# Total Internal Reflection

To know what the critical angle is and be able to calculate it

To be able to explain what fibre optics are and how they are used

To be able to explain how cladding helps improve the efficiency of a fibre optic
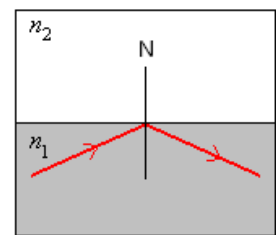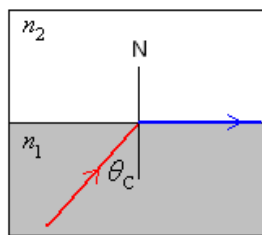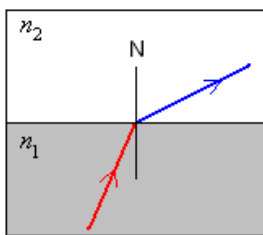
## Total Internal Reflection

We know that whenever light travels from one material to another the majority of the light refracts but a small proportion of the light also reflects off the boundary and stays in the first material.

When the incident ray strikes the boundary at an angle *less than* the critical angle the light refracts into the second material.

When the incident ray strikes the boundary at an angle *equal to* the critical angle all the light is sent along the boundary between the two materials.

When the incident ray strikes the boundary at an angle *greater than* the critical angle all the light is reflected and none refracts, we say it is total internal reflection has occurred.



## Critical Angle

We can derive an equation that connects the critical angle with the refractive indices of the materials.

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1}$$ but at the critical angle $\theta_2$ is equal to 90° which makes $\sin\theta_2 = 1$ → $$\frac{\sin \theta_1}{1} = \frac{n_2}{n_1}$$

$\theta_1$ is the critical angle which we represent as $\theta_C$ making the equation:
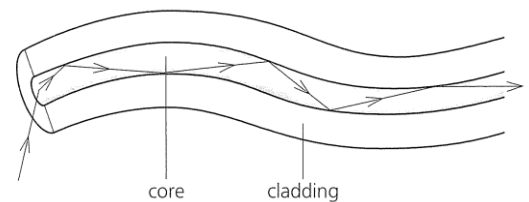
$$\boxed{\sin \theta_C = \frac{n_2}{n_1}}$$

When the second material is air $n_2 = 1$, so the equation becomes:

$$\boxed{\sin \theta_C = \frac{1}{n_1}}$$ or $$\boxed{n_1 = \frac{1}{\sin \theta_C}}$$

## Optical Fibres/Fibre Optics

An optical fibre is a thin piece of flexible glass. Light can travel down it due to total internal reflection. Thier uses include:
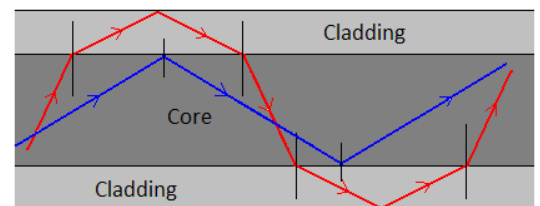
*Communication such as phone and TV signals: they can carry more information that electricity in copper wires.

*Medical endoscopes: they allow us to see down them and are flexible so they don't cause injury to the patient.



## Cladding

Cladding is added to the outside of an optical fibre to reduce the amount of light that is lost. It does this by giving the light rays a second chance at TIR as seen in the diagram.

It does increase the critical angle but the shortest path through the optical fibre is straight through, so only letting light which stays in the core means the signal is transmitted quicker.



Consider the optical fibre with a refractive index of 1.5…

Without cladding $n_2 = 1$ $$\sin \theta_C = \frac{n_2}{n_1}$$ $$\sin \theta_C = \frac{1}{1.5}$$ $$\theta_C = 41.8°$$

With cladding $n_2 = 1.4$          $\sin \theta_C = \dfrac{n_2}{n_1}$          $\sin \theta_C = \dfrac{1.4}{1.5}$          $\theta_C = 69.0°$

If the cladding had a lower refractive index than the core it is easier for light to travel through so the light would bend away from the normal,                    *Total Internal Reflection.*

If the cladding had a higher refractive index than the core it is harder for light to travel through so the light would bend towards the normal,                    *Refraction.*