

Bending light: refraction, critical angle and lenses

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems train you to apply the law of reflection, the refractive index equation and the critical angle formula, and to draw and interpret ray diagrams for converging lenses. They start with recall and move to multi-step calculations and explanations.

The set suits GCSE, IGCSE, O Level and Class 9-10 students. Give angles to one decimal place, draw rays with a ruler and add arrowheads.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** IGCSE 3.2

Problem 1 Law of reflection (easy)

Emma in Leeds stands in front of a bathroom mirror. A ray from her torch hits the mirror at an angle of incidence of 35° .

1. State the angle of reflection.
2. Calculate the angle between the incident ray and the mirror surface.
3. Calculate the angle between the incident ray and the reflected ray.

Problem 2 Bending at a boundary (easy)

A ray of light passes from air into a glass block, then out of the glass back into air.

1. State whether the ray bends towards or away from the normal when it enters the glass.
2. State whether it bends towards or away from the normal when it leaves the glass.
3. Name the effect that changes the direction of the ray.

Problem 3 Index of an acrylic block (easy)

Aarav in Pune shines a ray onto an acrylic block. The angle of incidence is 30.0° and the angle of refraction is 19.5° . Use $\sin 30.0^\circ = 0.500$ and $\sin 19.5^\circ = 0.334$.

1. Write the equation for refractive index.
2. Calculate the refractive index of the acrylic.

Problem 4 Light in water (easy)

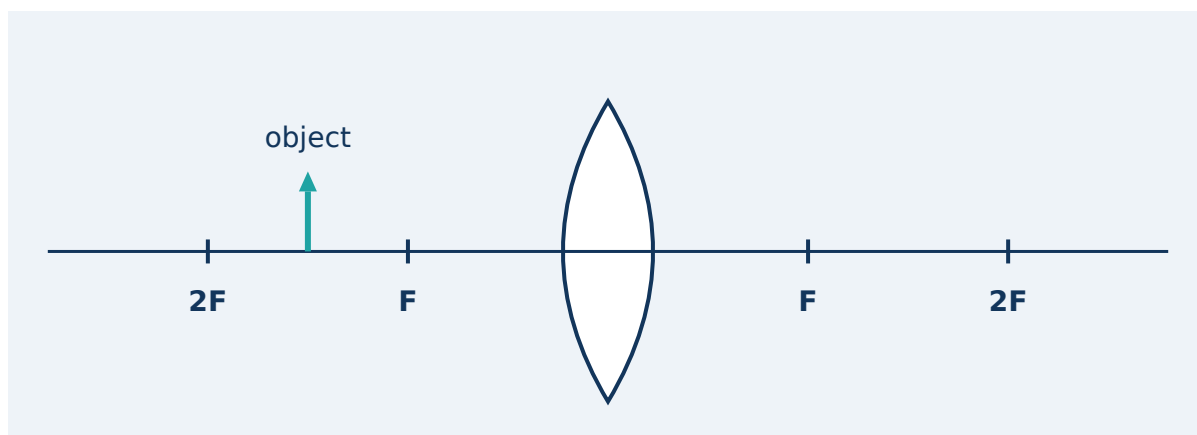
Light travels at 3.00×10^8 m/s in air. In water its speed is 2.25×10^8 m/s.

1. Calculate the refractive index of water using $n = c \div v$.
2. Explain why the answer has no unit.

Problem 5 Three rays at a lens (easy)

The diagram shows a converging lens with an object, using F for the principal focus.

1. State what happens to a ray travelling parallel to the principal axis.
2. State what happens to a ray passing through the centre of the lens.
3. Define the focal length of the lens.



F is the principal focus on each side of the lens and 2F is twice the focal length from it. The sketch is not to scale.

Problem 6 Conditions for total internal reflection (easy)

Bilal in Lahore wants to bounce a laser beam inside a glass rod.

1. State the two conditions needed for total internal reflection.
2. Name one device that uses total internal reflection.

Problem 7 Finding the refraction angle (medium)

Diego in Texas shines a ray at 50° onto a glass paperweight of refractive index 1.50.

1. Rearrange $n = \sin i \div \sin r$ to make $\sin r$ the subject.
2. Calculate $\sin r$.
3. Calculate the angle of refraction.

Problem 8 Spearfishing angle (medium)

Kofi in Accra watches a fish from a boat. A light ray from the sky hits the sea surface at 60° to the normal. The refractive index of seawater is 1.33.

1. Calculate the angle of refraction in the water.
2. State whether the refracted ray is closer to or further from the normal than the incident ray.

Problem 9 Critical angle of perspex (medium)

A perspex rod has refractive index 1.49.

1. Write the equation linking critical angle and refractive index.

2. Calculate the critical angle.
3. State what happens to a ray inside the rod that hits the surface at 50° .

Problem 10 Experimental readings (medium)

Mei in Singapore records angles for a ray entering a glass block.

i (°)	20	40	60	80
r (°)	13	25	35	40

1. Calculate $\sin i$ and $\sin r$ for each pair of angles (3 decimal places).
2. Calculate n for each pair and find the mean.
3. Suggest why the mean is more reliable than one value.

Problem 11 Why fibres carry the internet (medium)

Chiamaka in Lagos reads that undersea internet cables use thin glass fibres.

1. Explain how light travels along a fibre without escaping through the sides.
2. Explain why the light must meet the wall at a large angle of incidence.

Problem 12 Magnifying a seed (medium)

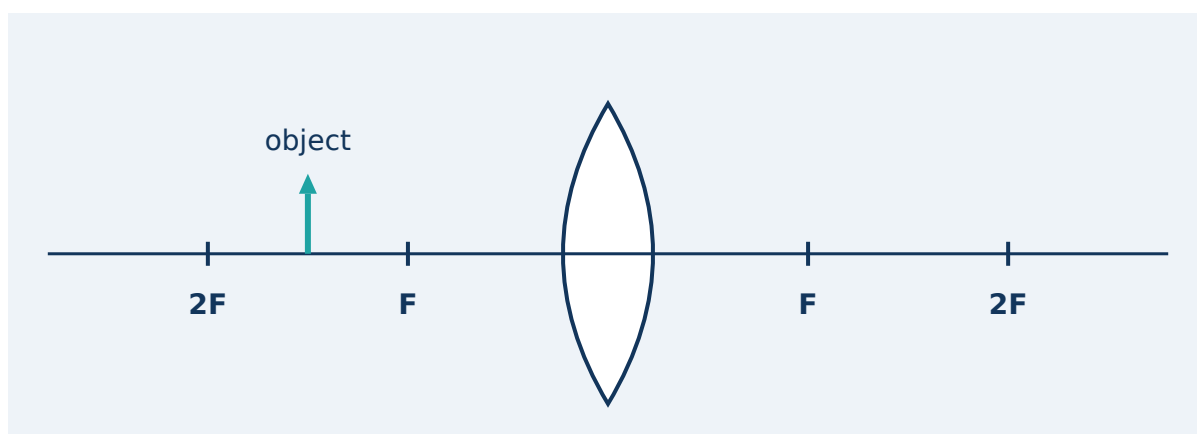
Wanjiru in Nairobi uses a lens to photograph a bean seed. The seed is 12 mm long and its image is 30 mm long.

1. Calculate the magnification.
2. A second image has magnification 2.5 for an object 8.0 mm long. Calculate the image height.

Problem 13 Real image on a screen (medium)

An object 3.0 cm tall stands 12 cm from a converging lens of focal length 8.0 cm. Use the axes below, with the lens at the centre, to answer.

1. Draw a ray diagram to scale to find the image.
2. State the image distance, image height and two properties of the image.



F is the principal focus on each side of the lens and 2F is twice the focal length from it. The sketch is not to scale.

Problem 14 Camera, projector or magnifier (medium)

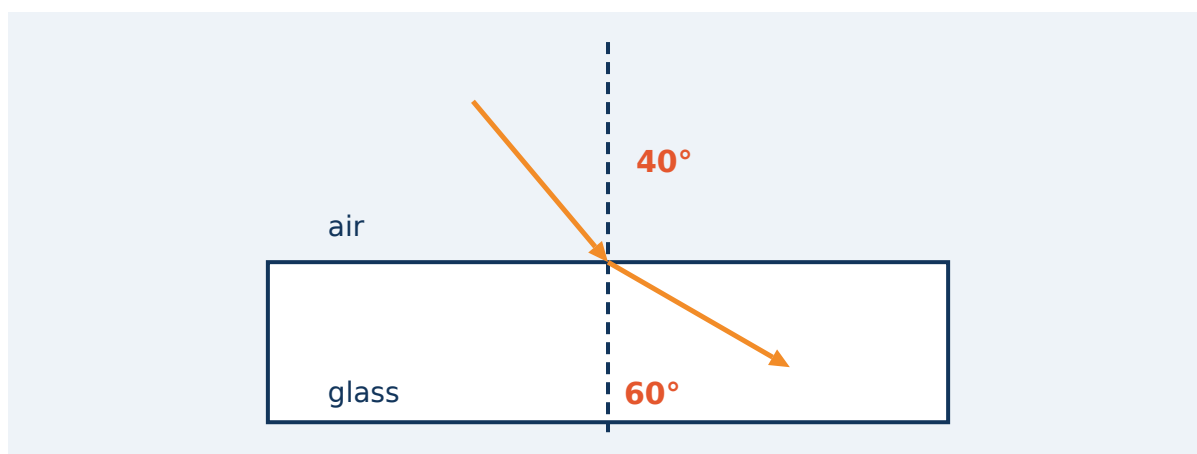
Compare the images formed when an object is placed beyond 2F, between F and 2F, and inside F of a converging lens.

1. State the image type and size in each case.
2. Match each case to camera, projector or magnifying glass.

Problem 15 Spot the error (medium)

Aarav drew the diagram below for a ray entering glass from air. His angles are marked.

1. Identify the mistake in his diagram.
2. Redraw the ray correctly: calculate the angle of refraction for $n = 1.50$.



Aarav's diagram of a ray entering a glass block ($n = 1.50$).

Problem 16 Light through a parallel block (hard)

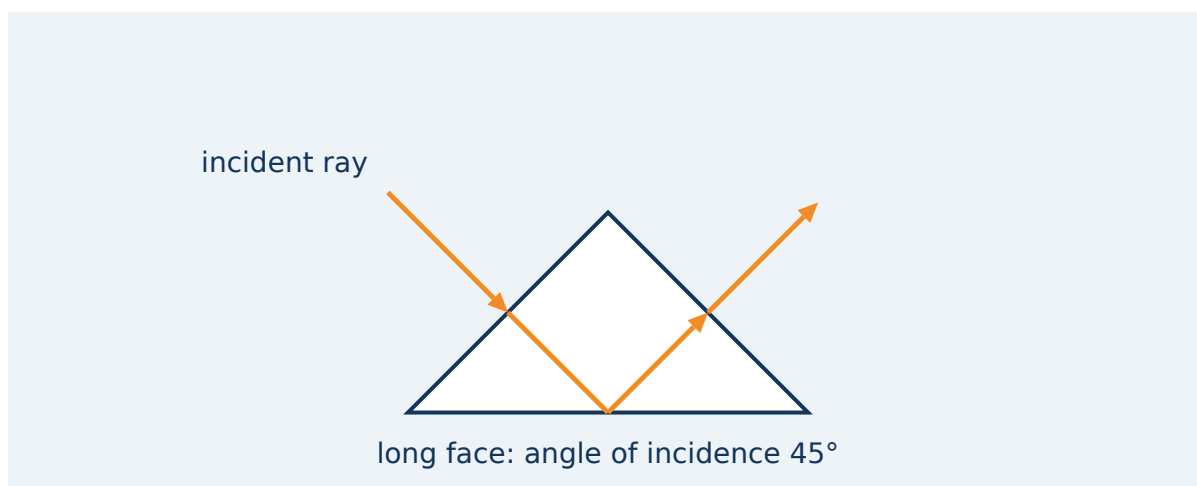
Diego sends a ray at 45° through a rectangular glass block of refractive index 1.50, with parallel faces.

1. Calculate the angle of refraction at the first face.
2. State the angle of incidence at the second face and explain your reasoning.
3. Calculate the angle at which the ray emerges and compare it with the incident ray.

Problem 17 A plastic prism that fails (hard)

A periscope uses a 45° - 45° - 90° prism. Light enters a short face along the normal and hits the long face at 45° (see figure).

1. Calculate the critical angle for glass of $n = 1.52$.
2. Explain why the glass prism reflects all the light.
3. Calculate the critical angle for a plastic of $n = 1.38$ and state whether it would work.



Light enters the left face along the normal, so it is not bent. It then meets the long face at 45° .

Problem 18 Light from underwater (hard)

A diver in a pool sends a torch beam upwards to the water surface ($n = 1.33$). Calculate what happens at two angles of incidence.

1. At 30° calculate the angle of refraction in air.
2. At 50° find $\sin r$ and explain what the result shows.
3. Calculate the critical angle for water.

Problem 19 Virtual image in a magnifier (hard)

Mei holds a magnifying glass of focal length 5.0 cm. A seed 2.0 mm tall is 3.0 cm from the lens.

1. Draw a scale ray diagram. Extend the refracted rays backwards.
2. State the position, nature and height of the image.
3. Explain why you cannot catch this image on a screen.

Problem 20 Unknown liquid (hard)

Wanjiru measures a liquid in a transparent tank: a ray in air at 52° refracts at 36° in the liquid. Use $\sin 52^\circ = 0.788$ and $\sin 36^\circ = 0.588$.

1. Calculate the refractive index of the liquid.
2. Calculate the critical angle for the liquid-air boundary.
3. Predict whether a ray inside the liquid at 45° to the surface normal leaves the liquid.