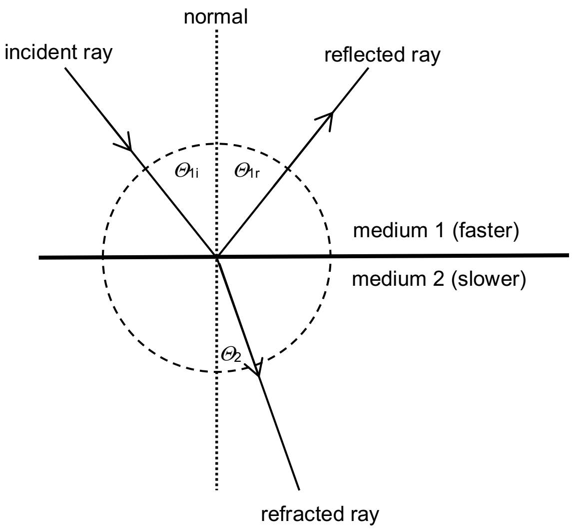
Refraction and total internal reflection

The speed of light in vacuum is $c_{vacuum} = 2.998 \cdot 10^8 \frac{m}{s}$. In another transparent medium, for example water or glass, the speed of light is less.

When light strikes the boundary between two media of different speeds of light, part of it is reflected, and part of it is refracted.
The refracted light ray which passes into the other medium *bends*, or, as you may also say, it *changes direction* at the boundary.



Index of refraction

The index of refraction of a material is defined as the ratio of the speed of light in vacuum to the speed of light in that material.

$$n_{medium} = \frac{c_{vacuum}}{c_{medium}}$$

A medium in which light travels fast has a small index of refraction and vice versa.

The speed of light in air is nearly the same as in vacuum ($c_{air} = 2.997 \cdot 10^8 \frac{m}{s}$). Therefore, in calculations, we can use $n_{air} = n_{vacuum} = 1.00$.

Law of refraction (also Snell's law)

$$n_1 \cdot \sin(\Theta_1) = n_2 \cdot \sin(\Theta_2)$$

$$c_2 \cdot \sin(\Theta_1) = c_1 \cdot \sin(\Theta_2)$$

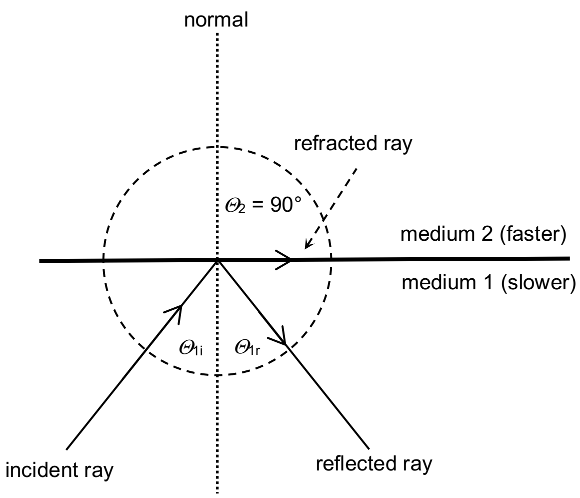
where:
- Θ_1: angle in material 1
- Θ_2: angle in material 2
- n_1: refractive index of material 1
- n_2: refractive index of material 2
- c_1: speed of light in material 1
- c_2: speed of light in material 2

Total internal reflection

If a light ray coming from a medium of a higher index of refraction (where light travels slower) strikes the boundary to a medium of a lower index of refraction (where light travels faster) the light ray is totally reflected into the material with the higher index of refraction, if the angle of incidence is large enough.
The *critical angle* is the smallest angle of incidence (in the medium where light travels slower) for total internal reflection to occur:

$$\Theta_{critical} = \arcsin\left(\frac{c_{slower}}{c_{faster}}\right) = \arcsin\left(\frac{n_{lower}}{n_{higher}}\right)$$

The angle in the faster medium is always larger than the angle in the slower medium. If a light ray strikes the boundary coming from the slower medium, the largest angle of refraction in the faster medium is 90 °.
The corresponding angle in the slower medium is the critical angle.



From $c_{faster} \cdot \sin(\Theta_{slower}) = c_{slower} \cdot \sin(\Theta_{faster})$

and $\Theta_{faster} = 90\,°$

we get $c_{faster} \cdot \sin(\Theta_{slower}) = c_{slower} \cdot \sin(90°) = c_{slower} \cdot 1$

and $\sin(\Theta_{slower,\ critical}) = \dfrac{c_{slower}}{c_{faster}}$