Total internal reflection and optical fibres

Student activity • investigation and reasoning

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The question

When does a ray remain inside a transparent material?

Observe a ray at an acrylic–air boundary and bracket the critical angle before applying the idea to optical fibres.

Equipment

- Semicircular acrylic block and LED ray box
- Paper, protractor, ruler and calculator

Use intact smooth acrylic and a low-voltage LED ray box. Keep beams on the bench and out of eyes. Do not look into fibre ends or use laser sources. Switch off before repositioning; keep leads clear.

Course coverage: Shared Physics / Double Award: 3.20–3.22. Critical angle, optical fibres and prisms.

Plan, model or apparatus sketch

Draw a labelled wave, ray or apparatus diagram appropriate to this activity.

Method and reasoning

Read the whole sequence before starting

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1. Trace a semicircular acrylic block and mark the centre of its flat face. Use a low-voltage LED ray box aimed through the curved face along a radius towards that centre.

2. Start with a small internal incidence angle at the flat face. Trace the transmitted ray in air and any reflected ray inside the block. Draw the normal at the flat face.

3. Increase the internal incidence gradually. Record a lower angle at which a transmitted ray is clearly visible and an upper angle at which it is absent and internal reflection is clear.

4. Narrow this interval using small adjustments and repeat the judgement three times. Report an interval or an estimate with uncertainty; do not claim an exact critical angle from a broad beam.

5. For a labelled practice material with n = 1.50 bordering air, calculate c using sin c = 1/n. Compare the prediction with the condition i > c for total internal reflection.

6. Draw a fibre core with a lower-index cladding and a prism ray path. Explain how light can remain confined when the relevant internal incidence exceeds the critical angle. State that cladded fibres need the index ratio, not simply 1/ncore.

Cleanup

- Switch off and store blocks without scratching; retain angle brackets and diagrams.

Record your evidence

Blank spaces are for your own work

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Reference and task data

Total internal reflection requires travel from higher to lower refractive index and incidence greater than the critical angle. At the critical angle the refracted direction is along the boundary. For an air boundary, sin c ≈ 1/n; for a core–cladding boundary, sin c = ncladding/ncore.

Trial	Transmitted visible / °	TIR clear / °
1		
2		
3		

Show your calculations, labelled model or correction here.

Explain and evaluate

Use evidence and show calculation steps where relevant

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1. Which medium contains the critical angle?

2. What two conditions are needed for total internal reflection?

3. What is the refracted angle at c?

4. Find c when n = 1.50 and the other medium is air.

5. Can air-to-acrylic entry produce total internal reflection?

6. Why must fibre cladding have a lower index than the core?