Wave Behaviour at Boundaries

When waves cross a boundary, they can be absorbed, transmitted, reflected, refracted... Read on for more.

Waves Are Absorbed, Transmitted and Reflected at Boundaries

When a wave meets a boundary between two materials (a material interface), three things can happen:

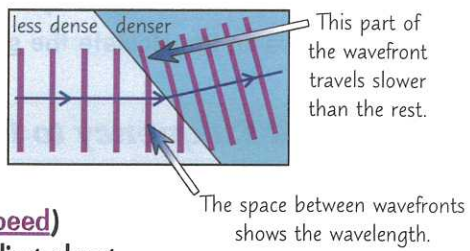
1) The wave is ABSORBED by the second material — the wave transfers energy to the material's energy stores. Often, the energy is transferred to a thermal energy store, which leads to heating (this is how a microwave works, see page 170).
2) The wave is TRANSMITTED through the second material — the wave carries on travelling through the new material. This often leads to refraction (see below). This can be used in communications (p.170) as well as in the lenses of glasses and cameras.
3) The wave is REFLECTED — this is where the incoming ray is neither absorbed or transmitted, but instead is 'sent back' away from the second material. This is how echoes are created.

What actually happens depends on the wavelength of the wave and the properties of the materials involved.

Refraction — Waves Changing Direction at a Boundary

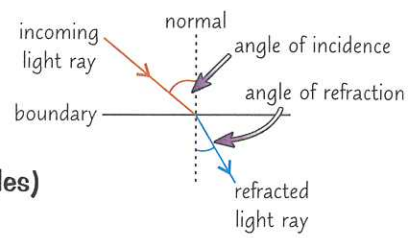
You might see refraction of light talked about in terms of 'optical density'.

1) Waves travel at different speeds in materials with different densities. So when a wave crosses a boundary between materials it changes speed.
2) If the wave hits the boundary at an angle, this change of speed causes a change in direction — refraction.
3) If the wave is travelling along the normal (see below) it will change speed, but it's NOT refracted.
4) The greater the change in speed, the more a wave bends (changes direction).
5) The wave bends towards the normal if it slows down. It bends away from the normal if it speeds up.
6) Electromagnetic (EM) waves (see p.168) like light usually travel more slowly in denser materials, so entering glass from air they would bend towards the normal if refracted.
7) How much a wave refracts depends on its wavelength (as the frequency of a wave doesn't change between boundaries, p.164). EM waves with shorter wavelengths bend more.
8) Wavefront diagrams can help to show refraction. When one part of the wavefront crosses a boundary into a denser material, that part travels slower than the rest of the wavefront.
9) So by the time the whole wavefront crosses the boundary, the faster part of the wavefront will have travelled further than the slower part of the wavefront.
10) This difference in distance travelled (caused by the difference in speed) by the wavefront causes the wave to bend. (Imagine a toy car rolling along — if one of its front wheels got caught in some mud, the car would turn.)



The Normal is An Imaginary Line

Ray diagrams can be used to show the path that a wave travels.
Rays are straight lines that are perpendicular to wavefronts.
You need to understand the following terms for ray diagrams:



1) The normal is an imaginary line that's perpendicular (at right angles) to the point where the incoming wave hits the boundary.
2) The angle of incidence is the angle between the incoming (incident) ray and the normal.
3) The angle of refraction is the angle between the refracted ray and the normal.

Time to reflect on what you've read and really absorb it...

Refraction has loads of uses (e.g. in glasses, cameras and telescopes) so make sure you really understand it.

Q1 A light ray enters air from water. How does it bend relative to the normal? [1 mark]

Wave Behaviour at Boundaries

Warm-Up

At the boundary with a new material, a wave can be reflected, absorbed or transmitted. Draw a line to match each option to the description which best matches it.

wave is reflected	it passes through the material
wave is absorbed	it bounces back off the material
wave is transmitted	it transfers all its energy to the material

1 In each of the following situations, a wave encounters a boundary between two materials. Describe the effects you would expect to see for the following wave behaviours.

Grade 4-6

a) A sound wave reflecting off a hard, flat surface.

.....

[1]

b) A ray of visible light being absorbed by a black object.

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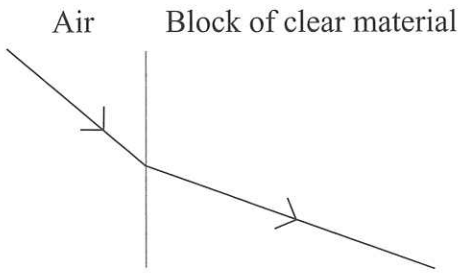
[1]

[Total 2 marks]

2 **Figure 1** shows a ray of light travelling from air into a clear, rectangular block of an unknown material.

Grade 6-7

Figure 1



a) What is the angle of incidence for the light ray entering the block? Use a protractor to accurately measure the angle.

Angle of incidence = ... °

[1]

b) State and explain **one** conclusion you can make about the material of the block, compared to air.

.....

.....

[2]

[Total 3 marks]