Signed lens and mirror images

GRE undergraduate preparation · local supported objectives

Signed lens and mirror images

- Use the thin-lens and mirror equations with one sign convention.
- Tell a **real image 实像** from a **virtual image 虚像** from the signs.
- Find the **magnification 放大率** and whether the image is upright.
- Follow light through two lenses.

The sign convention

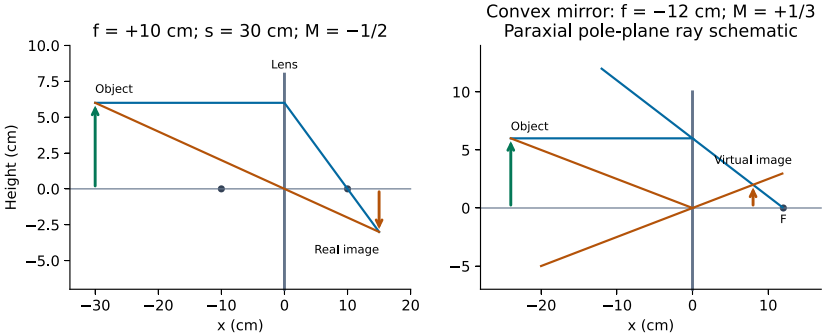
- A real object has $s > 0$; a **real image** has $s' > 0$; a virtual image has $s' < 0$.
- A **converging lens 会聚透镜** has a positive **focal length 焦距**, $f > 0$; a **diverging lens 发散透镜** has $f < 0$.
- A concave mirror has $f = R/2 > 0$; a convex mirror has $f < 0$.

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}, \qquad M = -\frac{s'}{s}$$

Lens images

- Object beyond f: real, inverted image on the far side.
- Object inside f: virtual, upright, enlarged image on the same side (a magnifying glass).
- Object at f: parallel rays, no image. A **diverging lens** with a real object always gives a virtual, upright, smaller image.
- Ray rules: a ray parallel to the axis passes through the far focus; a ray through the centre goes straight on.

Figure: Lens images



- Thin-lens equation: $s = 30$ cm, $f = 10$ cm gives $s' = 15$ cm and $M = -1/2$
- Read the axes and units first.

Mirrors

- A real mirror image forms in front of the mirror, where the light is; a virtual image is behind it.
- A convex mirror (car wing mirrors, shop mirrors) always gives a virtual, upright, smaller image, which shows a wide view.

Two lenses

- If the first image lies beyond the second lens, the light is still converging when it arrives: a virtual object with $s_2 < 0$.
- The total **magnification** is $M = M_1 M_2$.
- Lens power in dioptres is $P = 1/f$ with f in metres; thin lenses in contact add powers.

Worked example: one lens, two positions

- Object at 30 cm: $1/s' = 1/10 - 1/30$, so $s' = 15$ cm and $M = -\frac{1}{2}$: real, inverted, half size.
- Object at 5.0 cm: $1/s' = 1/10 - 1/5$, so $s' = -10$ cm and $M = +2$: virtual, upright, twice the size.
- A negative s' is a location (the image is on the incoming side), not a mistake to remove with an absolute value.

Worked example: a mirror and a two-lens system

- Convex mirror, $f = -12$ cm, object at 24 cm: $1/s' = -1/12 - 1/24$, so $s' = -8.0$ cm and $M = +\frac{1}{3}$, upright, behind the mirror.
- Two lenses of $f = 10$ cm, at $x = 0$ and $x = 40$ cm, object at $x = -30$ cm. First image at $x = 15$ cm with $M_1 = -\frac{1}{2}$.
- Second lens: $s_2 = 40 - 15 = 25$ cm, $s_2' = 50/3 = 16.7$ cm, $M_2 = -\frac{2}{3}$. Total $M = +\frac{1}{3}$: upright and a third of the size.

Common errors

- Dropping the sign of s' and losing the virtual image.
- Using the lens spacing as the second object distance; measure from the first image.
- Forgetting that a convex mirror has a negative **focal length**.

Common errors (2)

- Adding magnifications instead of multiplying them.
- Putting a real mirror image behind the mirror.

Key terms

- **real image**: An image formed where light actually meets; it can be shown on a screen.
- **virtual image**: An image that light only seems to come from; it cannot be shown on a screen.
- **magnification**: The ratio of image height to object height, $-s'/s$.
- **converging lens**: A lens that brings parallel rays together; $f > 0$.

Check yourself

- An object is 20 cm from a **diverging lens** with $f = -20$ cm. Where is the image, and what is M?
- A concave mirror has $R = 40$ cm and an object at 30 cm. Find the image.
- What is the power of a lens with $f = 25$ cm?