

Reflection, refraction and images from mirrors and lenses

AP Physics 2 (algebra-based) · Worksheet answers

Each answer gives the equation, the substitution and the result in bold. Check that your image distance has the right sign and that your description of the image (real or virtual, upright or inverted) matches your sketch.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 13

Problem 1 Law of reflection

1. $\theta_r = \theta_i = \mathbf{35^\circ}$.
2. $90^\circ - 35^\circ = \mathbf{55^\circ}$.
3. $35^\circ + 35^\circ = \mathbf{70^\circ}$.

Problem 2 Refractive index

1. $n = c/v = 3.00 \times 10^8 / 2.00 \times 10^8 = \mathbf{1.50}$.
2. $v = c/n = 3.00 \times 10^8 / 1.33 = \mathbf{2.26 \times 10^8 \text{ m/s}}$.

Problem 3 Air to glass

1. $\sin \theta_2 = \sin 30^\circ / 1.50 = 0.500 / 1.50 = 0.333$, so $\theta_2 = \mathbf{19.5^\circ}$.
2. **Towards** the normal, since the glass has a larger index.

Problem 4 Image in a plane mirror

1. The image is as far behind the mirror as the object is in front: **1.2 m**.
2. $1.2 + 1.2 = \mathbf{2.4 \text{ m}}$.
3. The image also moves 0.50 m/s towards the mirror, so the gap closes at $0.50 + 0.50 = \mathbf{1.0 \text{ m/s}}$.

Problem 5 Focal length of a mirror

1. $f = R/2 = 40 / 2 = \mathbf{20 \text{ cm}}$.
2. A concave mirror has **positive f**.

Problem 6 Lens facts

1. f is **positive**.
2. A **real, inverted, reduced** image.
3. A **virtual, upright, reduced** image.

Problem 7 Magnification

1. $|m| = 3.0 / 1.5 = \mathbf{2.0}$.
2. For an inverted image, $m = \mathbf{-2.0}$.

Problem 8 Real image from a lens

1. $1/d_i = 1/15 - 1/45 = 2/45$, so $d_i = \mathbf{22.5\text{ cm}}$.
2. $m = -22.5 / 45 = \mathbf{-0.50}$.
3. Real, inverted and half the size of the object.

Problem 9 Magnifying glass

1. $1/d_i = 1/10 - 1/6.0 = -2/30$, so $d_i = \mathbf{-15\text{ cm}}$.
2. $m = -(-15)/6.0 = \mathbf{+2.5}$.
3. **Virtual** (negative d_i), upright and 2.5 times larger.

Problem 10 Concave mirror

1. $1/d_i = 1/12 - 1/36 = 2/36$, so $d_i = \mathbf{18\text{ cm}}$.
2. $m = -18/36 = \mathbf{-0.50}$.
3. d_i is positive, so the image is real and **can be projected** on a screen.

Problem 11 Convex mirror

1. $1/d_i = -1/20 - 1/60 = -4/60$, so $d_i = \mathbf{-15\text{ cm}}$.
2. $m = 15/60 = \mathbf{+0.25}$.
3. A convex mirror always gives a virtual, upright, reduced image, so a wide area fits into the mirror.

Problem 12 Critical angles

1. $\sin \theta_c = 1/2.42 = 0.413$, so $\theta_c = \mathbf{24.4^\circ}$.

- $\sin \theta_c = 1/1.33 = 0.752$, so $\theta_c = \mathbf{48.8^\circ}$.
- Diamond traps light more easily because its critical angle is smaller.

Problem 13 Refraction data

- $\sin 50^\circ / \sin 30.7^\circ = 0.7660 / 0.5105 = \mathbf{1.50}$.
- $n = \sin \theta_1 / \sin \theta_2$, so a graph of $\sin \theta_1$ (y) against $\sin \theta_2$ (x) is a straight line through the origin whose gradient is n .
- The ratio is about 1.5 in every row, so $\mathbf{n = 1.5}$.

Problem 14 Water to air

- $1.33 \times \sin 30^\circ = 1.00 \times \sin \theta_2$, so $\sin \theta_2 = 0.665$ and $\theta_2 = \mathbf{41.7^\circ}$.
- Away from** the normal, since air has a smaller index.

Problem 15 Slide projector

- $1/d_o = 1/8.0 - 1/240 = 29/240$, so $d_o = \mathbf{8.28 \text{ cm}}$.
- $m = -240 / 8.28 = \mathbf{-29}$.
- $h_i = 29 \times 24 \text{ mm} = \mathbf{0.70 \text{ m}}$, inverted.

Problem 16 Camera focusing

- For a distant object, $d_i = \mathbf{f = 50 \text{ mm}}$.
- $1/d_i = 1/50 - 1/2000 = 39/2000$, so $d_i = \mathbf{51.3 \text{ mm}}$.
- The lens moves $51.3 - 50 = \mathbf{1.3 \text{ mm}}$ away from the sensor.

Problem 17 Optical fibre

- $\sin \theta_c = n_2/n_1 = 1.46 / 1.48 = 0.9865$, so $\theta_c = \mathbf{80.6^\circ}$.
- The ray angle to the boundary normal must be at least 80.6° , so the angle with the fibre axis is at most $90^\circ - 80.6^\circ = \mathbf{9.4^\circ}$.

Problem 18 Mirror image changes

- At 20 cm: $1/d_i = 1/15 - 1/20 = 1/60$, so $d_i = \mathbf{60 \text{ cm}}$, $m = -3.0$, $h_i = \mathbf{-9.0 \text{ cm}}$. At 10 cm: $1/d_i = 1/15 - 1/10 = -1/30$, so $d_i = \mathbf{-30 \text{ cm}}$, $m = +3.0$, $h_i = \mathbf{+9.0 \text{ cm}}$.
- The image changes from **real and inverted** to **virtual and upright** as the object moves inside the focal length.

Problem 19 Coin in a pool

1. $\tan \theta_1 = 1.0 / 1.0$, so $\theta_1 = \mathbf{45^\circ}$.
2. $1.33 \times \sin 45^\circ = \sin \theta_2$, so $\sin \theta_2 = 0.940$ and $\theta_2 = \mathbf{70.2^\circ}$.
3. The eye traces the bent ray back in a straight line, which meets the vertical through the coin above the real position, so the coin seems **shallower** (about 0.36 m deep for this ray).

Problem 20 Spot the errors

1. Light **slows down** in glass and bends **towards** the normal.
2. A diverging lens gives only virtual images of real objects. $1/d_i = -1/10 - 1/30 = -4/30$, so $d_i = \mathbf{-7.5\text{ cm}}$, virtual, and $m = 7.5/30 = \mathbf{+0.25}$, upright and reduced.