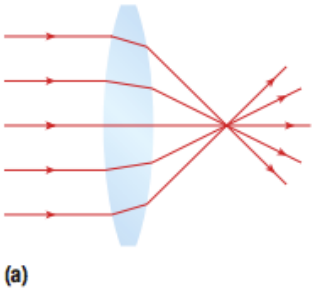
Grade 10 Science

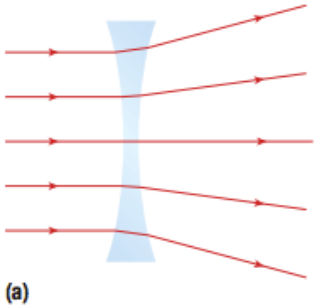
Light and Geometric Optics

Class 12

Lenses



(a)

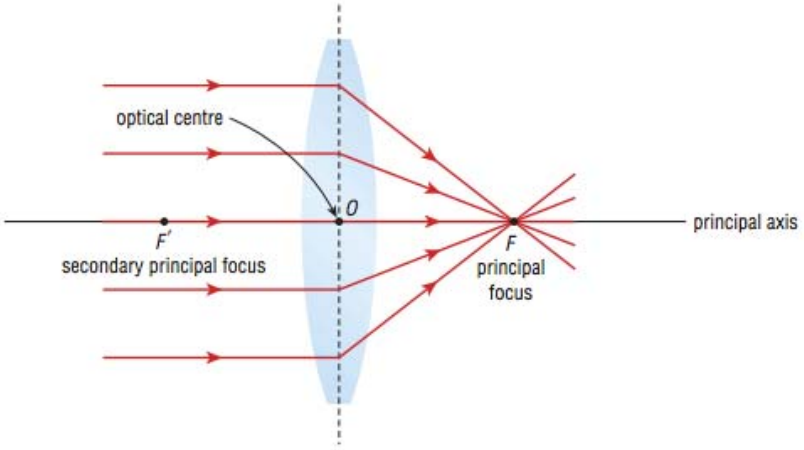


(a)

- **Converging Lens** – lens that is thickest in the middle and causes incident parallel light rays to converge through a single point
- **Diverging Lens** – lens that is thinnest in the middle and that causes the incident parallel light rays to spread apart

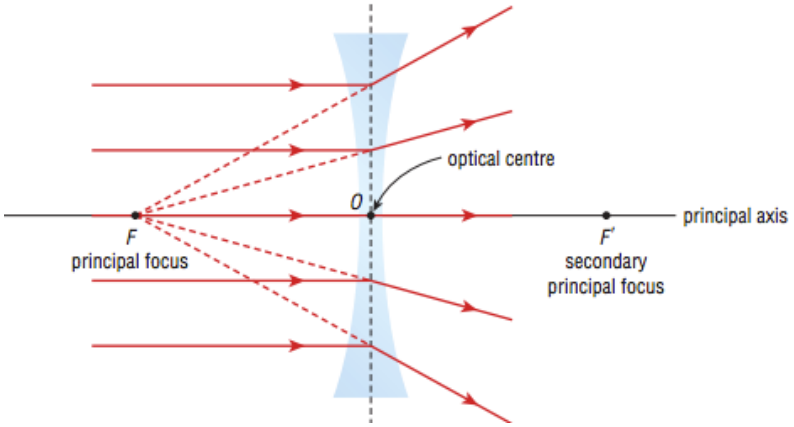
Terms in Converging Lens

- **Optical Centre** – the centre of the lens
- **Principal Axis** – the line perpendicular to the lens
- **Principal Focus** – the point where light rays converge after refraction



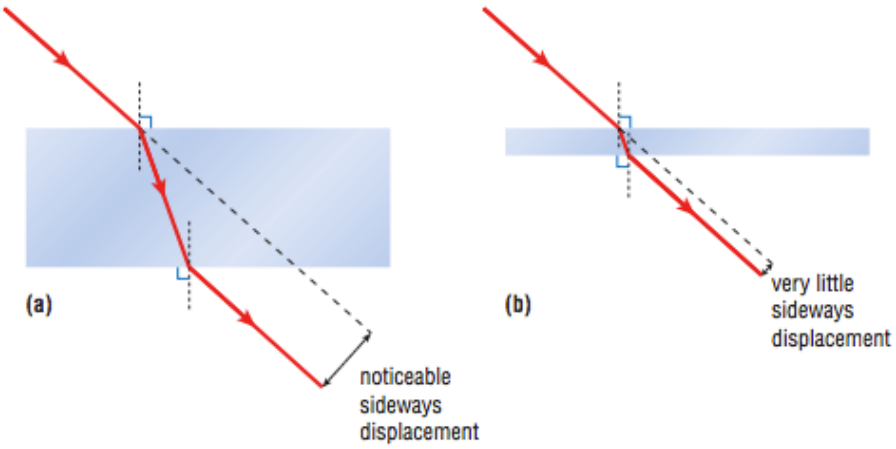
Terms in Diverging Lens

- **Principal Focus** – where the diverging lines converge backwards
- **Secondary Principal Focus (F')** – the other side of the lens; the same distance apart from the lens as F



Emergent Ray

- Emergent Ray – the light ray that leaves a lens after refraction



Locating an Image - Converging

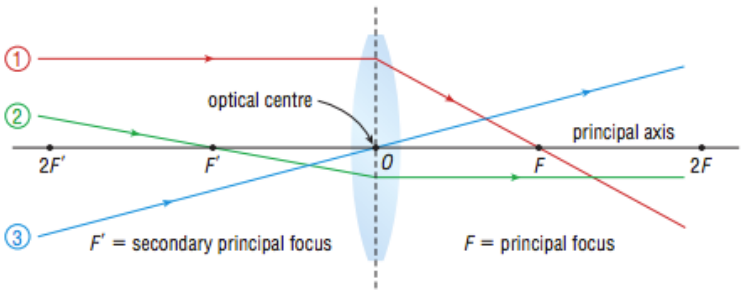


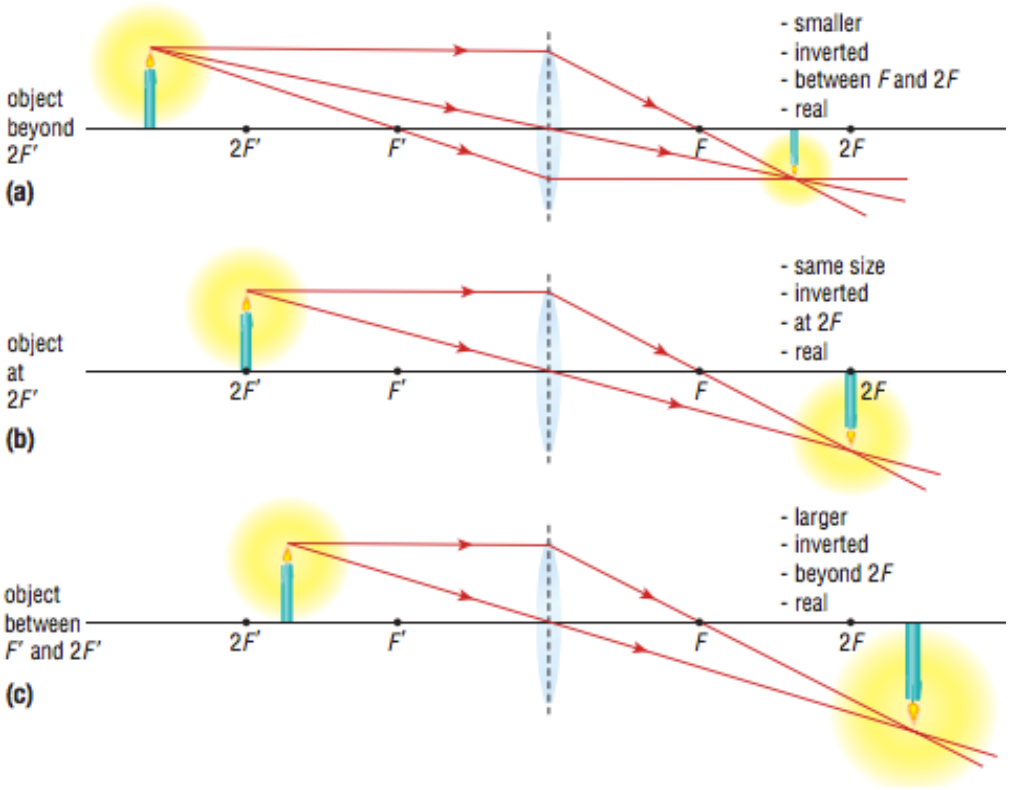
Figure 2 Imaging rules for a converging lens

① A ray parallel to the principal axis is refracted through the principal focus (*F*).

② A ray through the secondary principal focus (*F'*) is refracted parallel to the principal axis. This rule comes from the reversibility of light.

③ A ray through the optical centre (*O*) continues straight through without being refracted. This is true because the middle part of the lens acts like a very thin rectangular prism with no noticeable sideways displacement.

- Note: Only true for thin lenses



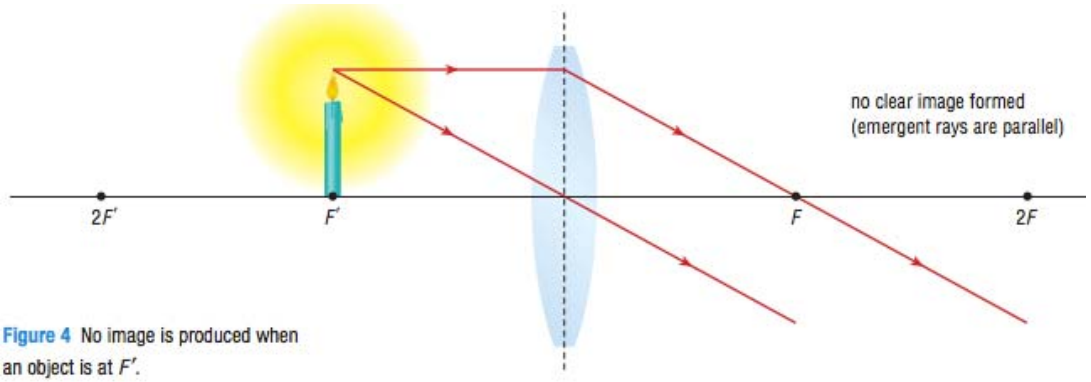


Figure 4 No image is produced when an object is at F'.

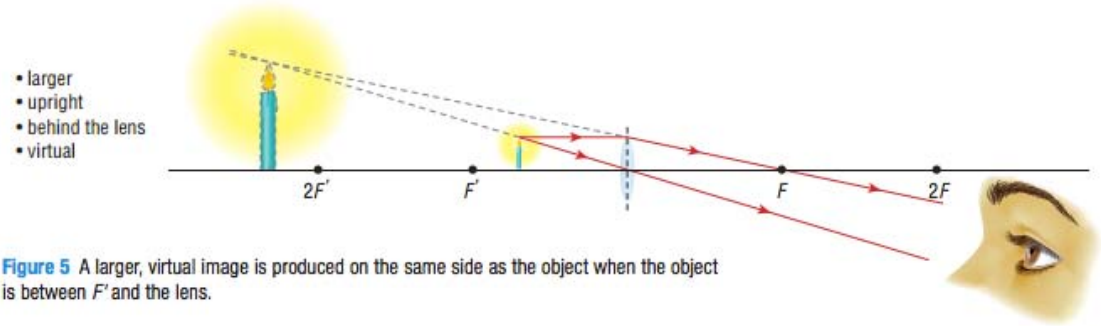
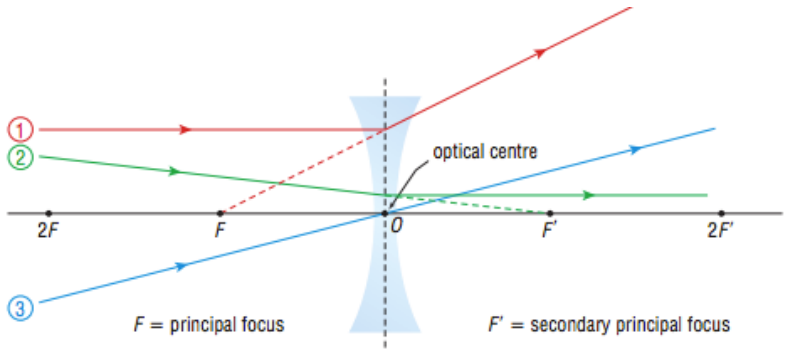


Figure 5 A larger, virtual image is produced on the same side as the object when the object is between F' and the lens.

Table 1 The Imaging Properties of a Converging Lens

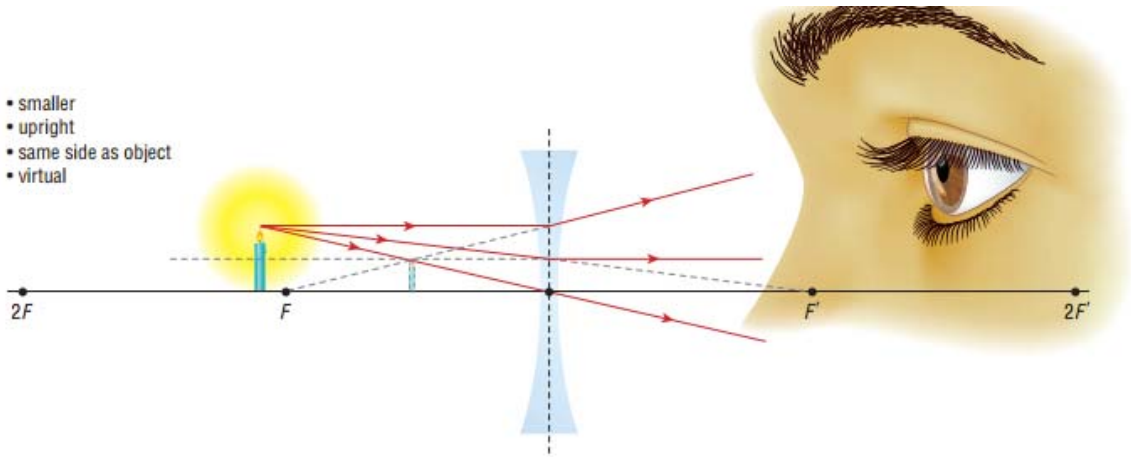
OBJECT	IMAGE			
Location	**Size**	**Attitude**	**Location**	**Type**
beyond $2F'$	smaller	inverted	between $2F$ and F	real
at $2F'$	same size	inverted	at $2F$	real
between $2F'$ and F'	larger	inverted	beyond $2F$	real
at F'	no clear image			
inside F'	larger	upright	same side as object (behind lens)	virtual

Locating an Image - Diverging



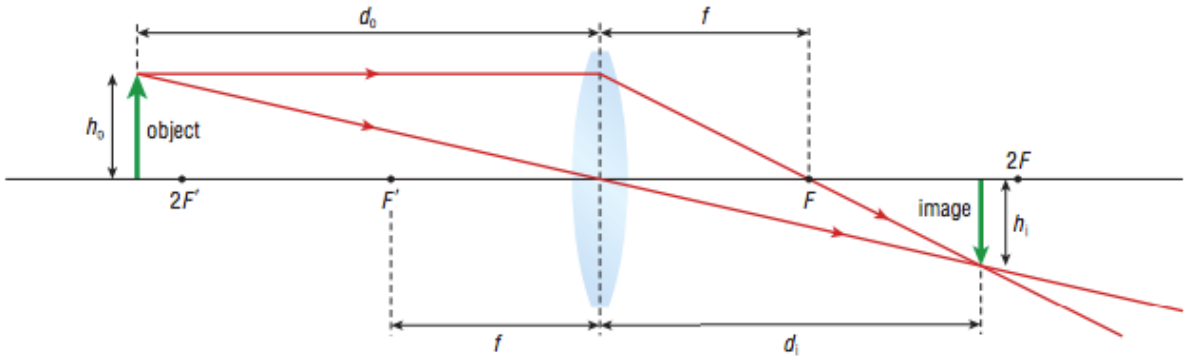
1. A ray parallel to the principal axis is refracted as if it had come through the principal focus (F).
2. A ray that appears to pass through the secondary principal focus (F') is refracted parallel to the principal axis.
3. A ray through the optical centre (O) continues straight through on its path.

Figure 6 Imaging rules for a diverging lens



The Lens Equation

- Besides a diagram, you can also use algebra to determine the characteristics of an image
- Variables:
  - d_0 = distance from the object to the optical centre
  - d_i = distance from the image to the optical centre
  - h_0 = height of the object
  - h_i = height of the image
  - f = focal length of the lens; distance from the optical centre to the principal focus



The Thin Lens Equation

$$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$$

- Object distances (d_0) are always positive
- Image distances (d_i) are positive for real images (opposite side) and negative for virtual (same side)
- The focal length is positive for converging lenses and negative for diverging lenses

Checkpoint

a) A converging lens has a focal length of 17cm. A candle is located 48cm from the lens. What type of image will be formed and where will it be located?

b) A diverging lens has a focal length of 29cm. A virtual image of a marble is located 13cm in front of the lens. Where is the marble located?

The Magnification Equation

$$M = \frac{h_i}{h_0} = -\frac{d_i}{d_0}$$

- Object (h_0) and image (h_i) heights are positive when measure upward from the principal axis and negative when measured downward
- Magnification is positive for an upright image and negative for an inverted image

Checkpoint

a) A toy of height 8.4cm is balanced in front of a converging lens. An inverted, real image of height 23cm is noticed on the other side of the lens. What is the magnification of the lens?

b) A coin of height 2.4cm is placed in front of a diverging lens. An upright, virtual image of height 1.7cm is noticed on the same side of the lens as the coin. What is the magnification of the lens?

Table 1 Sign Conventions for Lenses

Variable	Positive	Negative
(object distance) d_o	always	never
(image distance) d_i	real image (image is on opposite side of lens as object)	virtual image (image is on same side of lens as object)
(height of object) h_o	when measured upward	when measured downward
(height of image) h_i	when measured upward	when measured downward
(focal length) f	converging lens	diverging lens
(magnification) M	upright image	inverted image