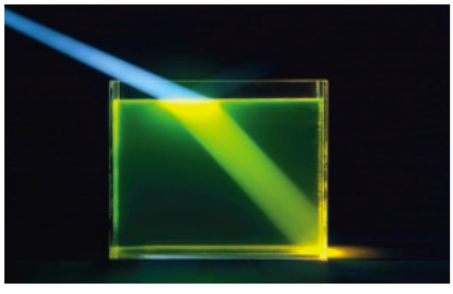
Grade 10 Science

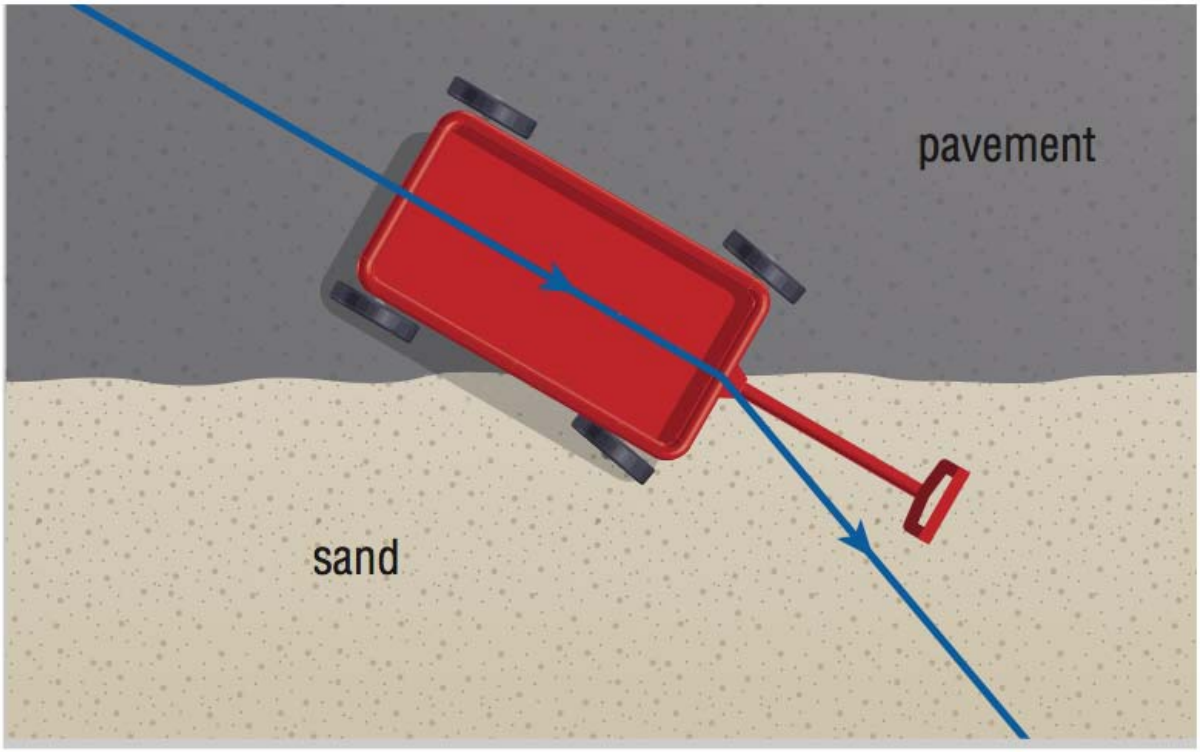
Light and Geometric Optics

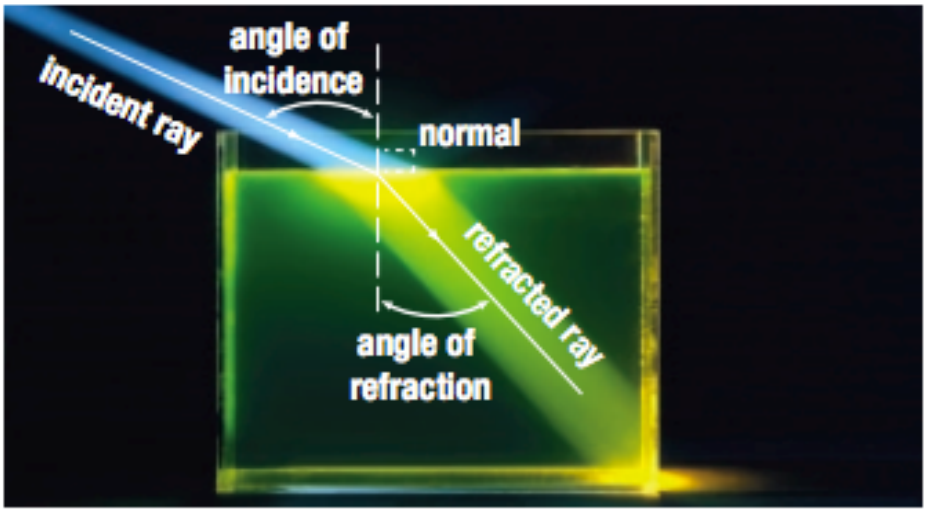
Class 10

Refraction

- **Refraction** – the bending or change in direction of light when it travels from one medium into another
- Light slows down when it travels in different medium
  - Vacuum = 3.0 x 10^8 m/s (ideal)
  - Water = 2.26 x 10^8 m/s
  - Acrylic = 1.76 x 10^8 m/s







- Light bends towards the normal when the speed of light in the second medium is less than the speed of light in the first medium
- Light bends away from the normal when the speed of light in the second medium is greater

The Index of Refraction

- The speed of light is different for each medium but it is always less than the speed of light in a vacuum
- Index of refraction (n) = c/v
  - c = speed of light in vacuum
  - v = speed of light in the medium
- Index of refraction (n) = $\sin\theta_i/\sin\theta_R$
  - θ_i = angle of incidence
  - θ_R = angle of refraction

Checkpoint

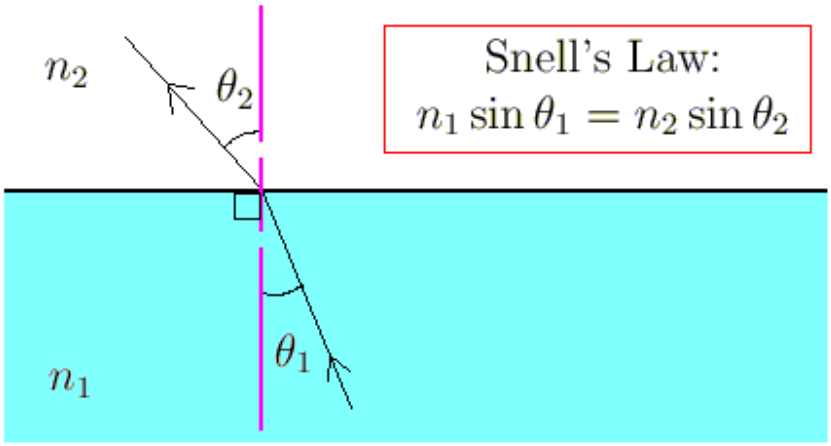
Medium	Index of refraction (*n*)
air/vacuum	1.00
ice	1.31
pure water	1.33
ethyl alcohol	1.36
quartz	1.46
vegetable oil	1.47
olive oil	1.48
acrylic	1.49
glass	1.52
zircon	1.92
diamond	2.42

a) The speed of light in NaCl is 1.96×10^8 m/s. Calculate the index of refraction for NaCl.

b) Calculate the speed of light in olive oil

Snell's Law

- Used to find the indices of refraction OR the angle of refraction



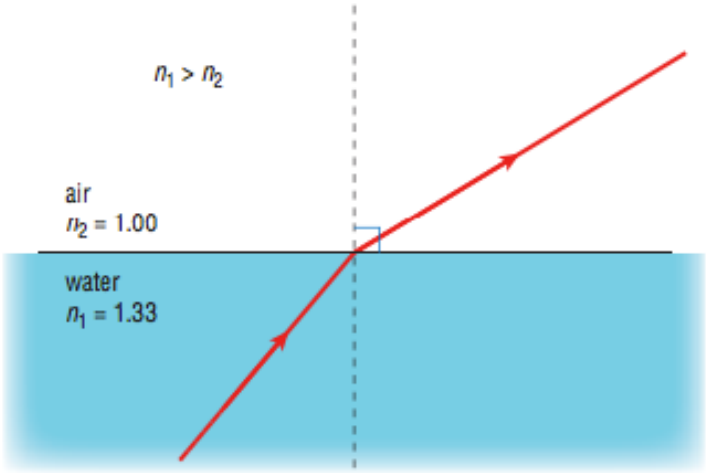
Checkpoint

a) A ray of light is passing from air (n=1.00) to water (n=1.33) at an angle of incidence of 45°, calculate the angle of refraction.

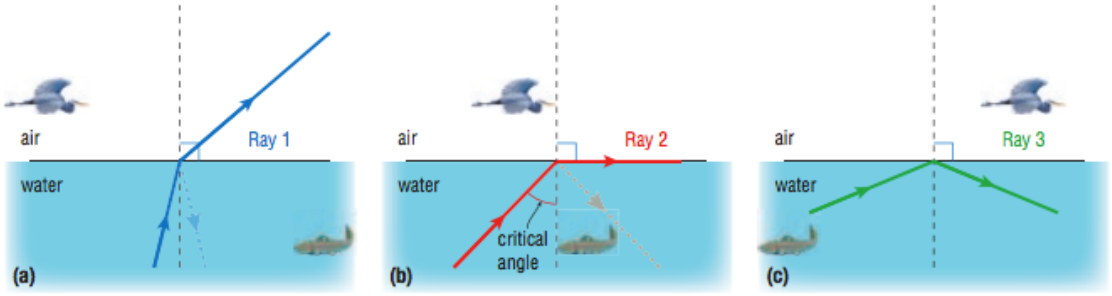
a) You have an unknown medium. You pass a ray of light from air (n=1.00) to the medium at an angle of incidence of 52° and find that the angle of refraction is 35.4°. What is the unknown medium?

Total Internal Reflection

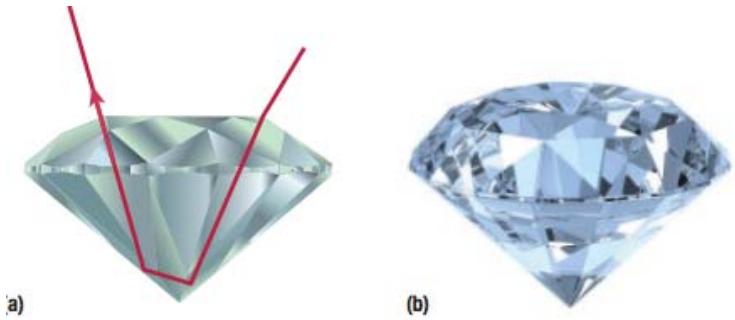
- Critical Angle = the angle of incidence that produces a refracted angle of 90°

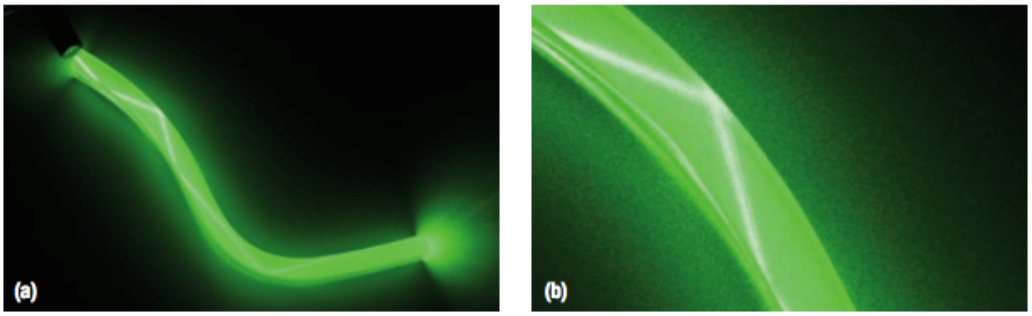


- When you increase the angle of incidence past the critical angle, the refracted ray will no longer exit the medium but will reflect back instead
- Total Internal Reflection Occurs when:
  1. Light is travelling more slowly in the first medium than in the second
  2. The angle of incidence is large enough that no refraction occurs in the second medium.
- Water has a critical angle of 48.8°



- The sparkle in diamonds is due to the total internal reflection of the light inside the diamond

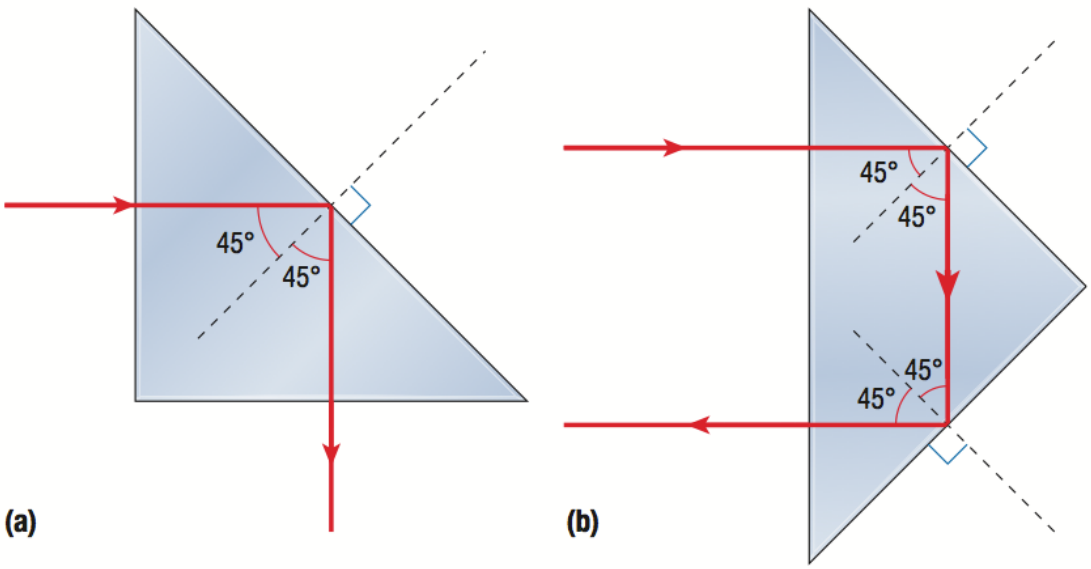




- Fibre Optics must transmit information using light so the cable must have a small critical angle
- Prisms are also objects that can undergo total internal reflection

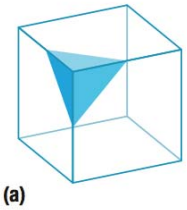
Triangular Prisms

- Critical angle for glass is 41.1°
- If angle of incidence is greater than 41.1°, total internal reflection will result
- Prisms reflect better than mirrors since mirrors absorb some light and the silvered surface of the mirror deteriorates over time
- Most optical devices such as cameras and binoculars use prisms instead of mirrors



Retro-reflectors and Prisms

A retro-reflector is an optical device that returns incident light back the same direction from which it came



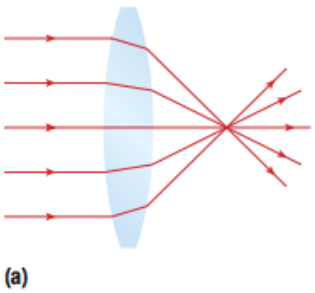
(a)

(b)

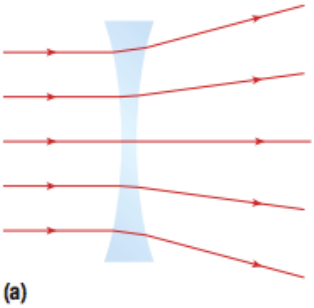
(c)

Found in road signs and road paint

Lenses



(a)

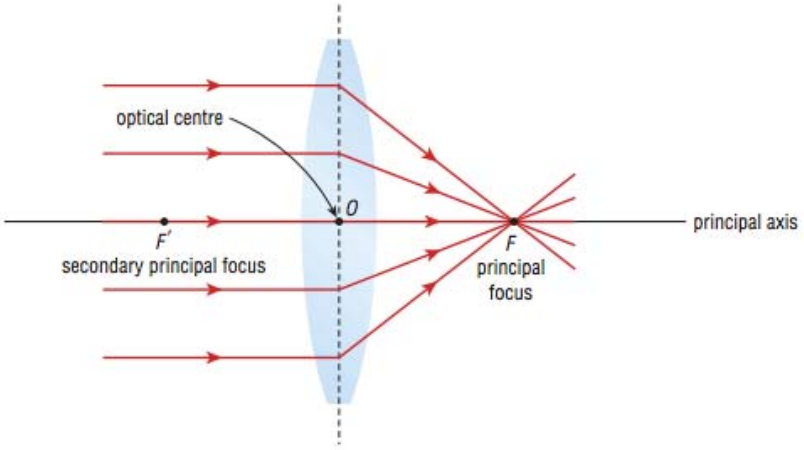


(a)

- **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

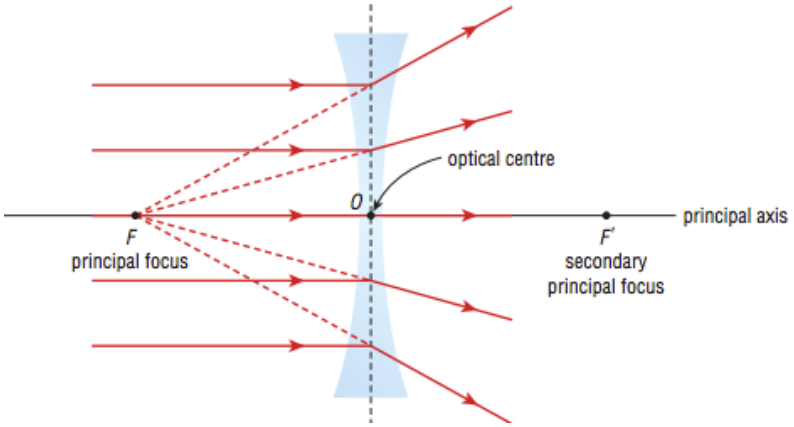
Terms in Converging Lens

- **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



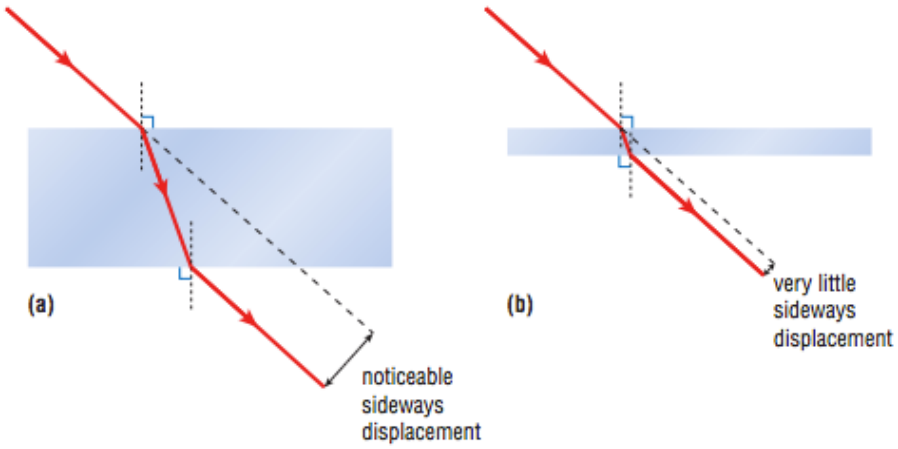
Terms in Diverging Lens

- **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

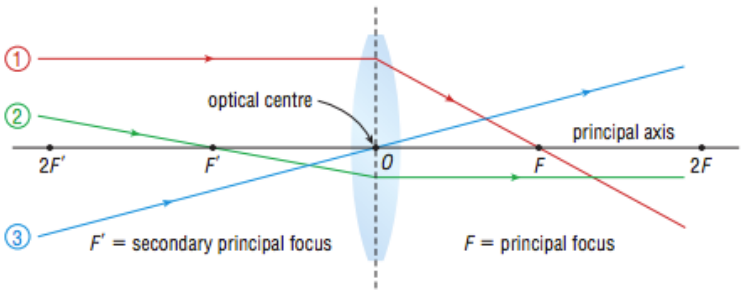


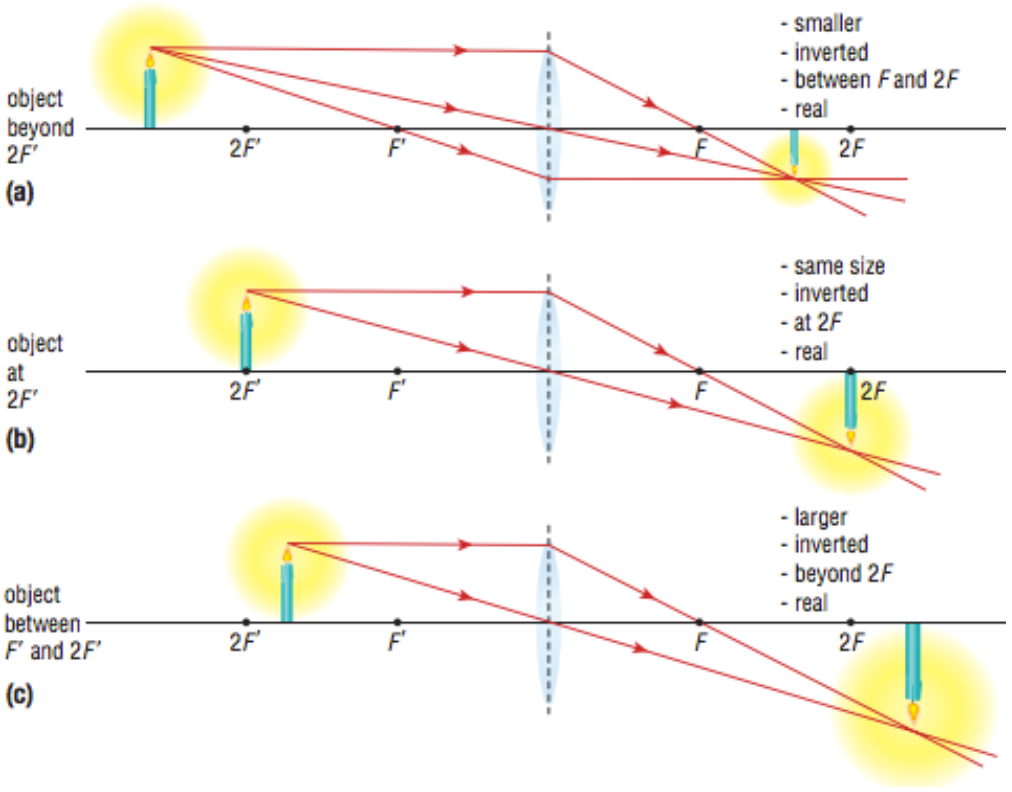
Figure 2 Imaging rules for a converging lens

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



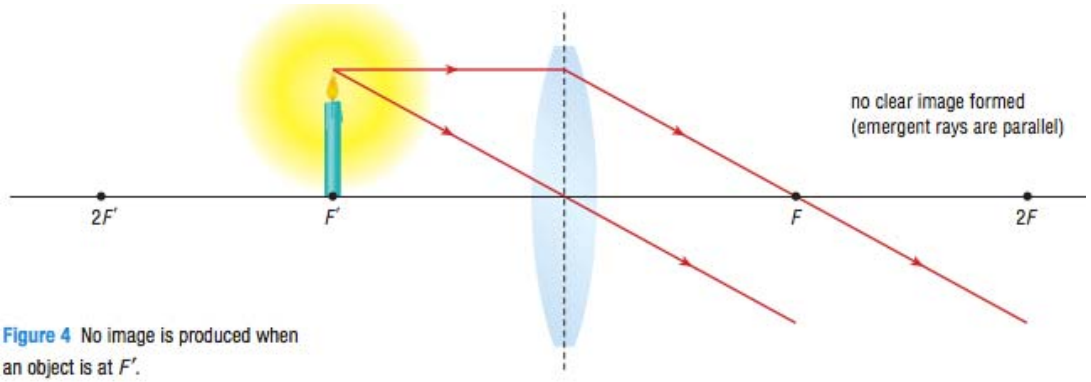


Figure 4 No image is produced when an object is at F'.

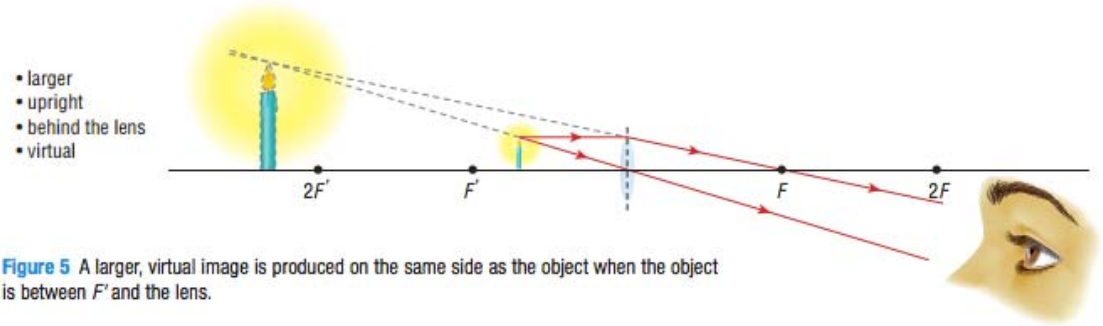
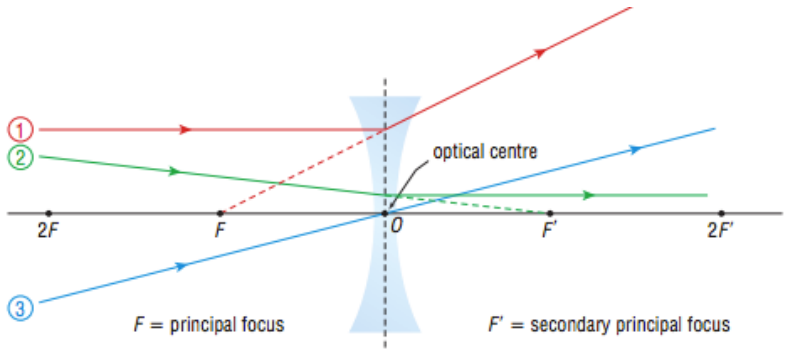


Figure 5 A larger, virtual image is produced on the same side as the object when the object is between F' and the lens.

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

- smaller
- upright
- same side as object
- virtual