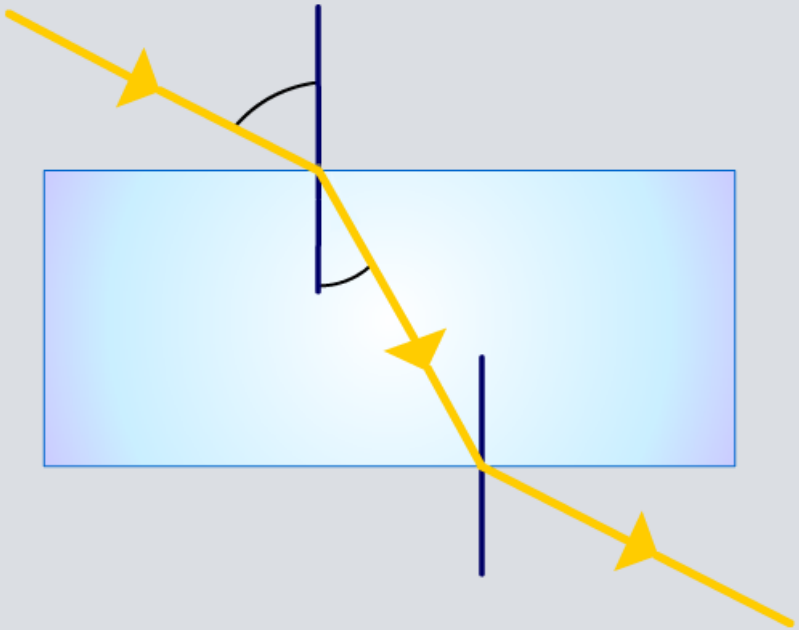
Refraction

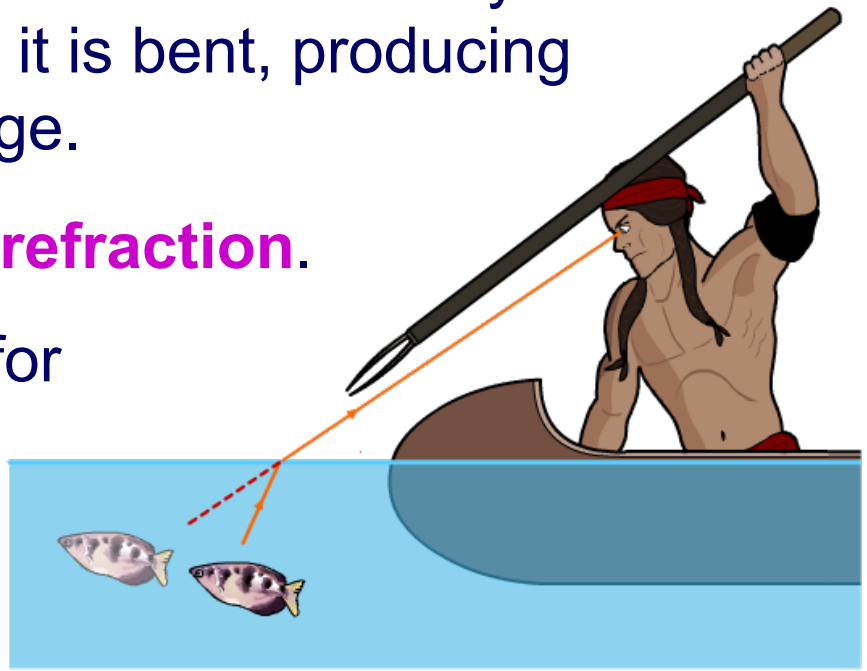


What is refraction?

The straw appears to be bent in the liquid. What is causing this effect?

As the light crosses the boundary between fluid and glass, it is bent, producing a distorted image.

This known as **refraction**.

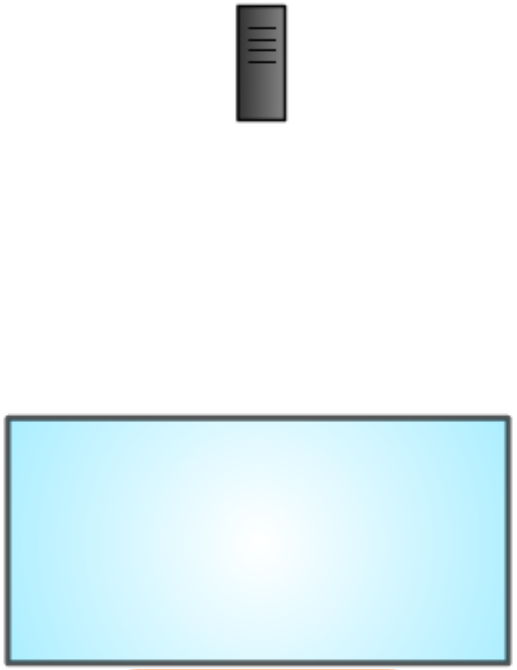


Spear fishing has been used for centuries and is still practiced by subsistence communities.

To accurately spear the fish, fishermen learn to aim a short distance behind the fishes' image, in order to compensate for the effect of refraction.

Refraction in a glass block

What happens when light crosses the air-glass boundary?



start

show angles

air to glass

glass to air

ray box control

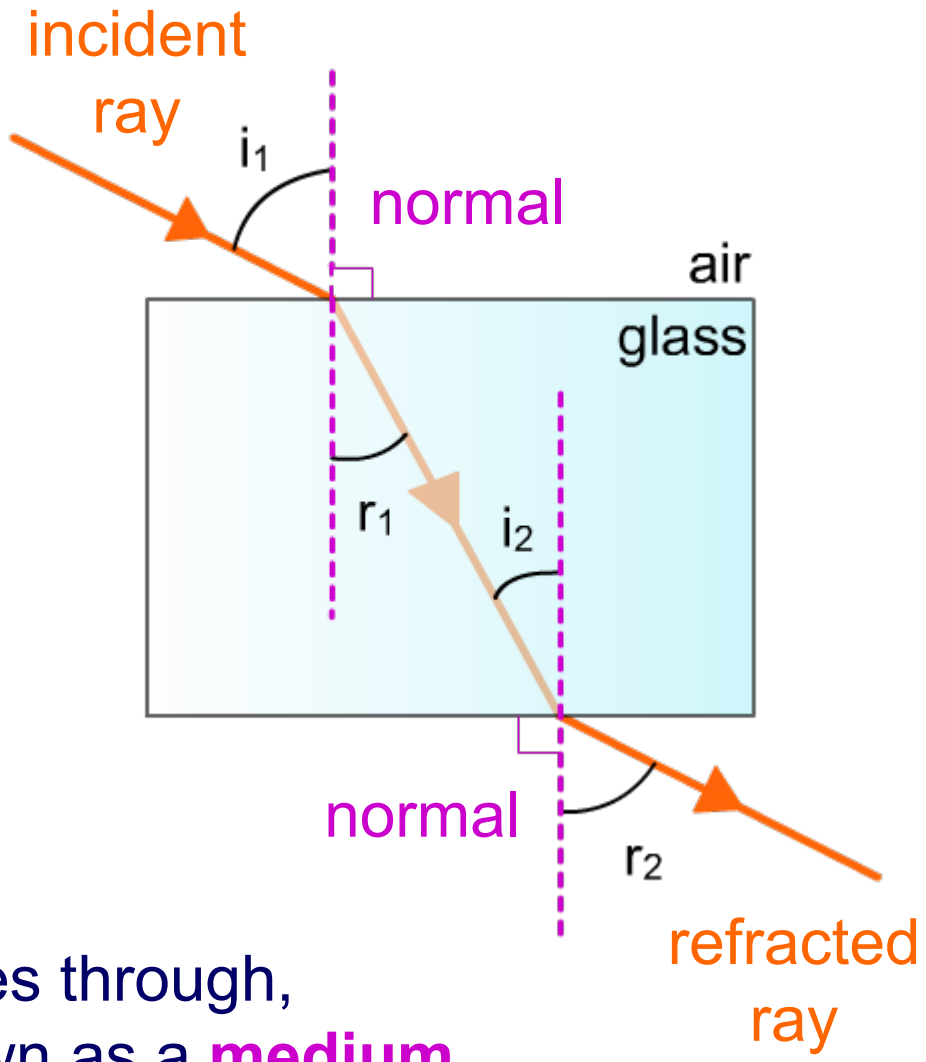
on

off

Refraction – labeling diagrams

If an incident ray enters glass at an angle, then it is refracted, and bends towards the normal.
The angle of incidence (*i*) is larger than the angle of refraction (*r*).

When the light leaves the glass, the opposite happens: it bends away from the normal.



A material which light passes through, such as glass or air, is known as a **medium**.

Refraction summary

What are the missing words about refraction?

The information in the following table was collected during an investigation of refraction at an air to glass boundary. Use the results to help fill in the missing words.

Click on **start** to begin.

start

?

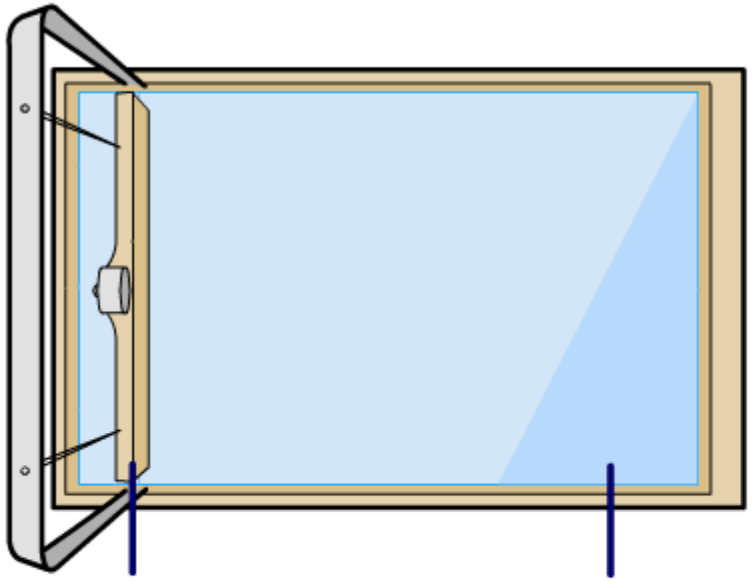
C

solve

Refraction in water waves

When waves travel through water of varying depth they are refracted.

Click **"play"** to investigate this in the ripple tank.

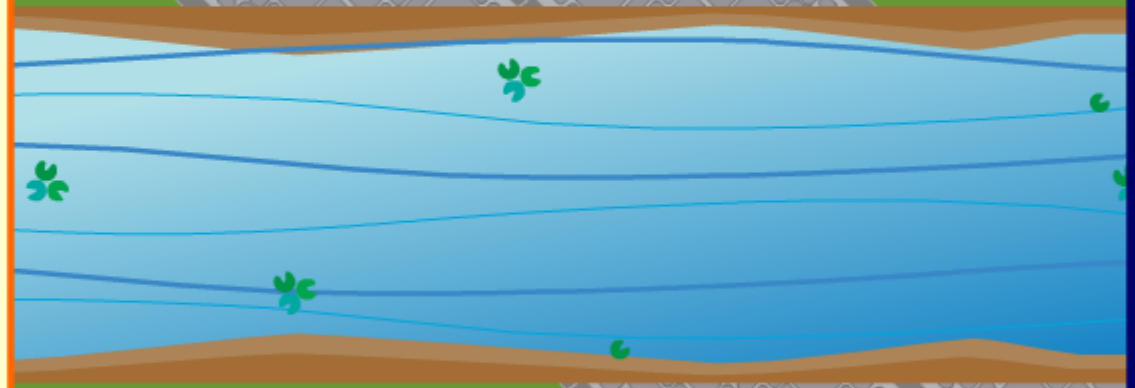


A model for refraction

Why does slowing a wave cause it to bend?

How can the behavior of a wave as it enters a new medium be modeled using Roman soldiers and a muddy stream?

Click "**play**" to find out more.



Refractive index

Refractive index is a measure of how much a substance slows down light. The higher its value, the more a medium slows light. The more the light is slowed, the more it bends towards the normal.

Refractive index is calculated by comparing speed of light in a vacuum to that in a given medium:

$$\text{refractive index} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

The speed of light in a vacuum is 300,000,000 m/s, and the speed of light in water is 225,000,000 m/s. What is the refractive index of water?

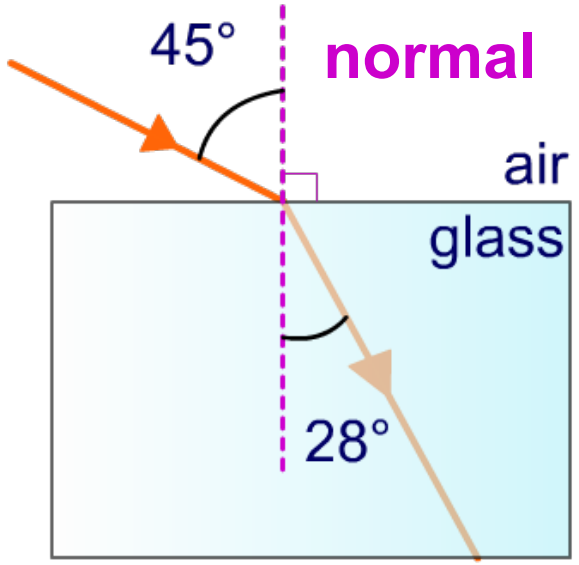
$$\text{refractive index} = \frac{300{,}000{,}000}{225{,}000{,}000} = \mathbf{1.33}$$

Snell's Law

The refractive index can also be calculated using Snell's Law, which uses the angle of incidence (i) and angle of refraction (r) to establish how much a medium slows light.

$$\text{refractive index } (n) = \frac{\sin i}{\sin r}$$

Use the information in the diagram to find the refractive index of glass.



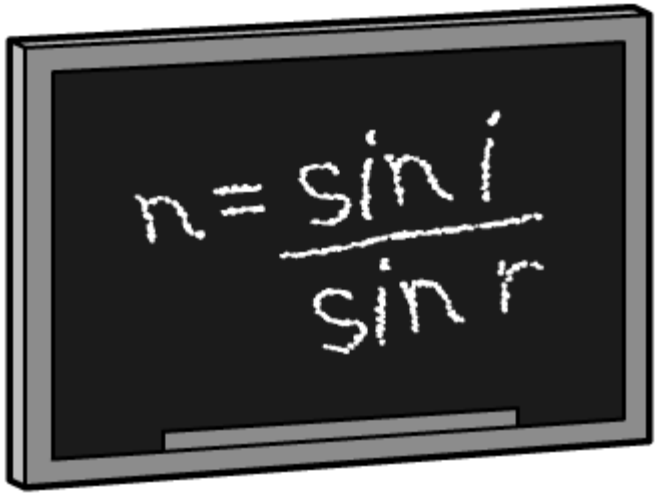
$$\text{refractive index} = \frac{\sin 45°}{\sin 28°}$$

refractive index = **1.5**

Using Snell's Law

Use Snell's Law to answer the following:

Acrylic glass has a refractive index of 1.5. If a ray of light passing into a acrylic glass block has an angle of refraction of 24°, find the angle of incidence.



$\sin i = \sin r \times$ refractive index

$\sin i = (\sin 24°) \times 1.5 = 0.61$

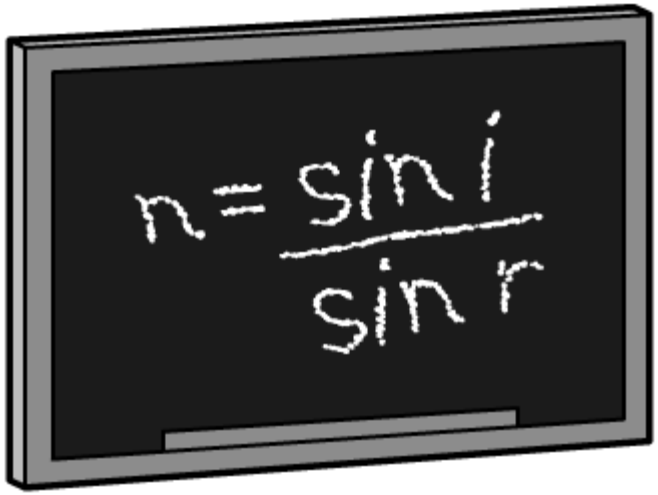
$i = \sin^{-1} 0.61$

$i =$ **37.6°**

Using Snell's Law

Use Snell's Law to answer the following:

If a ray of light enters water at an angle of 15° and has an angle of refraction of 11.2°, find its refractive index.



$$\text{refractive index} = \frac{\sin 15}{\sin 11.2}$$

refractive index = **1.33**

Refraction – true or false?

Are these statements about refraction true or false?

1.	The speed of light does not depend on the material through which it is traveling.	
2.	Light rays traveling from air into glass bend towards the normal.	
3.	Light rays traveling from glass into air bend towards the normal.	
4.	When light enters a more dense medium, the angle of incidence is greater than the angle of refraction.	
5.	When the angle of incidence is 0 degrees, refraction does not occur.	
6.	The speed of light in glass is faster than the speed of light in air.	

true false

?

solve