PHYS 111

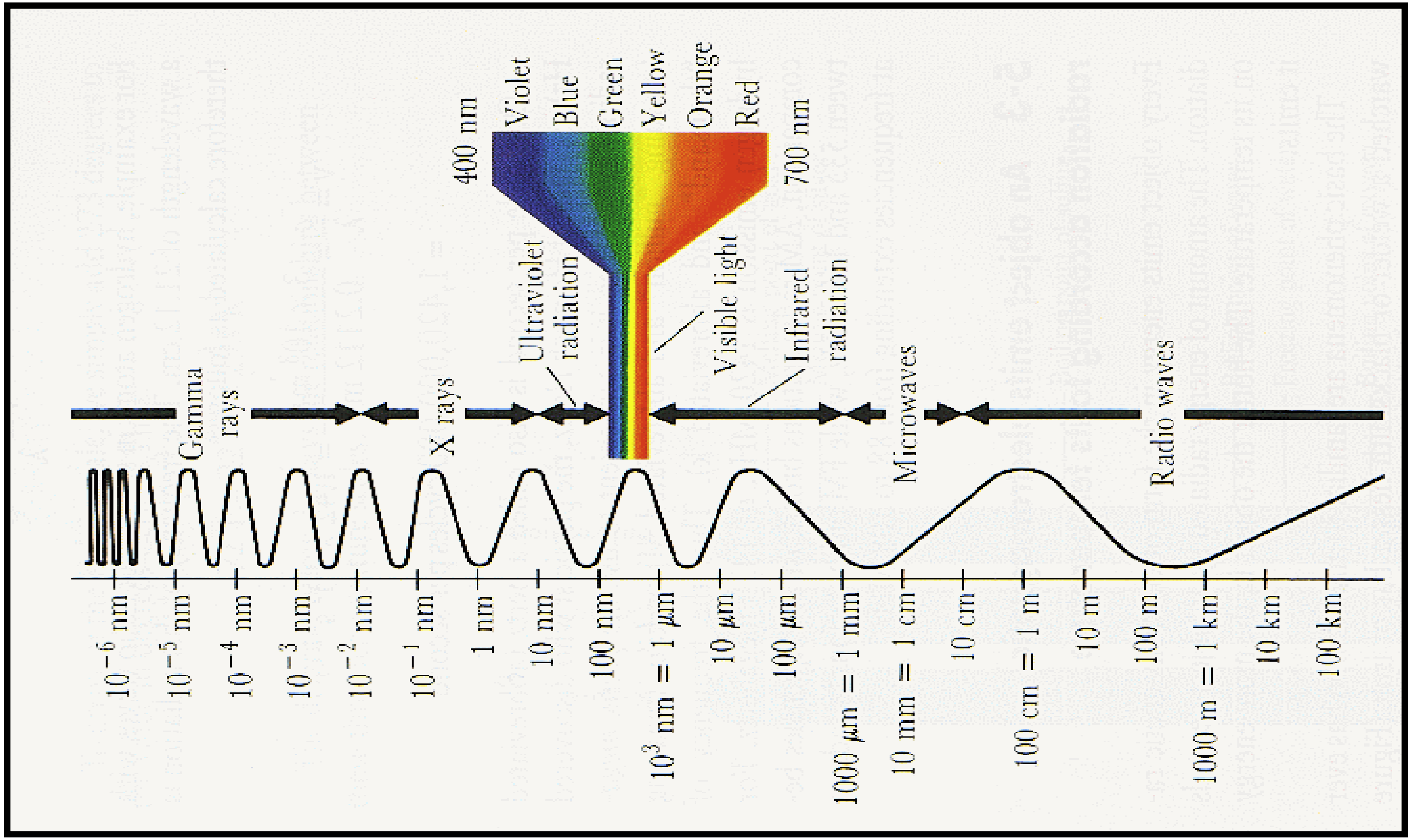
1ST semester 1446

Prof. OMAR H. M. ABD-ELKADER

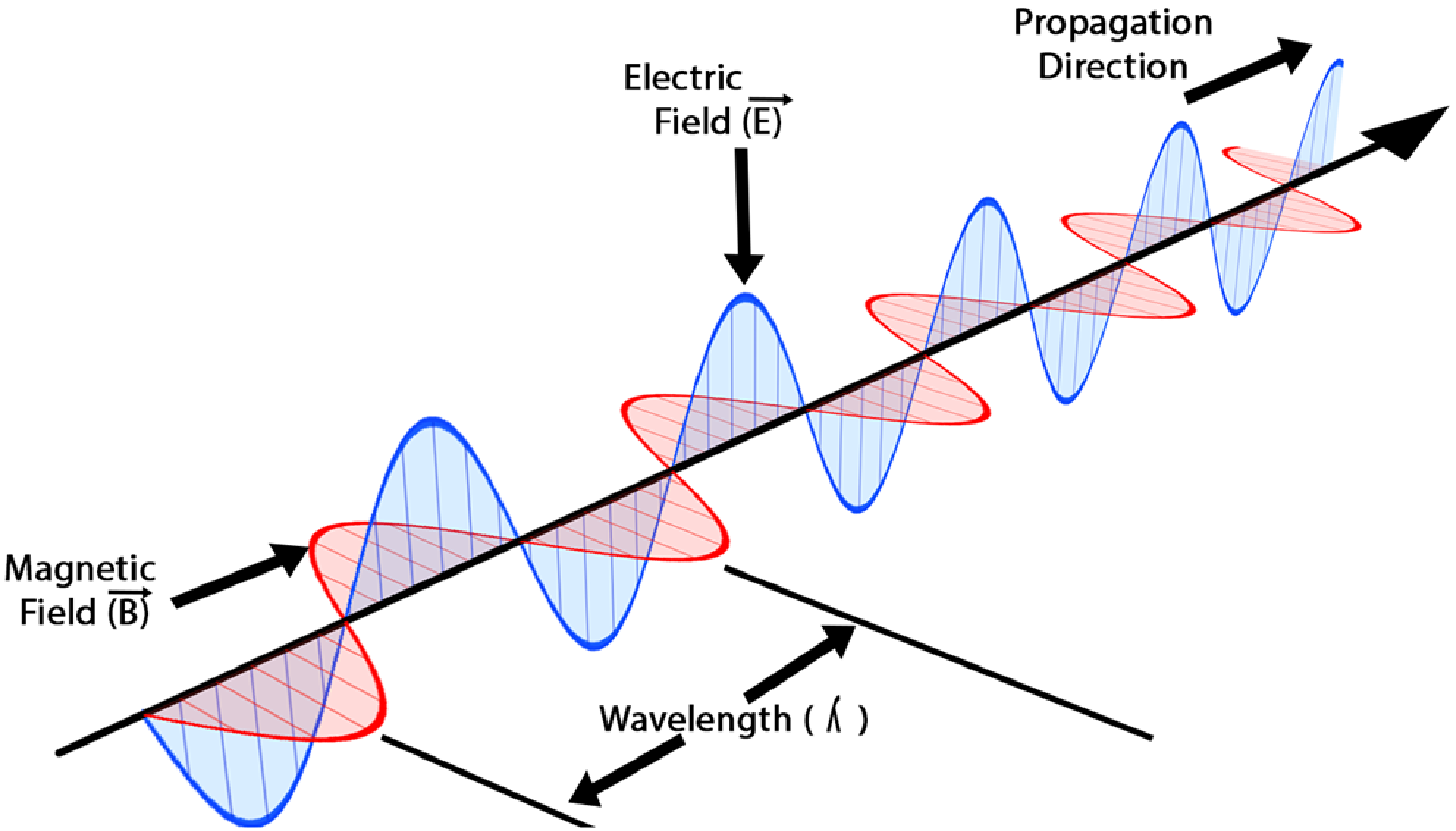
Lecture 8

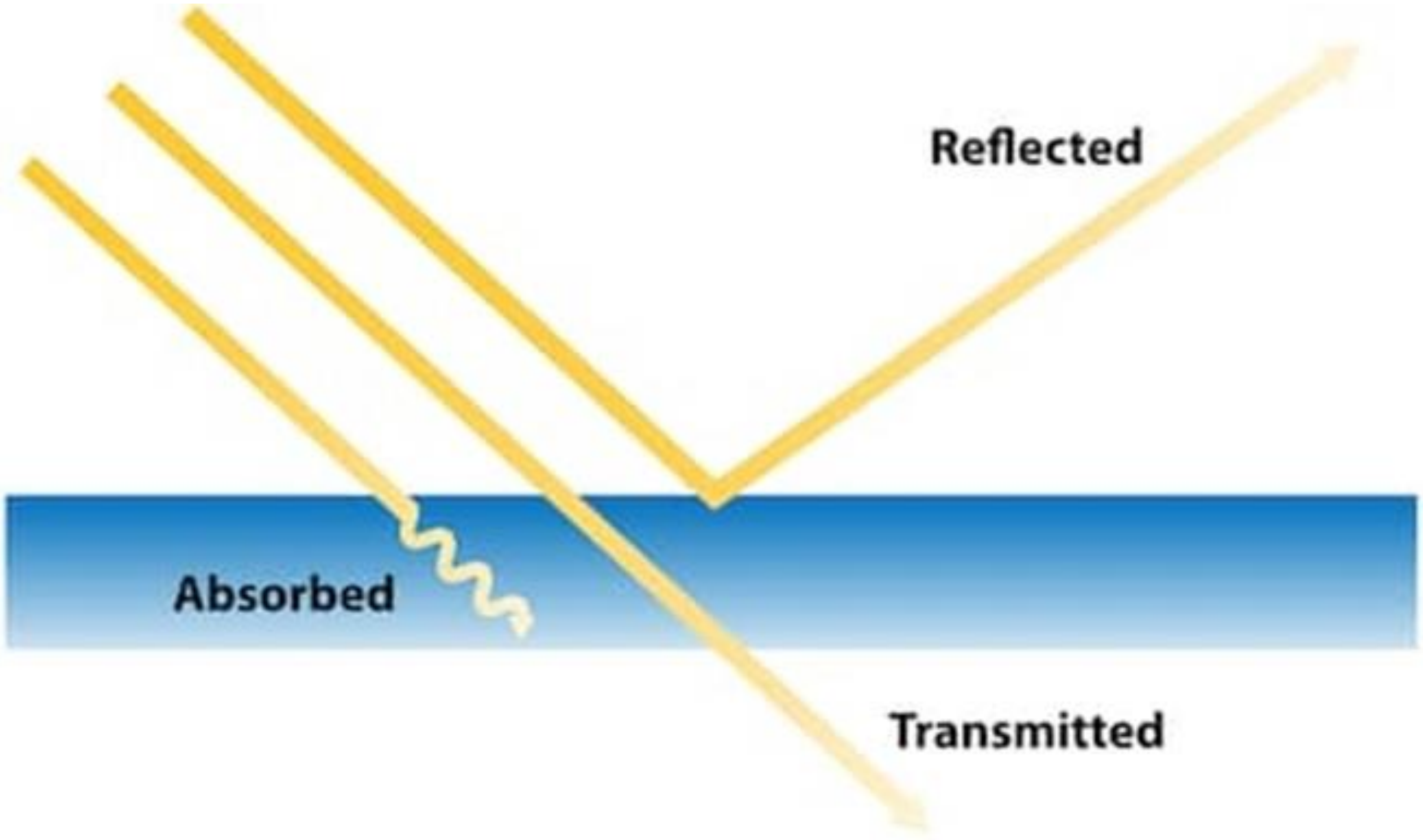
CHAPTER 35 • The Nature of Light and the Laws of Geometric Optics

THE NATURE OF LIGHT

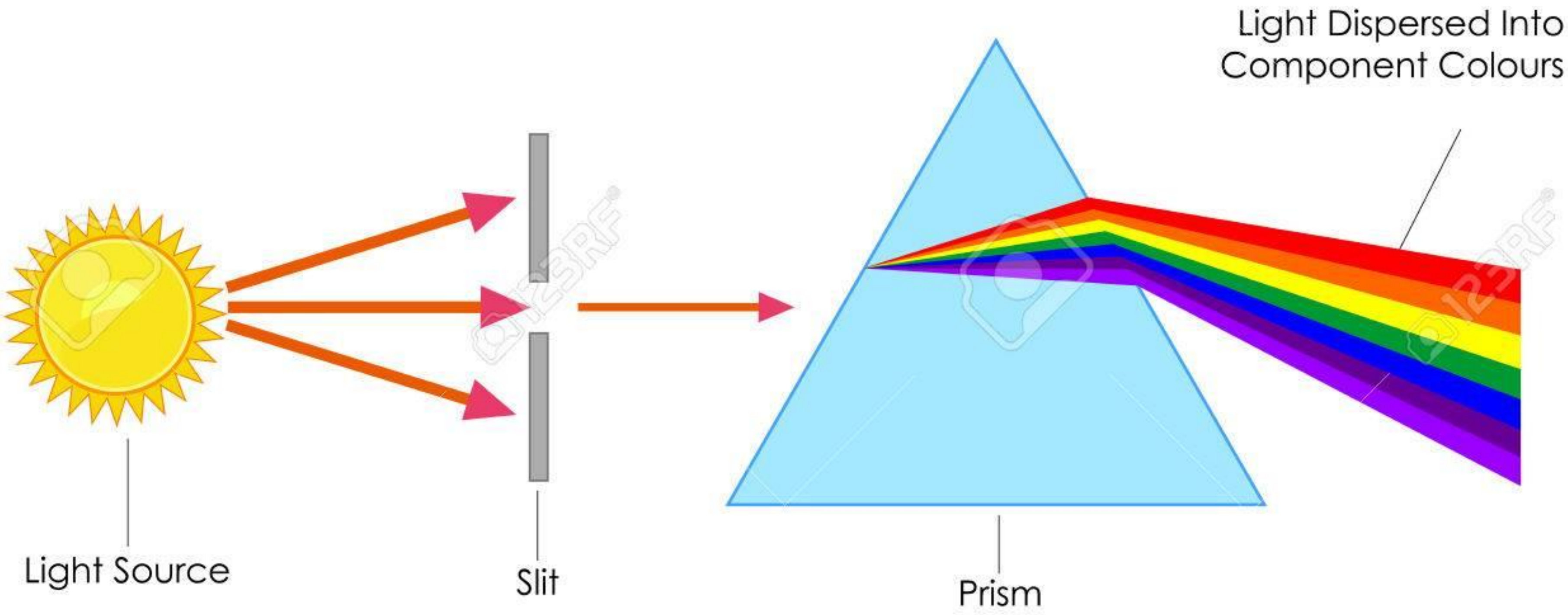


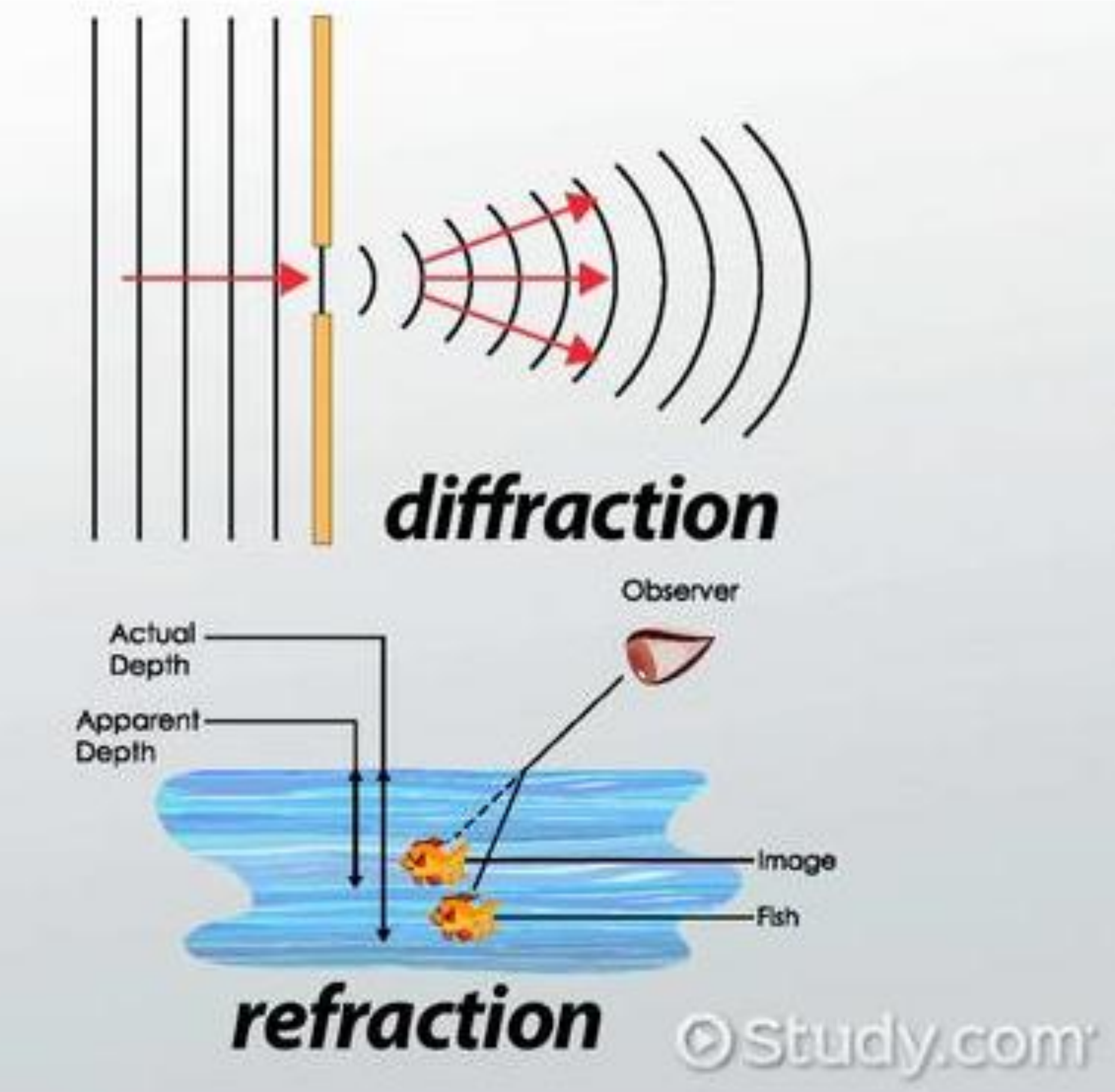
Electromagnetic Wave




Reflected
Absorbed
Transmitted

Dispersion of Light Through Prism




diffraction
Observer
Actual Depth
Apparent Depth
Image
Fish
refraction
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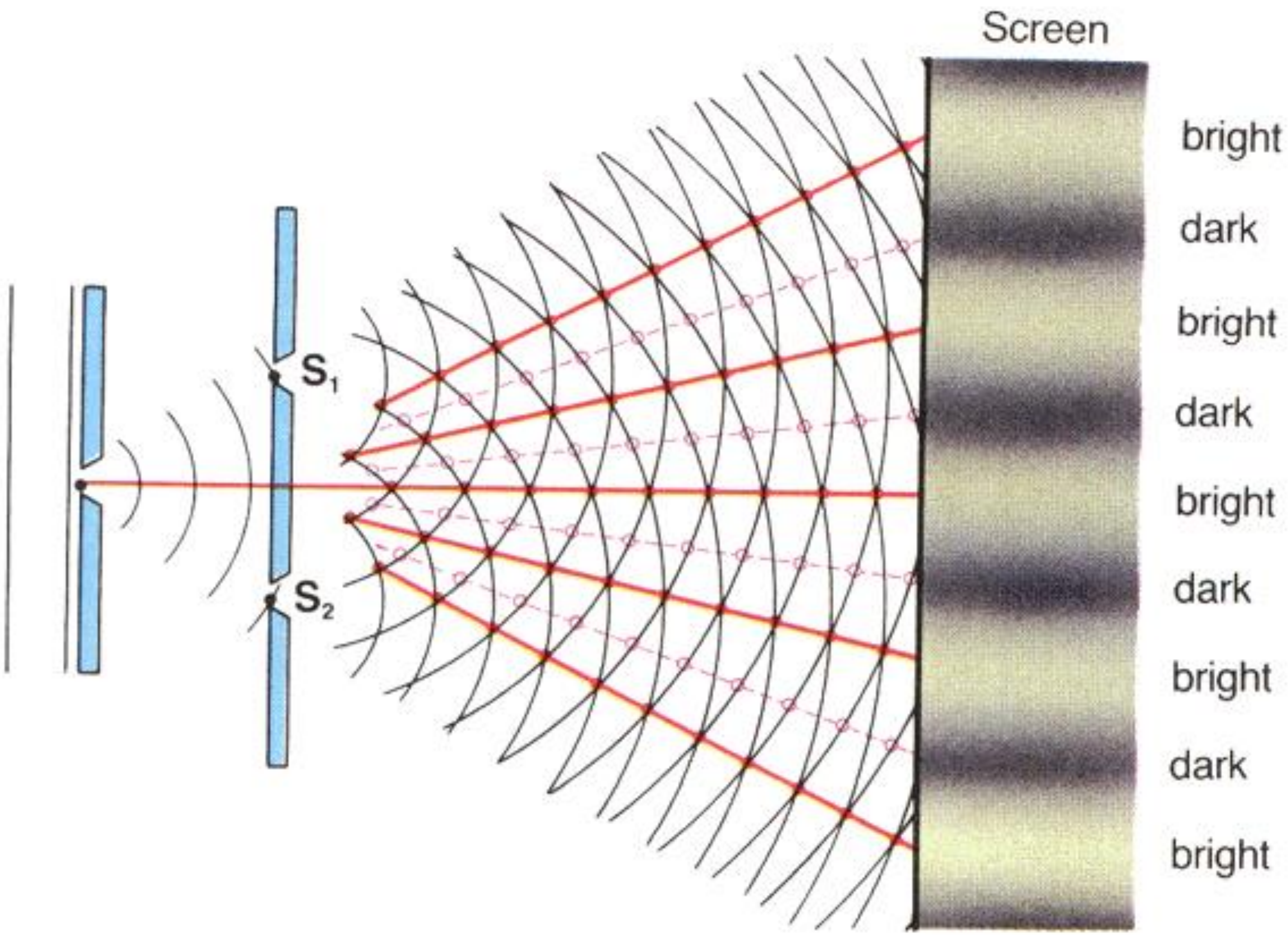
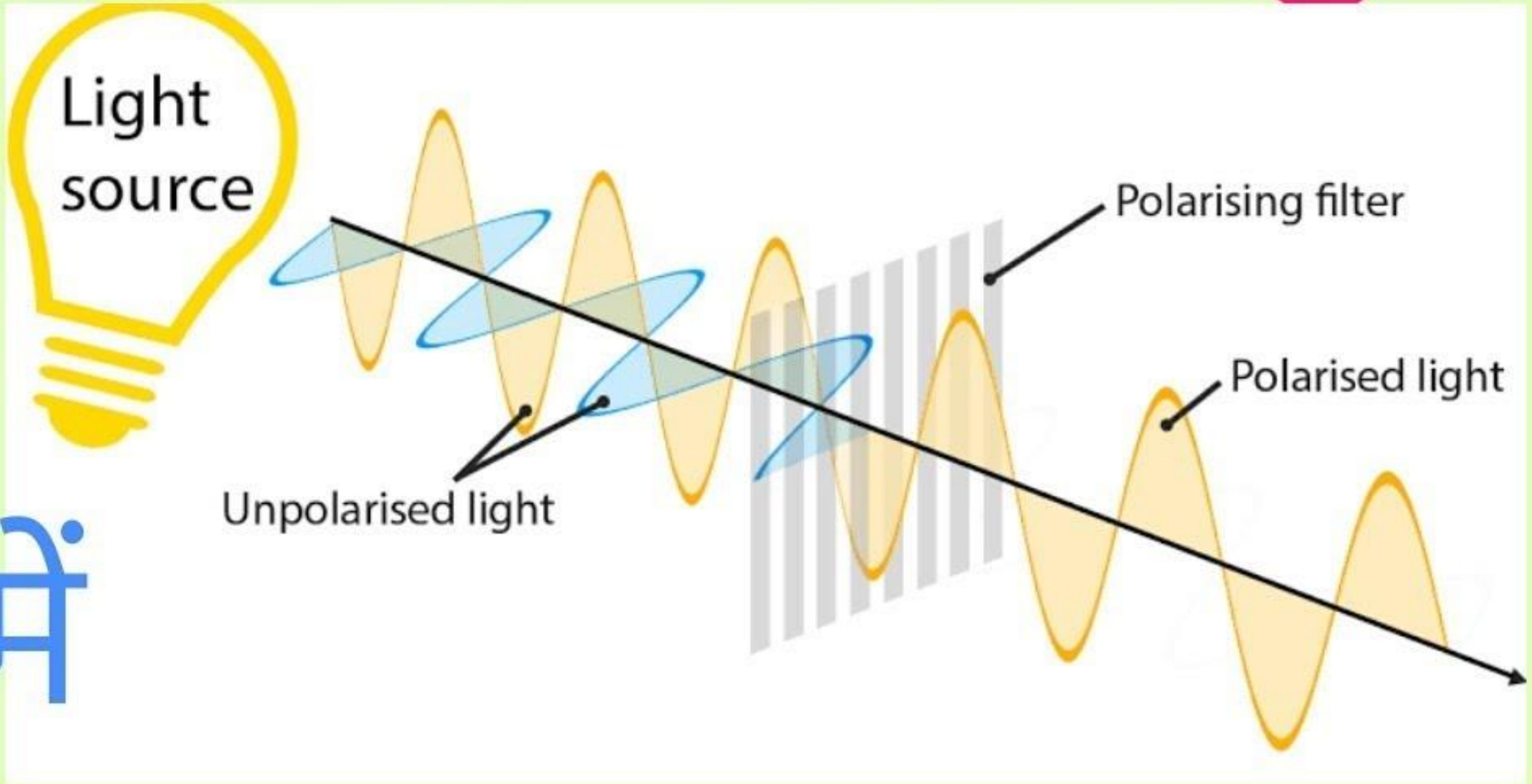
Interference Patterns



Polarization of light



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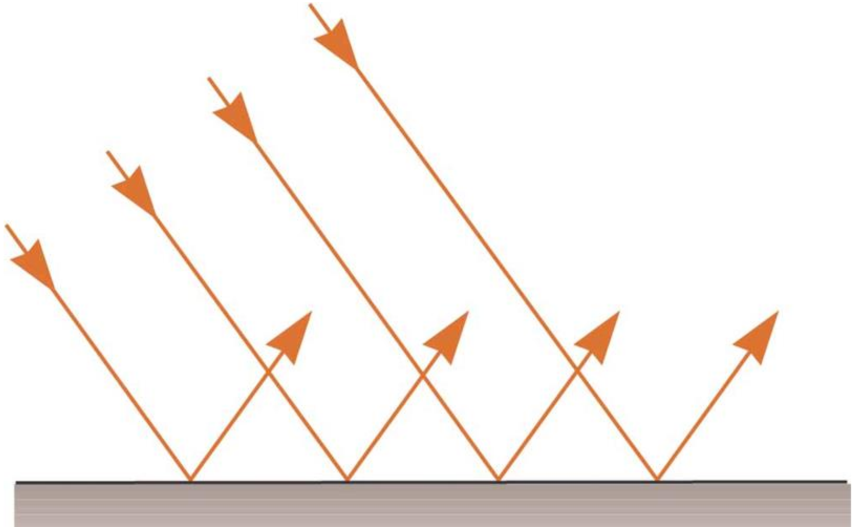
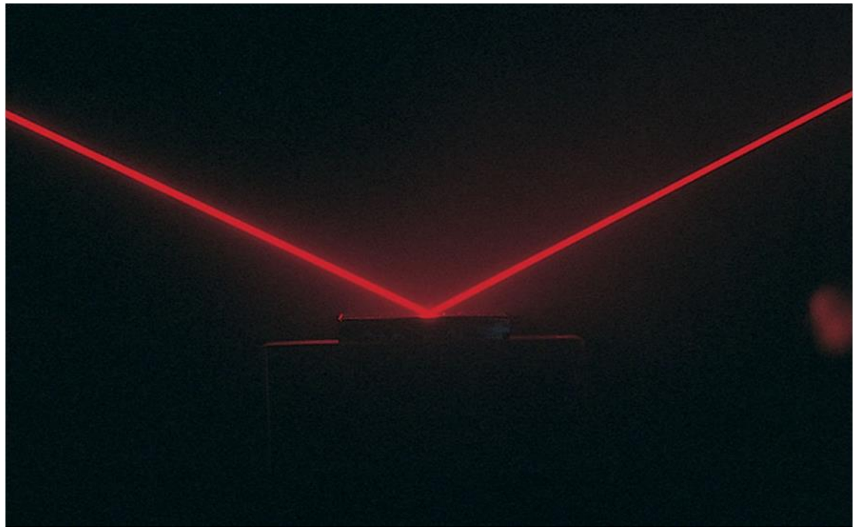
REFLECTION OF LIGHT

Specular reflection, where the reflected rays are all parallel to each other

Photographs of specular reflection using laser light.





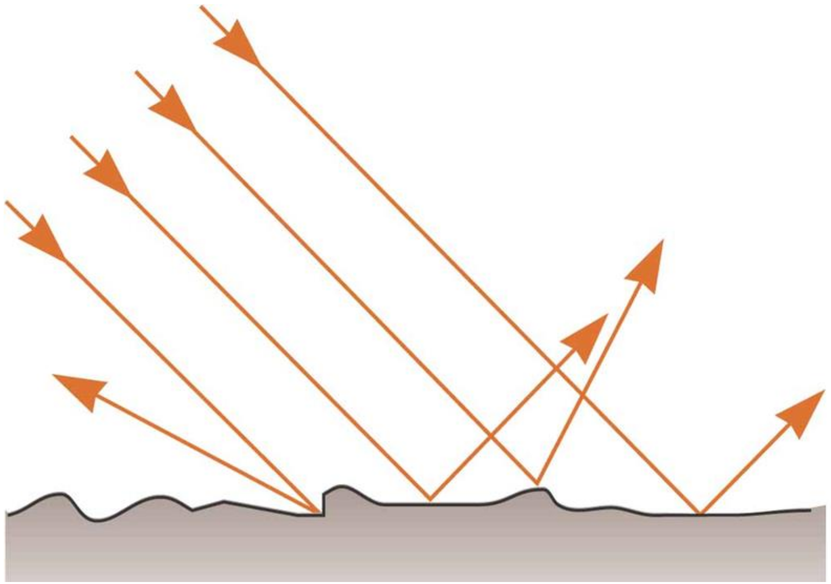
- light rays **change direction** (are “refracted”) when they move from one medium to another

- refraction takes place because light travels with different speeds in different media

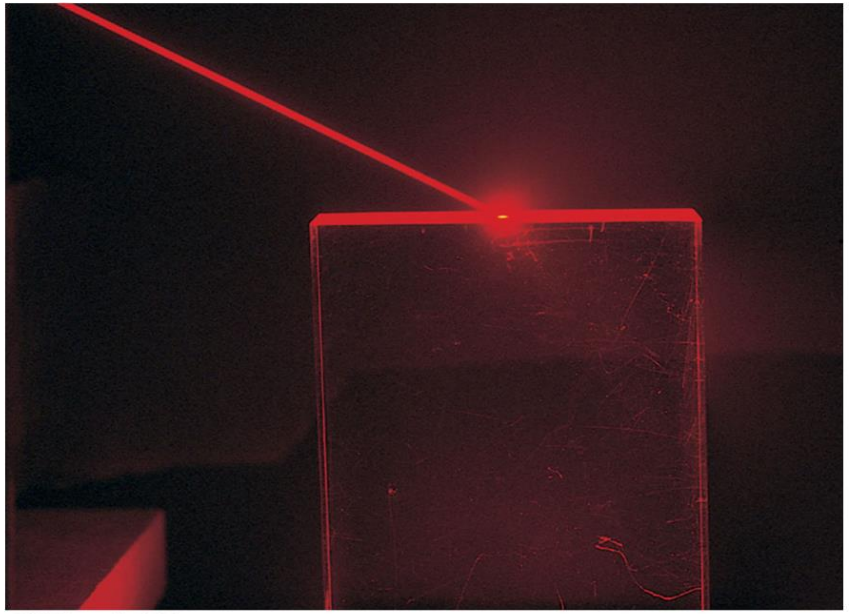
Speed of light in vacuum:

$c = 2.9979\text{x}10^8$ m/s (just use $3\text{x}10^8$ m/s)

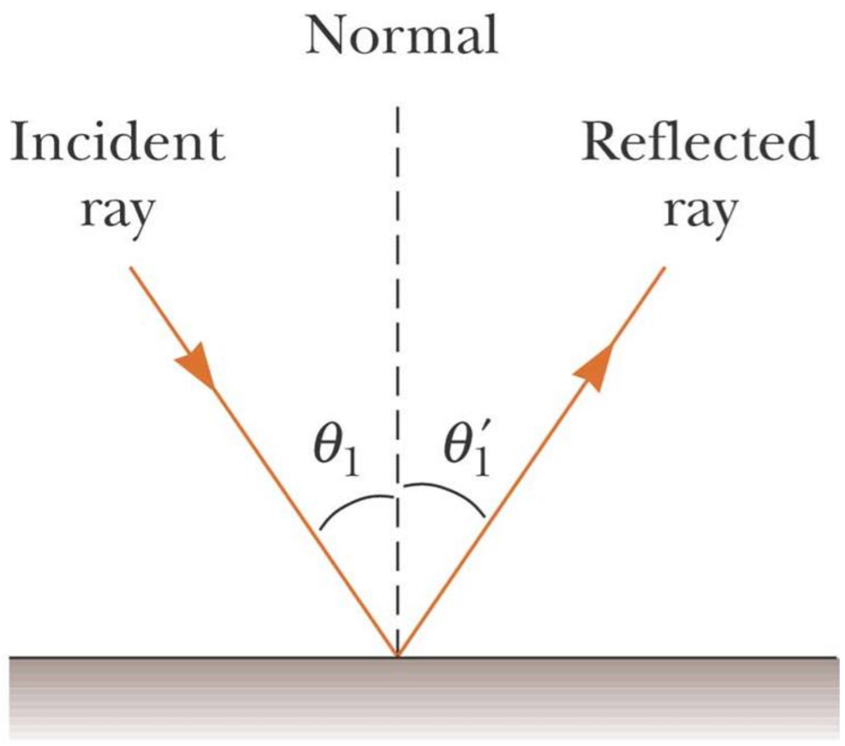
Diffuse reflection, where the reflected rays travel in random directions.



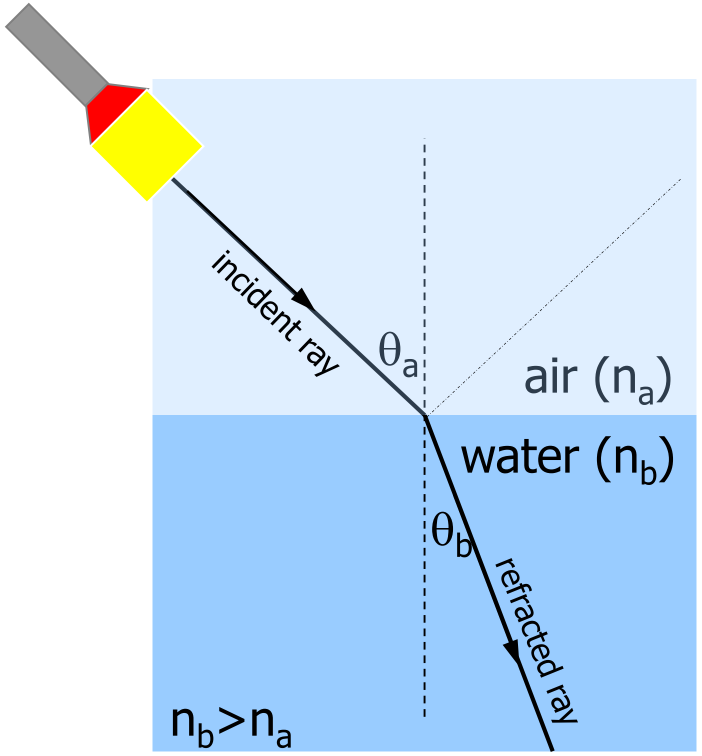
Photographs of diffuse reflection using laser light.

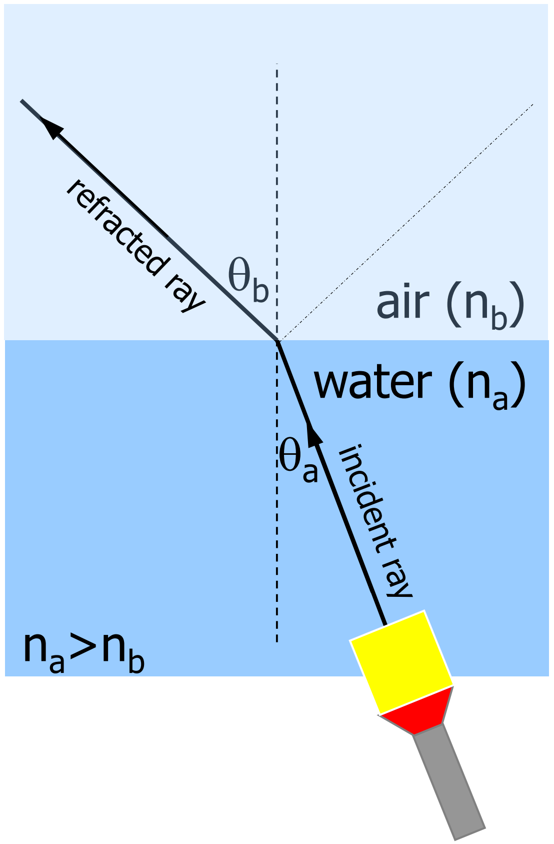


The angle of reflection equals the angle of incidence
This relationship is called the law of reflection.

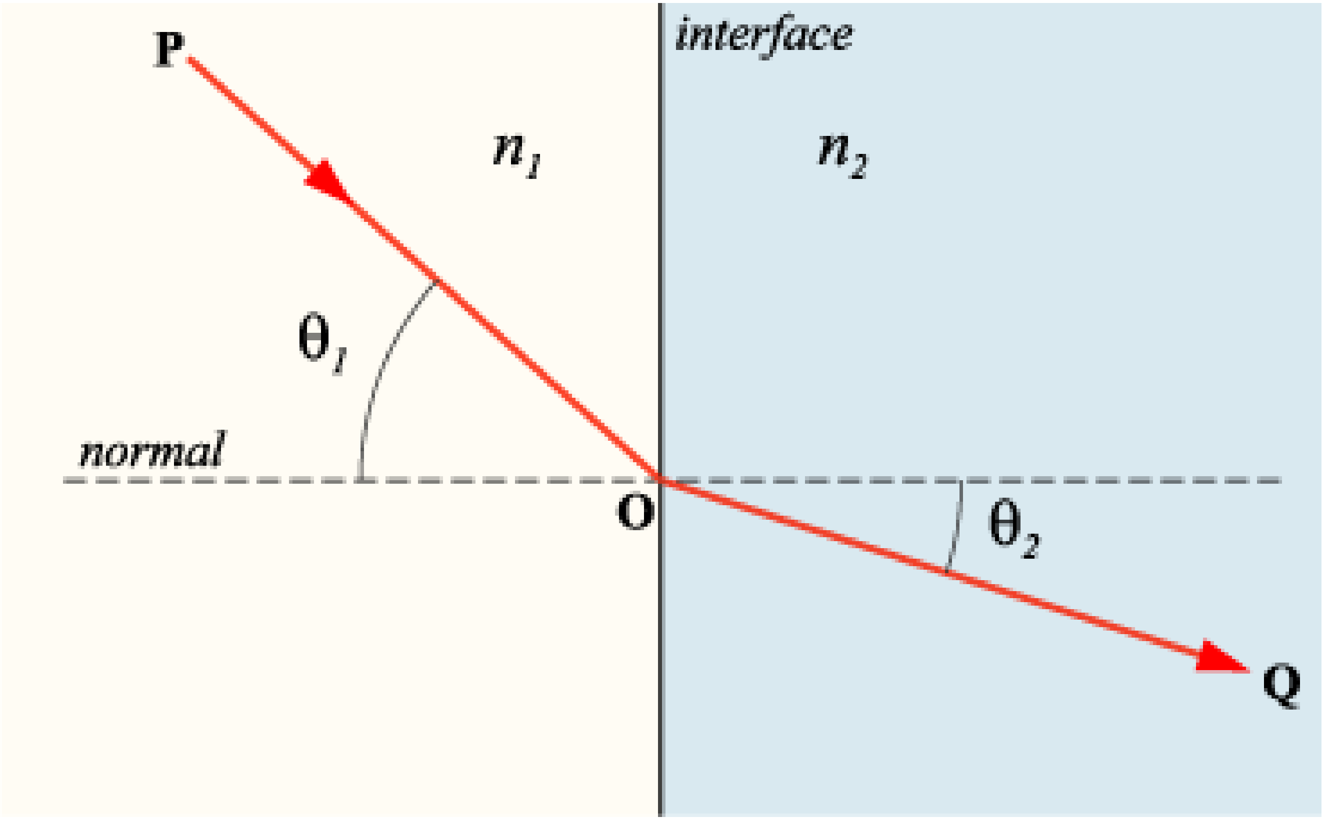


$$\theta_1' = \theta_1$$





$$n_a \sin(\theta_a) = n_b \sin(\theta_b)$$

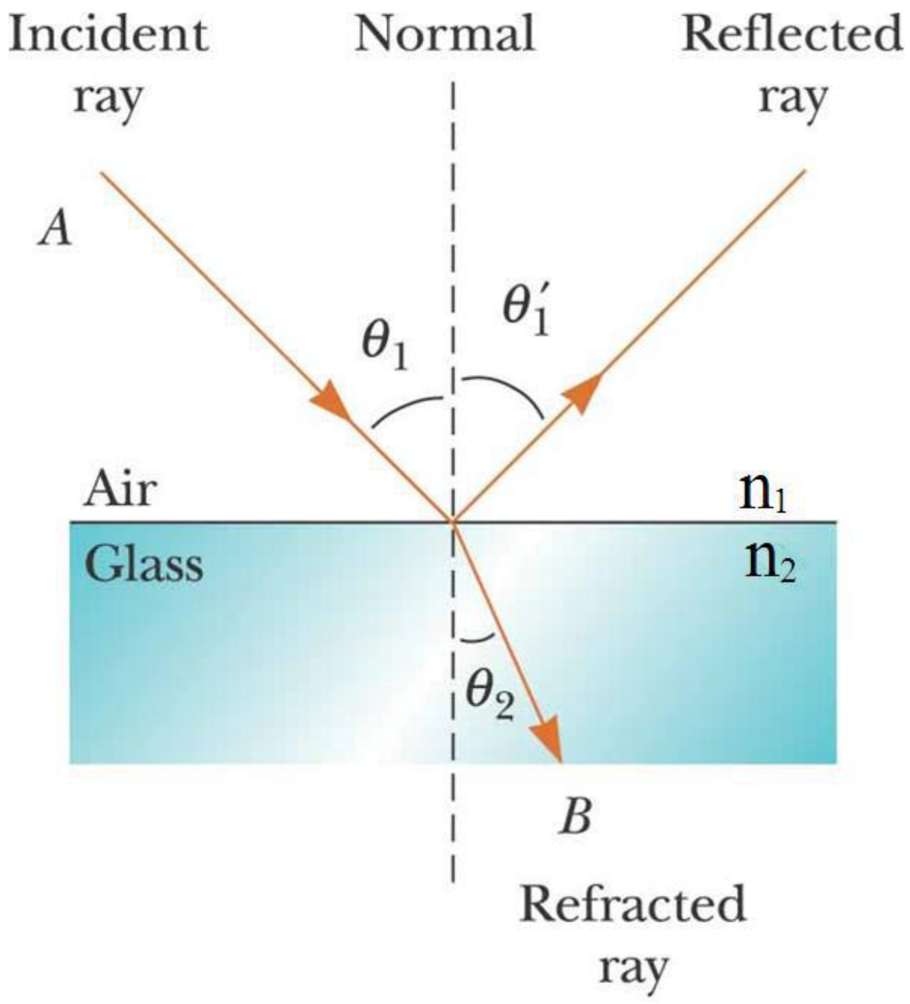


$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

قانون الانكسار:

الشعاع الساقط والشعاع المنكسر والعامود على نقطة السقوط تقع جميعها في مستوى واحد.
وزاويتا السقوط والانكسار والوسطان تربطهم العلاقة:

$$\mathbf{Sin\ \theta_2 / Sin\ \theta_1 = n_1 / n_2}$$



$$n = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ material}$$

Index of Refraction

In general, the speed of light in any material is *less* than its speed in vacuum. In fact, *light travels at its maximum speed in vacuum.* It is convenient to define the **index of refraction** n of a medium to be the ratio

$$n \equiv \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v} \qquad (35.4)$$

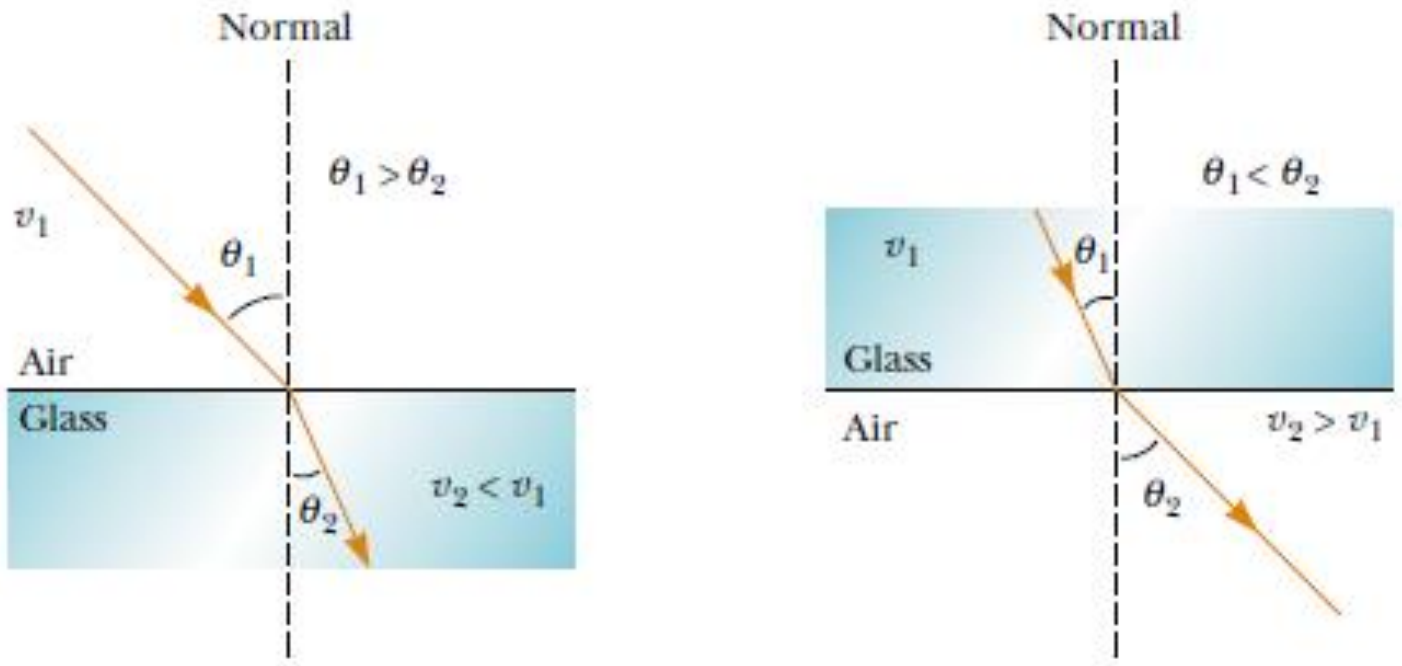
Material	Index of Refraction
Vacuum	1.0000
Air	1.0003
Ice	1.3100
Water	1.3330
Ethyl Alcohol	1.3600
Plexiglas	1.5100
Crown Glass	1.5200
Light Flint Glass	1.5800
Dense Flint Glass	1.6600
Zircon	1.9230
Diamond	2.4170
Rutile	2.9070
Gallium phosphide	3.5000

معامل الانكسار

هي نسبة سرعة الضوء في الفراغ إلى سرعته في المادة وهي دائما أكبر من واحد (تساوي 1 في الفراغ)

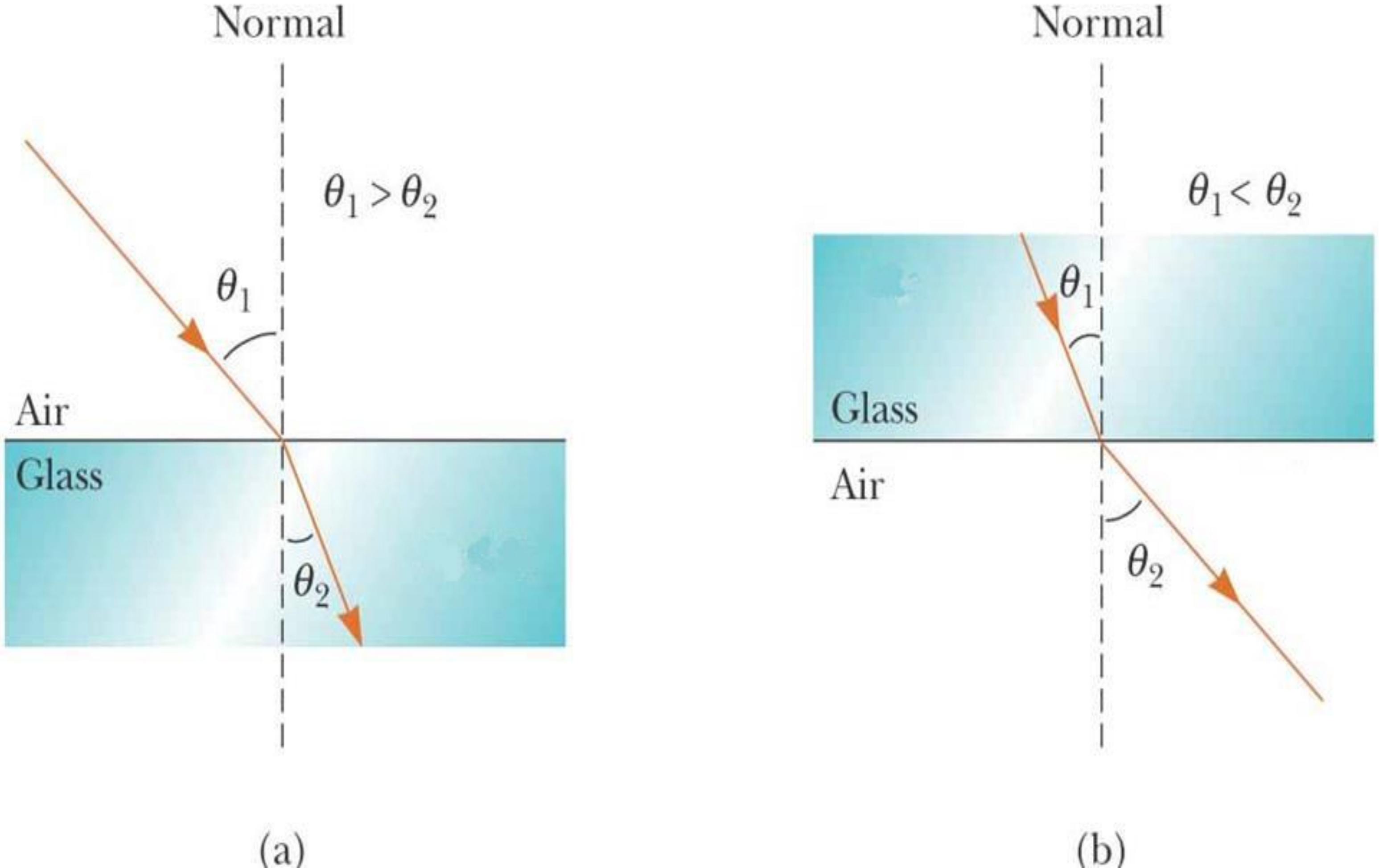
الوسط الذي معامل انكساره كبير يقال عنه أكثف ضوئيا

$$n = c / v$$



we can infer that when light moves from a material in which its speed is high to a material in which its speed is lower, as shown in Figure 35.11a, the angle of refraction θ_2 is less than the angle of incidence θ_1, and the ray is bent *toward* the normal. If the ray moves from a material in which light moves slowly to a material in which it moves more rapidly, as illustrated in Figure 35.11b, θ_2 is greater than θ_1, and the ray is bent *away* from the normal.

تغير قيمة زاوية الانكسار حسب سرعة الضوء في الوسطين:



(a): $n1 < n2$ therefore $\theta 1 > \theta 2$

(b): $n1>n2$ therefore $\theta 1 < \theta 2$

$$\sin\theta_2 / \sin\theta_1 = n_1 / n_2 = v_2/v_1 = \lambda_2 / \lambda_1$$

من العلاقتين (1) و (2) نحصل على:

$$n_1 = c / v_1 \quad 1$$

$$n_2 = c / v_2 \quad 2$$

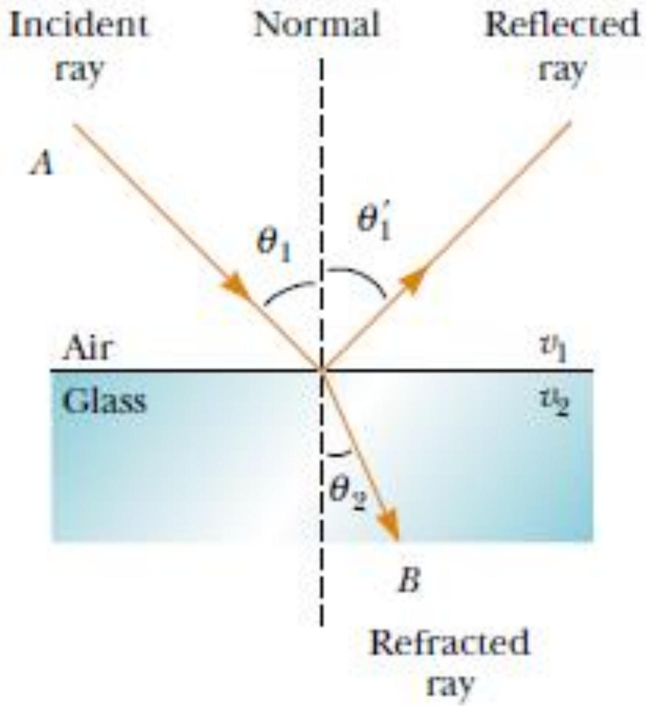
$$n_1/ n_2 = v_2 / v_1 \quad 3$$

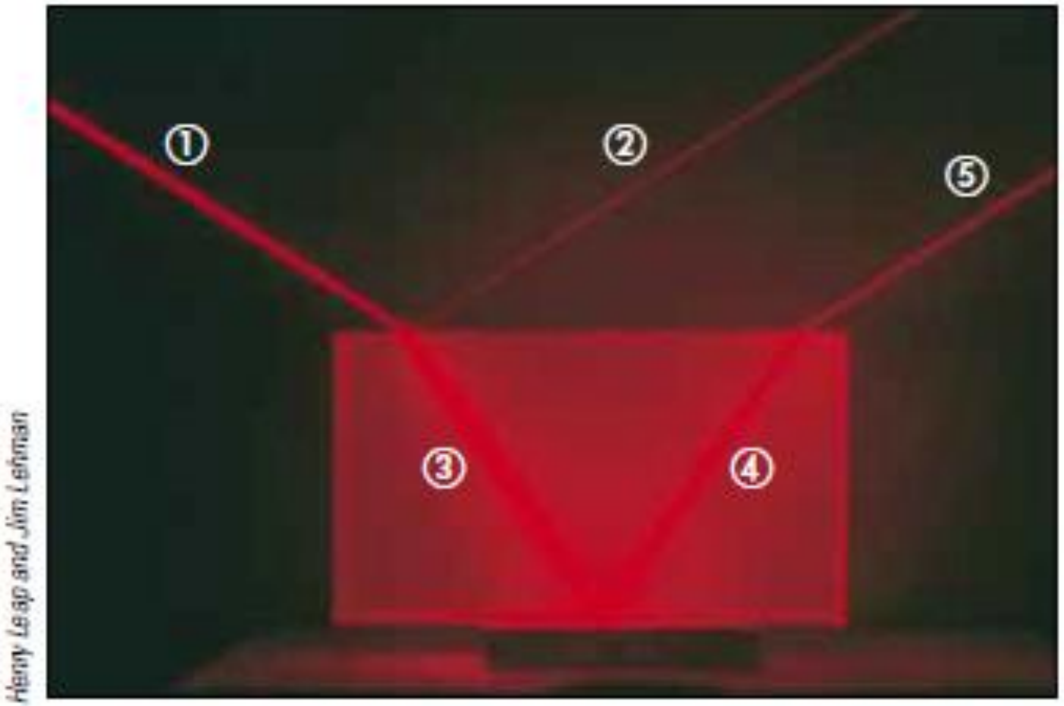
يبقى تردد الضوء ثابتا عند انتقاله في وسطين مختلفين بينما يتغير الطول الموجي

$$V = \lambda f \qquad V_2 = \lambda_2 f \qquad n_1/ n_2 = \lambda_2 / \lambda_1 \quad 4$$

$$V_1 = \lambda_1 f$$

REFRACTION OF LIGHT





$$\frac{\sin\,\theta_2}{\sin\,\theta_1} = \frac{v_2}{v_1} = \text{constant}$$

مثال 1:
إذا كان طول موجة شعاع ليزر هيليوم نيون He-Ne هو 632.8 nm فما هو التردد له وكم هو الطول الموجي في زجاج معامل إنكساره 1.5؟

$$f = v / \lambda = 3 \times 10^{8} \text{ m/sec} / 632.8 \times 10^{-9} \text{ m}$$

$$f = 4.74 \times 10^{14} \text{ Hz.}$$

$$n_1/n_2 = \lambda_2/\lambda_1$$

$1/1.5 = \lambda 2/ 632.8$

$\lambda 2 = 421.9$ nm

Example 35.3 An Index of Refraction Measurement

A beam of light of wavelength 550 nm traveling in air is incident on a slab of transparent material. The incident beam makes an angle of 40.0° with the normal, and the refracted beam makes an angle of 26.0° with the normal. Find the index of refraction of the material.

Solution Using Snell's law of refraction (Eq. 35.8) with these data, and taking $n_1 = 1.00$ for air, we have

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

$$n_2 = \frac{n_1 \sin \theta_1}{\sin \theta_2} = (1.00)\frac{\sin 40.0^\circ}{\sin 26.0^\circ}$$

$$= \frac{0.643}{0.438} = \boxed{1.47}$$

From Table 35.1, we see that the material could be fused quartz.

Example 35.4 Angle of Refraction for Glass

A light ray of wavelength 589 nm traveling through air is incident on a smooth, flat slab of crown glass at an angle of 30.0° to the normal, as sketched in Figure 35.15. Find the angle of refraction.

Solution We rearrange Snell's law of refraction to obtain

$$\sin \theta_2 = \frac{n_1}{n_2} \sin \theta_1$$

From Table 35.1, we find that $n_1 = 1.00$ for air and $n_2 = 1.52$ for crown glass. Therefore,

$$\sin \theta_2 = \left(\frac{1.00}{1.52}\right) \sin 30.0° = 0.329$$

$$\theta_2 = \sin^{-1}(0.329) = \boxed{19.2°}$$

Because this is less than the incident angle of 30°, the refracted ray is bent toward the normal, as expected. Its change in direction is called the *angle of deviation* and is given by $\delta = |\theta_1 - \theta_2| = 30.0° - 19.2° = 10.8°$.

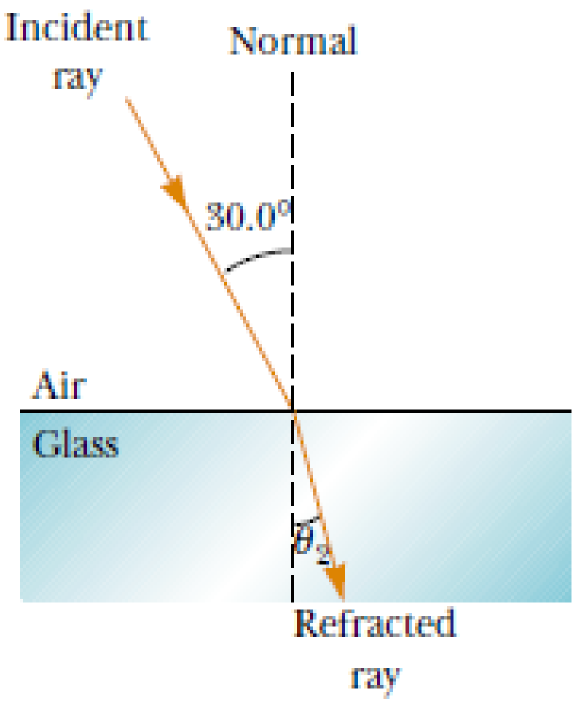


Figure 35.15 (Example 35.4) Refraction of light by glass.

Example 35.5 Laser Light in a Compact Disc

Example 35.5 Laser Light in a Compact Disc

A laser in a compact disc player generates light that has a wavelength of 780 nm in air.

(A) Find the speed of this light once it enters the plastic of a compact disc ($n = 1.55$).

Solution We expect to find a value less than 3.00×10^8 m/s because $n > 1$. We can obtain the speed of light in the plastic by using Equation 35.4:

$$v = \frac{c}{n} = \frac{3.00 \times 10^8 \text{ m/s}}{1.55}$$

$$v = \boxed{1.94 \times 10^8 \text{ m/s}}$$

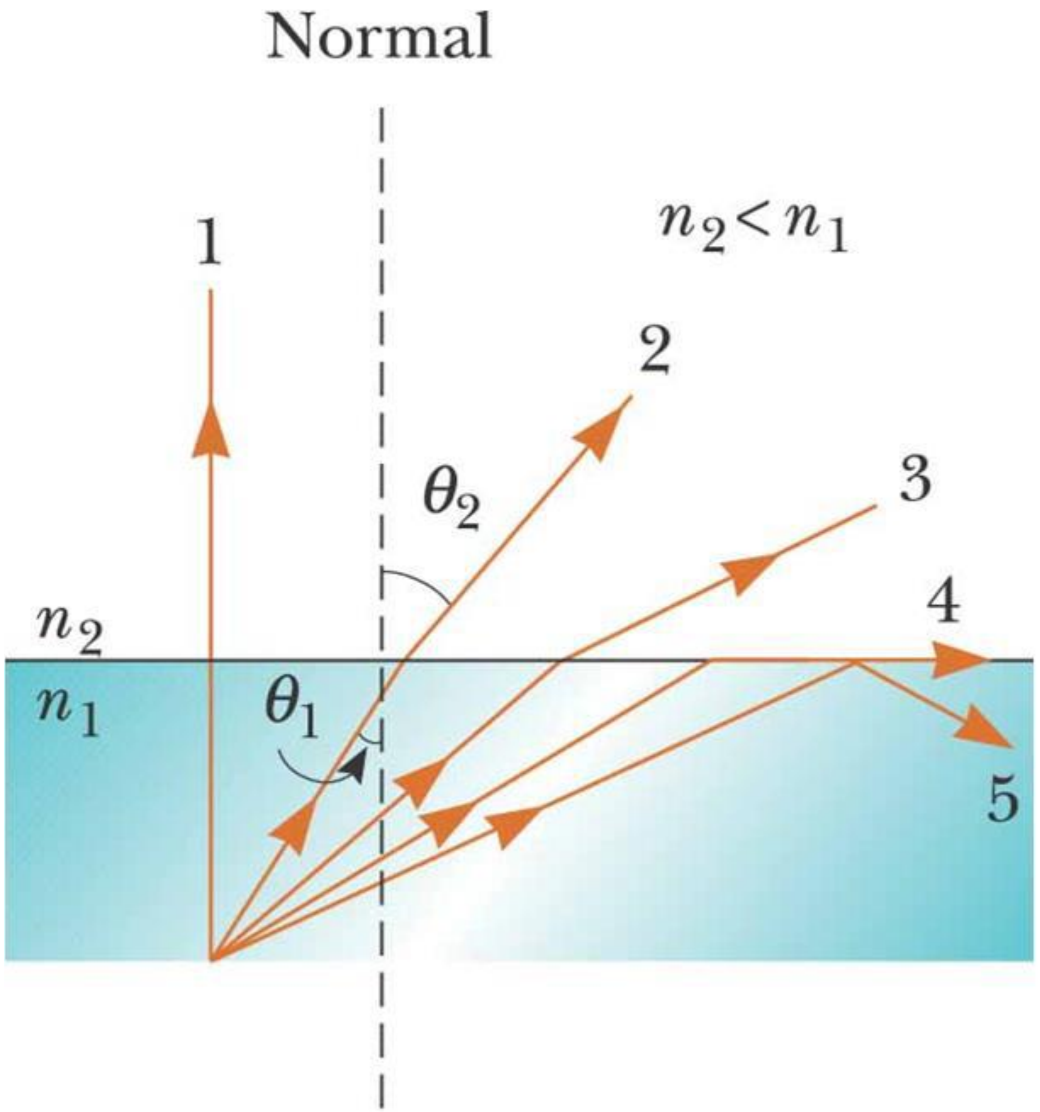
(B) What is the wavelength of this light in the plastic?

Solution We use Equation 35.7 to calculate the wavelength in plastic, noting that we are given the wavelength in air to be $\lambda = 780$ nm:

$$\lambda_n = \frac{\lambda}{n} = \frac{780 \text{ nm}}{1.55} = \boxed{503 \text{ nm}}$$

35.8 Total Internal Reflection

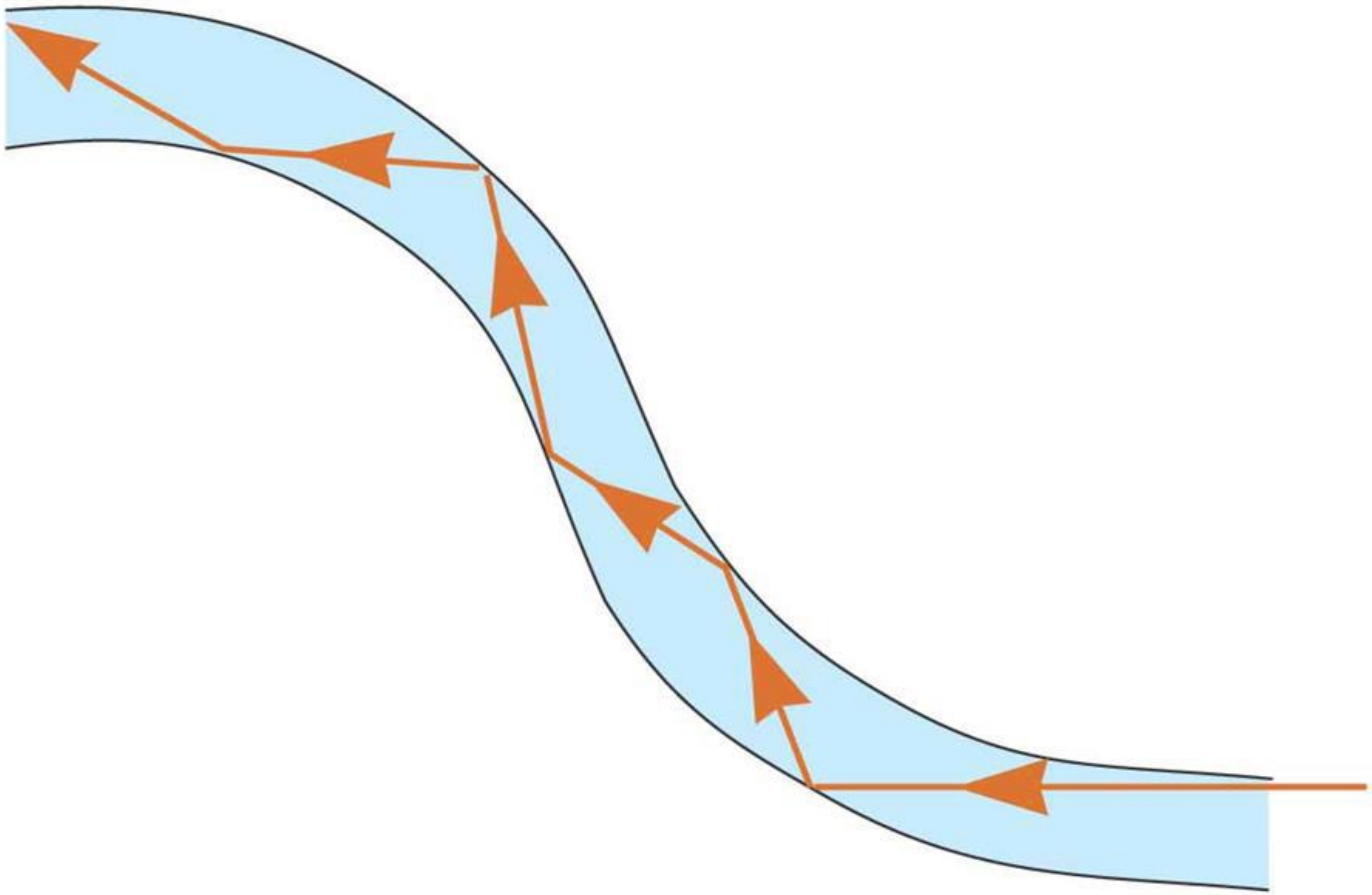
An interesting effect called total internal reflection can occur when light is directed from a medium having a given index of refraction toward one having a lower index of refraction. Consider a light beam traveling in medium 1 and meeting the boundary between medium 1 and medium 2, where n_1 is greater than n_2 .Various possible directions of the beam are indicated by rays 1 through 5. The refracted rays are bent away from the normal because n_1 is greater than n_2. At some particular angle of incidence *&c* , called the critical angle, the refracted light ray moves parallel to the boundary so that $\theta_2 = 90°$



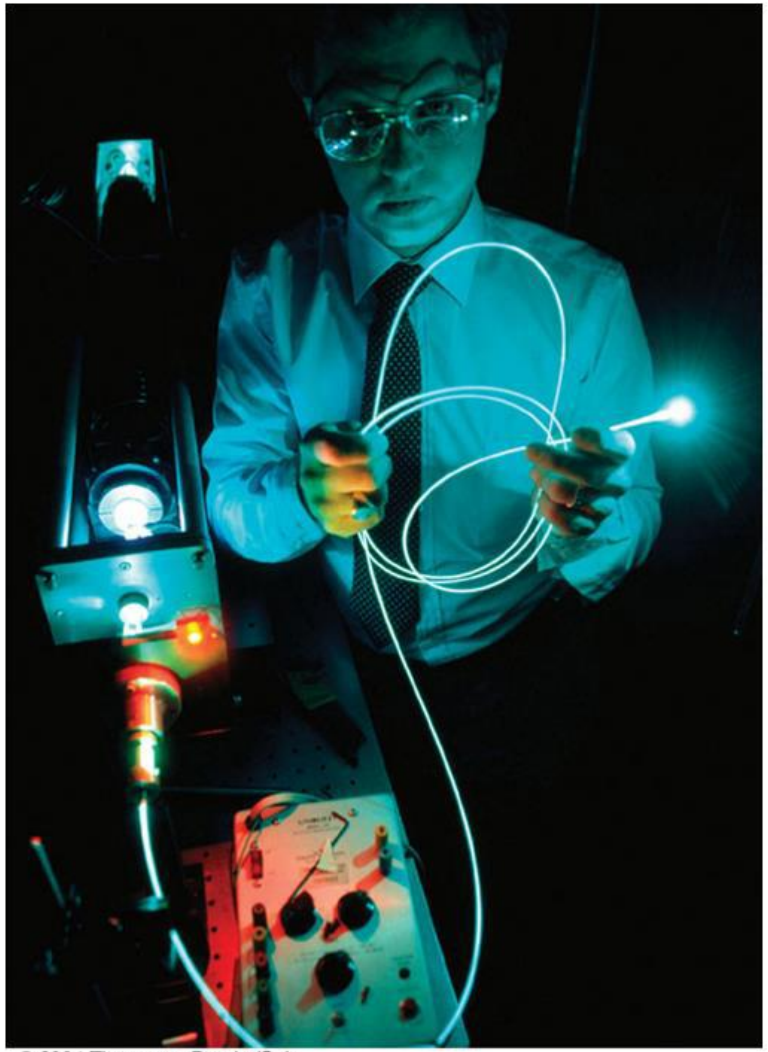
الانعكاس الكلي الداخلي

كلما زادت زاوية السقوط تزيد زاوية الانكسار إلى أن تصبح قيمتها 90 (الشعاع رقم 4). وبزيادة زاوية السقوط نحصل على انعكاس كلي داخلي Total internal reflection (الشعاع رقم 5)

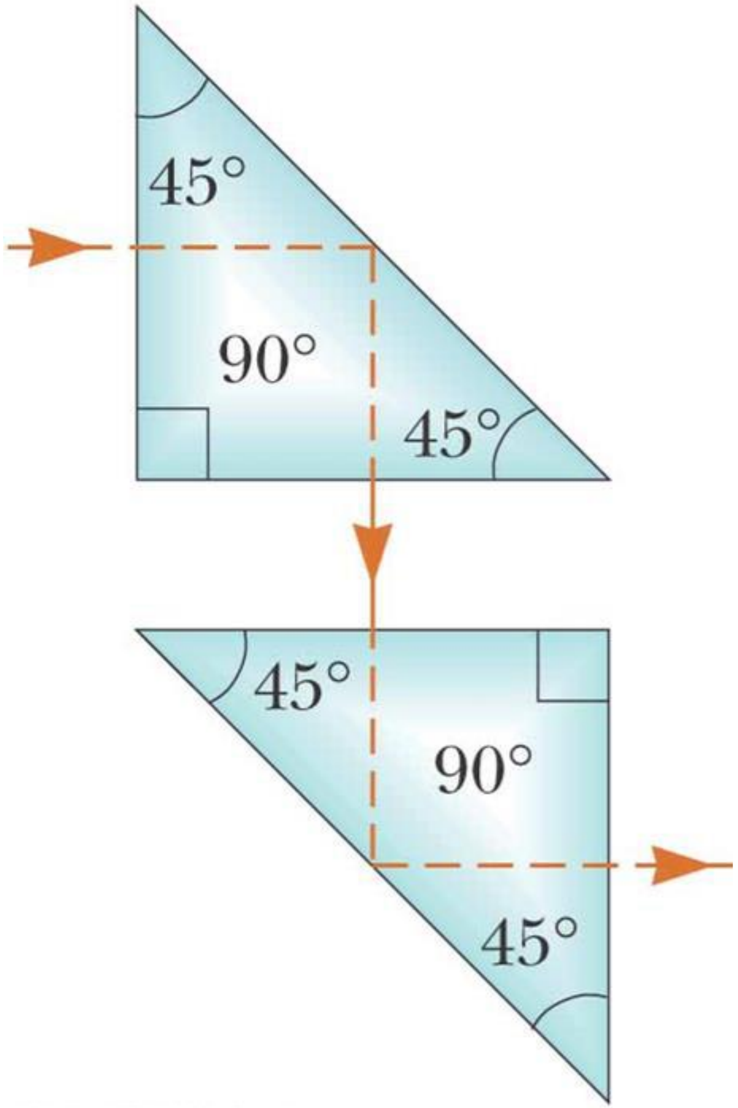
الانعكاس الكلي الداخلي

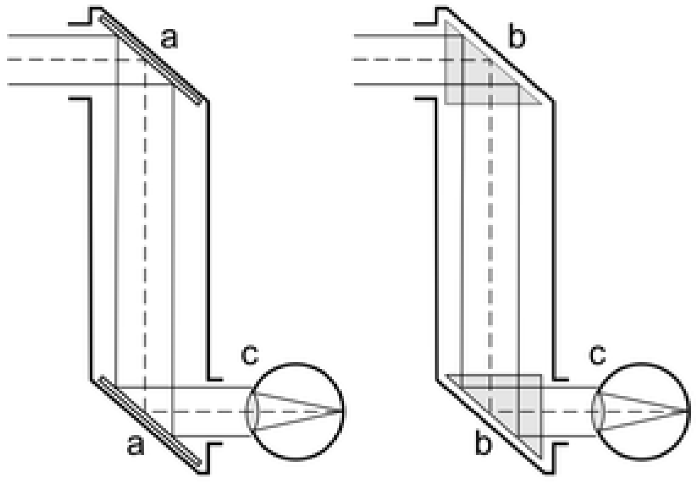


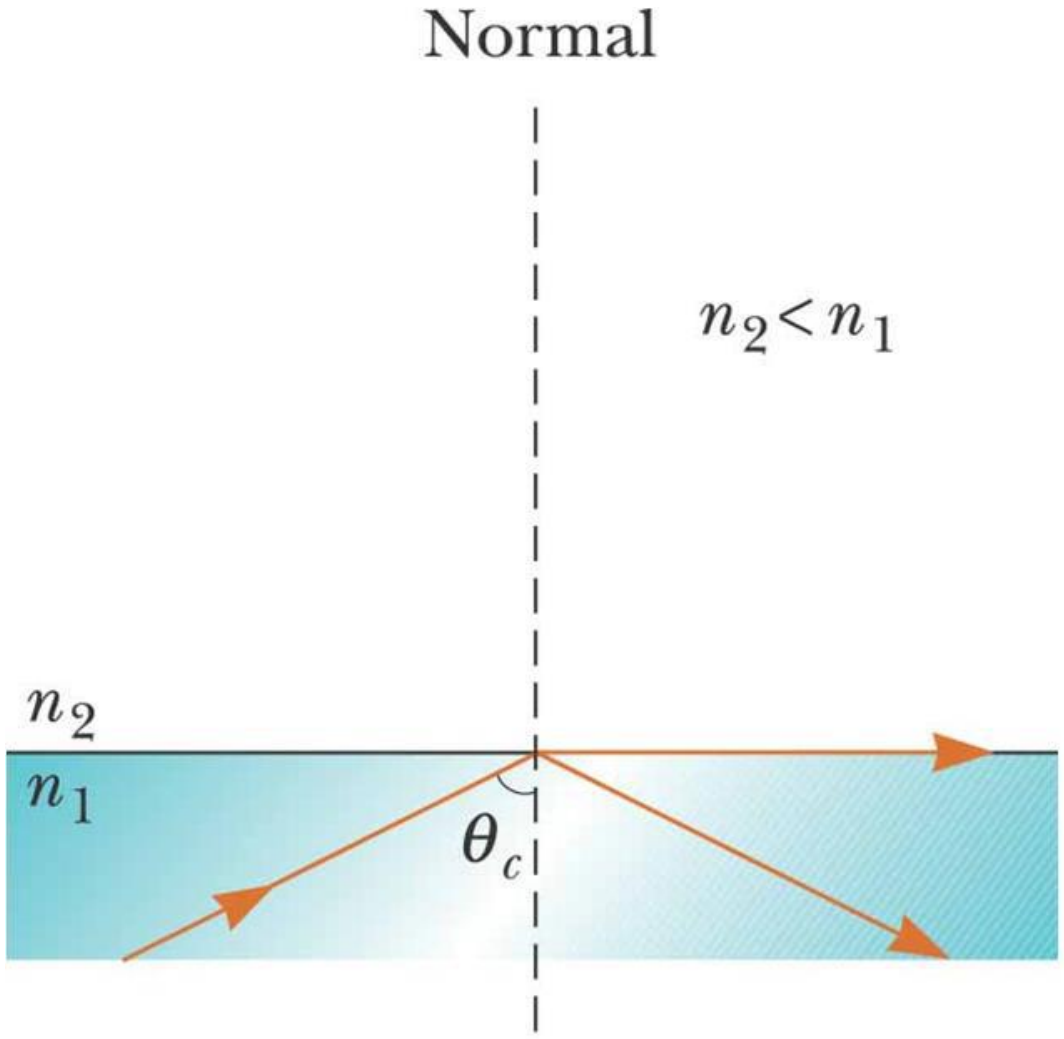
الانعكاس في الألياف البصرية
مثال للانعكاس الكلي الداخلي



الانعكاس في الموشور مثال
للانعكاس الكلي الداخلي







الزاوية الحرجة

θc Critical angle الزاوية الحرجة

هي زاوية السقوط التي تعطي زاوية انكسار قدرها 90 درجة في الوسط الآخر الذي له معامل انكسار أقل.

جميع طاقة الضوء الساقط تنعكس عند هذه الزاوية.

$$\sin \theta_c = n_2 / n_1$$

6) كم مقدار الزاوية الحرجة لشعاع خارج من الزجاج إلى الماء إذا علمت أن معامل انكسار الزجاج 1.5 ومعامل انكسار الماء 1.33

$$\sin \theta_c = n_2 / n_1$$

$$\theta c = \sin^{-1} n_2 / n_1$$

$$\theta c = 62.45^{o}$$

7) إذا كان معامل انكسار الالماس هو 2.42 فما هي الزاوية الحرجة للضوء عندما ينتقل من الالماس إلى الهواء.

$$\mathbf{Sin\ \theta_c = n_2 / n_1}$$
$$\mathbf{\theta c = Sin^{-1}\ n_2 / n_1}$$
$$\mathbf{\theta c = 24.40\ ^o}$$

8) احسب الزاوية الحرجة للمواد التالية إذا كانت محاطة بالهواء:
أ) الكوارتز)معامل انكساره 1.458 (
ب) زجاج الفلنت)معامل انكساره 1.66 (
ج) الثلج)معامل انكساره 1.309 (

$\text{Sin}\,\theta_c = n_2 / n_1$
$\theta c = \text{Sin}^{-1} n_2 / n_1$
$\theta c = 43.30\,^o$

$\text{Sin}\,\theta_c = n_2 / n_1$
$\theta c = \text{Sin}^{-1} n_2 / n_1$
$\theta c = 37.04\,^o$

$\text{Sin}\,\theta_c = n_2 / n_1$
$\theta c = \text{Sin}^{-1} n_2 / n_1$
$\theta c = 49.81\,^o$

9) يبعث جسم مضيء في قاع بركة ماء عمقها 150 cm أشعة ضوئية في جميع الجهات، تكونت دائرة ضوئية على سطح الماء بسبب الانعكاس الداخلي والانكسار للأشعة في الهواء، احسب نصف قطر تلك الدائرة)معامل انكسار الماء 1.33

$$\sin \theta_c = n_2 / n_1$$

$$\theta c = \sin^{-1} n_2 / n_1$$

$$\theta c = 48.70^{o}$$

$$0.75 = r / 150$$

$$r = 112.77 \text{ cm}$$