Unit 17 · Lenses

ANSWER KEY · FOR TEACHERS

Full marks 37

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. convex
2. optical center
3. principal axis
4. focal plane
5. power
6. diopters
7. visual angle
8. angular magnification

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. biconcave
2. plano-convex
3. concavo-convex
4. convexo-concave

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** −2 D — A · 1

P = 1/f with f in meters: f = −0.50 m (concave), so P = −2 D.

ii. **b.** concave — U · 1

A concave lens forms only virtual, upright, diminished images of a real object. A convex lens gives a virtual image only when the object is inside its focus, and then it is enlarged.

iii. **c.** nothing, since its radius is infinite — K · 1

A flat face is a sphere of infinite radius, so 1/R = 0.

iv. **c.** the visual angle the object subtends at the eye — U · 1

$h' = \theta \times a$, with a (about 17 mm) fixed for a given eye, so $h' \propto \theta$.

v. **b.** 3.5 — A · 1

M = 1 + D/f = 1 + 25/10 = 3.5.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ The point on the axis of a thin lens through which a ray goes undeviated.

b. MARKING SCHEME — K · 1

✓ The power of a lens of focal length 1 m.

c. MARKING SCHEME — U · 1

✓ Zero ($P = P_1 + (-P_1) = 0$).

5 Short answers

a. MARKING SCHEME — U · 2

✓ Linear magnification m = size of image ÷ size of object (= v/u).

✓ Angular magnification M = visual angle of the image ÷ visual angle of the object at the least distance of distinct vision (β/α).

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b. MARKING SCHEME U · 2

- ✓ The powers of lenses in contact simply add, $P = P_1 + P_2$ (the eye's own power and the lens's).
- ✓ Focal lengths don't add; the reciprocals would have to be added ($1/F = 1/f_1 + 1/f_2$).

c. MARKING SCHEME A · 2

- ✓ Reading glasses are convex (converging): they bring the Sun's parallel rays to a point at their focus, concentrating the energy.
- ✓ Glasses for short sight are concave (diverging): they spread the light out, so it never comes together.

6 Long answer

ANSWER U · 4

A point object is at distance u. The first lens alone would form an image I′ at v′: $1/f_1 = 1/u + 1/v'$. The rays leaving it converge towards I′, so for the second lens I′ is a virtual object at $-v'$; it forms the final image at v: $1/f_2 = -1/v' + 1/v$. Adding, the v′ terms cancel: $1/f_1 + 1/f_2 = 1/u + 1/v$. A single lens of focal length F giving the same image has $1/F = 1/u + 1/v$, so $1/F = 1/f_1 + 1/f_2$.

MARKING SCHEME

- ✓ First lens: $1/f_1 = 1/u + 1/v'$.
- ✓ For the second lens the first image is a virtual object at $-v'$: $1/f_2 = -1/v' + 1/v$.
- ✓ Adding: $1/f_1 + 1/f_2 = 1/u + 1/v$.
- ✓ Compared with one lens, $1/F = 1/u + 1/v$, so $1/F = 1/f_1 + 1/f_2$.

7 Numerical problems

a. ANSWER A · 3

f = −15 cm, u = +30 cm. $1/v = 1/f - 1/u = -1/15 - 1/30 = -3/30$, so v = **−10 cm**: 10 cm from the lens on the object's side.
$m = v/u = -10/30 = -1/3$, so $I = 4.0 \times 1/3 =$ **1.3 cm**: virtual, upright and diminished.

MARKING SCHEME

- ✓ $1/v = -1/15 - 1/30$.
- ✓ v = −10 cm (virtual, on the object's side).
- ✓ Image 1.3 cm tall, upright, diminished.

b. ANSWER A · 3

$1/f = (\mu - 1)(1/R_1 + 1/R_2) = 0.6 \times (1/20 + 1/30) = 0.6 \times 5/60 = 0.05\ \text{cm}^{-1}$, so f = **20 cm**.
$P = 1/f = 1/0.20\ \text{m} =$ **+5 D**.

MARKING SCHEME

- ✓ The lens maker's formula with both radii positive.
- ✓ f = 20 cm.
- ✓ P = +5 D.

c. ANSWER A · 4

i. $P = 3.0 - 1.25 =$ **+1.75 D**: converging. $F = 1/1.75 = 0.571\ \text{m} =$ **57.1 cm**.

ii. u = 0.50 m: $1/v = 1/F - 1/u = 1.75 - 2.0 = -0.25\ \text{m}^{-1}$, so v = **−4.0 m** (a virtual image 4 m away on the page's side). $m = v/u = -4.0/0.50 = -8$: upright and **8 times** larger.

MARKING SCHEME

- ✓ P = +1.75 D, converging.
- ✓ F = 57.1 cm.
- ✓ v = −4.0 m (virtual).
- ✓ m = −8: upright, 8 times larger.

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8 Think

ANSWER HA · 3

No. Every point of the candle sends rays to the whole lens, and the uncovered top half still brings rays from every point to the same image point (all parallel rays meet at F whatever their height, as the lens maker's derivation shows). So the **whole** image still forms in the same place, the same size; only half as much light reaches it, so it is **dimmer**.

MARKING SCHEME

- ✓ The whole image still forms.
- ✓ Each point of the object sends light through the uncovered half, which still focuses it to the same image point.
- ✓ The image is dimmer (less light), not cut in half.

9 Activity: The focal length of a lens (Activity 17.1)

(not marked)

WHAT STUDENTS SHOULD FIND

The window's image is nearly at the focus, so its distance from the lens is about f. In the two positions u and v swap places, and both give the same f, close to the first value. A typical magnifying glass has f about 10–25 cm (4–10 D); reading glasses of +2.0 D have f = 50 cm.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Rays of Light** (exhibit): Three parallel beams meet at a convex lens's principal focus; a concave lens spreads them as if they came from a focus on the lasers' side.
- **The Single Lens Camera** (exhibit): The lens casts a real, inverted image of the scene outside on the box's screen, about one focal length behind the lens for faraway objects.
- **The Fresnel Lens** (exhibit): This flat sheet focuses like a thick lens: by the lens maker's formula, focal length depends on the surfaces' curvature and μ, and the rings keep the curves.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	11	14	3	**37**

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