

Lenses ray diagrams and magnification

AQA GCSE Separate Physics 8463 | Paper 2 | Foundation and Higher

Worked answers and construction guidance | 29 parts | 49 marks

Specification points covered

4.6.2.5: refraction by convex and concave lenses; principal focus and focal length

4.6.2.5: construct ray diagrams; distinguish real and virtual images

4.6.2.5: magnification = image height / object height; use matching height units

A conservation laboratory examines tiny details in artwork. The team needs a lens to project details onto a screen and a hand lens for close inspection. Use evidence from ray constructions and measurements to choose suitable arrangements. Tests are separate unless stated otherwise.

Use alongside pupil Figures 1–3. Exact ray paths and image coordinates are given below; completed raster ray traces are not included. Accept valid alternative principal rays. This is an original PhysicsUK resource, not an official AQA paper or mark scheme.

1 Understanding the lenses

The team begins by checking the language used in its lens test reports.

1(a) State what is meant by the principal focus of a convex lens for rays parallel to its principal axis. **[1 mark]**

Answer / mark points: The point where rays initially parallel to the principal axis converge/meet after passing through the lens. [1]

1(b) Define the focal length of a lens. **[1 mark]**

Answer / mark points: The distance from the optical centre of the lens to its principal focus. [1] Do not confuse the focus (a point) with focal length (a distance).

1(c) The team shines a narrow bundle of parallel rays through a convex lens and then through a concave lens. Describe the different effects on the rays. **[2 marks]**

Answer / mark points: A convex lens converges the rays towards a principal focus. [1] A concave lens makes the rays diverge/spread out, as if they came from a principal focus on the incident side. [1]

1(d) A trainee says, “If a lens image cannot be formed on a screen, nobody can see it.” Explain why this is wrong. **[2 marks]**

Answer / mark points: A virtual image can be seen by looking through the lens / emergent rays enter the eye. [1] The rays do not actually meet at the apparent image position, so that image cannot be formed on a screen. [1]



2 The first projection test

Figure 1 shows a convex lens. Each grid interval represents 2 cm in either direction. The artwork detail is represented by the black object arrow.

Use Figure 1 in the pupil worksheet. The marking coordinates and ray paths below define the correct construction.

2(a) Use Figure 1 to determine the focal length of the lens. **[1 mark]**

Answer / mark points: Two grid intervals $\times$ 2 cm = 4 cm. [1]

2(b) On Figure 1, use two principal rays from the top of the object to locate the image. Represent the image with an arrow and show the direction of light travel. **[3 marks]**

Answer / mark points: Draw a ray parallel to the axis from the object tip to the lens, then through the right-hand F. [1] Draw a second ray from the same tip straight through the optical centre, undeviated. [1] Place an inverted image arrow where the rays meet: three grid intervals (6 cm) right of the lens, from the axis down one interval (2 cm). [1] Direction arrows should point towards and then away from the lens. Accept another valid pair of principal rays. Allow ± 0.2 grid intervals for the image tip; rays must pass through the appropriate centre/focus within about 1 mm on the printed grid.

Teacher prompt: Construction coordinates: lens centre (0,0); object tip (-12,+4) cm; right F (+4,0) cm; image tip (+6,-2) cm. These coordinates are marking guidance, not a thin-lens-equation task.

2(c) Read the height of the image from your construction. **[1 mark]**

Answer / mark points: Approximately 2 cm (one vertical grid interval). [1] Accept a consistent reading from a sensible construction.

2(d) The object height in Figure 1 is 4 cm. Use your image height to calculate the magnification. **[1 mark]**

Answer / mark points: Magnification = $2 / 4 = 0.50$. [1] Use height magnitudes; the magnification has no unit. Accept a correct ratio using the pupil's sensible image height.

2(e) State whether the image in Figure 1 is real or virtual. Explain your answer using the rays. **[2 marks]**

Answer / mark points: Real. [1] The refracted rays actually converge/meet at the image position. [1] A real image could be formed on a screen placed there.

2(f) The team wants an enlarged projection of the detail. Explain why this first arrangement does not meet that aim. **[1 mark]**

Answer / mark points: The image is smaller than the object / the magnification is less than 1, so it is not enlarged. [1]



3 Using the hand magnifier

In Figure 2, the same convex lens is used with a smaller object closer to it. Each grid interval still represents 2 cm. Use Figure 2 in the pupil worksheet. The marking coordinates and ray paths below define the correct construction.

3(a) On Figure 2, construct two principal rays to locate the image. Show any necessary backward extensions and draw the image arrow. **[3 marks]**

Answer / mark points: Ray from object tip parallel to the axis, refracted towards the right-hand F. [1] Second ray straight through the optical centre; extend the emergent ray paths backwards with dashed lines. [1] The backward extensions meet two intervals (4 cm) left of the lens and two intervals (4 cm) above the axis; draw an upright image there. [1] Accept an equally valid alternative construction. Allow ± 0.2 grid intervals for the image tip.

Teacher prompt: Coordinates: object tip $(-2, +2)$ cm; lens $(0, 0)$; F at ± 4 cm; image tip $(-4, +4)$ cm. Actual emergent rays travel rightwards and diverge; dashed lines on the left are not light travelling backwards.

3(b) Read the image height from your Figure 2 construction. **[1 mark]**

Answer / mark points: Approximately 4 cm (two vertical intervals). [1] Accept a consistent reading from a sensible construction.

3(c) The object in Figure 2 is 2 cm high. Calculate its magnification. **[1 mark]**

Answer / mark points: Magnification = $4 / 2 = 2.0$. [1] No unit.

3(d) Give two differences between the Figure 2 image and the Figure 1 image. **[2 marks]**

Answer / mark points: Any two paired comparisons: Figure 2 is virtual, whereas Figure 1 is real; Figure 2 is upright, whereas Figure 1 is inverted; Figure 2 is enlarged, whereas Figure 1 is diminished. [1 each, maximum 2] Accept a correct positional comparison tied to the incident/object side versus the far side.

3(e) Explain why placing a screen at the apparent image position in Figure 2 will not give a focused image there. **[1 mark]**

Answer / mark points: The actual emergent rays do not meet there; only their backward extensions intersect. [1] "It is virtual" without an explanation does not by itself answer why.



4 Testing the concave lens

Figure 3 shows a concave lens with a real object on its left. Each grid interval represents 2 cm in either direction. Use Figure 3 in the pupil worksheet. The marking coordinates and ray paths below define the correct construction.

4(a) On Figure 3, construct two principal rays and their necessary backward extensions to locate the image. Draw an image arrow. **[3 marks]**

Answer / mark points: A ray initially parallel to the axis emerges diverging as if it came from the left-hand F; show its dashed backward extension through that F. [1] A ray through the optical centre continues straight. [1] The image is upright, one interval (2 cm) left of the lens and one interval (2 cm) above the axis, at the intersection with the backward extension. [1] Accept a different correct pair of rays; allow ± 0.2 intervals for the image tip.

Teacher prompt: Coordinates: object tip $(-4, +4)$ cm; lens $(0, 0)$; near F $(-4, 0)$ cm; virtual image tip $(-2, +2)$ cm. For the initially parallel ray, the emergent ray slopes upwards-right, away from the axis. Its extension, not the actual outgoing ray, goes through near F.

4(b) Read the image height from your Figure 3 construction. **[1 mark]**

Answer / mark points: Approximately 2 cm. [1] Accept a consistent sensible construction reading.

4(c) The Figure 3 object height is 4 cm. Calculate the magnification. **[1 mark]**

Answer / mark points: Magnification = $2 / 4 = 0.50$. [1] No unit.

4(d) A trainee says, "The rays leaving the concave lens spread apart, so the lens forms no image of the object." Explain the mistake. **[2 marks]**

Answer / mark points: A virtual image is formed, even though no real image is formed. [1] The diverging emergent rays appear to come from the point where their backward extensions meet. [1]

4(e) Compare the images in Figures 2 and 3. Give one similarity in image type or orientation and one difference in size compared with their objects. **[2 marks]**

Answer / mark points: Similarity: both images are virtual, or both are upright. [1] Difference: the convex-lens image in Figure 2 is enlarged but the concave-lens image in Figure 3 is diminished. [1]



5 Checking detail sizes

The following are separate laboratory measurements. Use magnification = image height / object height. Magnification has no unit; use the same units for both heights.

5(a) A projected detail is 9.0 mm high and its object is 1.8 mm high. Calculate the magnification. **[1 mark]**

Answer / mark points: Magnification = $9.0 / 1.8 = 5.0$. [1]

5(b) A hand lens gives a magnification of 3.2 for a 2.5 mm mark. Calculate the image height. **[1 mark]**

Answer / mark points: Image height = magnification $\times$ object height = $3.2 \times 2.5 = 8.0$ mm. [1]

5(c) A projected line is 42 mm high at a magnification of 6.0. Calculate the original line height. **[1 mark]**

Answer / mark points: Object height = image height / magnification = $42 / 6.0 = 7.0$ mm. [1]

5(d) A detail is 0.50 cm high. Its image is 15 mm high. Calculate the magnification. **[2 marks]**

Answer / mark points: Convert 0.50 cm = 5.0 mm, or 15 mm = 1.5 cm. [1] Magnification = $15 / 5.0 = 3.0$ (or $1.5 / 0.50$). [1]

Teacher prompt: Dividing heights in different units produces a wrong ratio. Magnification is not measured in mm or cm.

5(e) A test produces an image 1.8 cm high at a magnification of 0.60. Calculate the object height. **[1 mark]**

Answer / mark points: Object height = $1.8 / 0.60 = 3.0$ cm. [1] An image can be smaller than its object.

5(f) Test P uses magnification 2.0 with a 6.0 mm object. Test Q uses magnification 3.0 with a 3.0 mm object. Calculate both image heights and identify which test gives the taller image. **[2 marks]**

Answer / mark points: P: $2.0 \times 6.0 = 12$ mm. [1] Q: $3.0 \times 3.0 = 9.0$ mm, so P gives the taller image. [1] A higher magnification does not guarantee a taller image when the objects differ.



6 Choosing the final arrangements

The team compares the lenses in Table 1. The object is 6.0 cm from the lens in the initial projection test. Use ray behaviour and focal distances, not a thin-lens equation.

Table 1

Lens	Type	Focal length
A	Convex	4.0 cm
B	Convex	8.0 cm
C	Concave	4.0 cm

6(a) Choose the lens in Table 1 that can project an enlarged real image when the object is 6.0 cm from it. Use the focal distances to justify your choice and explain why each of the other lenses is unsuitable. **[4 marks]**

Answer / mark points: A is suitable: the object is beyond its 4.0 cm focus but inside $2F = 8.0$ cm.

[1] A convex lens in this arrangement forms an enlarged real image, which can be projected onto a screen. [1] For B, the object is inside the 8.0 cm focus, giving a virtual image, not a screen image.

[1] C is concave and forms a virtual diminished image of a real object, not an enlarged real projection. [1] No image-distance calculation or thin-lens equation is required.

6(b) With lens A, the team moves the object from 6.0 cm to 8.0 cm from the lens, exactly at $2F$. State the new image position and its size compared with the object. **[2 marks]**

Answer / mark points: The image forms at $2F$ on the opposite side, 8.0 cm from the lens. [1] It is the same size as the object (magnification 1). [1] It is also real and inverted, but those are not extra marks here.

6(c) The team checks the focal length of a convex lens using a ray box that supplies rays parallel to the principal axis. Describe how to use these rays, a white screen and a ruler to obtain the focal length. **[3 marks]**

Answer / mark points: Direct the parallel rays through the lens along its principal axis. [1] Move the screen on the other side until the rays meet in a sharp point/focus on it. [1] Measure from the optical centre of the lens to that focus/screen with the ruler. [1] Do not measure from the ray box, object or front edge of the bench. Do not look into the beam.

Teacher prompt: This is a practical application of principal focus and focal length, not a claim that an AQA required practical has been completed.

Review and improve

Prioritise straight centre rays, focal-point accuracy and the distinction between actual rays and backward extensions. A virtual image can be seen, but cannot be caught on a screen. An inverted image has a positive size magnification at GCSE; use height magnitudes. Timing is estimated and awaits classroom trial.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

