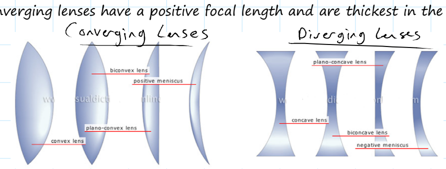
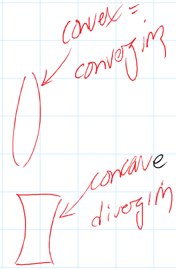
Lenses

A lens is a carefully shaped piece of glass that can focus light rays.

<u>Various Lens Shapes</u>

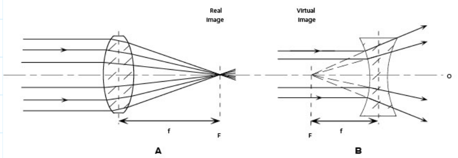
Converging lenses have a positive focal length and are thickest in the middle.





Diverging lenses have a negative focal length and are thickest at the edges.

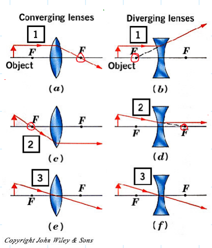
Lenses use refraction to focus the light rays.



All the light rays converge at one spot. All the light rays spread out.

<u>3 Rules are used to find the images formed by lenses.</u>

1) Light rays that are parallel to the principal axis of a lenses are refracted through the focal point.
2) Light rays that pass through the focal point are refracted parallel to the principal axis.
3) Light rays passing through the center pass through without being refracted.



☆ Remember which focal point to use.

<u>Real Image</u> - the actual rays pass through the focal point. Real Rays meet at image

<u>Virtual Image</u> - The rays do not pass through the focal point. Trace rays back to find image

<u>Sign Convention for Thin Lenses:</u>

1. Focal length is + for converging lenses and - for diverging lenses.
2. d_o is + if the object is on the side of lens from which the light is coming, otherwise it is negative.
3. d_i is + if on the opposite side of the lens from where the light is coming, otherwise it is negative. Positive for Real image / Negative for Virtual image
4. h_i and h_o are positive above the Principal Axis and negative below Axis.

If M (magnification) is +, the image is erect (right side up)

If M (magnification) is -, the image is inverted (upside down)

The Lens Maker's Equation:

d_o = distance from object to lens.

d_i = distance from image to lens.

f = focal point (half the distance to center) of Curvature)

$f = \frac{C}{2}$

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \Rightarrow f = \frac{d_o d_i}{d_o + d_i}$$

(The units are any unit of length, just keep them the same)

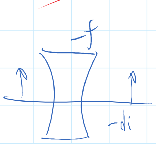
The Magnification Equation:

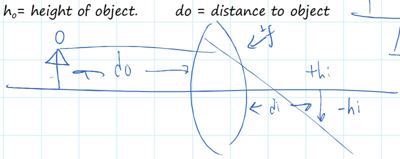
Same as Mirrors

$$M=\frac{h_i}{h_o} \quad \textbf{OR} \quad M=-\frac{d_i}{d_o}$$

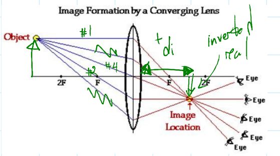
h_i = height of image. di = distance to image

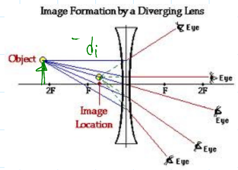
h_o= height of object. do = distance to object

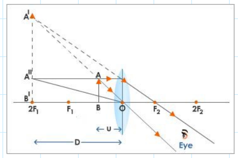




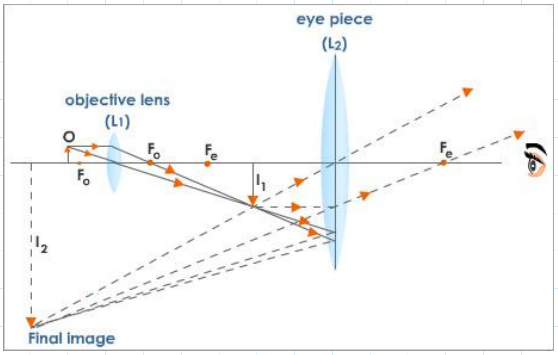
http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=48



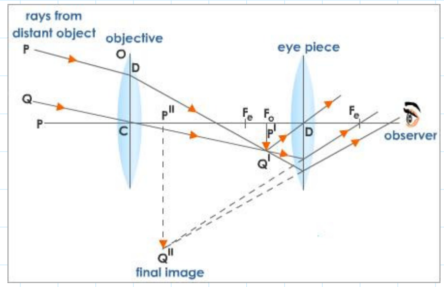




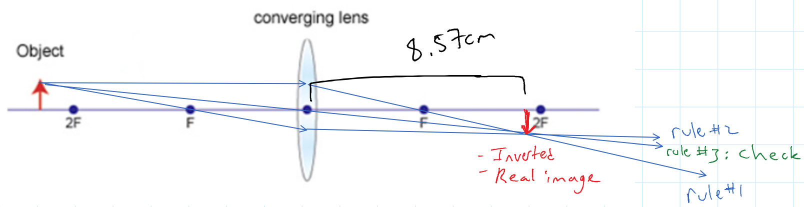
Magnifying glass



Microscope



Telescope



$f = 5cm$
$d_o = 12cm$
$h_o = 2cm$
$h_i = ?$
$d_i = ?$

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

$$\frac{1}{12} + \frac{1}{d_i} = \frac{1}{5}$$

$$\frac{1}{d_i} = \frac{1}{5} - \frac{1}{12}$$

$$d_i = \frac{1}{\frac{1}{5} - \frac{1}{12}}$$

or $d_i = ($[illegible]

$d_i = 8$[illegible]

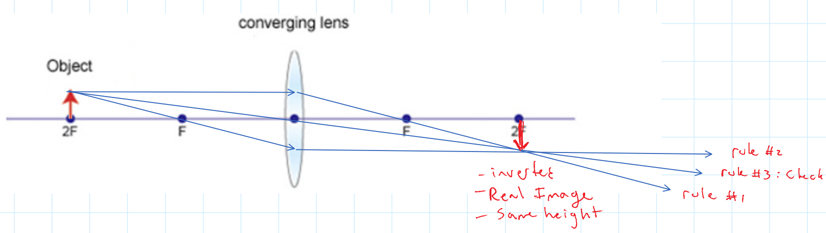
$$M = -\frac{d_i}{d_o}$$

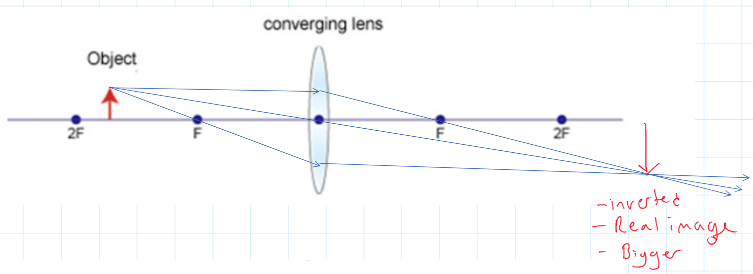
$$M = -\frac{8.57}{12}$$

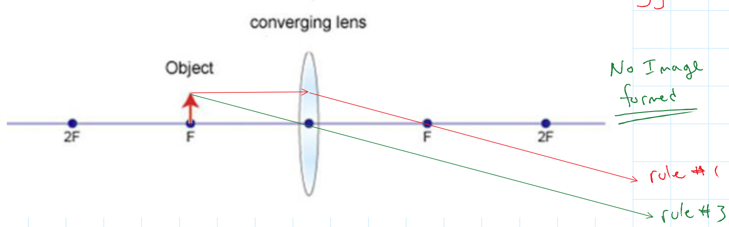
$$M = -0.714$$

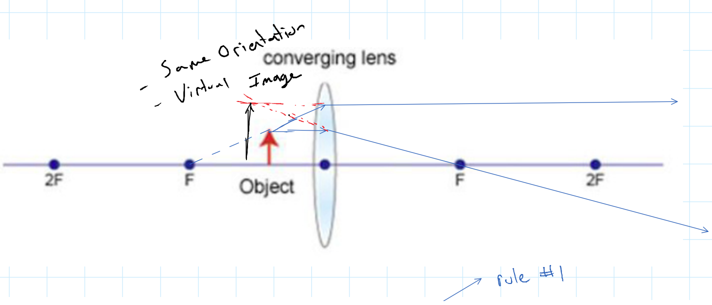
$$\frac{h_i}{h_o} = M$$

$$h_i = (-0.714)(2) = -1.43cm$$









$d_o = 3cm$
$f = 5cm$
$h_o = 2cm$

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

$$\frac{1}{3} + \frac{1}{d_i} = \frac{1}{5}$$

$$\frac{1}{d_i} = \frac{1}{5} - \frac{1}{3}$$

$$d_i = \left(\frac{1}{5} - \frac{1}{3}\right)^{-1}$$

$d_i = -7.5$[illegible]

$$M = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$$

$$\frac{-(-7.5)}{3}(2) =$$ [illegible]

$5cm =$ [illegible]

$\frac{1}{5} - \frac{1}{12})^{-1}$

$.57$

h_i

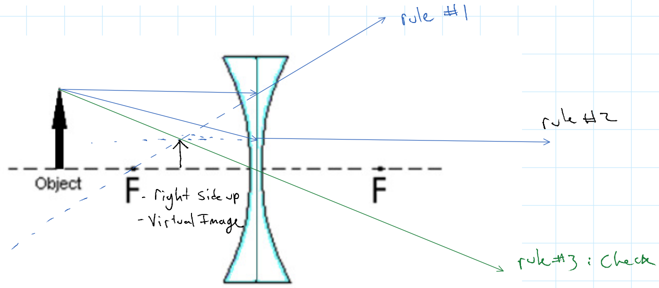
h_i

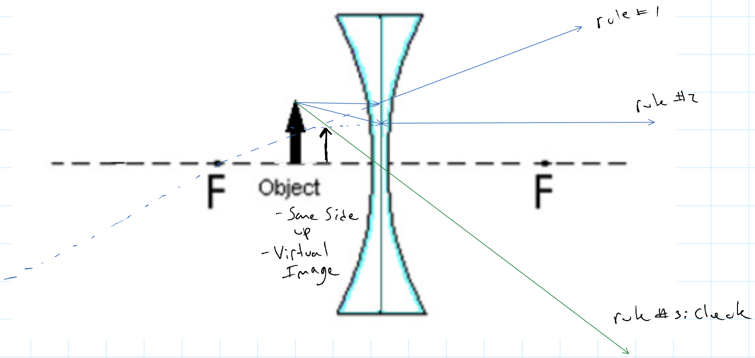
$$d_i = \left(\frac{1}{5} - \frac{1}{3}\right)^{-1}$$

$$d_i = -7.5\,cm$$

3

5cm=





$d_o = 7cm$

$h_o = 11cm$

$f = -17cm$

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

$$d_i = \left(\frac{1}{-17} - \frac{1}{7}\right)^{-1}$$

$$d_i = -5\,cm$$

$$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

$$h_i = -\frac{d_i h_o}{d_o}$$

$$h_i = -\frac{(-5)(11)}{7}$$

$$h_i = 7.9\,cm$$

Wave Properties

$T = \frac{1}{f}$ — T: Period (seconds per wave)

f: frequency (waves per second)

$V = \frac{d}{t}$ — λ: wavelength

$V = \frac{\lambda}{T}$ — t: time

d: distance

V: Speed

Refraction / Reflection

$n' = \frac{c}{v'}$ — C: Speed of light $(3.00 \times 10^8\, m/s)$ in Vacuum

V': Speed of light in medium

n': index of refraction for the medium

$n_i \sin\theta_i = n_r \sin\theta_r$ — n_i: incident medium

n_r: refraction medium

θ_i: incident angle

θ_r: refraction angle

$\theta_{incident} = \theta_{reflection}$

Test Tuesday

$\sin\theta_c = \frac{n_r}{n_i}$ — θ_c = critical angle

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ — f = focal point

d_o = distance to object

$M = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$ — d_i = distance to image

h_i = height of image

h_i

h_o = height of object