Unit 14 · Reflection at Curved Mirrors

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 34

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

His mistake is the sign of f. A convex mirror's focus is virtual, so in the real-is-positive convention f = −20 cm. Then 1/v = −1/20 − 1/30 = −5/60, so v = **−12 cm**: a virtual image 12 cm behind the mirror, with m = v/u = −12/30 = −0.4, upright and smaller. A real object never gives a real image in a convex mirror, so his answer should have warned him.

MARKING SCHEME

- ✓ The error: f should be −20 cm (a convex mirror's focus is virtual).
- ✓ v = −12 cm, virtual, behind the mirror.
- ✓ m = −0.4: upright and diminished.

2 Work backwards

ANSWER A · 4

i. For a real image m = v/u is positive, so v = mu. Then 1/f = 1/u + 1/(mu) = (m + 1)/(mu), so u = f(m + 1)/m.

ii. With m = 3, u_1 = 4f/3; with m = 2, u_2 = 3f/2. $u_2 - u_1$ = 3f/2 − 4f/3 = f/6 = 5 cm, so **f = 30 cm**. Then u_1 = **40 cm** (image at 120 cm) and u_2 = **45 cm** (image at 90 cm). Check: 1/40 + 1/120 = 1/30 and 1/45 + 1/90 = 1/30.

MARKING SCHEME

- ✓ v = mu put into the mirror formula, giving u = f(m + 1)/m.
- ✓ u_1 = 4f/3 and u_2 = 3f/2.
- ✓ $u_2 - u_1$ = f/6 = 5 cm, so f = 30 cm.
- ✓ u_1 = 40 cm and u_2 = 45 cm.

3 Check the readings

ANSWER HA · 4

(The readings are made up, from a mirror of focal length 15 cm with small errors.)

i. 0.0668, 0.0622, 0.0662, 0.0670, 0.0665 cm^{-1}.

ii. Leaving out the odd one, the average of 1/u + 1/v is about 0.0666 cm^{-1}, so **f ≈ 15.0 cm**.

iii. The reading at u = 25 cm (0.0622 gives 16.1 cm). With f = 15 cm, 1/v = 1/15 − 1/25 = 2/75, so v should have been **37.5 cm**.

iv. Any sensible reason: she judged the sharpest image badly (it was blurred over a range and she took its far end), or misread or miscopied 37.5 as 45.0.

MARKING SCHEME

- ✓ The row 0.0668, 0.0622, 0.0662, 0.0670, 0.0665.
- ✓ f ≈ 15 cm from the four that agree.
- ✓ The odd reading is u = 25 cm; v should be 37.5 cm.
- ✓ A sensible cause (focusing or reading error).

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

4 Predict, then explain

ANSWER HA · 3

The image moves **away** from the mirror (out towards C, 40 cm away), and here **more slowly** than the object. At u = 60 cm, 1/v = 1/20 − 1/60 = 1/30, so v = 30 cm; at u = 40 cm (at C), v = 40 cm. The object moves 20 cm in 2 s (10 cm/s), the image only 10 cm (5 cm/s). (Between C and F it would be the other way round: the image races out to infinity as the object nears F.)

MARKING SCHEME

- ✓ The image moves away from the mirror as the object moves in.
- ✓ v = 30 cm at u = 60 cm and v = 40 cm at u = 40 cm.
- ✓ The image moves 10 cm against the object's 20 cm: slower (5 cm/s against 10 cm/s).

5 Show that

MARKING SCHEME A · 3

- ✓ $f < u < 2f$ gives $0 < 1/v < 1/(2f)$.
- ✓ So v is positive and $v > 2f$: real, beyond C.
- ✓ $m = v/u > 1$ and positive: enlarged and inverted.

6 How near is near enough?

ANSWER A · 3

i. $1/v = 1/1.2 - 1/3000$, so v = **1.2005 m**: only 0.5 mm beyond F. For any object so much farther away than f, 1/u is tiny beside 1/f, so $v \approx f$.

ii. $m = v/u = 1.2005/3000 = 4.0 \times 10^{-4}$, so the image is $30 \times 4.0 \times 10^{-4} = 0.012$ m = **12 mm** tall (inverted).

MARKING SCHEME

- ✓ v = 1.2005 m.
- ✓ It differs from f by about 0.5 mm, because 1/u is tiny beside 1/f.
- ✓ Image height 12 mm.

7 A real setting

ANSWER A · 4

i. f = −1.0 m. At u = 20 m: 1/v = −1 − 0.05, v = −0.952 m, m = −0.0476, image **0.14 m**. At u = 5.0 m: 1/v = −1 − 0.2, v = −0.833 m, m = −0.167, image **0.50 m**.

ii. 0.50 ÷ 0.143 = **3.5 times**.

iii. In a plane mirror the image would have grown 4 times, as the bus itself looks to the eye. In the convex mirror every image is diminished, and it grows less than the bus comes closer; the image also stays between the pole and F, moving only from 0.95 m to 0.83 m behind the mirror. The brain judges distance by size, so the bus seems farther away and to come on more slowly than it does.

MARKING SCHEME

- ✓ 0.14 m at 20 m.
- ✓ 0.50 m at 5.0 m.
- ✓ A factor of 3.5, less than 4.
- ✓ The image is small and changes less than the real distance, so distance and speed are misjudged.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

8 Correct the misconceptions

ANSWER U · 3

1. A convex mirror's focal length is **negative** in the real-is-positive convention: its focus is virtual (behind it).
2. A mirror's focal length **does not change** under water: f = R/2 depends only on its shape, and reflection obeys the same law in every medium.
3. A real image of a real object is **inverted**, not upright; only a virtual image of a real object is upright.

MARKING SCHEME

✓ Convex: f is negative (a virtual focus).
✓ Under water f stays the same (f = R/2, the law of reflection is the same).
✓ A real image (of a real object) is inverted.

9 Design it

MARKING SCHEME A · 3

✓ Concave, with m = −2 (v = −40 cm).
✓ f = 40 cm, R = 80 cm.
✓ At 50 cm she is beyond F: a real, inverted image, so it won't work.

10 Think

ANSWER HA · 2

In a spherical mirror only rays near the axis (paraxial rays) pass through F; rays far from the axis cross nearer the mirror. Run backwards, light from a lamp at F leaves the outer parts of the mirror at an angle to the axis, so the beam spreads (spherical aberration). A parabola sends every ray from its focus out parallel to its axis, near or far, so the whole beam stays narrow.

MARKING SCHEME

✓ In a wide spherical mirror, rays far from the axis don't pass through F (spherical aberration), so light from F leaves the outer parts at an angle: the beam spreads.
✓ A paraboloid reflects every ray from its focus parallel to the axis.

11 Make your own

ANSWER HA · 2

For example: "A concave mirror of focal length 15 cm gives a virtual image 30 cm behind it. Where is the object?" 1/u = 1/f − 1/v = 1/15 + 1/30 = 3/30, so u = 10 cm (m = −3, upright, enlarged). Any problem with u = 10 cm inside F and a virtual image is right.

MARKING SCHEME

✓ A sensible problem with a concave mirror and a virtual image (u inside F).
✓ Solved correctly to u = 10 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.

- **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	0	6	17	11	**34**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking