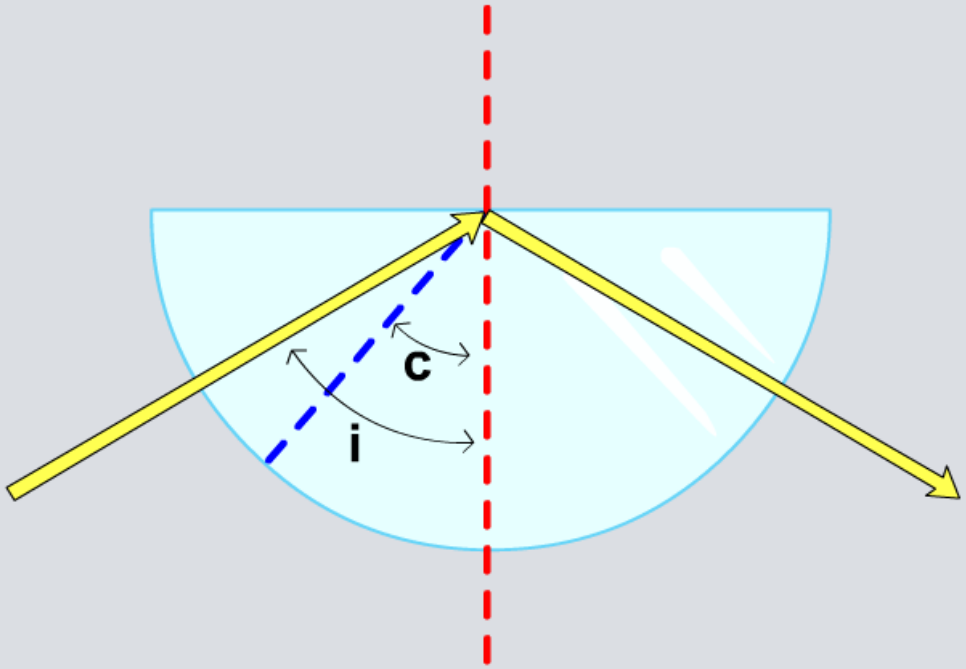
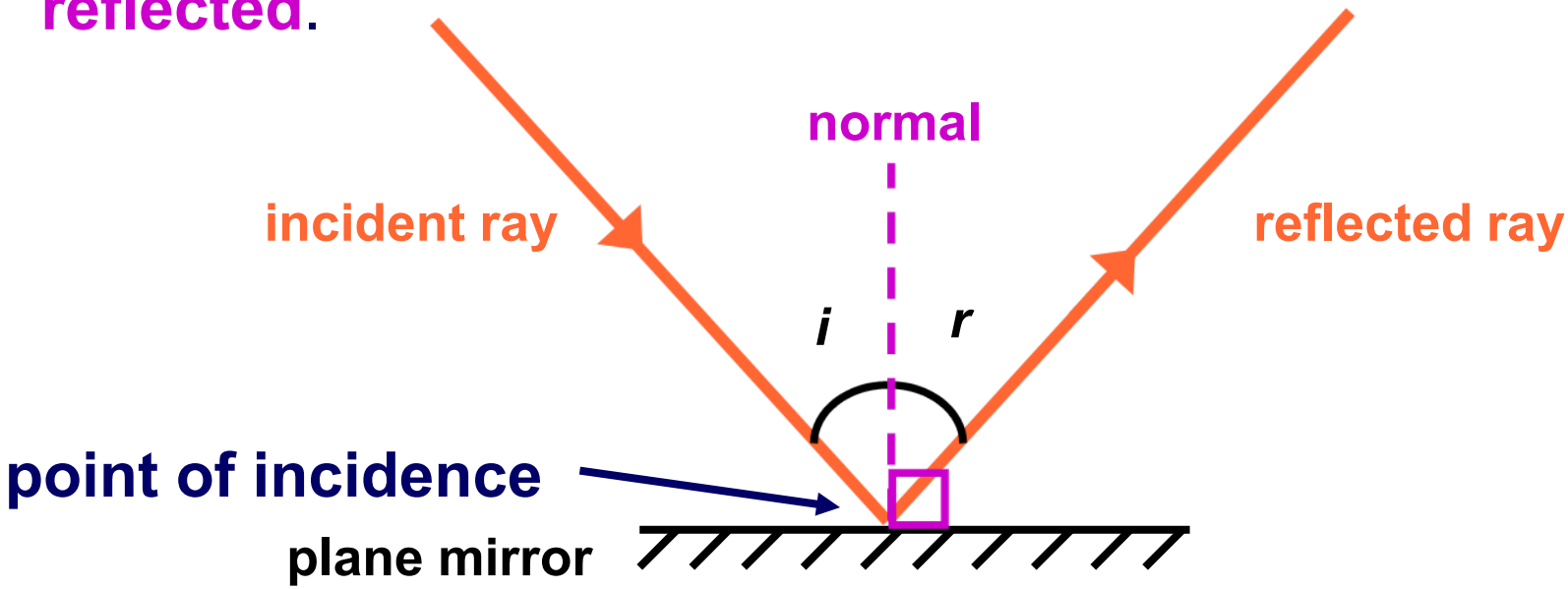
Reflection



The law of reflection

When a light ray hits a mirror it changes direction: the ray is **reflected**.

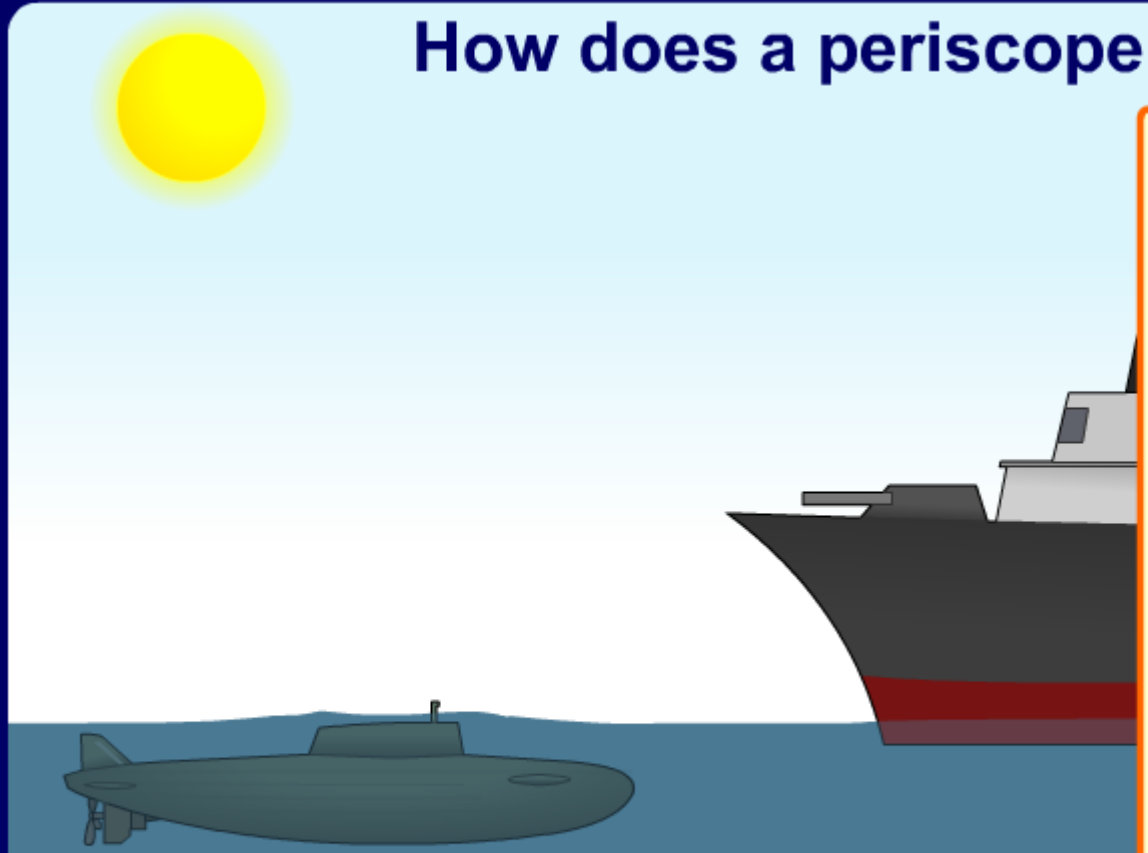


angle of incidence (*i*) = angle of reflection (*r*)

This is called the **law of reflection** and is true for any type of wave being reflected from a surface.

The law of reflection in action

How does a periscope work?

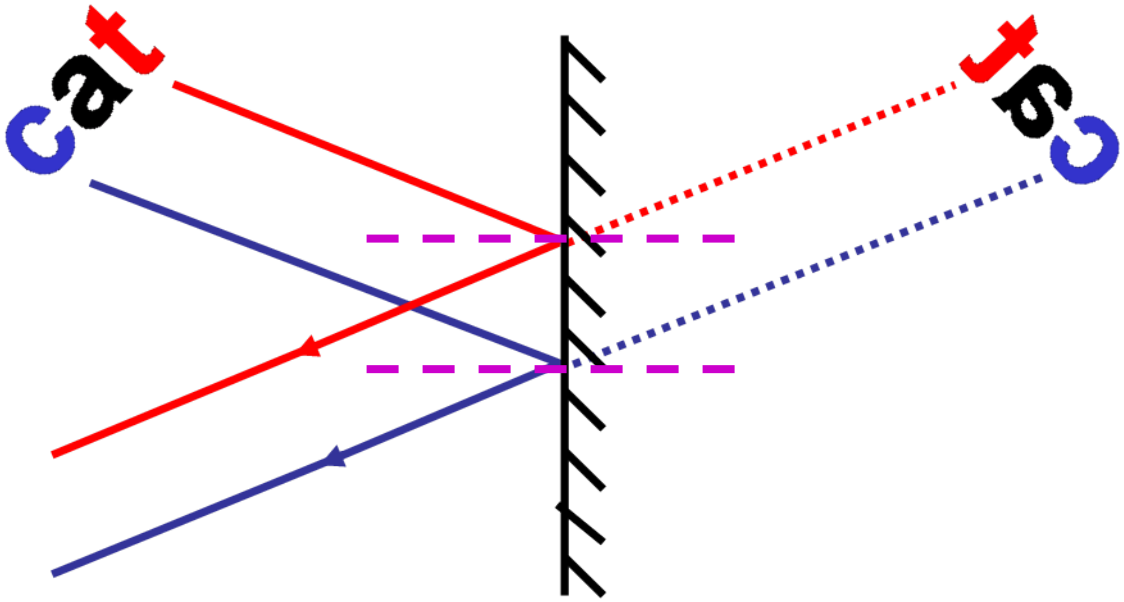


Periscopes are used by the crew of submarines to see above the water's surface. But how do they work?

Click **"play"** to investigate.

Images in plane mirrors

If we look into a mirror, we see an image.



What kind of image is formed in the plane mirror?

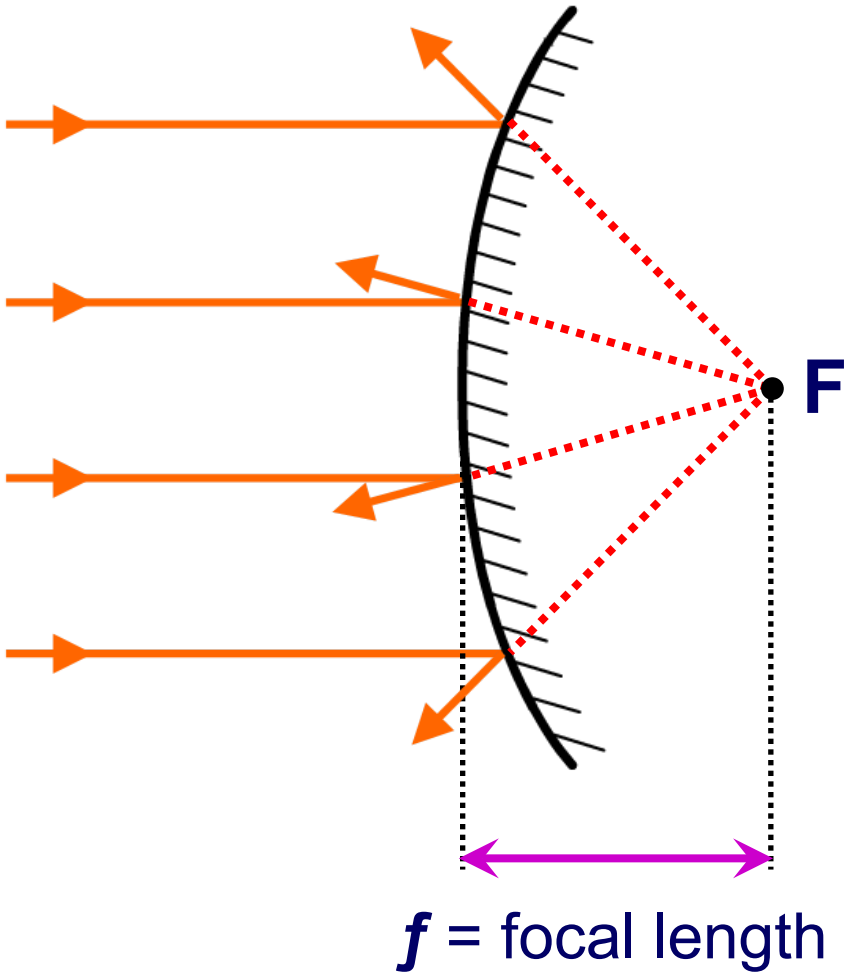
- laterally inverted
- same size as the object
- virtual.

Convex mirrors

Convex mirrors are curved so that they bulge outwards.

Convex mirrors are **diverging** mirrors. They reflect rays of light away from a **focal point (F)** which lies behind the mirror.

Rays parallel to the mirror's central axis are reflected so that they appear to have come from this focal point.

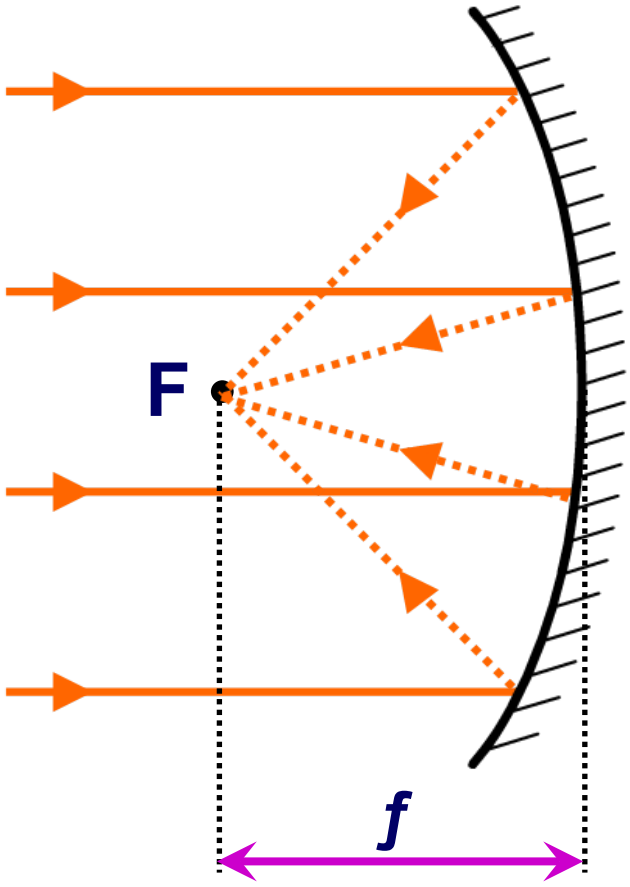


Concave mirrors

Concave mirrors are **converging** mirrors, as they reflect rays of light towards a focal point (F).

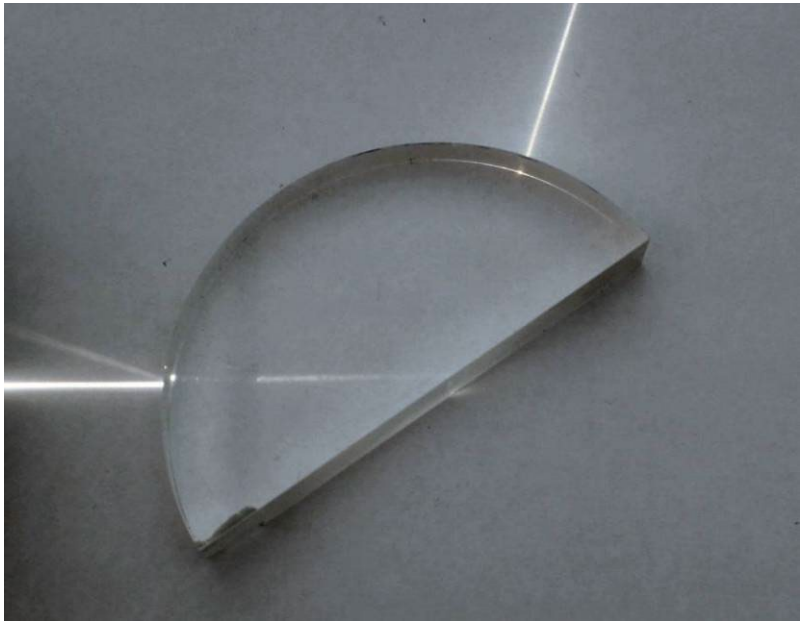
If a light source is placed at the focal point, the mirror will produce a beam of parallel light rays.

The distance between the mirror and the focal point is called the focal length (f). f becomes smaller as the mirror's curve increases.



Total internal reflection

Total internal reflection is when a light ray hits the boundary between two materials of different densities, and is reflected rather than refracted.



There are **two** conditions for total internal reflection:

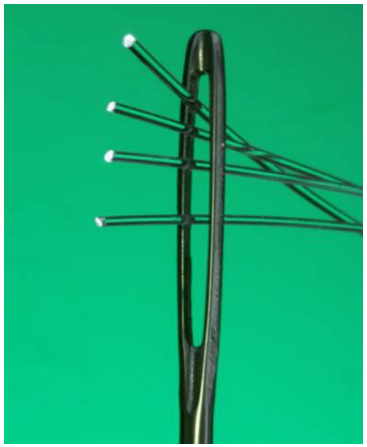
1. The angle of incidence must be greater than the **critical angle**.
2. The light must be passing from a high refractive index to a low one.

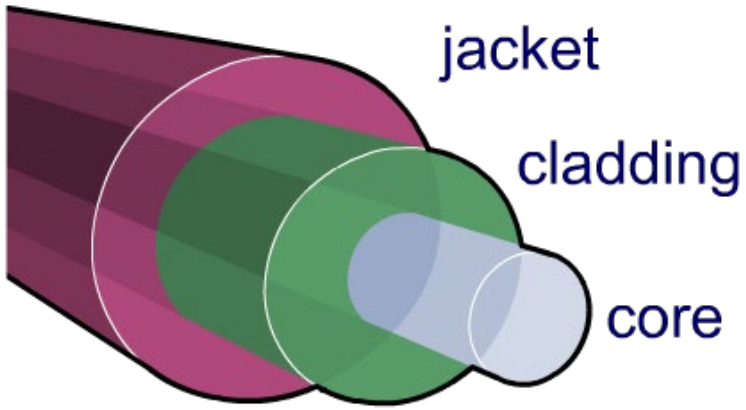
Sometimes only part of a light ray will be reflected, while the rest crosses the boundary and is refracted.

Optical fibers

Optical fibers are thin strands of solid glass which are widely used in communication, medicine, lighting and as sensors.

They exploit total internal reflection in order to carry beams of light over long distances and along winding paths.





The glass core is often encased in a layer of cladding, which prevents light escaping the core. A protective plastic jacket surrounds the whole fiber.

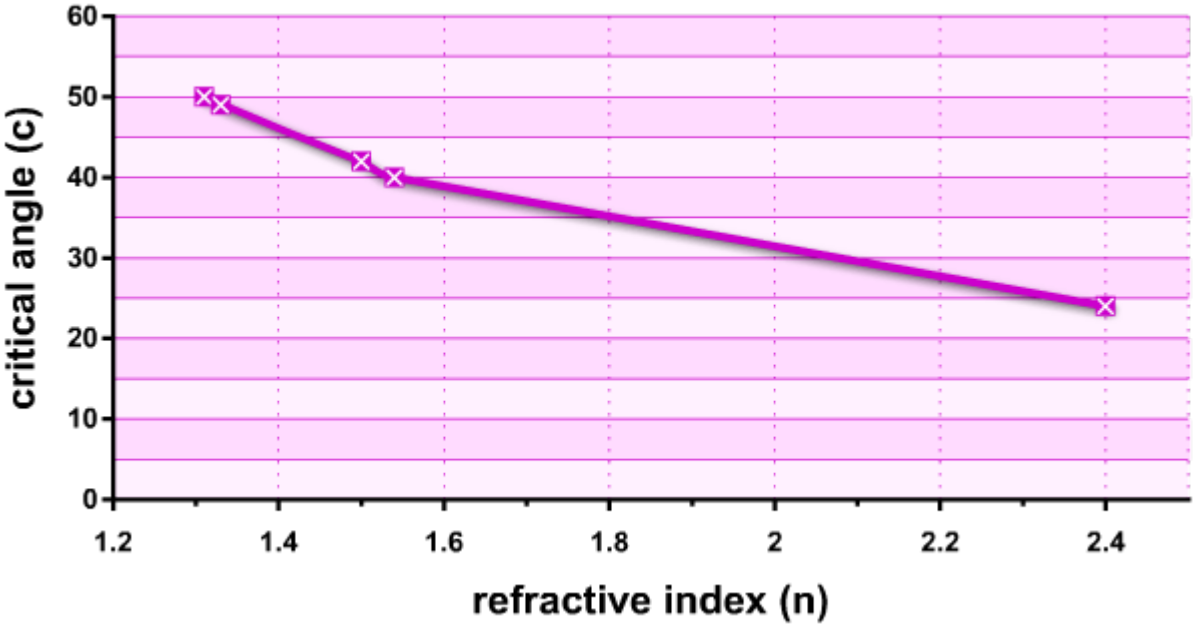
Why are the materials used to make the core and cladding of an optical fiber important?

Critical angle in different materials

Different materials have different critical angles.

How does the refractive index (*n*) of different materials affect the critical angle (*c*) at a boundary with air?

medium	*n*	*c*
ice	1.31	50°
water	1.33	49°
glass	1.5	42°
quartz	1.54	40°
diamond	2.4	24°

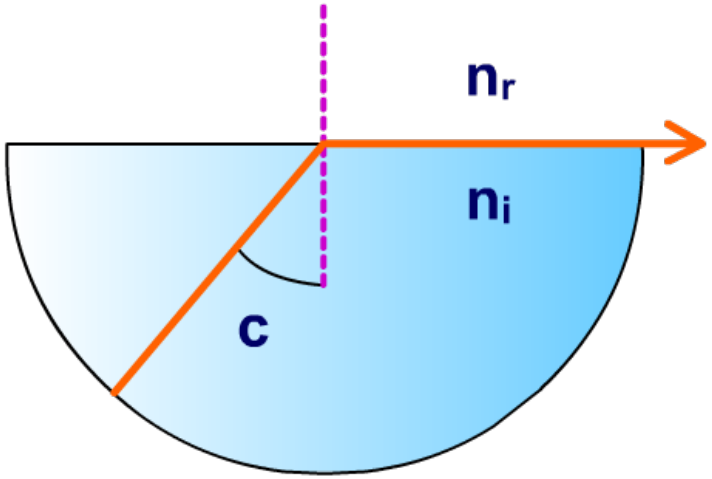


The greater the refractive index, the smaller the critical angle.

Calculating the critical angle

Each medium has a different critical angle. We can calculate the critical angle if we know the refractive index:

$$\sin c = \frac{n_r}{n_i}$$



What do you notice about this equation?

The critical angle varies depending on the refractive index (n) of both materials at a boundary.

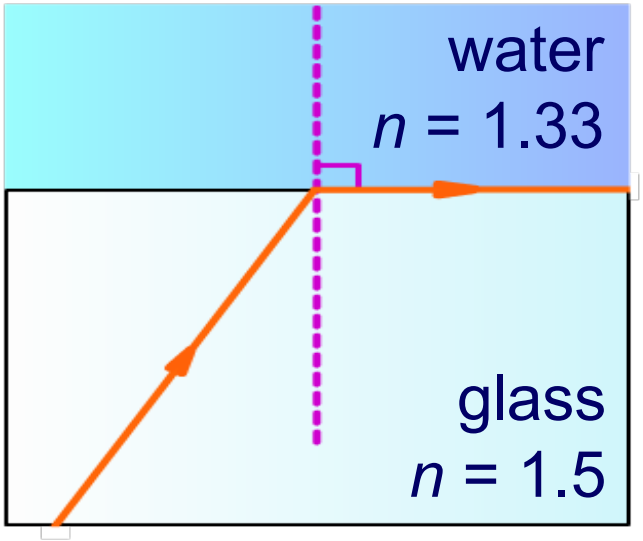
Calculate the critical angle of acrylic glass at an acrylic glass to air boundary.

acrylic glass: $n = 1.5$ $\sin c = \frac{1}{1.5} = 0.67$ $c = \sin^{-1} 0.67$

air: $n = 1$ $c = \mathbf{42°}$

Calculating the critical angle – examples

Calculate the critical angle for this glass to water boundary.



$$\sin c = \frac{1.33}{1.5} = 0.89$$

$c = \sin^{-1} 0.89$ $\quad$ $c = \mathbf{63°}$

Now repeat your calculation for an air to glass boundary.

When light hits a medium with a higher refractive index:

$$\frac{n_i}{n_r} > 1$$

As sin (x) has a maximum value of one, total internal reflection is impossible.

Total internal reflection – true or false?

Are these statements on total internal reflection true or false?

1.	If the incidence angle is smaller than the critical angle then total internal reflection occurs.	
2.	If the incidence angle equals the critical angle then the ray exits along the boundary of the materials.	
3.	The bigger the refractive index, the smaller the critical angle for that medium.	
4.	When light goes from glass to air, total internal reflection **never** occurs.	
5.	Refractive index is a measure of how much a substance slows down light.	
6.	Total internal reflection **only** occurs if light is travelling from a low to high refractive index.	

true false

?

solve