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.

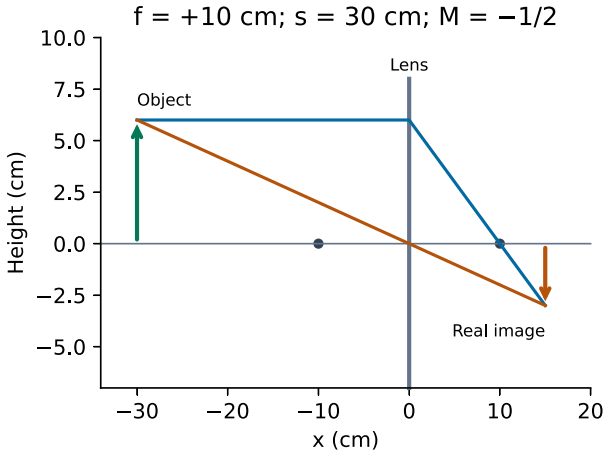
For two lenses locate the first image in the common coordinate system, then assign the second signed object distance. A converging input can be a virtual object. Multiply signed magnifications; do not use element separation as the object distance.

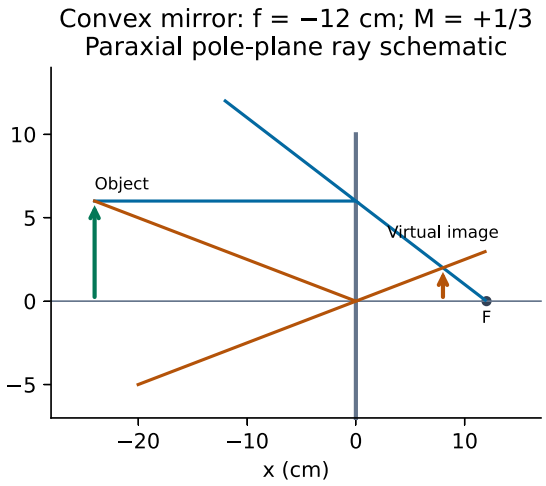
■ Worked method

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 Choose one answer. A converging lens has f=12 cm and a real object s=8 cm. Which image result is correct? [1]

- **A** $s'=24$ cm, $M=-3$
- **B** $s'=-24$ cm, $M=+3$
- **C** $s'=-4.8$ cm, $M=+0.6$
- **D** $s'=4.8$ cm, $M=-0.6$
- **E** Image at infinity

2.2 Choose one answer. A concave mirror has f=10 cm and real object s=30 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 cm and s=30 cm. Signed image distance is _____ cm. Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: For a converging thin lens with a real object exactly at its front focal point, the ideal output rays are parallel and the finite-image formula has no finite solution. [2]

3 Exam-style questions

3.1 A converging lens at x = 0 has f1 = 10 cm and a real object at x = -30 cm. A second converging lens of f2 = 10 cm is at x = 10 cm. Locate the final image and calculate total signed magnification. Identify the second lens's object as real or virtual. [5]

Solutions

2.1 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 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.