# Refraction

To be able to calculate the refractive index of a material and to know what it tells us
To be able to describe and explain the direction light takes when entering a different material
To be able to calculate the relative refractive index of a boundary

## *Refractive Index*

The refractive index of a material is a measure of how easy it is for light to travel through it. The refractive index of material $s$ can be calculated using:

$$\boxed{n = \frac{c}{c_s}}$$

where $n$ is the refractive index, $c$ is the speed of light in a vacuum and $c_s$ is the speed of light in material $s$.

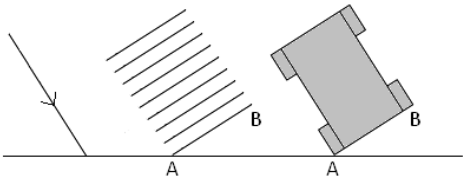
**Refractive Index, n, has no units**

If light can travel at $c$ in material $x$ then the refractive index is: $n = \frac{c}{c_x} \rightarrow n = \frac{c}{c} \rightarrow n = 1$

If light can travel at $c/2$ in material $y$ then the refractive index is: $n = \frac{c}{c_y} \rightarrow n = \frac{c}{c/2} \rightarrow n = 2$

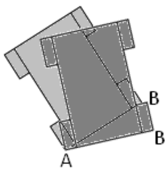
The higher the refractive index the slower light can travel through it
The higher the refractive index the denser the material

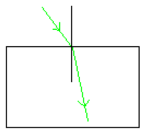
## *Bending Light*




When light passes from one material to another it is not only the speed of the light that changes, the direction can change too.
If the ray of light is incident at 90° to the material then there is no change in direction, only speed.
It may help to imagine the front of the ray of light as the front of a car to determine the direction the light will bend. Imagine a lower refractive index as grass and a higher refractive index at mud.

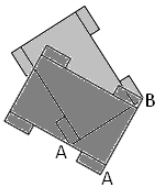
### *Entering a Denser Material*

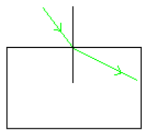




The car travels on grass until tyre A reaches the mud. It is harder to move through mud so A slows down but B can keep moving at the same speed as before. The car now points in a new direction.
*Denser material – higher refractive index – bends towards the Normal*

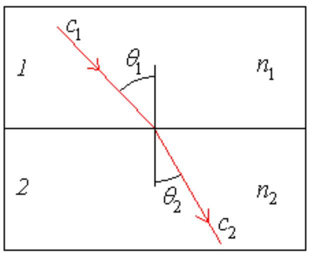
### *Entering a Less Dense Material*





The car travels in mud until tyre A reaches the grass. It is easier to move across grass so A can speed up but B keeps moving at the same speed as before. The car now points in a new direction.
*Less dense material – lower refractive index – bends away from the Normal*

## *Relative Refractive Index*




Whenever two materials touch the boundary between them will have a refractive index dependent on the refractive indices of the two materials. We call this the relative refractive index.
When light travels from material *1* to material *2* we can calculate the relative refractive index of the boundary using any of the following:

$$\boxed{{}_1n_2 = \frac{n_2}{n_1} = \frac{c_1}{c_2} = \frac{\sin\theta_1}{\sin\theta_2}}$$

**Relative Refractive Index, $_1n_2$, has no units**

Some questions may involve light travelling through several layers of materials. Tackle one boundary at a time.

$$ {}_{w}n_{g} = \frac{n_g}{n_w} = \frac{c_w}{c_g} = \frac{\sin\theta_w}{\sin\theta_g} $$ ---------------------------->

$$ {}_{g}n_{a} = \frac{n_a}{n_g} = \frac{c_g}{c_a} = \frac{\sin\theta_g}{\sin\theta_a} $$ ---------------------------->