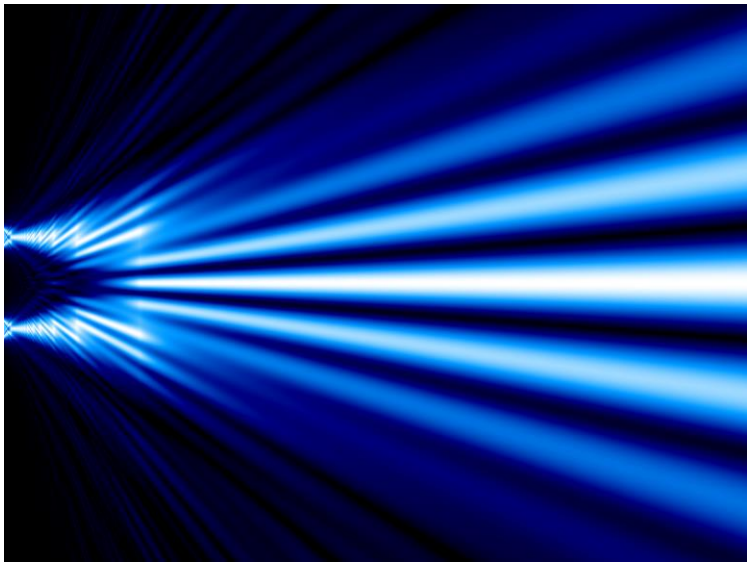
Waves & The Particle Nature of Light

2015 EdExcel A Level Physics Topic 5

Reflection & refraction

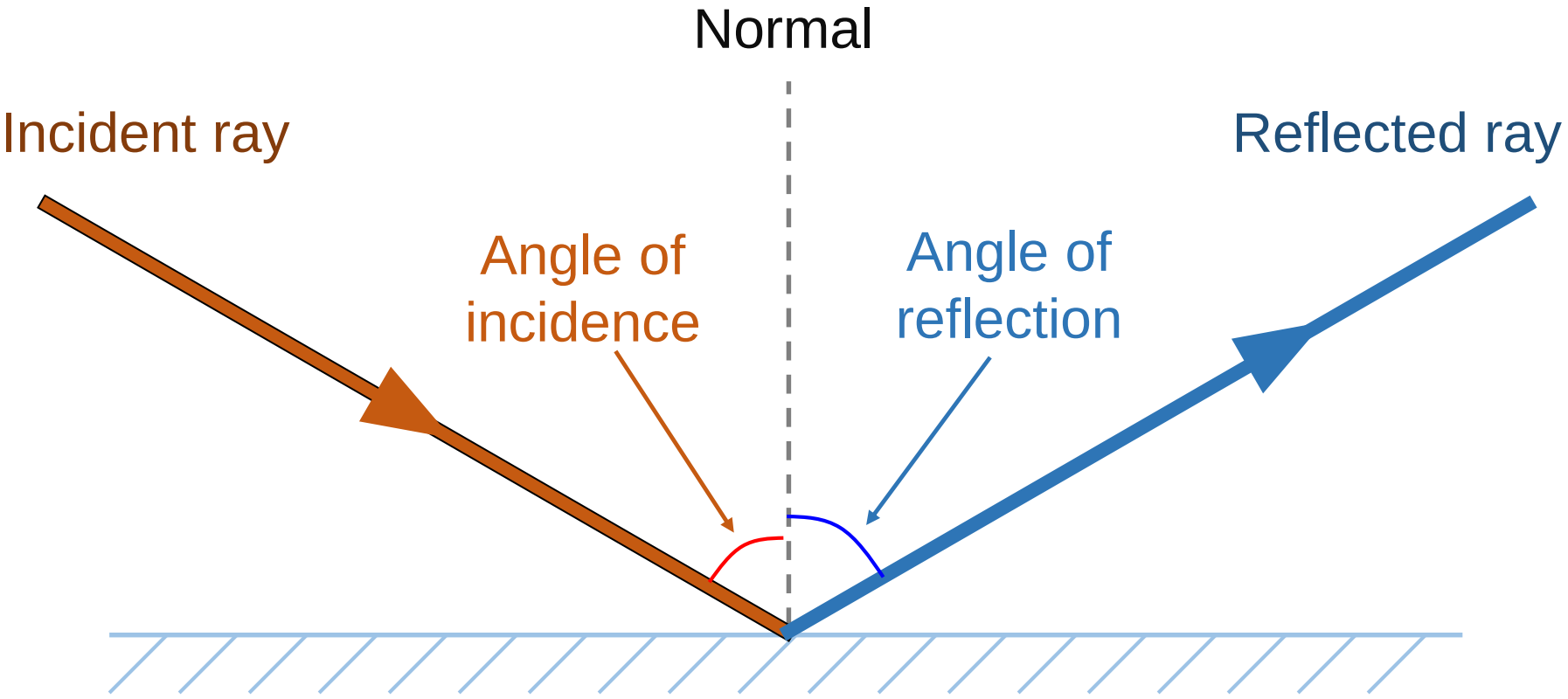


Physics Tutor Online

Reflection revision

Reflection is the bouncing of light rays off a surface

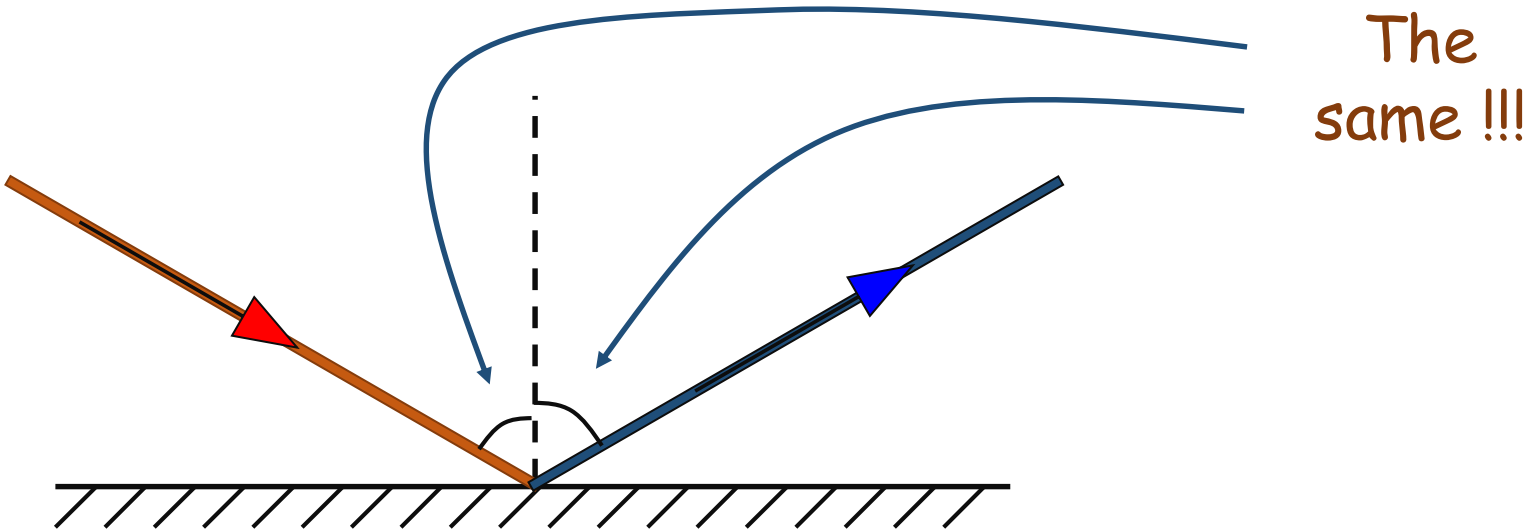
Reflection from a mirror:



The Law of Reflection

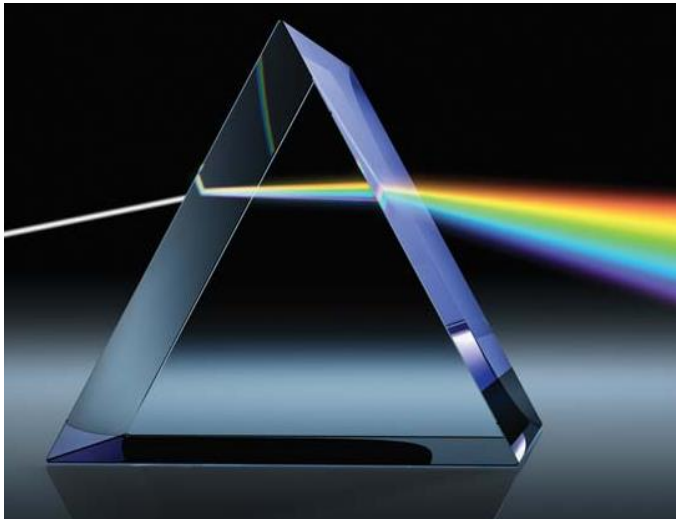
Angle of incidence = Angle of reflection

In other words, light gets reflected from a surface at THE SAME ANGLE it hits it.

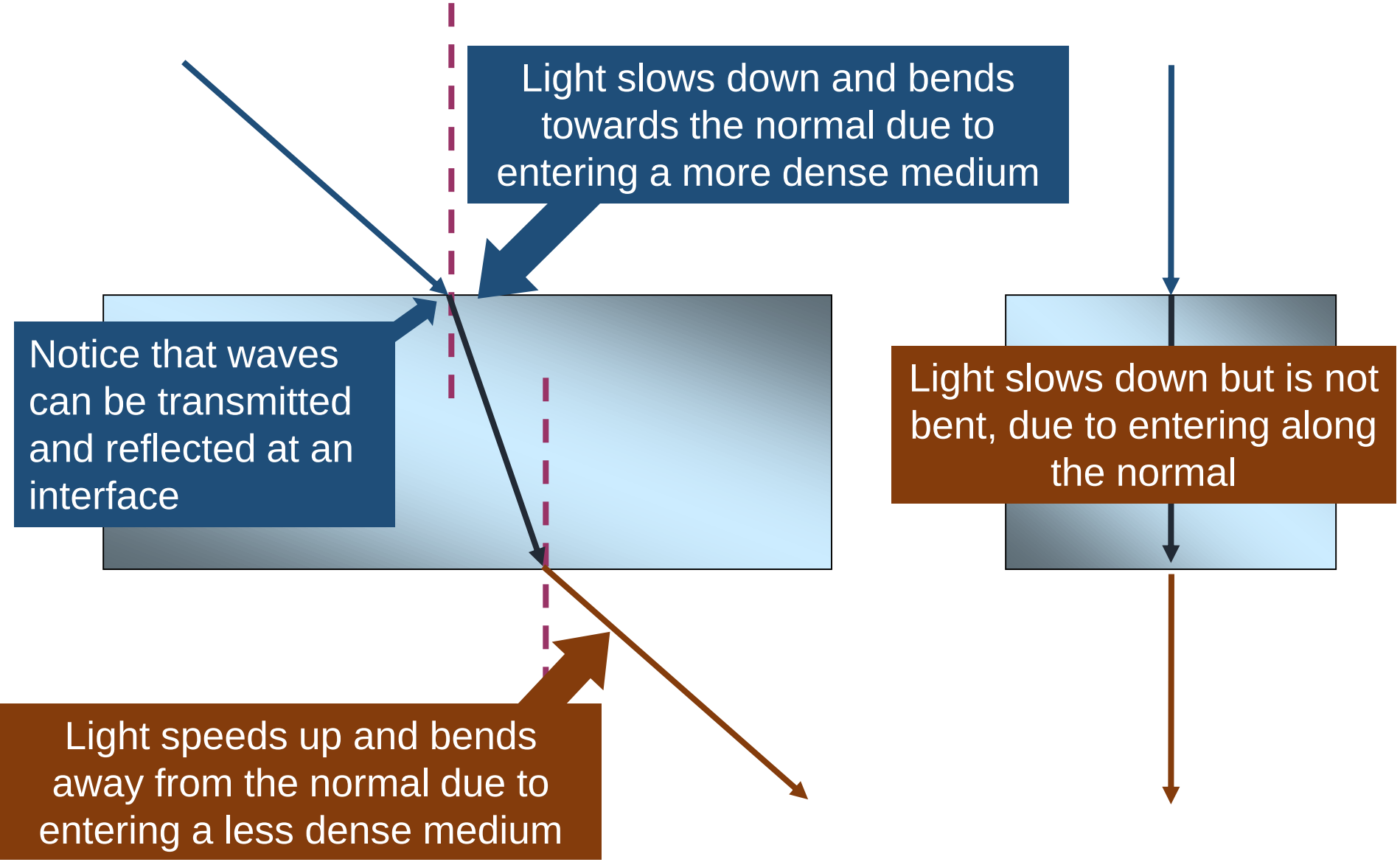


Refraction Revision

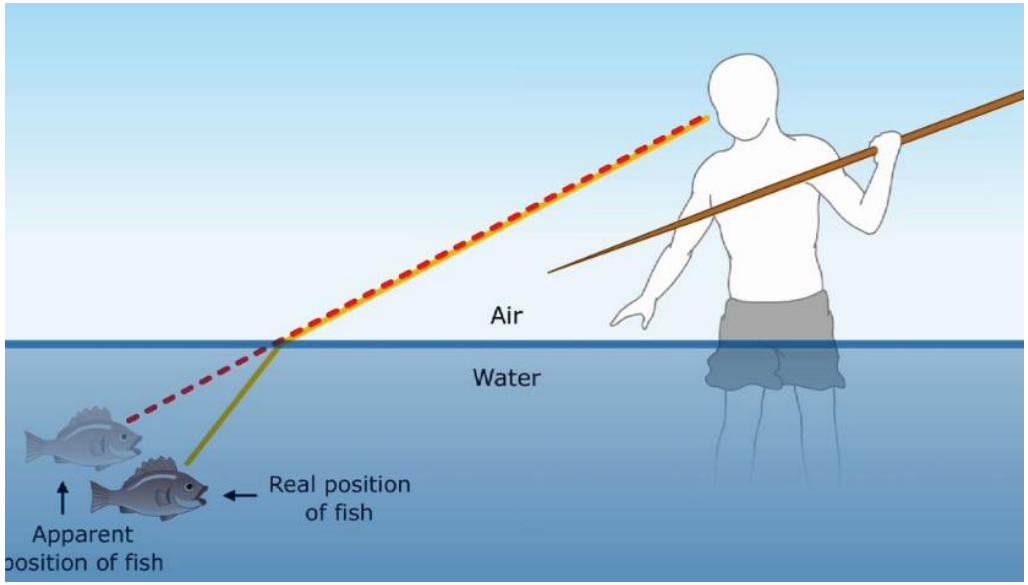
Refraction is the bending of light when it enters from one transparent medium into another.
It is caused by the different speeds of light in different media.
The greater the optical density of the medium, the slower the speed of light.



Refraction through a glass block



Refraction



Snell's Law

My law describes the relationship between the angle of incidence and the angle of refraction.

Willebrord Snell
(1580-1626)

- The degree to which light is bend depends on the medium and the density of the medium.
- Snell's Law states that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \qquad n = c/v$$

Practice Questions (Snell's Law)

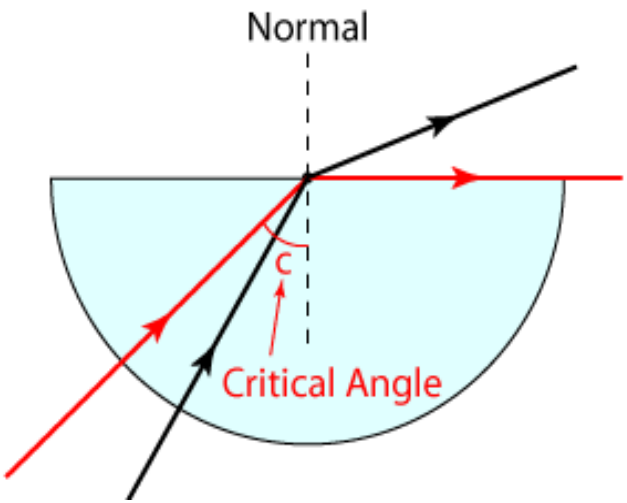
1) Light travels from air into diamond with an angle of refraction (θ_r) of 11.3 °. What is the angle of incidence (θ_i) if the refractive index of air is 1 and the refractive index of diamond is 2.4

2) Light travels from diamond into water with an angle of incidence (θ_i) of 14.2 °. What is the angle of refraction (θ_r) if the refractive index of diamond is 2.4 and the refractive index of water is 1.33.

3) A ray of light travels through a vacuum and is incident upon a glass block (of refractive index 1.5) at an angle of 32°. The ray then passes into water. Draw an accurate diagram to show the path of this light as it travels from the vacuum through the glass and into the water.

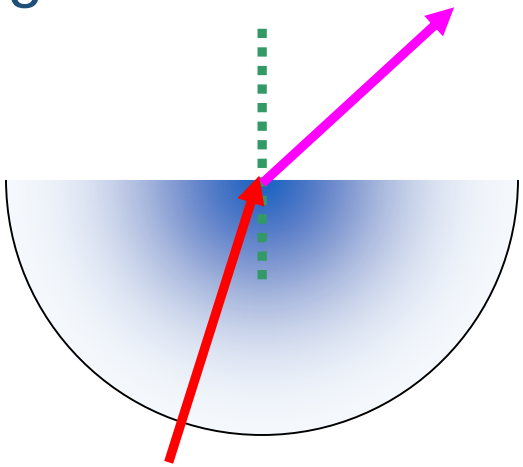
Critical Angle

The critical angle of an optical (transparent) medium is the limiting angle of incidence that results in an angle of refraction equal to 90°.

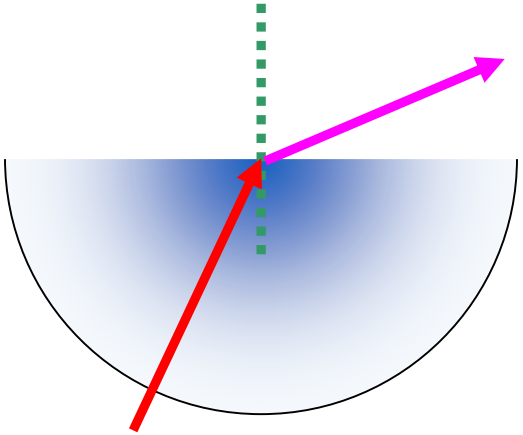


Finding the Critical Angle...

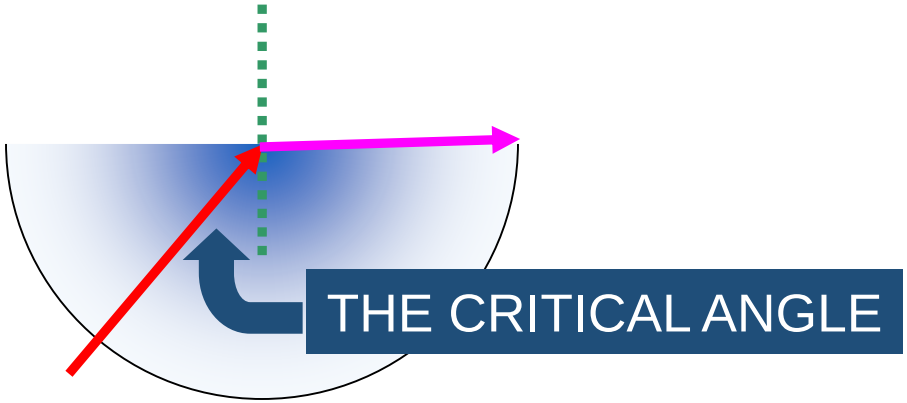
1) Ray gets refracted



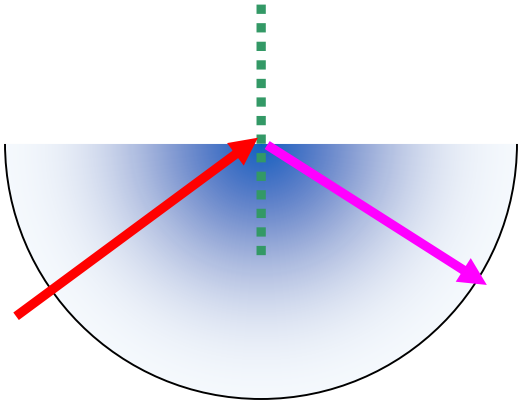
2) Ray still gets refracted



3) Ray still gets refracted (just!)

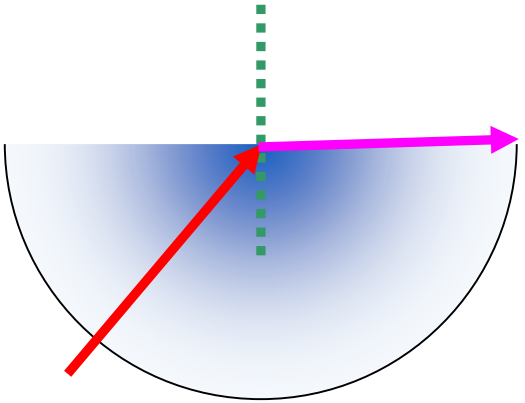


4) Ray gets internally reflected



The Maths of the Critical Angle

Consider a ray of light emergent from a semi-circular block at 90°:



…and now recall Snell's Law from earlier:

$$\mu_1 \sin \theta_1 = \mu_2 \sin \theta_2$$

Applying this equation to this situation, we can state the following:

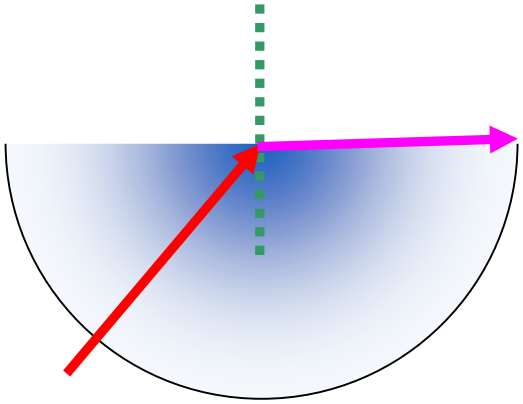
$\mu_1 = n$ (for the material)	$\mu_2 = 1$ (n for air)
$\sin \theta_1 = \sin c$ (critical angle)	$\sin \theta_2 = \sin 90^{O}$

Or, to simplify:

$$\sin c = \frac{1}{n}$$

Example

Q.In the situation here the critical angle is 45°. What is the refractive index of the material?



Example

Q.In the situation here the critical angle is 45°. What is the refractive index of the material?

Solution

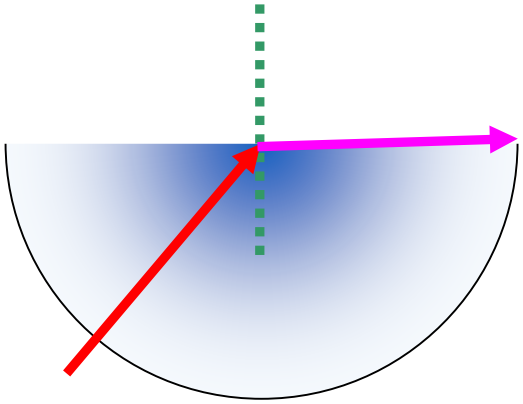
$c=45^o$

$n=?$

$$\sin c = \frac{1}{n}$$

$$n = \frac{1}{\sin c} = \frac{1}{\sin 45^{\,o}}$$

$$n = 1.414$$



Practice Questions

1) What is the critical angle for light traveling from diamond into fiber optic cable, given that the refractive index of diamond is 2.4 and the refractive index of fiber optic cable is 1.6?

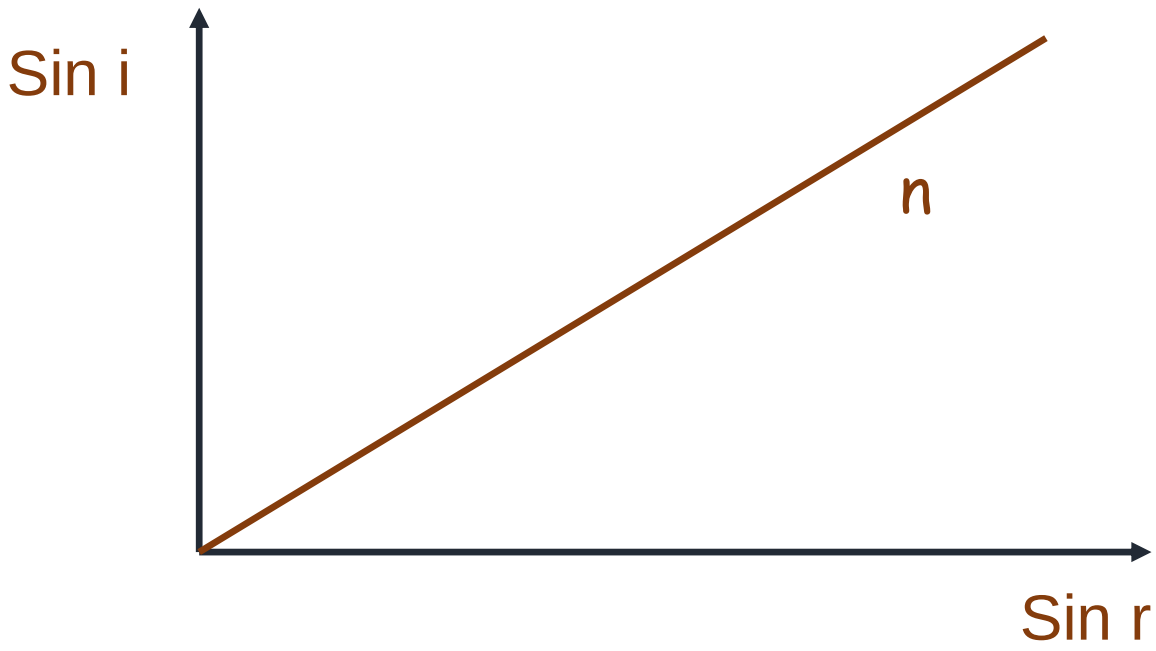
2) What is the critical angle for light traveling from glass into water, given that the refractive index of glass is 1.5 and the refractive index of water is 1.33?

Measuring the Refractive Index

Using Snell's Law we can measure the refractive index of a material:

$$n = \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sin i}{\sin r}$$

From this equation a graph of sin i against sin r will have a gradient of the refractive index:



Example

Q.The index of refraction of a particular liquid is 1.60. A ray of light inside the liquid strikes the liquid-air surface with an angle of incidence of 42°.Determine whether the ray will exit into the air or be totally reflected back into the liquid.

Example

Q.The index of refraction of a particular liquid is 1.60. A ray of light inside the liquid strikes the liquid-air surface with an angle of incidence of 42°.Determine whether the ray will exit into the air or be totally reflected back into the liquid.

Solution:

$n_1 = 1.60$

$n_2 = 1$

$r = 90^o$

$$n_1 \sin i = n_2 \sin r$$

$$\sin i = \frac{n_2 \sin r}{n_1} = \frac{1x \sin 90^o}{1.60} = 0.625$$

$i = 39^o$

Since the given angle of incidence (42°) is greater than the critical angle (39°), the incident ray will not emerge from the liquid but instead will be reflected back into the liquid

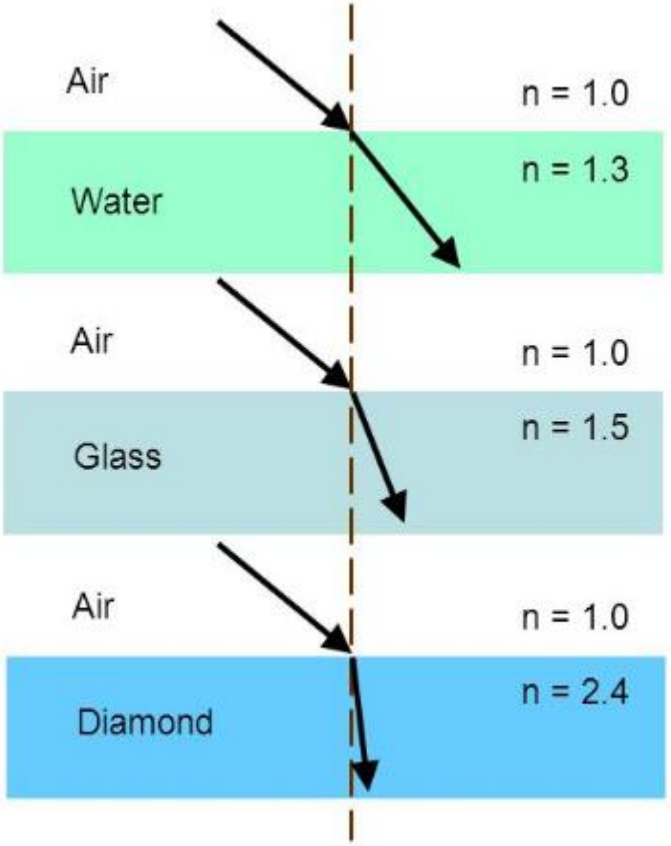
Lenses

Lenses use the idea of refraction.

When light enters a MORE DENSE medium it slows down.

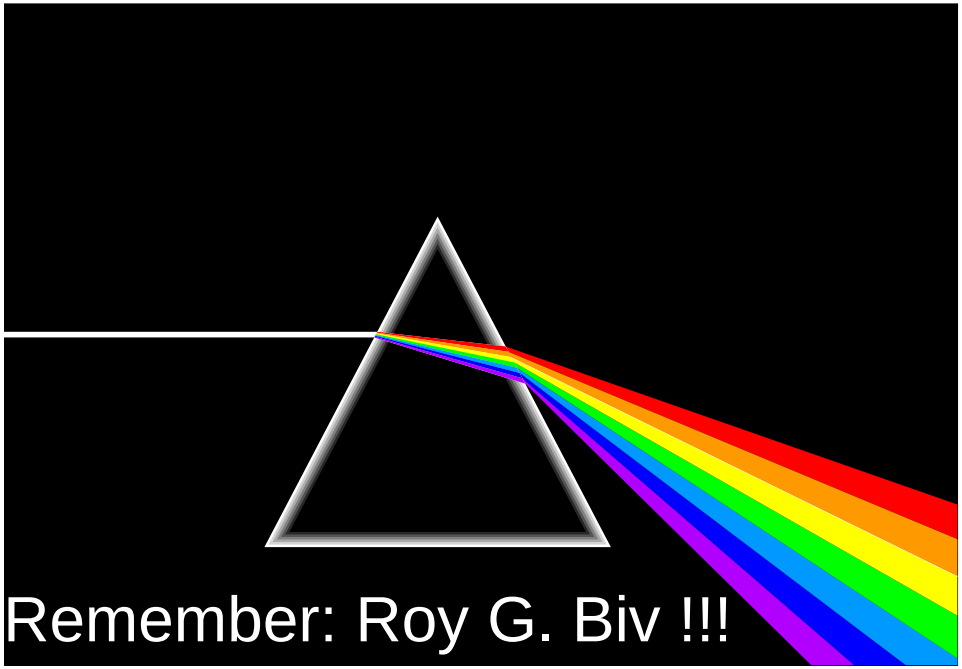
Optical density is measured by the refractive index, n.

The larger the difference between the indices at an interface, the larger the angle of refraction for light rays crossing the interface.



The colours of the rainbow:

A prism uses this idea to split light. This happens because violet light is refracted more than red light



- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet