Unit 14 · Reflection at Curved Mirrors

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. concave
2. pole
3. center of curvature
4. principal axis
5. paraxial
6. focal length
7. real
8. spherical aberration

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. O, real object
2. I, virtual image
3. I, real image
4. O, virtual object

U · 2

Each carries 0.5 mark.

3 Multiple choice

i. **a.** −15 cm — K · 1

f = R/2, and a convex mirror's focus is virtual, so f = −30/2 = −15 cm.

ii. **b.** real, inverted and the same size, at the center of curvature — U · 1

With u = 2f, the mirror formula gives v = 2f, and m = v/u = +1: real, inverted, the same size, at C.

iii. **b.** real, inverted and twice the size — U · 1

A positive m means a real image (inverted, for a real object); its size, 2, means twice as tall.

iv. **c.** the mirror has a wide aperture — K · 1

The derivation needs a **small** aperture (so that FN ≈ FP); a wide one gives spherical aberration.

v. **c.** 36 cm — A · 1

Light from a distant object arrives nearly parallel, so the image is at the focus: f ≈ 18 cm, and R = 2f = 36 cm.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ The point behind the mirror from which paraxial rays parallel to the axis appear to diverge after reflection.

b. MARKING SCHEME — K · 1

✓ The diameter of the mirror's rim (the width of its reflecting surface).

c. MARKING SCHEME — U · 1

✓ A parabolic mirror brings all parallel rays, even far from the axis, to one point (no spherical aberration).

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5 Short answers

a. MARKING SCHEME — U · 2

- ✓ m = −1: virtual, upright, same size, from a plane mirror.
- ✓ m = +1: real, inverted, same size, from a concave mirror with the object at C.

b. MARKING SCHEME — U · 2

- ✓ A mirror can be supported all over its back, while a lens meters across would sag under its own weight and could not be made free of defects.
- ✓ Reflection bends every color equally, while a lens splits colors.

c. MARKING SCHEME — A · 2

- ✓ The convex mirror's image is diminished, and the brain judges distance partly by size, so the car seems farther away.
- ✓ The plane mirror shows sizes truly (so distance and speed can be judged), though with a narrower field of view.

6 Long answer

ANSWER — U · 4

A ray OA parallel to the axis meets the mirror at A and is reflected through F. CA is a radius, so it is the normal at A: the angle of incidence ∠OAC = i equals the angle of reflection ∠CAF = i. OA is parallel to CP, so ∠ACF = ∠OAC = i (alternate angles). Triangle FAC has equal angles at A and C, so FA = FC. For a small aperture A is very close to P, so FA ≈ FP; then FP = FC, F is halfway between P and C, and f = R/2.

MARKING SCHEME

- ✓ A diagram with the parallel ray, the normal CA and the reflected ray through F, labelled.
- ✓ ∠OAC = ∠CAF = i (law of reflection, CA the normal) and ∠ACF = i (alternate angles).
- ✓ Triangle FAC is isosceles, so FA = FC.
- ✓ Small aperture: FA ≈ FP, so FP = FC = CP/2, f = R/2.

7 Numerical problems

a. ANSWER — A · 3

f = R/2 = +25 cm (concave), u = +15 cm.
1/v = 1/f − 1/u = 1/25 − 1/15 = (3 − 5)/75 = −2/75, so v = **−37.5 cm**: 37.5 cm behind the mirror.
m = v/u = −37.5/15 = **−2.5**: virtual, upright, 2.5 times as large.

MARKING SCHEME

- ✓ f = +25 cm and 1/v = 1/25 − 1/15.
- ✓ v = −37.5 cm (behind the mirror).
- ✓ m = −2.5: virtual, upright and enlarged 2.5 times.

b. ANSWER — A · 3

f = −1.0 m (convex), u = +20 m.
1/v = 1/f − 1/u = −1 − 1/20 = −21/20, so v = **−0.95 m** (0.95 m behind the mirror, virtual).
m = v/u = −0.95/20 = −0.048; image height I = m × O = −0.048 × 3.0 = −0.14 m: **14 cm tall**, upright.

MARKING SCHEME

- ✓ f = −1.0 m and 1/v = −1 − 1/20.
- ✓ v = −0.95 m, virtual, behind the mirror.
- ✓ I = 0.14 m (14 cm), upright.

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c. **ANSWER** A · 4

Real image: m = +2, so v = 2u. 1/12 = 1/u + 1/(2u) = 3/(2u), so u = **18 cm** (v = 36 cm): real, inverted, enlarged, beyond C.
Virtual image: m = −2, so v = −2u. 1/12 = 1/u − 1/(2u) = 1/(2u), so u = **6 cm** (v = −12 cm): virtual, upright, enlarged, behind the mirror.

MARKING SCHEME

- ✓ Real case m = +2, v = 2u, giving u = 18 cm.
- ✓ That image is real and inverted (v = 36 cm).
- ✓ Virtual case m = −2, v = −2u, giving u = 6 cm.
- ✓ That image is virtual and upright (v = −12 cm).

8 Think

ANSWER HA · 3

Far away, the image is real, inverted and small, just beyond F. As he comes towards C, the image moves out towards C and grows; at C it is real, inverted and his own size, at C. Between C and F, it is real, inverted and enlarged, beyond C, moving farther out and growing; with him at F it goes off to infinity. Closer than F, the image is virtual, upright and enlarged, behind the mirror.

MARKING SCHEME

- ✓ Beyond C: real, inverted, diminished, between F and C; at C: same size at C.
- ✓ Between C and F: real, inverted, enlarged beyond C; at F: at infinity.
- ✓ Inside F: virtual, upright, enlarged, behind the mirror.

9 Activity: The focal length of a concave mirror

(not marked)

WHAT STUDENTS SHOULD FIND

The image of the distant window is almost at the focus, so its distance is roughly f. The five values of uv ÷ (u + v) come out nearly the same (within a few percent of one another) and close to that distance, which shows that 1/u + 1/v is the same for every position, as the mirror formula says. When u is less than f no image forms on the card (the image is virtual).

See it at Science Playground

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- **The Mirascope — A Real Image in Mid-Air** (exhibit): The ball floating above the opening is a real image: the light really meets there, yet your fingers pass straight through it.
- **Catch a Real Image** (exhibit): Move the object, then slide the screen to a sharp image: as an object beyond the focus nears the mirror, its real image moves away.
- **The Concave Mirror — A Swinging Reflection** (exhibit): Watch the pendulum's image as it swings nearer and farther: inverted and changing size beyond the focus, upright and magnified close to the mirror.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	13	13	3	**37**

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