Physics Ninja

Lenses

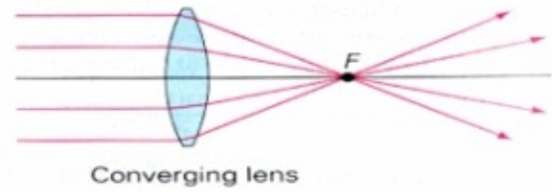
We want to be able to answer four questions for lenses.

1) Where is the image?

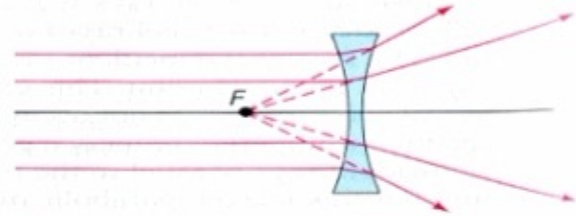
2) Is the image real or is it virtual?

3) Is the image upright or is it inverted?

4) How tall is the image (compared to the object)?



Converging lens



Diverging lens

Lenses

Converging lens
(convex lens)
f is positive

Diverging lens
(concave lens)
f is negative

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

i positive ⟶ real image (other side of lens)
i negative ⟶ virtual image (same side as object)

$$m = -\frac{i}{o}$$

m positive ⟶ image upright
m negative ⟶ image inverted

Lenses form images by *refracting* light (rather than by reflecting light, as is the case for mirrors). For lenses, *real* images are formed on the *opposite* side of the lens from the object, while *virtual* images are formed on the *same* side of the lens as the object.

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Mirrors

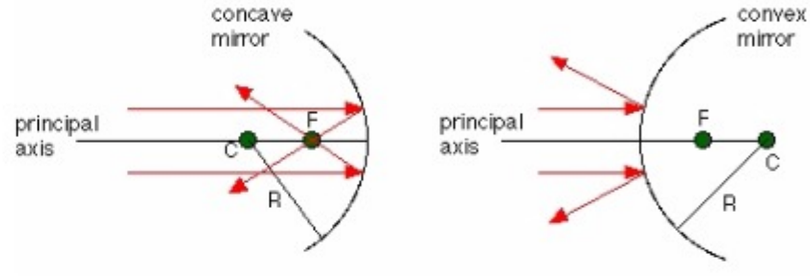
We want to be able to answer four questions for lenses.

1) Where is the image?

2) Is the image real or is it virtual?

3) Is the image upright or is it inverted?

4) How tall is the image (compared to the object)?



Mirrors

radius of curvature **R = 2*f***

Concave Mirror
f is positive

Convexe Mirror
f is negative

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

i positive ⟶ real image (in front of mirror)
i negative ⟶ virtual image (behind mirror)

$$m = -\frac{i}{o}$$

m positive ⟶ image upright
m negative ⟶ image inverted

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Lenses and Mirrors

Practice Problems:

1) An object is placed 10 cm in front of a diverging lens with a focal length of -40 cm, the the image will be located:

A. 5 cm in front of lens.
B. 5 cm behind the lens.
C. 8 cm in front of the lens.
D. 8 cm behind the lens.

2) An object of height 10 cm is held 50 cm in front of a convex lens with a focal length of magnitude 40 cm.
Describe the image.

3) Describe the image formed in a plane mirror

A. Real and upright
B. Read and inverted
C. Virtual and upright
D. Virtual and inverted

4) In an object is placed very far from a concave mirror, where will the image be formed?

A. Halfway between the focal point and the mirror
B. At the focal point
C. At the center of curvature
D. At infinity

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Lenses and Mirrors

Practice Problems:

5) An object is placed 40 cm in front of a concave mirror with a radius of curvature of 60 cm. Locate and describe the image.

6) An object is placed 40 cm in front of a convex mirror with a radius of curvature of -60 cm. Locate and describe the image.

7) A convex mirror forms an upright image 12 cm behind the mirror and an object of height 15 cm is placed 20 cm in front of it. What is the height of the image?

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1) An object is placed 10 cm in front of a diverging lens with a focal length of -40 cm, the the image will be located:

A. 5 cm in front of lens.
B. 5 cm behind the lens.
C. 8 cm in front of the lens.
D. 8 cm behind the lens.

Solution: We use the lens equation to find *i*:

$$\frac{1}{10\ cm}+\frac{1}{i}=\frac{1}{-40\ cm} \quad \rightarrow \quad \frac{1}{i}=-\frac{1}{40}-\frac{1}{10}=\frac{-1-4}{40}=\frac{-5}{40}=-\frac{1}{8}$$

i = -8 cm

This eliminates choices A and B. Because *i* is negative, the image is virtual, and for lenses, virtual images are formed on the same side of the lens as the object.

Therefore, the answer is C.

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2) An object of height 10 cm is held 50 cm in front of a convex lens with a focal length of magnitude 40 cm.
Describe the image.

Solution: The fact that the lens is convex means that it's a converging lens, with a *positive* focal length; therefore, $f = +40\ cm$. The lens equation now gives us i:

$$\frac{1}{50\ cm}+\frac{1}{i}=\frac{1}{40\ cm} \quad \rightarrow \quad \frac{1}{i}=\frac{1}{40}-\frac{1}{50}=\frac{5-4}{200}=\frac{1}{200}=\frac{1}{200}$$

$$i = 200 \text{ cm}$$

Since i is positive, we know that the image is *real*; also, it's located 200 cm from the lens on the *opposite* side of the lens from the object.

$$m=-\frac{i}{o}=\frac{-200}{50}=-4$$

The image is 4 times the height of the object and is inverted.

All real images are inverted!

3) Describe the image formed in a plane mirror

A. Real and upright
B. Read and inverted
C. Virtual and upright
D. Virtual and inverted

Solution: First, eliminate choices A and D; real always goes with inverted, and virtual always goes with upright. We know from common experience that the image formed in a flat mirror is upright, so the answer must be C.

4) In an object is placed very far from a concave mirror, where will the image be formed?

A. Halfway between the focal point and the mirror
B. At the focal point
C. At the center of curvature
D. At infinity

Solution: Use the mirror equation. If the "object is placed very far from a mirror" that means we take *o=infinity,* so *1/o=0*. The mirror equation then say *1/f=1/i, so i=f*. The image is formed at the focal point of the mirror, choice B.

5) An object is placed 40 cm in front of a concave mirror with a radius of curvature of 60 cm. Locate and describe the image.

Solution:

Since *f=r/2*, we know that *f = 30 cm.* The mirror equation now gives

$$\frac{1}{40\ cm}+\frac{1}{i}=\frac{1}{30\ cm} \quad \rightarrow \frac{1}{i}=\frac{1}{30}-\frac{1}{40}=\frac{4-3}{120}=\frac{1}{120} \quad \rightarrow i=120\ cm$$

Since *i* is positive, we know the image is real; also, it's located 120 cm from the mirror on the same side of the mirror as the object.

$$m=-\frac{i}{o}=\frac{-120}{40}=-3$$

We know that the image is 3 times the height of the object and inverted

6) An object is placed 40 cm in front of a convex mirror with a radius of curvature of -60 cm. Locate and describe the image.

Solution: For this case, the mirror and magnification equations gives.

$$\frac{1}{40\ cm}+\frac{1}{i}=\frac{1}{-30\ cm} \quad \rightarrow \frac{1}{i}=-\frac{1}{30}-\frac{1}{40}=\frac{-4-3}{120}=\frac{-7}{120} \quad \rightarrow i=-\frac{120}{7}\ cm$$

$$m=-\frac{i}{o}=-\frac{\left(-\frac{120}{7}\right)}{40}=+\frac{3}{7}$$

Since *i* is negative, we know the image is virtual; also, it's located 120/7~17cm from the mirror. We know the image is 3/7 times the height of the object and upright. The sign of *f* changes everything about the image.

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7) A convex mirror forms an upright image 12 cm behind the mirror and an object of height 15 cm is placed 20 cm in front of it.
What is the height of the image?

Solution: To find the height of the image, we need the magnification. We're given that *o = 20 cm* and *i = -12 cm*. We know *i* is negative because we know convex mirrors only form virtual images and the questions also says that the image is formed behind the mirror. Therefore,

$$m = -\frac{i}{o} = -\frac{(-12)}{20} = +\frac{3}{5}$$

Multiplying the height of the object by the magnification gives the height of the image. Therefore, the height of the image is ***(3/5)(15 cm) = 9 cm.***