

Reflection and refraction required practical

AQA GCSE Separate Physics 8463 | Paper 2 | Required practical 9 | Foundation and Higher

Worked answers and marking guidance | 25 parts and 43 marks per tier route

Specification points covered

4.6.1.3: reflection, transmission and required practical 9 (Physics only)

4.6.2.2: refraction ray diagrams; speed and wavefront explanations are Higher only

4.6.2.6: smooth and diffuse reflection (selected content)

Higher support: 4.6.1.2, wave speed, frequency and wavelength

A museum inspection team tests glass viewing windows and reflective panels for a new display enclosure. Use ray measurements and evidence to check the team's conclusions. Each test uses the values given for that test.

Choose one tier route: section 5 for Foundation or section 7 for Higher, not both. Green rays and graph marks show completed answers. This is an original PhysicsUK practice resource, not an official AQA paper or mark scheme.

1 Checking the measurement procedure

The team uses a narrow ray of light and a plane mirror on paper.

1(a) State what is meant by the normal to a surface at the point where a ray meets it. **[1 mark]**

Answer / mark points: A line at 90° / perpendicular to the surface at that point. [1]

1(b) The angle of incidence on the mirror is 30° . State the angle of reflection. **[1 mark]**

Answer / mark points: 30° . [1]

1(c) A trainee measures 60° between an incident ray and the mirror surface and records this as the angle of incidence. Give the correct angle of incidence. **[1 mark]**

Answer / mark points: $90^\circ - 60^\circ = 30^\circ$. [1] The angle is measured from the normal.

1(d) Explain one reason why a narrow ray makes the ray path easier to mark accurately than a broad beam. **[1 mark]**

Answer / mark points: Its centre/path can be located more precisely / there is less uncertainty in choosing where to mark it. [1]

1(e) The team can choose a protractor with divisions of 1° or 5° . Which has the finer resolution? **[1 mark]**

Answer / mark points: The protractor with 1° divisions. [1] Resolution is the smallest scale increment.

1(f) A trainee moves the mirror after marking the incident ray but before marking the reflected ray. Explain why these marks should not be used as one result. **[2 marks]**

Answer / mark points: Moving the mirror changes the reflecting surface position/orientation, and hence its normal or point of incidence. [1] The marks therefore do not describe the incoming and outgoing rays for the same mirror setting/reflection. [1]

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2 Reflecting light at the display panel

Figure 1 is drawn for measurement. Complete the ray on the diagram.

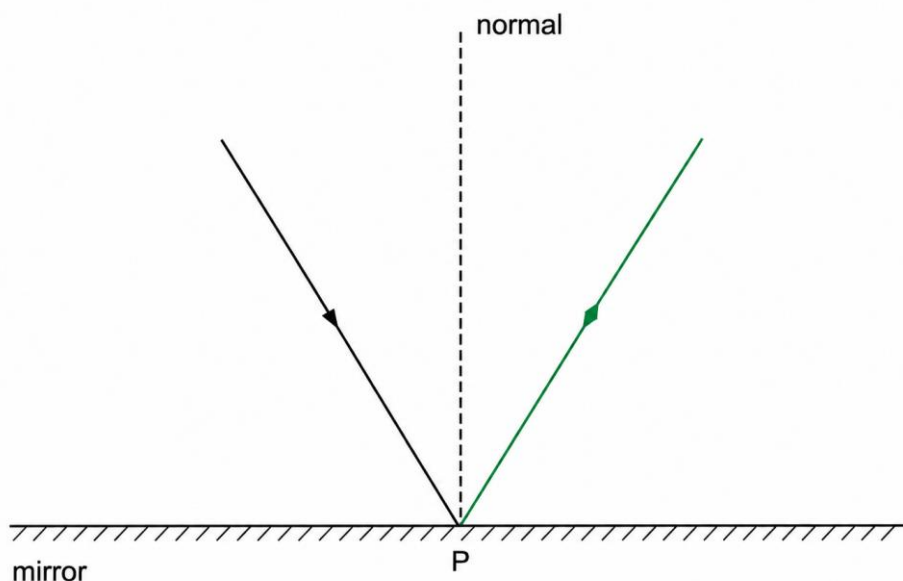


Figure 1

2(a) Measure the angle of incidence in Figure 1. **[1 mark]**

Answer / mark points: About 31° or 32° ; accept 30° – 34° . [1] Measure from the dashed normal, not the surface.

2(b) Use your answer to 2(a) to find the angle between the incident ray and the mirror surface. **[1 mark]**

Answer / mark points: $90^\circ - 31^\circ = 59^\circ$ (or $90^\circ - 32^\circ = 58^\circ$). [1] Accept the correct complement of the pupil's measured angle.

2(c) On Figure 1, draw the reflected ray from P and add an arrow to show its direction. **[2 marks]**

Answer / mark points: A straight ray from P upwards-right, making the same angle to the normal as the incident ray. [1] An arrow pointing away from P along that ray. [1] Allow $\pm 2^\circ$ for the drawn angle; do not accept a ray passing through the mirror.

2(d) A rough panel scatters parallel incident rays in different directions. Explain why this does not mean that the law of reflection has stopped applying. **[2 marks]**

Answer / mark points: Different small parts of the rough surface have different orientations/local normals. [1] At each part, the angle of reflection still equals the angle of incidence measured from its local normal. [1]

Teacher prompt: "Random reflection" alone is insufficient. Diffuse reflection is scattering due to surface orientations, not a failure of $i = r$.

2(e) Choose the surface that is more suitable for forming a clear reflected image: a polished plane mirror or a rough white panel. **[1 mark]**

Answer / mark points: The polished plane mirror. [1] Smooth/specular reflection preserves the ordered ray directions.

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3 Testing the transparent window

Figure 2 shows a ray entering a rectangular glass sample at P and reaching Q. The material outside both faces is air.

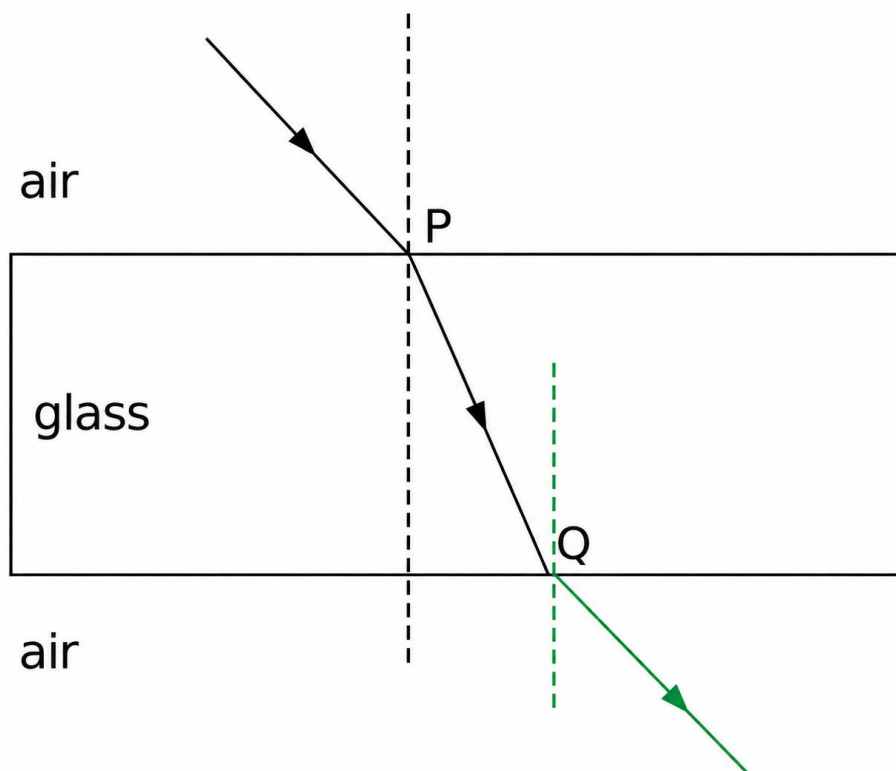


Figure 2

3(a) Measure the angle of incidence and the angle of refraction at P in Figure 2. **[2 marks]**

Answer / mark points: Angle of incidence approximately 43° (accept 41° – 45°). [1] Angle of refraction approximately 23° (accept 21° – 25°). [1] Both are measured from the normal at P, on the appropriate side of the boundary.

3(b) State whether the ray bends towards or away from the normal as it enters the glass. **[1 mark]**

Answer / mark points: Towards the normal. [1]

3(c) On Figure 2, draw the normal at Q. Complete the emergent ray in air, including its direction arrow. **[2 marks]**

Answer / mark points: Normal through Q perpendicular to the lower face. [1] Emergent ray from Q downwards-right, parallel to the incident ray, with an outward arrow. [1] Accept $\pm 2^\circ$ parallelism and a normal passing within 1 mm of Q at the printed scale. The exit ray bends away from the normal.

3(d) The team sends a second ray into the glass along the normal. State what happens to the direction of this ray at entry. **[1 mark]**

Answer / mark points: Its direction is unchanged / it continues straight along the normal. [1]

3(e) A trainee calls the internal ray PQ a reflected ray. Explain why PQ is instead a refracted ray. **[2 marks]**

Answer / mark points: PQ is transmitted into a different material, from air into glass, and changes direction at P. [1] A reflected ray would return into the original material (air), not travel through the glass as PQ does. [1]



4 Analysing the reflection results

Table 1 shows mean angles rounded to the nearest degree. The team tests the same plane mirror at five settings.

Table 1

Angle of incidence / degrees	10	20	30	40	50
Mean angle of reflection / degrees	10	20	30	40	50

4(a) Plot all five results from Table 1 on Figure 3. Draw a straight line of best fit. [3 marks]

Answer / mark points: Plot (10,10), (20,20), (30,30), (40,40), (50,50). [2 for all five; 1 for at least three correct] Tolerance: half a small grid square (2.5°) in either coordinate. Draw one straight best-fit line through the points, consistent with the origin. [1] Do not join the points with separate wandering segments.

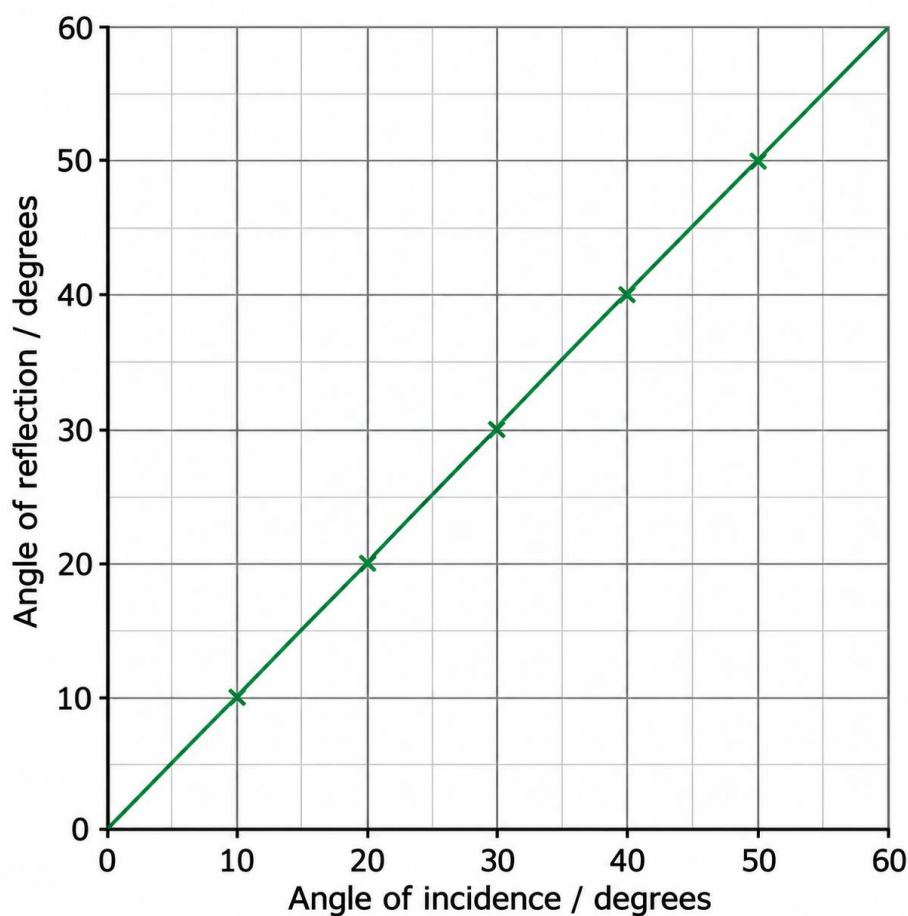


Figure 3

4(b) Use your graph to estimate the angle of reflection for an angle of incidence of 35° . [1 mark]

Answer / mark points: 35° ; accept 33° – 37° . [1] Accept a correct read-off from the pupil's own sensible best-fit line.

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4 Analysing the reflection results continued

4(c) Explain how these results support the law of reflection. [2 marks]

Answer / mark points: For each setting the angle of reflection is equal to the angle of incidence / the graph follows $r = i$. [1] Support with one paired example, such as incidence 40° and reflection 40° , or a numerical read-off showing equality. [1] A straight line alone does not establish equal angles; it must have the appropriate values.

4(d) At one fixed incident angle the team obtains reflected angles of 39° , 40° and 41° . Calculate the mean reflected angle. [1 mark]

Answer / mark points: Mean = $(39 + 40 + 41) / 3 = 40^\circ$. [1]

4(e) A single reading gives incidence 40° and reflection 41° . Individual angle readings are reliable only to about $\pm 2^\circ$. A trainee says this disproves the law of reflection. Evaluate this claim. [2 marks]

Answer / mark points: The 1° difference is small compared with the stated reading uncertainty / the possible reading ranges overlap. [1] It does not disprove the law; repeat at the same setting and examine the mean/spread or obtain more reliable measurements. [1] No propagation-of-uncertainty calculation is required.

5 Foundation route only

Complete 5(a)–5(c) on the Foundation route. Higher pupils skip this section and complete section 7 instead.

5(a) A trainee records every angle as, for example, 40.00° using a protractor with 1° divisions. Explain why the two decimal places are not justified. [2 marks]

Answer / mark points: The smallest marked interval is 1° , not 0.01° . [1] The instrument does not provide the precision implied by the extra decimal places. [1]

5(b) The protractor is always aligned with the wrong zero, making every angle 3° too large. Explain why taking a mean of repeated readings will not remove this error. [2 marks]

Answer / mark points: Each reading contains the same systematic offset of $+3^\circ$. [1] Averaging retains that offset; the alignment must be corrected before taking new readings. [1]

5(c) The incident angle is fixed at 40° for three repeat readings. A trainee then changes it to 50° and adds that result to the same mean. Explain why the fourth result must not be included. [2 marks]

Answer / mark points: The incident angle, the independent variable, has changed. [1] The fourth result is a different test condition, not a repeat at 40° , so a separate result/mean is needed. [1]

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6 Writing the refraction method independently

The team now tests a new transparent rectangular window sample. Complete this task on either tier route.

6(a) Describe a method to investigate how the angle of refraction depends on the angle of incidence for the new window sample. Use a ray box, paper, pencil, ruler and protractor. Explain how you would obtain the two angles for a range of settings and improve confidence in the results. You may include a labelled diagram. **[6 marks]**

Answer / mark points: Model method: Put the sample on paper and trace its outline. Shine one narrow ray into a flat face at an angle. Keep the sample fixed while marking the entry and exit points and at least two well-separated points on each visible ray outside the sample. Remove the sample. Use a ruler to join the entry and exit points to reconstruct the path inside it; draw the incident path through its marks.

At the entry point, draw a normal perpendicular to the traced face. Measure incidence between the incident ray and normal in air, and refraction between the internal ray and normal in the sample.

Record paired angles with units. Repeat for several incident angles, for example 15° , 25° , 35° , 45° and 55° , using the same material and ray colour. Reposition only between complete traces and realign the block with its outline. Repeat each setting independently, check anomalies and calculate a mean refraction angle. Use fine pencil marks, a narrow ray and careful protractor alignment; do not look into the light beam.

Holistic levels: 5–6 marks for a clear, workable sequence that reconstructs the internal ray, measures both angles from a normal and samples several incidence settings, with a relevant reliability/precision improvement. 3–4 for a largely relevant method but a missing or unclear key step that could prevent valid paired measurements. 1–2 for isolated useful apparatus/actions without a workable sequence; 0 for no relevant content. Choose the level first, then the mark. Credit equally valid ray-tracing approaches and useful labelled diagrams; the model is not a compulsory word list. A mirror-only method does not investigate the requested refraction.

Teacher prompt: The refraction angle is not the angle between the incident and emergent rays. Pupils must reconstruct the ray inside the sample. This PhysicsUK levels rubric is informed by AQA assessment style, not an official AQA mark scheme.

Foundation route ends here. Higher pupils also complete section 7 instead of section 5. During review, correct one ray or one method step and explain the improvement.

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7 Higher replacement for section 5

Higher only: complete 7(a)–7(c) instead of 5(a)–5(c). Use Figure 2 and the idea of wavefronts. Light travels more slowly in glass than in air.

7(a) At P, one side of an angled wavefront enters the glass before the other. Explain, using the change in speed across the wavefront, why the ray bends towards the normal. **[2 marks]**

Answer / mark points: The part that enters glass first slows while the rest is still travelling faster in air. [1] The wavefront changes orientation; since the ray is perpendicular to the wavefront, its direction turns towards the normal. [1]

Teacher prompt: Do not accept “glass pulls the light” or only “it slows down” for a full wavefront explanation.

7(b) The light has the same frequency in air and glass. Use wave speed = frequency $\times$ wavelength to explain what happens to its wavelength on entering the slower medium. **[2 marks]**

Answer / mark points: The wavelength decreases. [1] At unchanged frequency, a lower wave speed requires a smaller wavelength so that $v = f \lambda$ remains satisfied. [1]

7(c) The ray in 3(d) travels straight into the glass along the normal. A trainee says no change in direction means no change in speed. Explain why this is wrong, using the wavefront. **[2 marks]**

Answer / mark points: The speed still decreases in glass. [1] At normal incidence all parts of a wavefront reach the boundary together, so the wavefront does not rotate and the direction remains unchanged. [1]

Review and improve

Ask pupils to distinguish a reflected ray from a refracted ray and a repeat from a new incident angle. Use “bends towards the normal”, not “bends towards the glass”. A mean does not remove a systematic offset. The six-mark method needs a workable sequence, not a list of apparatus names. Timing is an estimate awaiting classroom trial.

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