Unit 17 · Lenses

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 30

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

1 Spot the error

ANSWER U · 3

Focal lengths don't add; their reciprocals (the powers) do: $1/F = 1/20 + 1/30 = 5/60$, so **$F = 12$ cm**. The pair is **stronger** than either lens: two converging lenses bend the light more than one, so its focus is nearer.

MARKING SCHEME

✓ The error: $1/F = 1/f_1 + 1/f_2$, not $F = f_1 + f_2$.
✓ $F = 12$ cm.
✓ The pair is stronger (shorter focal length) than either lens.

2 Two sharp images

ANSWER HA · 4

i. The lens formula is unchanged if u and v swap, so if one position has (u, v), the other has (v, u) with the same object–screen distance $u + v$.
ii. $u + v = 90$ and $v - u = 30$, so $u = 30$ cm, $v = 60$ cm (and then $u = 60$ cm, $v = 30$ cm). $1/f = 1/30 + 1/60 = 3/60$, **$f = 20$ cm**.
iii. $m_1 = 60/30 = 2$ and $m_2 = 30/60 = 0.5$; $m_1 \times m_2 = \mathbf{1}$.

MARKING SCHEME

✓ The formula is symmetric in u and v, so the positions swap u and v.
✓ $u = 30$ cm and $v = 60$ cm (then swapped).
✓ $f = 20$ cm.
✓ $m = 2$ and 0.5, product 1.

3 What if?

ANSWER A · 4

In air: $1/20 = 0.5 \times (1/R_1 + 1/R_2)$, so $(1/R_1 + 1/R_2) = 1/10$ cm^{-1}.

i. Relative index $1.5/1.25 = 1.2$: $1/f = 0.2 \times 1/10 = 1/50$, **$f = 50$ cm**.
ii. Relative index $1.5/1.65 = 0.909$: $1/f = -0.0909 \times 1/10$, **$f = -110$ cm**.
iii. In the first liquid it still converges, but weakly (the liquid is less dense optically than the glass). In the second it **diverges**: the liquid is optically denser than the glass, so μ relative to the liquid is less than 1 and $\mu - 1$ is negative.

MARKING SCHEME

✓ $1/R_1 + 1/R_2 = 1/10$ cm^{-1} from the focal length in air.
✓ $f = 50$ cm in the first liquid.
✓ $f = -110$ cm in the second.
✓ Converging, then diverging, because the relative index falls below 1.

4 Estimate it

ANSWER A · 3

i. $\theta = 2.0/10 = 0.20$ rad, $h' = \theta \times a = 0.20 \times 17$ mm = **3.4 mm**.
ii. $\theta = 2.0/25 = 0.080$ rad, $h' = 0.080 \times 17$ mm = **1.4 mm**.
iii. The door: it subtends the larger visual angle, so its image on the retina is larger.

MARKING SCHEME

✓ 3.4 mm for the door.
✓ 1.4 mm for the coin.
✓ The door looks bigger because of its larger visual angle.

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5 A real setting

ANSWER A · 3

i. $M = 1 + D/f = 1 + 25/2.5 =$ **11**.

ii. The image is virtual at $v = -25$ cm: $1/u = 1/f - 1/v = 1/2.5 + 1/25 = 11/25$, so $u =$ **2.3 cm**, just inside the focus.

MARKING SCHEME

- ✓ $M = 1 + D/f = 11$.
- ✓ $v = -25$ cm (virtual).
- ✓ $u = 2.3$ cm.

6 Design it

ANSWER A · 3

$P = -2.0$ D, so $1/f = -0.02$ cm^{-1}. $1/f = (\mu - 1)(1/R_1 + 1/R_2)$: $-0.02 = 0.5 \times (1/50 + 1/R_2)$, so $1/R_2 = -0.04 - 0.02 = -0.06$ cm^{-1}, $R_2 =$ **−16.7 cm**. The **concave** face is curved more (smaller radius), as a convexo-concave lens must be, so the lens is thinner in the middle and diverges.

MARKING SCHEME

- ✓ $-0.02 = 0.5(1/50 + 1/R_2)$.
- ✓ $R_2 = -16.7$ cm.
- ✓ The concave face is curved more (a convexo-concave, diverging lens).

7 Which explanation fits the evidence?

ANSWER HA · 3

Sudarshan's. With goggles the light still passes through the same water, so if the water itself made things cloudy, goggles would not help. What goggles change is what touches the cornea: air instead of water. The cornea's power comes from the difference in refractive index at its surface; against water (μ 1.33, close to the eye's own) that difference is small, so it bends light much less (like a glass lens in water, whose power drops to about a quarter). With air in front, the cornea gets its power back.

MARKING SCHEME

- ✓ Sudarshan's explanation.
- ✓ Goggles don't remove the water between the object and the eye, so scattering in water can't be the cause.
- ✓ The cornea's power depends on the medium in front of it (μ relative to it): air restores it.

8 Correct the misconceptions

ANSWER U · 3

1. A convex shape converges only when the lens is optically denser than its surroundings: an air bubble in water, convex in shape, **diverges** light.
2. Power uses the focal length in **meters**: $P = 1/0.25 =$ **4 D**.
3. A negative magnification means a **virtual, upright** image (real is positive); the size of m, not its sign, says whether it is larger or smaller.

MARKING SCHEME

- ✓ A convex shape converges only if μ relative to the surroundings is more than 1 (an air bubble in water diverges).
- ✓ $P = 1/f$ in meters = 4 D.
- ✓ Negative m means virtual and upright; the size of m gives larger or smaller.

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9 Think

ANSWER HA · 2

μ relative to the liquid is 1, so $1/f = (1 - 1)(1/R_1 + 1/R_2) = 0$: f is **infinite**, its power zero. Light crosses the glass–liquid surface without bending or reflecting, so nothing shows where the lens begins or ends.

MARKING SCHEME

- ✓ μ relative to the liquid = 1, so $1/f = 0$: infinite focal length (zero power).
- ✓ No refraction or reflection at its surfaces, so it can't be seen.

10 Make your own

ANSWER HA · 2

The pair needs $P = 1/(-0.50\ \text{m}) = -2$ D. For example +3 D and −5 D: $P = 3 - 5 = -2$ D, $F = -50$ cm. Any convex lens of power P_1 with a concave lens of power $-(P_1 + 2)$ D is right.

MARKING SCHEME

- ✓ Powers that add to −2 D (one positive, one negative).
- ✓ Shown: $P = P_1 + P_2 = -2$ D, so $F = -50$ 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	0	6	13	11	**30**

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