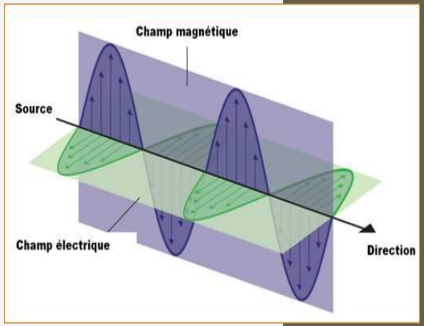
I.S.T.A

Optics



Dr. TACHEMA Abdennasser

Specialty: Surveyor-Topographer / L1

Different types of lenses

Particular points and sizes features

Magnification and conjugation relationships

Constructions for all configurations

Different types of lenses

Definition of a Lens

A lens is a transparent medium bounded by two diopters, both of which can be spherical or one spherical and the other flat (often referred to as spherical lenses).

A lens is thin if its diameter is much larger than its thickness or when its thickness is negligible compared to the radii of curvature of its two surfaces.

If we denote R1 as the radius of the first spherical diopter of the lens, R2 as the radius of its second diopter, and 'e' as the thickness of the lens; any lens is thin provided that $e \ll R1$, $e \ll R2$, and $e \ll |R1 - R2|$.

We should not forget that the thin spherical lens has the property of changing the direction of light propagation due to refraction occurring on each of its diopters.

Different types of lenses

Two types of Lenses

Two types of lenses are distinguished: those with thin edges and those with thick edges. The former are convergent, the latter are divergent.

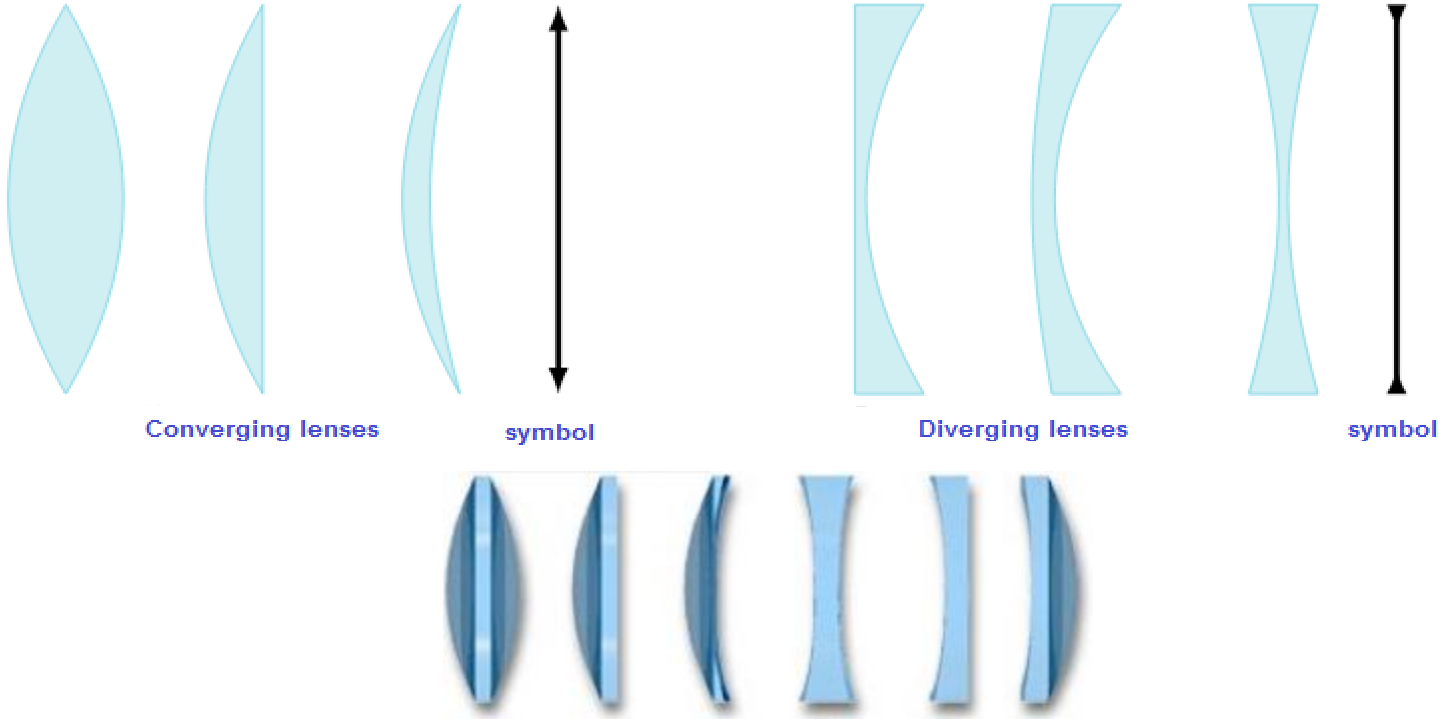
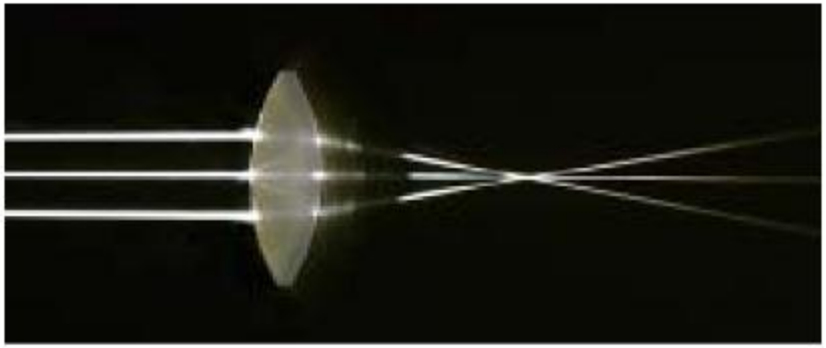


Fig.1: Different Types of Lenses and Their Symbols

Different types of lenses

Two types of Lenses

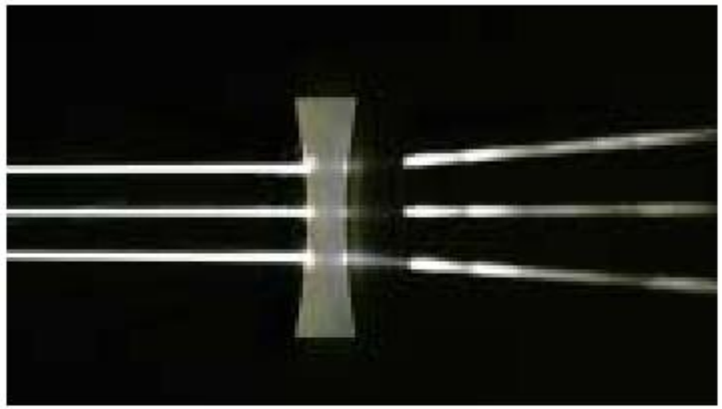
Converging Lenses



Converging lenses magnify the image (magnifying glass effect).

Two types of Lenses

Diverging Lenses



Diverging lenses reduce the size of the image observed through them.

Optical Center

The optical center of the lens, denoted by O, is the point on the optical axis of the lens through which the refracted ray corresponding to an incident ray passes.

The emergent ray is parallel // to the refracted ray.

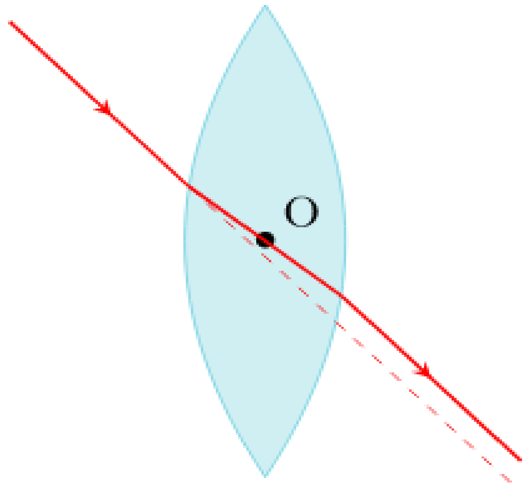


Fig.2: Definition of the Optical Center of the Lens

Focal Points

Case of a Converging Lens

A converging lens has two focal points, called the **primary object focal point** and the **primary image focal point:**

1. Any incident ray passing through F, the primary object focal point, emerges parallel to the optical axis. Therefore, this focal point has its image at infinity.

2. Any incident ray parallel to the optical axis emerges through F', the primary image focal point. Therefore, this focal point is the image of an object at infinity.

These focal points are symmetrical with respect to the optical center of the lens.

Particular points and sizes features

Focal Points

Case of a Converging Lens

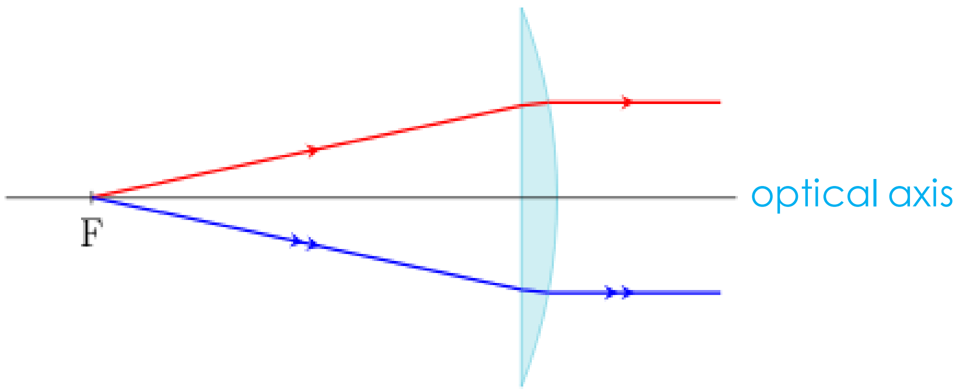


Fig.3: Primary object focal point of a converging lens

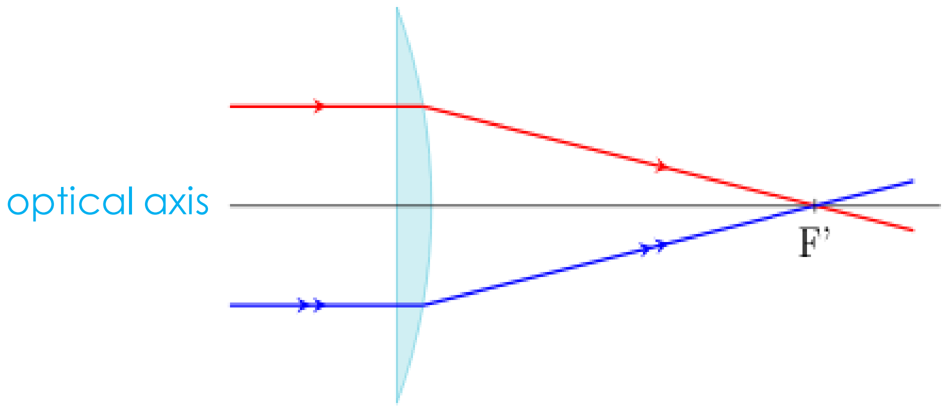


Fig.4: Primary image focal point of a converging lens

Particular points and sizes features

Focal Points

Case of a Converging Lens

Experiment:

A converging lens is placed facing the Sun in order to obtain the smallest possible bright spot on a piece of paper.

Interpretation:

A converging lens converges the Sun's rays to a point F called the focal point of the lens. At this point, it is possible to ignite a piece of paper because the energy from the Sun passing through the lens is concentrated there. The temperature at this point can be very high (up to several thousand degrees Celsius)!

Focal Points

Case of a Diverging Lens

A diverging lens also has two focal points, but their positions are reversed compared to those of a converging lens:

1. Any incident ray whose extension passes through F, the primary object focal point, emerges parallel to the optical axis.

2. Any incident ray parallel to the optical axis emerges in such a way that its extension passes through F', the primary image focal point.

These focal points are also symmetrical with respect to the optical center of the lens.

Focal Points

Case of a Diverging Lens

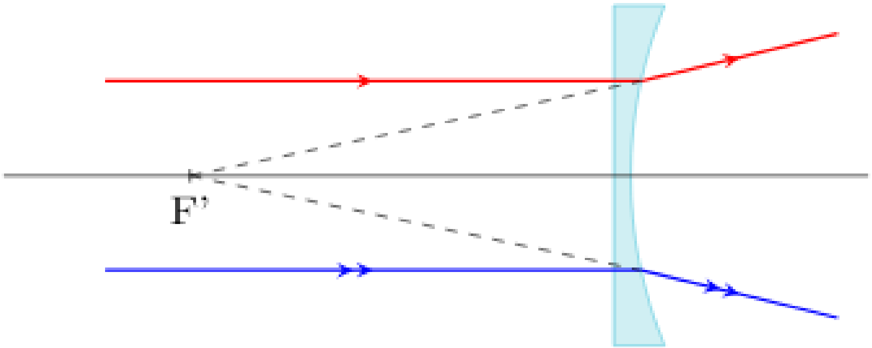


Fig.5: Primary image focal point of a diverging lens

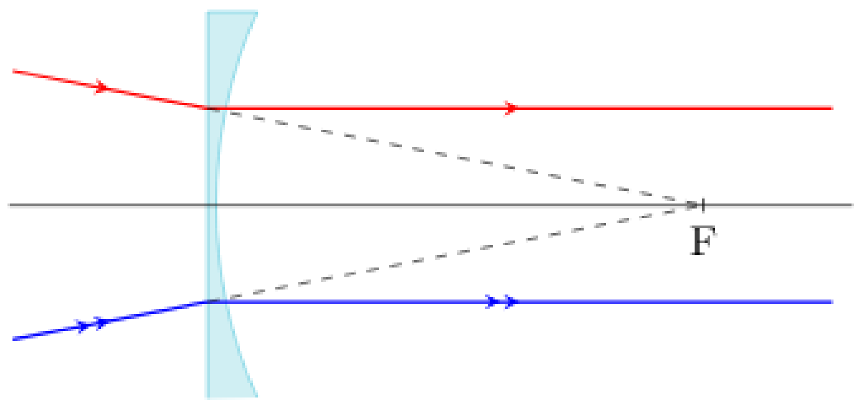


Fig.6: Primary object focal point of a diverging lens

Focal Length and Vergence

To remember:

- The focal length is an algebraic quantity $\overline{OF'}$ expressed in meters (m). It is positive for a converging lens but negative for a diverging lens.

- Vergence is defined as:

$$V = \frac{1}{\overline{OF'}}$$

It is expressed in diopters (δ) or (m-1). It is positive in the case of a converging lens, negative in the case of a diverging lens.

Magnification and conjugation relationships

To establish these, we use the most classic construction of the image of an object AB located beyond the focal point of the converging lens.

$(|\overline{OA}| > |\overline{OF}|)$

But it should be noted that this is valid regardless of the position of the object and regardless of the nature of the lens.

To perform this construction, we can trace three rays whose directions of propagation are known:

- The ray passing through the optical center of the lens is not deviated.
- The ray arriving parallel to the optical axis on the lens emerges through F'.
- The ray passing through F before intercepting the lens emerges parallel to the optical axis.

Magnification and conjugation relationships

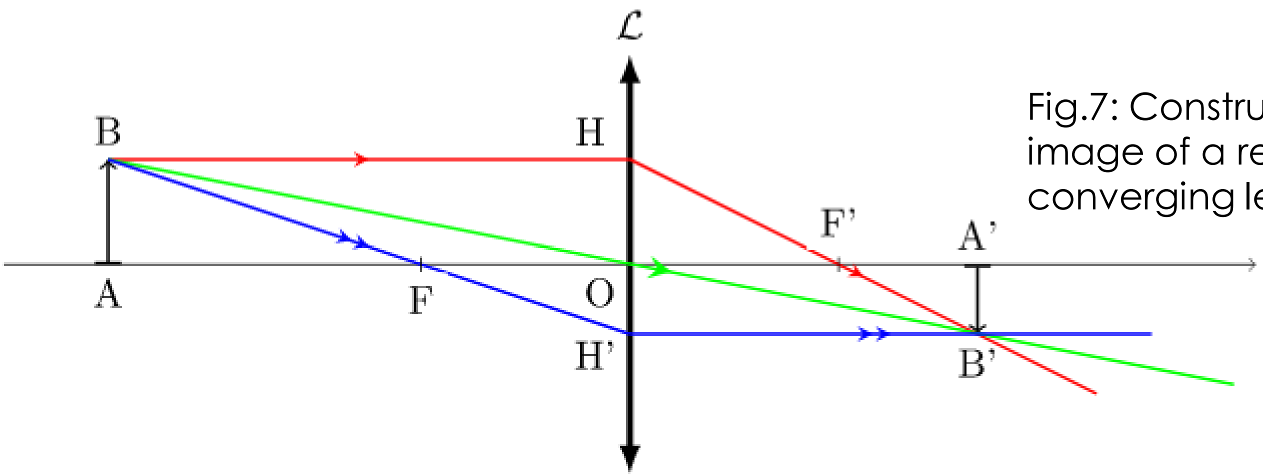


Fig.7: Construction of the real image of a real object by a converging lens

Newton's relations (origin at the focal points)

According to Thales' theorem applied in triangles ABF and OH'F

$$\gamma = \frac{\overline{A'B'}}{\overline{AB}} = \frac{\overline{OH'}}{\overline{AB}} = \frac{\overline{FO}}{\overline{FA}}$$

According to Thales' theorem applied in triangles HOF' and F'A'B'

$$\gamma = \frac{\overline{A'B'}}{\overline{AB}} = \frac{\overline{A'B'}}{\overline{OH}} = \frac{\overline{F'A'}}{\overline{F'O}}$$

By combining the two previous relations, we obtain:

$$\boxed{\overline{F'A'}\,\overline{FA} = \overline{F'O}\,\overline{FO} = -f'^2}$$

Descartes' relations (origin at the center)

To obtain the magnification, Thales' theorem is applied in triangles OAB and OA'B' :

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

To obtain the conjugate relation, we start from the Newton's relation and introduce point O :

$$(\overline{F'O} + \overline{OA'})(\overline{FO} + \overline{OA}) = -f'^2$$

We replace $\overline{F'O}$ with $-f'$ and $\overline{FO}$ with f', We expand, and the terms with f'^2 disappear. We have:

$$f'\,\overline{OA'} - f'\,\overline{OA} + \overline{OA}\,\overline{OA'} = 0$$

We expand, and the terms with $f'\,\overline{OA}\,\overline{OA'}$:

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

Adjacent Lenses

Let's consider two lenses with vergences V1 and V2 placed together: we assume their optical centers are coincident. The first lens forms an image that becomes the object for the second lens. Applying the conjugate relation to this system shows that this combination behaves like a single lens with vergence V = V1 + V2.

Therefore, we can apply the conjugate relation as if it were a single lens.

Attention! If the lenses are not placed together, the conjugate relation is no longer valid.

Constructions for all configurations

Case of a Converging Lens

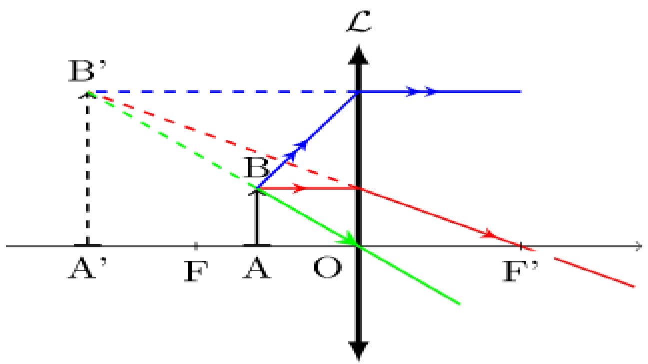


Fig.8: Converging lens: real object, virtual image (case: magnifying glass)

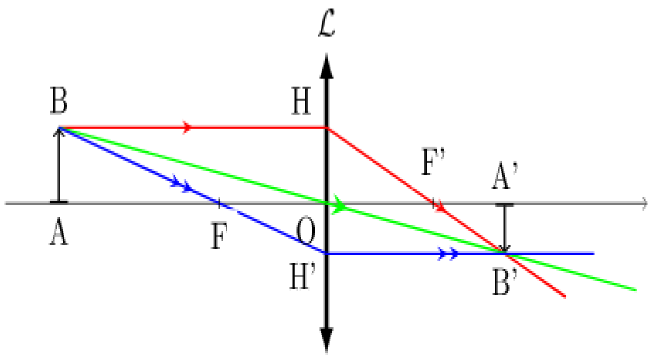


Fig.9: Construction of the real image of a real object by a converging lens

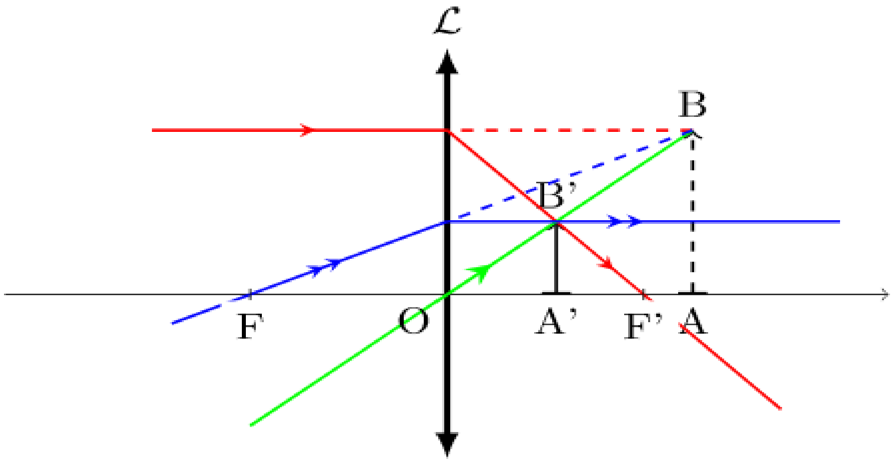


Fig.10: Converging lens: virtual object, real image

Constructions for all configurations

Case of a Diverging Lens

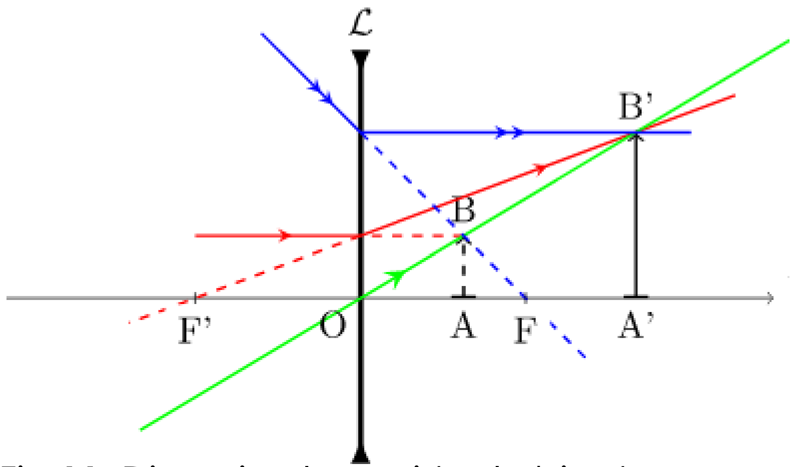


Fig.11: Diverging lens: virtual object, real image

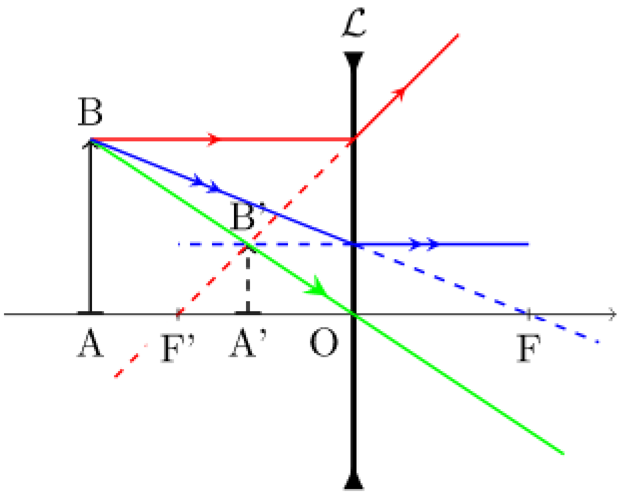


Fig.12: Diverging lens: real object, virtual image

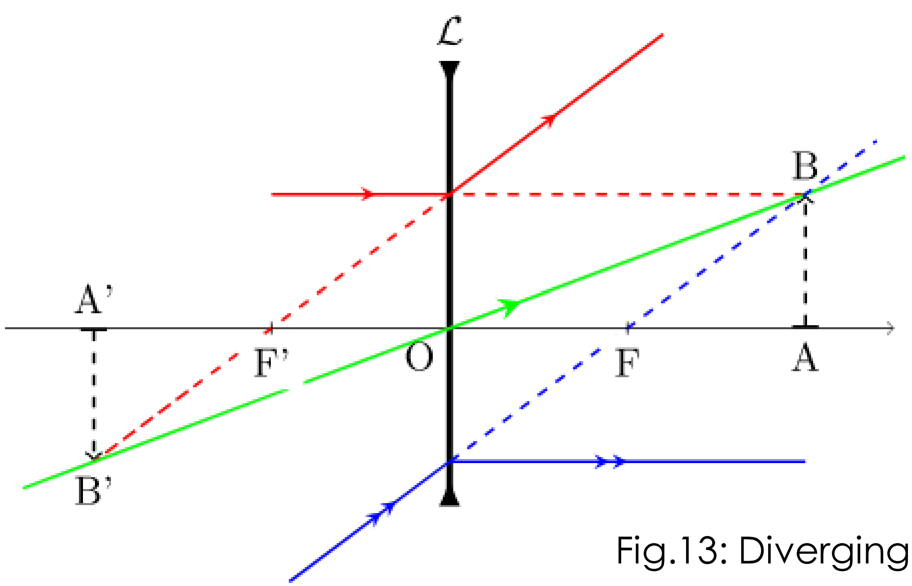


Fig.13: Diverging lens: virtual object, virtual image

University Aboubekr Belkaid, Tlemcen

Institute of Science and Applied Techniques

Lecturer : Dr. Abdennasser TACHEMA

Mail : abdennasser.tachema@univ-tlemcen.dz