Reflection and refraction of light

Answers, marking points and revision notes | AQA GCSE Physics 8463 only (not Combined Science)

GCSE science required practicals

This practical online

Answers

1 Look at Hamza's investigation.

a. Name the independent variable.

b. Name one dependent variable.

c. Give one control variable and say why it must be kept the same. (3 marks)

a. The angle of incidence.
b. The angle of refraction (or the angle of reflection).
c. The same glass block, because a different material would bend the light by a different amount.

Marking points

- Independent: angle of incidence
- Dependent: angle of refraction or angle of reflection
- Control with a reason, for example same block because different materials refract by different amounts

2 What is the normal, and where should it be drawn in this experiment? (2 marks)

The normal is an imaginary line at 90° to the surface. It is drawn at the point where the ray of light hits the side of the block.

Marking points

- A line at right angles (90°) to the surface
- Drawn at the point where the ray hits the block

3 Hamza marked each ray with two crosses placed as far apart as possible, rather than close together. Explain why. (2 marks)

A small error in placing a cross makes a big difference to the direction of a short line. With the crosses far apart, the same small error changes the direction of the line much less, so the angles measured are more accurate.

Marking points

- Small errors in placing crosses close together give a large error in the direction of the line
- Crosses far apart give a more accurate line, so more accurate angles

4 Give one hazard in this experiment and explain how to reduce the risk. (2 marks)

The ray box gets hot and could burn your fingers. Stand it on a heat-resistant mat, only hold it by the base and let it cool before moving it away.

Marking points

- Hazard: hot ray box (or trip hazard in the dark, or chipped glass)
- Matching control: heat mat, hold by base and allow to cool (or clear walkways, or check block)

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5 Use the table to state the relationship between the angle of incidence and the angle of reflection. (2 marks)

The angle of reflection equals the angle of incidence. For example, at 30° incidence the reflection was also 30°, and the others are within 1°.

Marking points

- Angle of incidence = angle of reflection
- Supported with data, with differences of only 1° put down to measurement

6 Describe what the results show about how light refracts when it goes from air into glass. (3 marks)

The angle of refraction is always smaller than the angle of incidence, so the light bends towards the normal as it enters the glass. As the angle of incidence increases, the angle of refraction increases too, from about 7° at 10° incidence to about 39° at 70°, but it does not go up in proportion.

Marking points

- Angle of refraction is smaller than the angle of incidence (bends towards the normal)
- As the angle of incidence increases, the angle of refraction increases
- Not proportional, with data, for example 10° gives about 7° but 70° gives only about 39°

7 Calculate the mean angle of refraction when the angle of incidence was 30°. Give your answer to 1 decimal place. (2 marks)

Mean = (20 + 19 + 20) ÷ 3 = 59 ÷ 3 = 19.7°

total = 20 + 19 + 20 = 59

mean = 59 ÷ 3

mean = 19.66...

mean = 19.7° (1 d.p.)

Marking points

- (20 + 19 + 20) ÷ 3
- 19.7°

8 Identify the anomalous result in the table and suggest one cause of it. (2 marks)

The 31° in trial 2 at 40° incidence is anomalous, because the other two trials were 25° and 26°. Hamza may have put a cross in the wrong place or read the wrong scale on the protractor.

Marking points

- 31° in trial 2 for 40° incidence
- Sensible cause, such as a misplaced cross, reading the wrong protractor scale or the ray not hitting where the normal meets the block

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9 Calculate the mean angle of refraction for an angle of incidence of 40°, leaving out the anomalous result. Show your working.

(3 marks)

Leave out 31°. Mean = (25 + 26) ÷ 2 = 25.5°

leave out the anomaly of 31°

total = 25 + 26 = 51

mean = 51 ÷ 2

mean = 25.5°

Marking points

- Leaves out the 31° reading
- (25 + 26) ÷ 2
- 25.5°

10 **Higher tier**

For an angle of incidence of 60°, Hamza's angles of refraction were 35°, 36° and 35°. The uncertainty can be taken as half the range. Calculate the uncertainty in his result.

(2 marks)

Range = 36 - 35 = 1°. Uncertainty = 1 ÷ 2 = ±0.5°.

range = largest - smallest = 36 - 35 = 1°

uncertainty = range ÷ 2

uncertainty = 1 ÷ 2

uncertainty = ±0.5°

Marking points

- Range = 36 - 35 = 1°
- Uncertainty = ±0.5°

11 **Higher tier**

Explain, in terms of wave fronts, why a ray of light changes direction when it enters the glass block at an angle.

(3 marks)

Light travels more slowly in glass than in air. When a wave front hits the block at an angle, one end of it enters the glass first and slows down, while the other end is still in the air moving faster. The two ends travel different distances in the same time, so the wave front turns and the ray bends towards the normal.

Marking points

- Light slows down in glass
- One side of the wave front reaches the glass and slows first while the other side is still moving faster
- So the wave front changes direction (the ray bends towards the normal)

12 Hamza's ray of light was quite wide, so it was hard to see exactly where to put his crosses. Suggest an improvement and explain why it helps.

(2 marks)

Use a narrower slit in front of the ray box to give a thinner ray. The centre of a thin ray is easier to mark exactly, so the drawn lines and the measured angles are more accurate.

Marking points

- Use a narrower slit, a thinner ray or a laser pointer with teacher supervision
- The centre of the ray can be marked more exactly, so the angles are more accurate

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13 Another pupil, Ellie, measured all her angles from the surface of the block instead of from the normal. What type of error is this, and how does it affect her results?

(2 marks)

It is a systematic error. Every angle she records is wrong in the same way: each one is 90° minus the true angle, so all her values are wrong even if her readings are consistent.

Marking points

- Systematic error
- Every angle is wrong in the same way (90° minus the true angle), so all results are inaccurate

14 Plan an investigation to compare how much light is refracted by glass, by Perspex and by water. You can use a rectangular glass block, a rectangular Perspex block and a thin-walled rectangular plastic box filled with water.

(6 marks)

Draw round the glass block on plain paper with a sharp pencil and draw a normal at 90° to one long side. Use a protractor to draw a line at an angle of incidence of 40° to the normal. Put the block back and aim a thin ray from a ray box along the line so it hits the block where the normal meets it. Mark the ray where it leaves the block with two crosses far apart. Remove the block, join up the crosses and draw the refracted ray inside the block. Measure the angle of refraction from the normal. Repeat at 20° and 60° too. Do exactly the same with the Perspex block and the box of water, using the same angles of incidence, the same ray box and the same colour of light. Repeat each measurement three times on fresh paper and find the mean angle of refraction. The material with the smallest angle of refraction for the same angle of incidence bends the light most. Put the ray box on a heat-resistant mat and keep water away from the power supply.

Marking points (any 6, with the method in a logical order)

- Draw round each block and draw a normal at 90° to the surface
- Use a protractor to set the same angle(s) of incidence for every material
- Aim a thin ray from a ray box at the point where the normal meets the surface
- Mark the emerging ray with crosses far apart and join up to draw the refracted ray
- Measure the angle of refraction from the normal
- Keep the same ray box, same colour of light and same angles for each material
- Repeat and find a mean for each material
- Compare: the smallest angle of refraction for the same incidence means the most refraction
- Safety: heat mat for the hot ray box and water kept away from electrics

How it is marked

- 5-6 marks: a clear, logical plan that would work, with normals drawn, the same angles of incidence for all three materials, angles measured from the normal, repeats and a clear way to compare
- 3-4 marks: a workable plan that shines light through each material and measures an angle, but with gaps such as not saying where angles are measured from or not keeping angles of incidence the same
- 1-2 marks: a few relevant ideas, such as shining a ray into each block, without a clear method

Revision notes: the method

Aim: To find out how light is reflected and refracted when it hits a glass block, by measuring the angles of reflection and refraction for different angles of incidence.

Equipment

- Ray box with a single-slit cover and power supply
- Rectangular glass block
- Sheet of plain A3 paper

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- Sharp pencil
- Ruler
- Protractor
- Heat-resistant mat for the ray box

Method

1. Place the glass block in the middle of the paper and draw round it with a sharp pencil.
2. Take the block off. Draw a normal: a line at 90° to one long side of the outline, about a third of the way along.
3. Use the protractor to draw lines from where the normal meets the outline at 10°, 20°, 30° and so on up to 70° from the normal.
4. Put the block back on its outline. Dim the room lights and aim a thin ray from the ray box along the 10° line so it hits the block where the normal meets the surface.
5. Mark the reflected ray with two small crosses well apart. Mark where the ray leaves the far side of the block with a cross, and mark the ray after it leaves with another cross.
6. Repeat for each angle of incidence.
7. Remove the block. Join the crosses with a ruler to draw the reflected ray and the ray that came out of the block, then join the point of entry to the point of exit to show the refracted ray inside the glass.
8. Measure the angle of reflection and the angle of refraction from the normal with the protractor.
9. Repeat the whole experiment twice more on fresh paper and find the mean angle of refraction for each angle of incidence.

Variables

- **Independent:** The angle of incidence (measured from the normal)
- **Dependent:** The angle of reflection and the angle of refraction, both measured from the normal with a protractor
- **Control:** The same glass block, because a different material refracts light by a different amount; The same colour of light (the same ray box and filter); The ray always hits the block at the point where the normal meets the surface

Hazards

Hazard	What could happen	How to reduce the risk
The ray box bulb gets very hot	Burns to the fingers	Stand it on a heat-resistant mat, hold it only by the handle or base and let it cool before putting it away
Working in a dimmed room	Tripping over bags or stools	Clear bags and stools from the floor and walkways before dimming the lights
Glass block dropped or chipped	Cuts from sharp edges	Keep the block in the middle of the bench and check it for chips before use

Key points

- Measure every angle from the normal (the line at 90° to the surface), never from the surface of the block
- Angle of incidence = angle of reflection

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- Light entering glass from air slows down and bends towards the normal, so the angle of refraction is smaller than the angle of incidence
- A ray travelling along the normal (angle of incidence 0°) passes straight through without bending
- Use a thin ray, mark crosses far apart along each ray and draw lines with a sharp pencil to make the angles more accurate
- A protractor has a resolution of 1°, so small differences of 1° between trials are expected

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