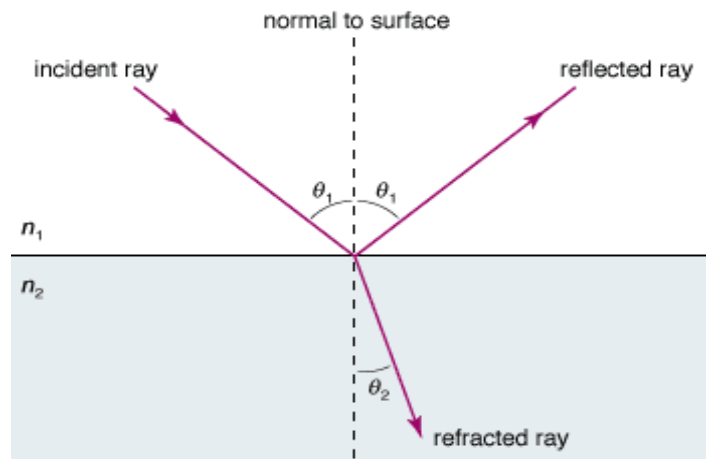


REFLECTION and REFRACTION

Light incident upon a surface will in general be:

- ✓ Partially reflected,
- ✓ Partially transmitted as a refracted ray,
- ✓ Partially absorbed.



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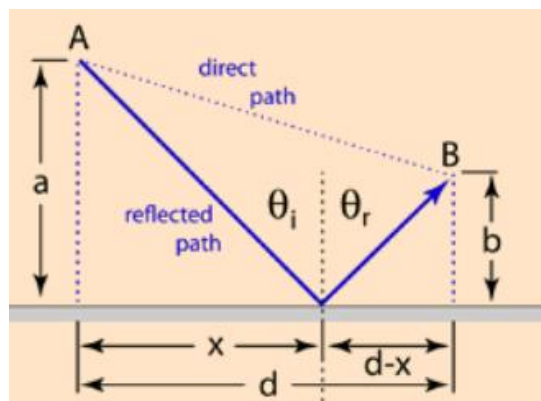
The laws of reflection and refraction, derived from Fermat's principle, are known as:

- Law of reflection,
- Law of refraction.

Fermat's Principle:

Light follows the path of least time.

I. Law of Reflection.



The path length L from A to B, along the reflected path, is

$$L = \sqrt{a^2 + x^2} + \sqrt{b^2 + (d - x)^2}$$

Since the speed is constant, the minimum time path is simply the minimum distance path. This may be found by setting the derivative of L with respect to x equal to zero.

$$\frac{dL}{dx} = \frac{1}{2} \cdot \frac{2x}{\sqrt{a^2 + x^2}} + \frac{1}{2} \cdot \frac{2(d-x)(-1)}{\sqrt{b^2 + (d-x)^2}} = 0$$

This reduces to,

$$\frac{x}{\sqrt{a^2 + x^2}} = \frac{d-x}{\sqrt{b^2 + (d-x)^2}}$$

Which is,

$$\sin \theta_i = \sin \theta_r$$

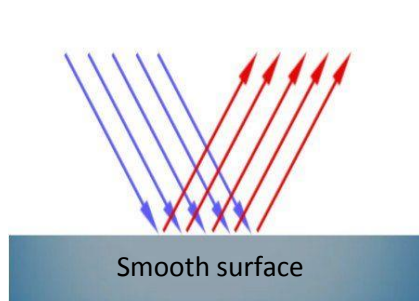
This shows that,

$$\begin{aligned} \text{Angle of incidence} &= \text{Angle of reflection} \\ \theta_i &= \theta_r \end{aligned}$$

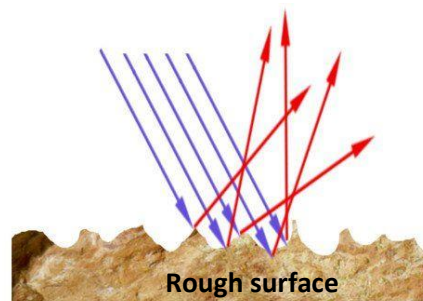
Law of Reflection

The reflection of light can be categorised into two types of reflection:

- i. Specular reflection, defined as light reflected from a smooth surface at a different angle.
- ii. Diffuse reflection, which is produced by rough surfaces that tend to reflect light in all directions.

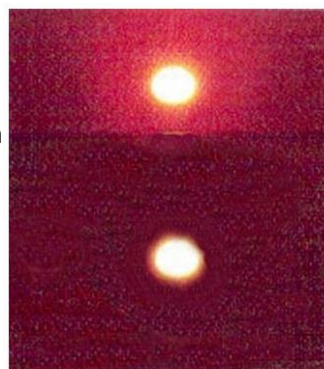


Specular Reflection



Diffuse Reflection

Image of the sun
preserved through
reflection



Smooth sea surface



Rough sea surface

Light is captured but
all of the information
from the light source
is lost.

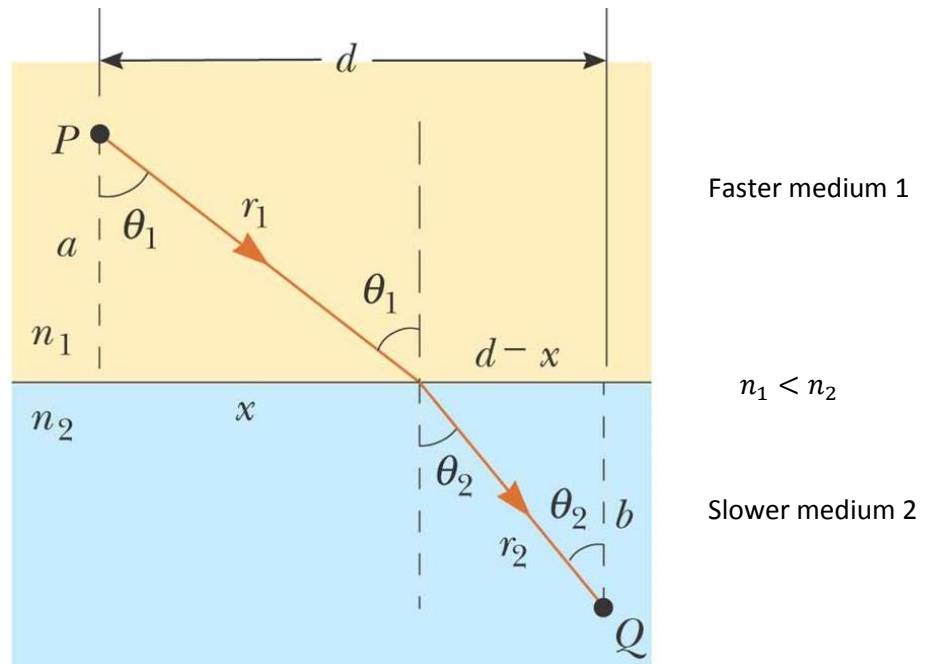
Everything that does not act as a mirror reflects light in a diffuse fashion.

II. Law of Refraction.

Refraction is the bending of a wave when it enters a medium where its speed is different. The refraction of light when it passes from a fast to a slow medium bends the light ray toward the normal to the boundary between the two media.

The amount of bending depends on the indices of refraction of the two media and is described quantitatively by Snell's Law.

1. Snell's Law.



Snell's law can be derived from Fermat's principle by setting the derivative of the time equal to zero. It shows how the refraction of light at an interface depends upon the indices of refraction,

$$t = \frac{\sqrt{a^2 + x^2}}{c_1} + \frac{\sqrt{b^2 + (d-x)^2}}{c_2}$$

$$\therefore \frac{dt}{dx} = \frac{x}{c_1 \cdot \sqrt{a^2 + x^2}} - \frac{d-x}{c_2 \cdot \sqrt{b^2 + (d-x)^2}} = 0$$

$$\therefore \frac{\sin \theta_1}{c_1} - \frac{\sin \theta_2}{c_2} = 0$$

$$\text{where } n_1 = \frac{c_0}{c_1} \text{ and } n_2 = \frac{c_0}{c_2}$$

Therefore,

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Snell's Law

2. Questions.

Based on the following table,

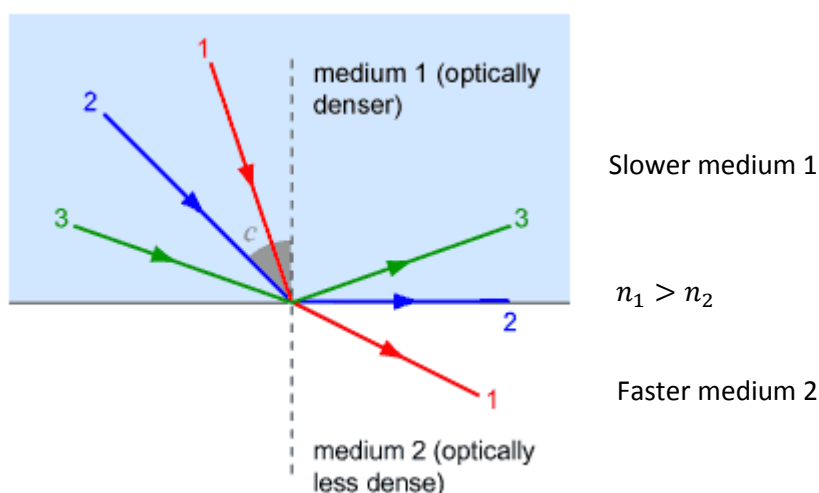
MEDIUM	REFRACTIVE INDEX
Vacuum	1.000
Air	1.003
Ice	1.300
Water	1.330
Glass	1.500
Diamond	2.420

Answer the subsequent questions,

- What is the speed of light in air?
- What is the speed of light in water?
- What is the speed of light in glass?
- A ray of light strikes an air-glass boundary at an incident angle of 30° . What is the angle of refraction?
- What is the angle of refraction and what is the angle through which the ray is deviated when light passes at an incident angle of 48° into water from air?

3. Total internal reflection and Critical Angle.

When a ray of light passes from a denser medium to a less dense medium (from glass to air for example), the angle of refraction is greater than the angle of incidence. If we increase the angle of incidence, we reach an angle beyond which all light is reflected.



At a particular value of angle of incidence, the angle of refraction is 90° . This particular angle of incidence is called the **critical angle**.

Beyond the critical angle we get **total internal reflection**. There is no transmission of light at all.

4. Calculation of Critical Angle.

According to Snell's law, at the critical angle we have,

$$n_1 \sin \theta_c = n_2 \sin 90^\circ$$

That is,

$$\sin \theta_c = \frac{n_2}{n_1}$$