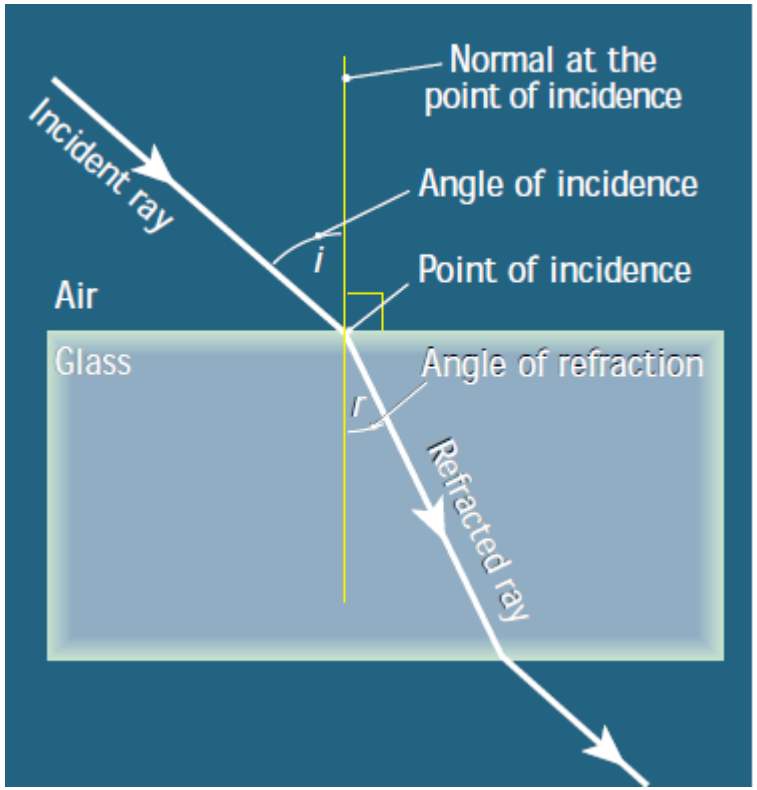
Chapter 4: Refraction

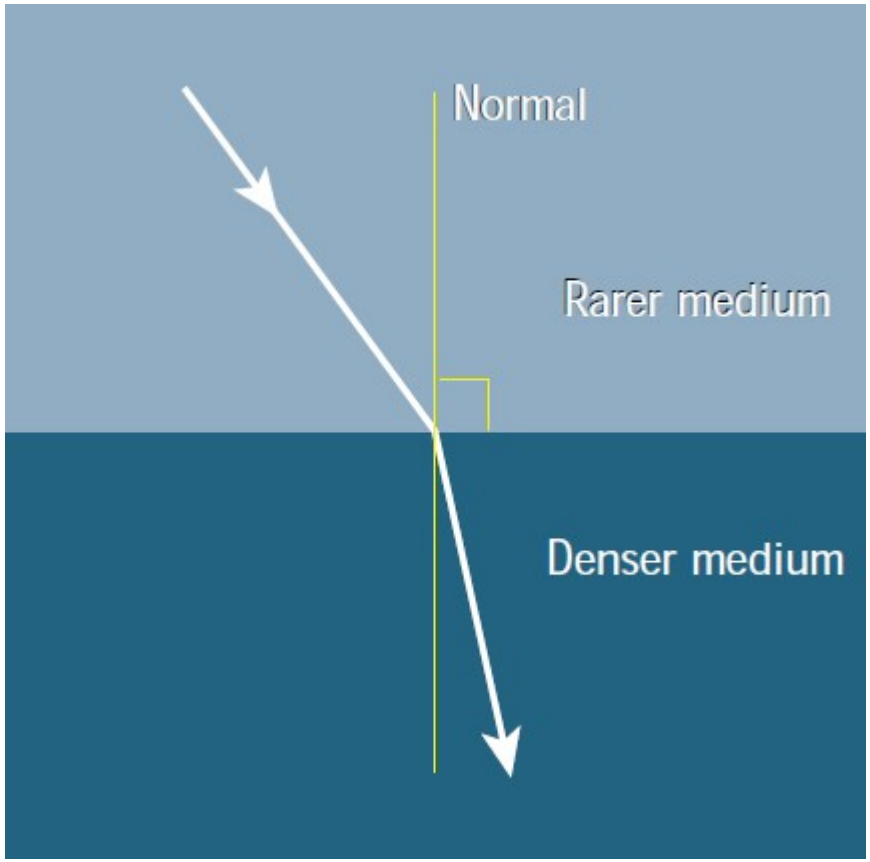
Def: Refraction is the bending of light when it goes from one medium to another.

Light travels in straight lines however when it travels from a ***rarer to a denser*** medium it is refracted ***towards the normal*** and *vice versa*

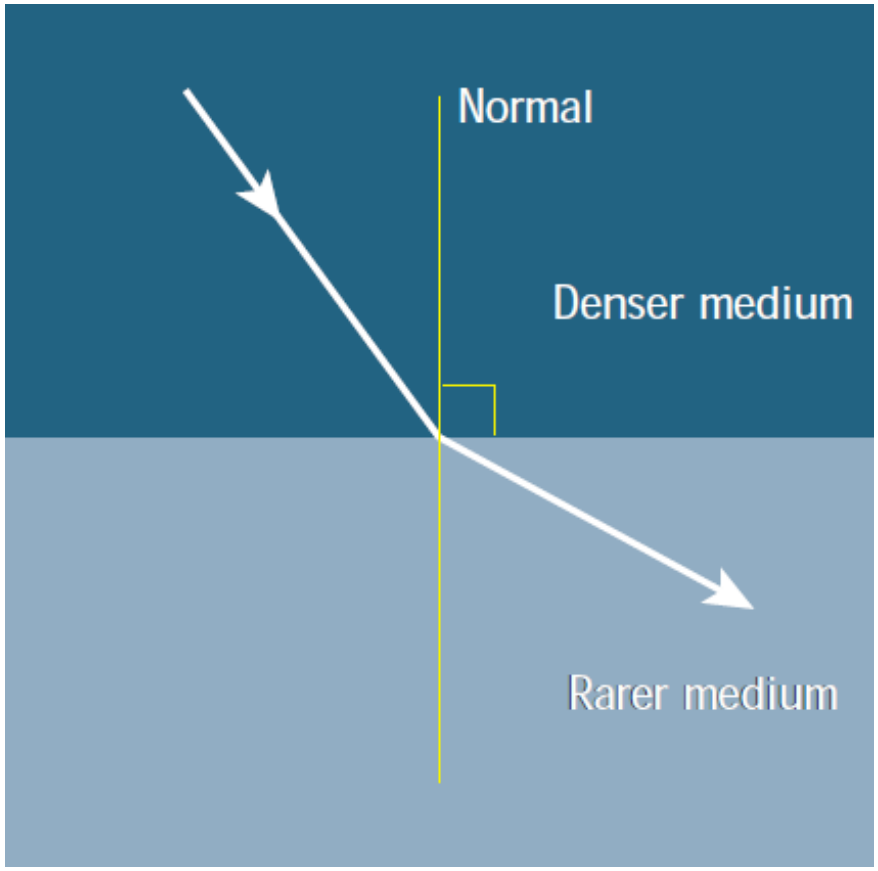


The terms are similar to reflection

- **Incident ray** is the light hitting the glass
- **Normal** is at right angle to the glass at the point of incidence
- **Refracted ray** is the light going through the glass
- **Angle of incidence** and **angle of refraction** is the angle the rays make with the normal.



Rarer to denser
Bent towards the normal



Denser to rarer
Bent away from the normal

Where have we seen refraction before? In junior cert, you may have put a spoon or pencil in water and seen it bent. Or, have you ever dropped swimming goggles in the pool and tried to get them but realised they were deeper than you first assumed?

The Laws of Refraction

Law 1: The incident ray, normal and refracted ray are all on the same plane.

Law 2: (SNELL'S LAW) The ratio of the sine of the angle of incidence to the sine of angle of refraction is a constant given by $\frac{Sin\ i}{Sin\ r} = n$

n is a constant and depends to the two media. It is called the **refractive index** between the two media.

The second law of refraction is also known as Snell's Law.
This leads to the following definition:

The Refractive Index of a Medium is the ratio of the sine of the angle of incidence to the sine of the angle of refraction *when light travels from a vacuum into that medium*.

The difference between light travelling in air and a vacuum is very small and can be neglected.

Note that if you see the phrase “the Refractive Index of glass is 1.5”, it means that when light travels *from air into glass* the refractive Index is 1.5.
This is written as ${}_{w}n_{g} = 1.5$

This is important because is light is going from glass into air there is a different refractive index. ${}_{g}n_{w} = 0.91$

For any 2 media x and y

$$ {}_{1}n_{2} = \frac{c_1}{c_2} $$

Example 4.1

A ray of light enters glass from air. The angle of incidence is 40^{o} and the angle of refraction is 25^{o}. What is the refractive index of glass.

Example 4.2

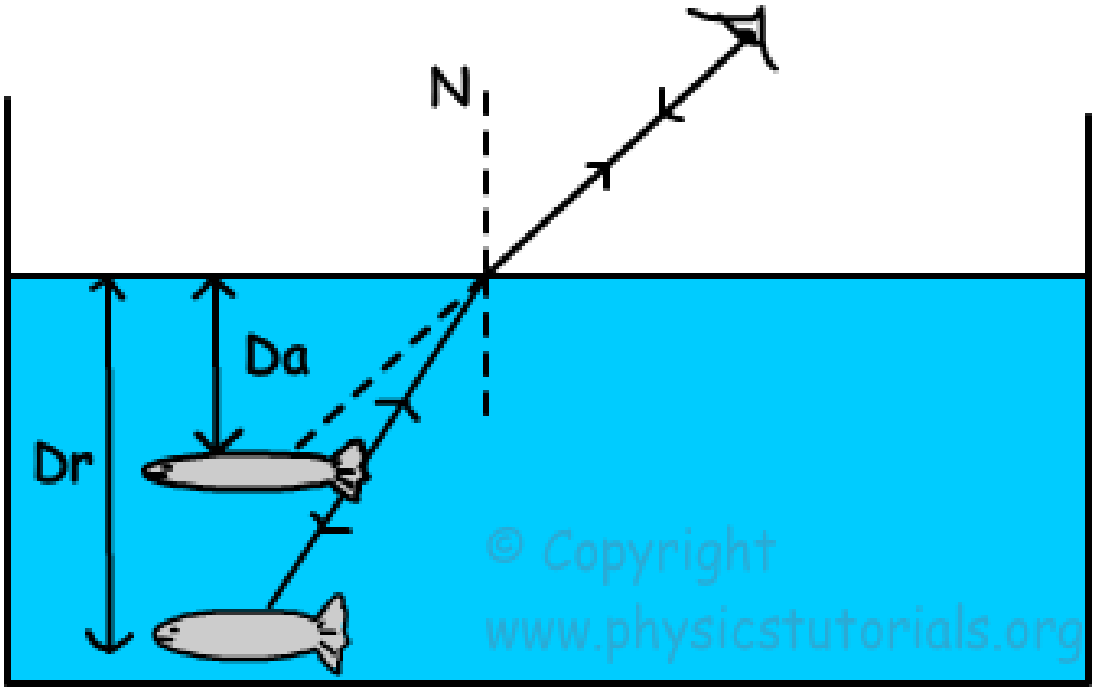
A ray of light enters diamond from air. If the angle of incidence is 30^{o}, find the angle of refraction. (refractive index of diamond is 2.4)

Example 4.3

The refractive index of water is 1.33. A ray of light passing from the inside of the water into air makes an angle of incidence of 40^{o}. Find the angle of refraction.

Real Depth and Apparent Depth

$$n = \frac{real\ depth}{apparent\ depth}$$



Example 4.4

A block of glass of thickness 8 cm is placed on top of a mark on the bench. When the mark is viewed perpendicularly through the glass, a virtual image of it appears 5.33 cm from the top of the block. Find the refractive index of the block

Refractive Index in Terms of Relative Speed

Light travels fastest in a vacuum, so when it enters another medium, it slows down and changes direction.

If medium 1 is c_1 and medium 2 is c_2, then we get:

$$_1n_2 = \frac{c_1}{c_2}$$

$$\frac{\text{Sin i}}{\text{Sin r}} = \frac{c_1}{c_2}$$

Example 4.5

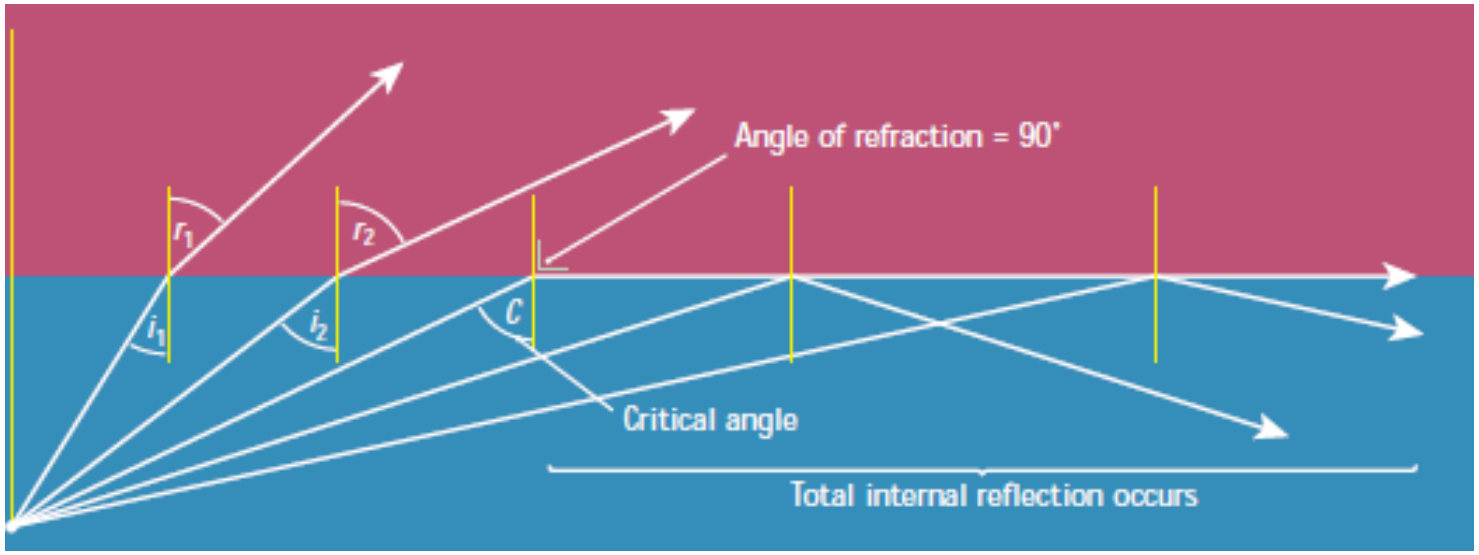
What is the speed of light in glass with a refractive index of 1.58

Total Internal Reflection

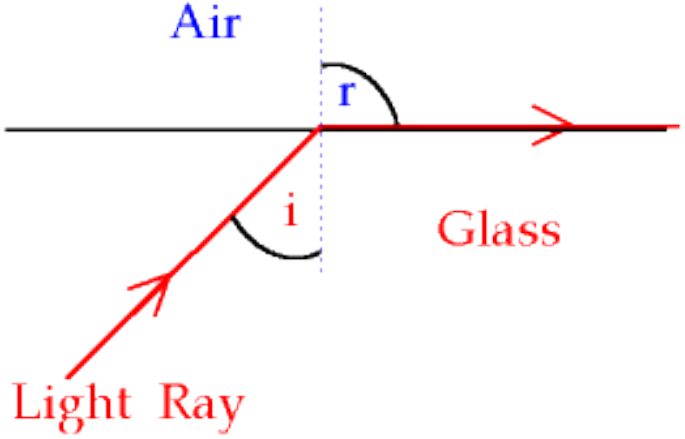
Def: Total internal Reflection occurs when the angle of incidence in the denser medium is greater than the critical angle

When light is passes from glass into air, it gets refracted away from the normal. As the angle of incidence is increased, the angle of refraction eventually reaches 90^o.

Def: The critical angle (C) is the angle of incidence in the denser medium corresponding to an angle of refraction of 90^o in the less dense medium.



2 Critical Angle



From the diagram, the ray of light is going from a dense to a rare medium.

$$ {}_{x}n_{y} = \frac{\text{Sin i}}{\text{Sin r}} = \frac{\text{Sin C}}{\text{Sin 90}} = \frac{\text{Sin C}}{1} = \text{Sin C} $$

But we need to look at it if its going the opposite direction.

$$ {}_{a}n_{x} = \frac{1}{{}_{x}n_{a}} = \frac{1}{SinC} $$

Example 4.6

The critical angle for a certain medium is 35^{o}. Find its refractive index (n).

Example 4.7

The refractive index for a piece of glass is 1.55. What is the critical angle for glass?

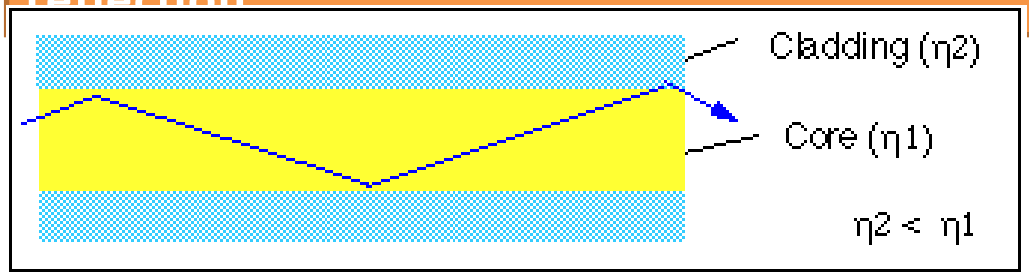
Snell's Window.

Snell's window is a phenomenon by which an underwater diver sees a circle of light on the surface of the water with darkness all around it.

Diagram:

Optical Fibres

Def: An Optical Fibre are made from a glass core (solid not hollow) with a layer of glass cladding (with lower n) where light can travel by total internal reflection



The glass is usually coated on the outside with plastic for protection. The signal is introduced at one end. As the light travels along, it strikes the boundary between the denser core and the less dense cladding at an angle greater than the critical angle.

However, light **can** escape before it reaches the end.
If the fibre is bent through too large an angle, the ray may strike at an angle less than the critical angle. It gets absorbed and leaves the fibre.

Science, Technology and Society.

Uses of optical fibres over copper in telecommunications

- Transmit much faster
- Occupy less space
- Cheaper raw material
- More flexible
- Don't corrode
- Less interference and use less power.

Optical Fibres in medicine.

An endoscope is used to see inside the body. Light is sent down some of the fibres and the image is sent back through other fibres

Advantages here include a much smaller incision is needed to allow the camera in.

Mirages.

Light from the sun travels from dense cold air to less dense hot air. As this occurs, the light gets bent away from the normal and eventually exceeds the critical angle. Here, we see an image of the sky, for example, on the road.