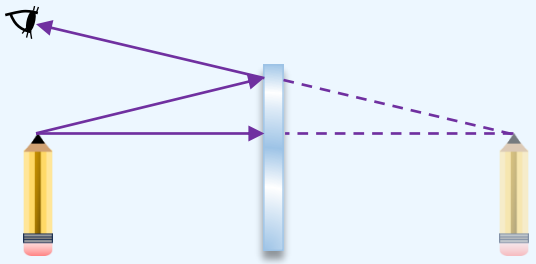
CONCEPT: INTRO TO SPHERICAL MIRRORS

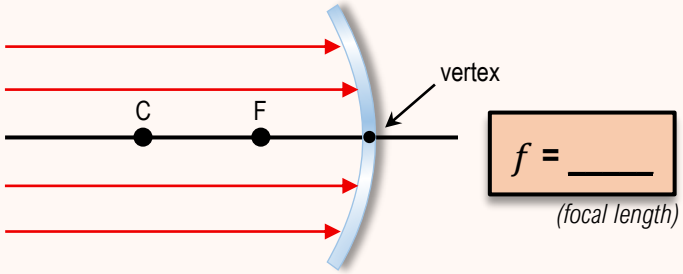
- Unlike plane mirrors, curved/spherical mirrors reflect light to a _____ to form images.
  - Incoming light from "far away" is approximately _____ to axis, then ALWAYS reflects towards F.
    ("paraxial rays")

PLANE MIRRORS



- Image is **[REAL | VIRTUAL]**
- Outbound rays *appear* to _____ F. You would see an image "inside" the mirror!

CON_____ MIRRORS



R = Radius of Curvature = distance from vertex to C

- Image is **[REAL | VIRTUAL]**
- Outbound rays *actually* _____ **F.** You would directly see an image if you put a projector screen here

EXAMPLE: You point a spherical, concave mirror towards the Sun. If the radius of curvature of the mirror is 3.4m, how far from the mirror does all the light from the Sun focus?

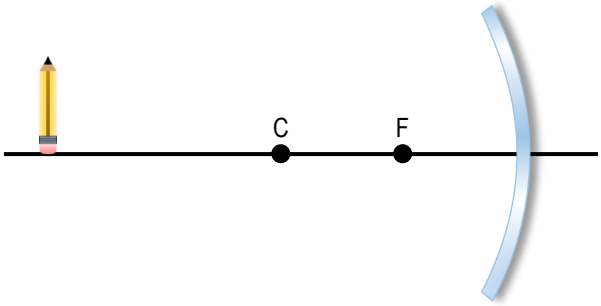
PRACTICE**:** You determine a concave mirror to have focal length f = 10cm**.** If you submerge the mirror in water (n = 1.33), what would be the new focal length?

A) 10cm
B) 11.3cm
C) 20cm
D) Cannot be determined

PRACTICE**:** A concave makeup mirror has a focal length of 12.0cm**.** What is the mirror's radius of curvature?

CONCEPT: PRINCIPAL-RAY DIAGRAMS FOR CONCAVE MIRRORS

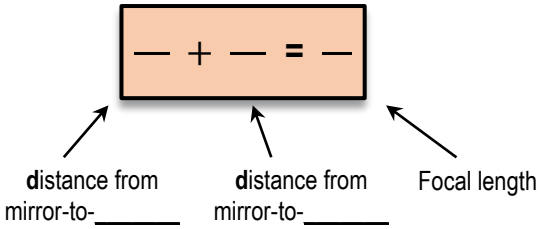
● When drawing diagrams with extended obj's, draw *ANY* 2 of the following rays**.** Image forms where outbound rays **_____.**



DRAWING RAY DIAGRAMS: CONCAVE MIRRORS

1) **P-ray: P**arallel to axis, then passes through F *after* reflection
2) **F-ray:** Passes through **F** *before* reflection, then parallel to axis
3) **C-ray:** Passes through **C**, then perfectly reflects back

● Distances between mirror, object, image, & focal length related by**:**



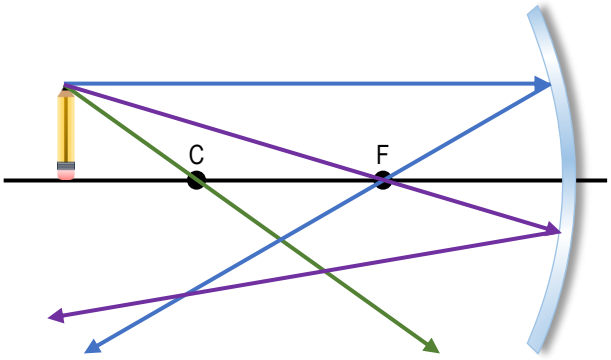
SIGN RULES FOR MIRRORS

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 F on same side as **OUT**bound rays

(Always use signs for KNOWN quantities)

EXAMPLE**:** In the diagram above, the object is 20cm to the left of the mirror, which has a focal length of 5cm**.** What is the position of the resulting image?

PRACTICE: For the following ray diagram, which ray is drawn incorrectly?



Drawing Principal-Ray Diagrams: Concave Mirrors

1) **P-ray**: **P**arallel to axis, then passes through F *after* reflection
2) **F-ray**: Passes through **F** *before* reflection, then parallel to axis
3) **C-ray**: Passes through **C**, then perfectly reflects back

PRACTICE: An object is placed 45.0cm from a concave mirror, producing a real image 15.0cm from the mirror. What is the focal length of the mirror?

SIGN RULES FOR MIRRORS

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 F on same side as **OUT**bound rays

(Always use signs for KNOWN quantities)

GEOMETRIC OPTICS

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

EXAMPLE**:** A concave mirror with radius of curvature R = 24.0cm forms a real image 20.0cm from the mirror**.** How far is the object from the mirror?

SIGN RULES FOR MIRRORS

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 F on same side as **OUT**bound rays

(Always use signs for KNOWN quantities)

GEOMETRIC OPTICS

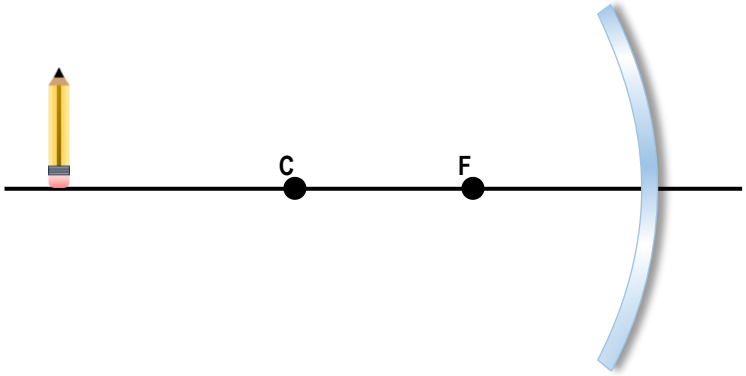
$$\frac{1}{d_O}+\frac{1}{d_i}=\frac{1}{f}$$

CONCEPT: MAGNIFICATION IN GEOMETRIC OPTICS

- Images are often different sizes and orientations from the original object. Magnification: $m = \frac{\text{—}}{\text{—}}$ OR —

  - If m is **[+ | −]**, the image is **[UPRIGHT | INVERTED]**
  - If $|m|$ is **[< 1 | > 1]**, the image is **[REDUCED | ENLARGED]**

EXAMPLE: An object 4cm-tall is placed 15cm from a concave mirror with a focal length of 5cm. The resulting image forms 7.5cm in front of the mirror. What is the magnification and height of the resulting image?



RAY DIAGRAMS: CONCAVE MIRRORS

1) P-ray: **P**arallel to axis, then passes through F
2) F-ray: Passes through **F**, then parallel to axis
3) C-ray: Passes through **C**, reflects back

PRACTICE: A person stands 20.0m in front of a large spherical mirror. A real image is formed 80.0m in front of the mirror. What is the magnification of this image?

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: Using a concave mirror telescope, you look at the planet Jupiter which has a diameter of 1.43×10^8 m. At its closest distance to Earth, Jupiter is approximately 5.88×10^{11} m away. What is the diameter of the image of Jupiter formed by the telescope if the focal length is 1.50m?

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 concave mirror forms a real image exactly twice as tall as the object, which is located 24cm from the mirror. What is the focal length of this mirror?

GEOMETRIC OPTICS

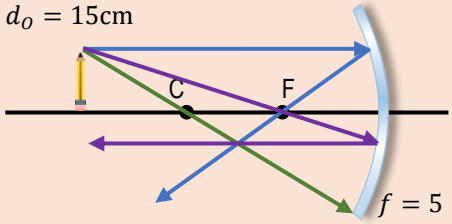
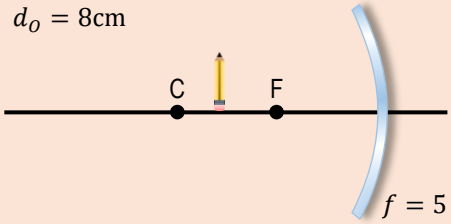
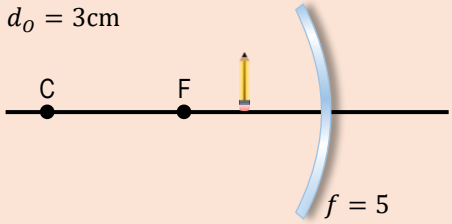
$$\frac{1}{d_O} + \frac{1}{d_i} = \frac{1}{f}$$

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

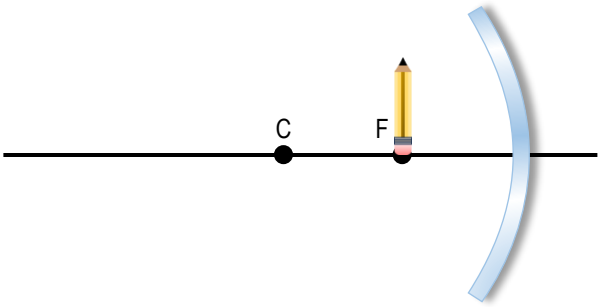
CONCEPT: RAY DIAGRAMS FOR VARIOUS DISTANCES IN CONCAVE MIRRORS

● Image properties depend on the object's _____ relative to **C**(enter of Curv.) and **F**(ocal point)**.**

EXAMPLE**:** For the scenarios below, draw the principal-ray diagrams**.** Determine the characteristics of the image, including type, orientation, and size**.**

RAY DIAGRAMS FOR CONCAVE MIRRORS			
Draw any 2: 1) **P-ray**: **P**arallel to axis, then passes through F *after* reflection; 2) **F-ray**: Passes through **F** *before* reflection, then parallel to axis; 3) **C-ray**: Passes through **C**, then perfectly reflects back			
Object farther than C		**Object between C and F**	**Object closer than F**
$d_o = 15\text{cm}$  Image ALWAYS between ___ and ___		$d_o = 8\text{cm}$  Image ALWAYS farther than _____	$d_o = 3\text{cm}$  Image ALWAYS on _____ side
Type	[**REAL** | VIRTUAL]	[REAL | VIRTUAL]	[REAL | VIRTUAL]
Orientation	[UPRIGHT | **INVERTED**]	[UPRIGHT | INVERTED]	[UPRIGHT | INVERTED]
Size	[**REDUCED** | ENLARGED]	[REDUCED | ENLARGED]	[REDUCED | ENLARGED]

EXAMPLE: Draw the principal-ray diagram for an object placed exactly at the focal point of a concave mirror. Where does the image form?



Principal-Ray Diagrams: Concave Mirrors

1) **P-ray**: **P**arallel, then through F
2) **F-ray**: Through **F**, then parallel
3) **C-ray**: Through **C**

PRACTICE: An object is placed 10cm in front of a concave mirror. If a real, enlarged image is formed even farther from the mirror than the object, which of the following is the most likely value for the focal length of the mirror?

A) f = 4cm
B) f = 8cm
C) f = 10cm
D) f = 20cm

EXAMPLE: A concave mirror has a focal length of 15cm. An object is placed 20cm from the mirror. Draw the principal-ray diagram to find where the image forms, then calculate the distance to the image. Determine the characteristics of the image, including the magnification, orientation, and type (real or virtual).

SIGN RULES FOR MIRRORS

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 F on same side as **OUT**bound rays

(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: You place an object 8cm in front of a concave mirror. Reflection from the mirror forms an image 24cm on the opposite side of the mirror. What is the focal length of this mirror?

SIGN RULES FOR MIRRORS

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 F on same side as **OUT**bound rays

(Always use signs for KNOWN quantities)

GEOMETRIC OPTICS

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

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