

33.1 Signed lens and mirror images

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS virtual image • transverse magnification

Objective

Locate paraxial thin-lens and spherical-mirror images with a declared sign convention; Use signed magnification to classify orientation and real or virtual character; Track successive image locations as the next element's object without resetting geometry. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Declare real-is-positive: real object $s > 0$, real image $s' > 0$, converging lens $f > 0$. Use $1/f = 1/s + 1/s'$ and $M = -s'/s$. For left-to-right light, lens image coordinate is lens coordinate $+s'$.

Parallel and centre rays locate a thin-lens image. For a converging lens, $s > f$ gives real/inverted; $0 < s < f$ gives virtual/upright. At $s = f$, rays emerge parallel; diverging lenses give virtual reduced images for real objects.

Concave mirror $f > 0$, convex $f < 0$, $f = R/2$ paraxially. A positive real mirror image lies in front; a negative virtual one lies behind. Keep this physical-side distinction from lens transmission.

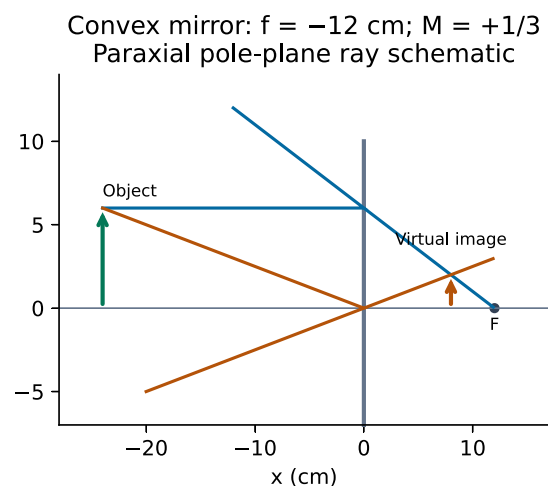
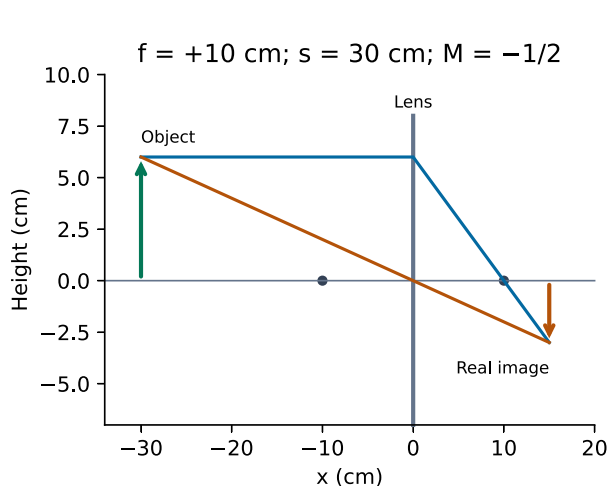
For two lenses locate the first image in the common coordinate system, then assign the second signed object distance. A converging input can be a virtual object. Multiply signed magnifications; do not use element separation as the object distance.

■ Worked method

Use real-is-positive distances and positive focal length for a converging lens. With $f = 12$ cm and real object distance $s = 8$ cm,

$$1/s' = 1/f - 1/s = 1/(12 \text{ cm}) - 1/(8 \text{ cm}) = -1/(24 \text{ cm}).$$

Thus $s' = -24$ cm and $M = -s'/s = +3$. The virtual image is upright, on the object's side. Signed distances identify the physical side; a negative distance is not an arithmetic failure.



2 Practice

2.1 A converging lens has $f=12 \text{ cm}$ and a real object $s=8 \text{ cm}$. Which image result is correct? [1]

- A. $s'=24 \text{ cm}$, $M=-3$
- B. $s'=-24 \text{ cm}$, $M=+3$
- C. $s'=-4.8 \text{ cm}$, $M=+0.6$
- D. $s'=4.8 \text{ cm}$, $M=-0.6$
- E. Image at infinity

2.2 A concave mirror has $f=10 \text{ cm}$ and real object $s=30 \text{ cm}$. The image is: [1]

- A. Virtual, behind, upright
- B. Real, behind, upright
- C. Real, in front, inverted
- D. Virtual, in front, inverted
- E. At the focus regardless of s

2.3 A diverging lens has $f=-15 \text{ cm}$ and $s=30 \text{ cm}$. Signed image distance is _____ cm. Show your relation and units. [2]

Solutions

2.1 Answer: B. $1/s' = 1/12 - 1/8 = -1/24$; $M = -(-24)/8 = +3$, virtual and upright.

Compare the rejected options: $s' = 24$ cm, $M = -3$; $s' = -4.8$ cm, $M = +0.6$; $s' = 4.8$ cm, $M = -0.6$; Image at infinity. Use the stated model and conditions.

2.2 Answer: C. $s' = 15$ cm and $M = -1/2$; a positive real mirror image is in front of the mirror.

Compare the rejected options: Virtual, behind, upright; Real, behind, upright; Virtual, in front, inverted; At the focus regardless of s . Use the stated model and conditions.

2.3 -10. $1/s' = -1/15 - 1/30 = -1/10$; $M = +1/3$.

2.4 True. $1/s' = 1/f - 1/f = 0$; the ideal image is at infinity.

3.1 First image has $s'_1 = 15$ cm and $M_1 = -1/2$. The second lens intercepts converging rays headed to $x = 15$ cm, so $s_2 = -5$ cm: a virtual object. $1/s'_2 = 1/10 - 1/(-5) = 3/10 \text{ cm}^{-1}$, hence $s'_2 = 10/3$ cm. Final coordinate $x = 10 + 10/3 = 40/3$ cm; $M_2 = -s'_2/s_2 = 2/3$; total $M = -1/3$. Award first image, signed second object, second image, final coordinate and magnification. The final image is real and inverted.