

- Unlike mirrors, light passes *through* a convex lens and then _____ (Law of Refraction) towards the focal point F.

- Sign rules for lenses are *very similar* to rules for mirrors, except $f > 0$ for convex lenses, $f < 0$ for concave.

$d_o > 0$ if object on same side as **IN**bound rays
 $d_i > 0$ if image on same side as **OUT**bound rays
 $f > 0$ if convex lens, < 0 for concave
 (Always use signs for KNOWN quantities)

PRACTICE: An object is placed 36cm to the left of a convex lens, an image is formed 20cm to the right of the lens. What is the focal length of this lens?

SIGN RULES FOR LENSES

$d_o > 0$ if object on same side as **IN**bound rays

$d_i > 0$ if image on same side as **OUT**bound rays

$f > 0$ if convex lens, < 0 for concave

(Always use signs for KNOWN quantities)

GEOMETRIC OPTICS

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

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

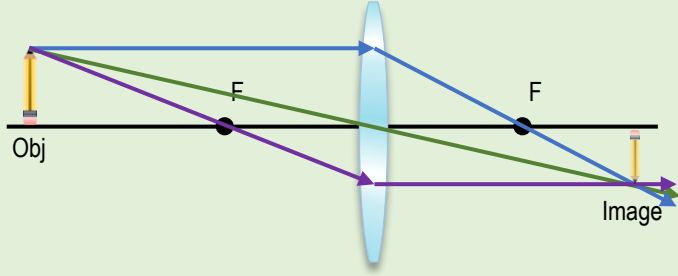
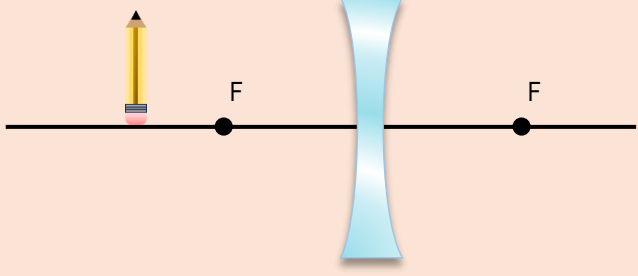
EXAMPLE: A student uses a convex lens with a focal length $f = 15\text{cm}$ to project a sharp image of a small candle onto a screen. The image forms 60cm from the lens on the opposite side as the candle.

a) How far is the candle from the lens?

b) What is the magnification of the image? Is it upright or inverted?

CONCEPT: RAY DIAGRAMS FOR CONCAVE LENSES

- Concave (“Diverging”) lenses bend light _____ from the near focal point **F**.
 - These lenses always have [**POSITIVE** | **NEGATIVE**] values of f .

RAY DIAGRAMS FOR LENSES	
CONVEX (“CONVERGING”)	CONCAVE (“DIVERGING”)
1) P-ray: Parallel, then towards far F 2) F-ray: Through near F, then parallel 3) M-ray: Through Midpoint 	1) P-ray: Parallel, then away from _____ F 2) F-ray: Towards _____ F, then parallel 3) M-ray: Through Midpoint 
Type	[REAL VIRTUAL]
Orientation	[UPRIGHT INVERTED]
Size	[REDUCED ENLARGED]

PRACTICE: You place a pencil in front of a concave lens with a focal length of -20.0cm . The magnification of the image is $m = \frac{1}{2}$. If you wanted to make the image even smaller, should you move the pencil closer to the lens or farther away?

- A) Closer
- B) Farther
- C) Neither

EXAMPLE: An object 10cm tall is placed 35cm in front of a concave lens with a focal length of $f = -12\text{cm}$. Find the distance and height of the image.

SIGN RULES FOR LENSES

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$d_i > 0$ if image on same side as **OUT**bound rays

$f > 0$ if convex lens, < 0 for concave

(Always use signs for KNOWN quantities)

GEOMETRIC OPTICS

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

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