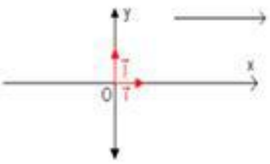
Nature de Objet-Image  • Si OA<0 (-) L'objet est **réel.** • Si OA>0 (+) L'objet est **Virtuel** • Si OA'>0 l'image est **réelle.** • Si OA'<0 l'image est **virtuelle.**	If $\overline{OA} < 0$ the object is real If $\overline{OA} > 0$the object is virtual If $\overline{OA'} > 0$ the image is real If $\overline{OA'} < 0$ the image is virtual

$$\gamma = \frac{\overline{A'B'}}{\overline{AB}} = \frac{\overline{OA'}}{\overline{OA}}$$

Taille de l'image

Taille de l'objet

Taille de Objet-Image



- Si $\gamma > 0$ (+) l'image est **droite** (elle a le même sens que l'objet).
- Si $\gamma < 0$ (-) l'image est **renversée** (sens inverse).
- Si $|\gamma| > 1$ l'image est **plus grande** que l'objet.
- Si $|\gamma| < 1$ l'image est **plus petite** que l'objet.
- Si $\gamma = 1$ l'image et l'objet ont **la même taille**.

- If $\gamma > 0$ (+) the image is straight (it has the same direction as the object).
- If $\gamma < 0$ (-) the image is reversed (reverse direction).
- If $|\gamma| > 1$ the image is larger than the object.
- If $|\gamma| < 1$ the image is smaller than the object.
- If $\gamma = 1$ the image and the object have the same size

5.4. Association of Thin Lenses: The Doublet

We consider Two lenses, L1 and L2, with optical centers O1 and O2, and focal lengths. $f_1' = \overline{O_1F_1'}$ and $f_2' = \overline{O_2F_2'}$ The optical axes are aligned. Their combination forms a system called a "doublet".

Doublet Lens: The optical centers O1 and O2 of the two lenses are such that the distance O1O2, the thickness of the doublet, can be considered negligible, and O1 and O2 coincide at O. These two lenses are considered as a single lens L with optical center O and focal length f ' such that:

$$\frac{1}{f'} = \frac{1}{f_1'} + \frac{1}{f_2'}$$

The vergence V of the equivalent lens: V = V1 + V2 • Unbonded doublet: An unbonded doublet is a combination of two lenses L1 and L2 separated by a non-zero distance e = O1O2.

Lens L1: The image A'B' of the object AB by lens L1 with optical center O1 is:

$$\frac{1}{\overline{O_1A'}} - \frac{1}{\overline{O_1A}} = \frac{1}{f_1'}$$

The magnification by lens L1: $\gamma_1 = \frac{\overline{A'B'}}{\overline{AB}} = \frac{\overline{O_1A'}}{\overline{O_1A}}$

The image A'B' formed by lens L1 will become the object for lens L2.

Lens L2 : the image A''B'' of the object A'B' by lens L2 with optical center O2 is :

$$\frac{1}{\overline{O_2A''}} - \frac{1}{\overline{O_2A'}} = \frac{1}{f_2'}$$

The magnification by lens L2: $\gamma_2 = \frac{\overline{A''B''}}{\overline{A'B'}} = \frac{\overline{O_2A''}}{\overline{O_2A'}}$