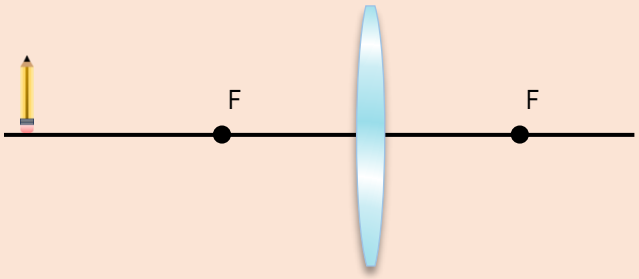
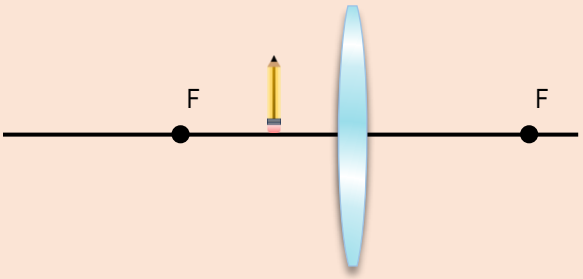
## CONCEPT: RAY DIAGRAMS FOR CONVEX LENSES

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

| RAY DIAGRAMS FOR CONVEX "CONVERGING" LENSES | | |
|---|---|---|
| Draw any 2: | 1) **P-ray**: **P**arallel, then *towards* _____ F<br>2) **F-ray**: *Through* _____ **F**, then parallel<br>3) **M-ray**: Straight *through* **M**idpoint of lens | |
| | **Object beyond F ($d_o > f$)** | **Object closer than F ($d_o < f$)** |
| |  |  |
| **Type** | [ REAL \| VIRTUAL ] | [ REAL \| VIRTUAL ] |
| **Orientation** | [ UPRIGHT \| INVERTED ] | [ UPRIGHT \| INVERTED ] |
| **Size** | [ REDUCED \| ENLARGED ] * (depends on _____) | [ REDUCED \| ENLARGED ] |

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

| SIGN RULES FOR LENSES |
|---|
| $d_o$ **> 0** if object on same side as **IN**bound rays<br>$d_i$ **> 0** if image on same side as **OUT**bound rays<br>$f$ **> 0** if convex lens, **< 0** for concave<br>*(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**

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

$$m=\frac{h_i}{h_O}=-\frac{d_i}{d_O}$$

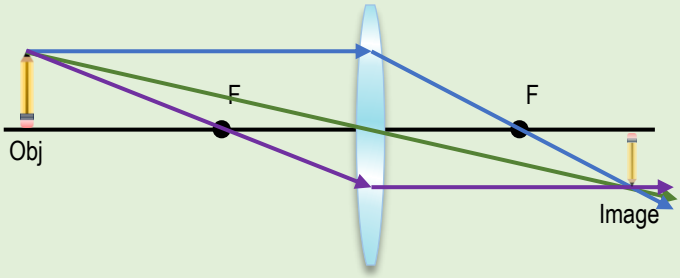
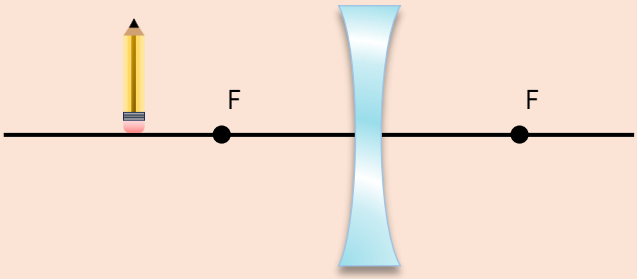
EXAMPLE: A student uses a convex lens with a focal length $f$ = 15cm to project a sharp image of a small candle onto a screen. The image forms 60cm from the lens on the opposite side as the candle.

**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: P**arallel, then towards **far F**<br>**2) F-ray:** *Through* **near F**, then parallel<br>**3) M-ray: *Through* M**idpoint<br>  <br> | **1) P-ray: P**arallel, then *away* from _____ F<br>**2) F-ray:** *Towards* ____ **F**, then parallel<br>**3) M-ray: *Through* M**idpoint<br>  <br> |
| | **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 $f$ = −12cm. Find the distance and height of the image.

**SIGN RULES FOR LENSES**

$\boldsymbol{d_O}$ **> 0** if object on same side as **IN**bound rays
$\boldsymbol{d_i}$ **> 0** if image on same side as **OUT**bound rays
$\boldsymbol{f}$ **> 0** if convex lens, **< 0** for concave

*(Always use signs for KNOWN quantities)*

**GEOMETRIC OPTICS**

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

$$m = \frac{h_i}{h_O} = -\frac{d_i}{d_O}$$