

## 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.

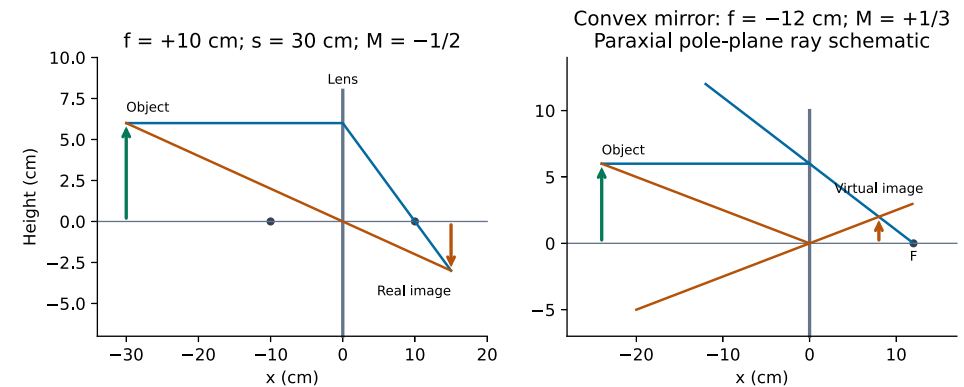
For two lenses locate the first image in the common coordinate system, then assign the second signed object distance. A converging input can be a virtual object. Multiply signed magnifications; do not use element separation as the object distance.

#### ■ 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]

### 3 Exam-style questions

[5]

## Solutions

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**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.