PhyzExamples: Light

Physical Quantities • Symbols • Units • Brief Definitions

Wavelength • λ • meter: m • Light wavelength is the distance between successive electric field maxima or minima or successive magnetic field maxima or minima.
Frequency • f or ν *(nu)* • hertz: Hz • The rate at which a source emits light waves or an observer receives light waves.
Speed • v • meters per second: m/s • The rate at which a light wave propagates through a transparent material.
Speed of Light in a Vacuum • $c = 3.0 \times 10^8$ m/s
Index of Refraction • n • unitless • The ratio of the speed of light in a vacuum to the speed of light in a transparent material.
Angle of Incidence • θ_1 • degrees: ° • The angle between an incident ray of light and the normal line from the point of incidence.
Angle of Refraction • θ_2 • degrees: ° • The angle between a normal line from the point of incidence and a refracted ray of light.
Critical Angle • θ_c • degrees: ° • The angle of incidence for a beam of light passing from a denser material to a lighter material such that the angle of refraction is 90°.

Equations

$c = f\lambda$ • *speed of light = frequency · wavelength*
$n = c/v$ • *index of refraction of a material = speed of light in vacuum / speed of light in the material*
$n_2/n_1 = v_1/v_2$ • *index of refraction of a second material / index of refraction of a first material = speed of light in first material / speed of light in second material* • $n = v_1/v_2$ (if first medium is air)
$n_2/n_1 = \lambda_1/\lambda_2$ • *index of refraction of a second material / index of refraction of a first material = wavelength of light in first material / wavelength of light in second material* • $n = \lambda_1/\lambda_2$ (if first medium is air)

Smooth Operations Examples

1. "Wild 107" broadcasts with a carrier frequency of 107.7 MHz. What is the wavelength of such radio waves?

1. $f = 107.7 \times 10^6$ Hz $c = 3 \times 10^8$ m/s $\lambda = ?$
$c = f\lambda$
$\lambda = c/f$
$\lambda = 3 \times 10^8$ m/s / 107.7×10^6 Hz
$\underline{\lambda = 2.79 \text{ m}}$

2. The speed of light in a crystal is 1.2×10^8 m/s. What is the index of refraction of the crystal?

2. $v = 1.2 \times 10^8$ m/s $n = ?$
$n = c/v$
$n = 3.0 \times 10^8$ m/s / 1.2×10^8 m/s
$\underline{n = 2.5}$

3. Light from a helium-neon laser emerges with a wavelength of 6328 Å. What is the wavelength when the light is passing through regular glass?

3. $\lambda_1 = 6328 \times 10^{-10}$ m $n_2 = 1.52$ $n_1 = 1.00$ (air)
$n_2/n_1 = \lambda_1/\lambda_2$
$\lambda_2 = \lambda_1 n_1/n_2$
$\lambda_2 = 6328 \times 10^{-10}$ m · 1.00 / 1.52
$\underline{\lambda_2 = 4163 \times 10^{-10} \text{ m}}$ $\underline{(= 4163 \text{ Å})}$

PhyzReference: Indices of Refraction

DEFINITION

By definition, the index of refraction *n* of a material is the ratio of the speed of light in a vacuum to the speed of light in the material.

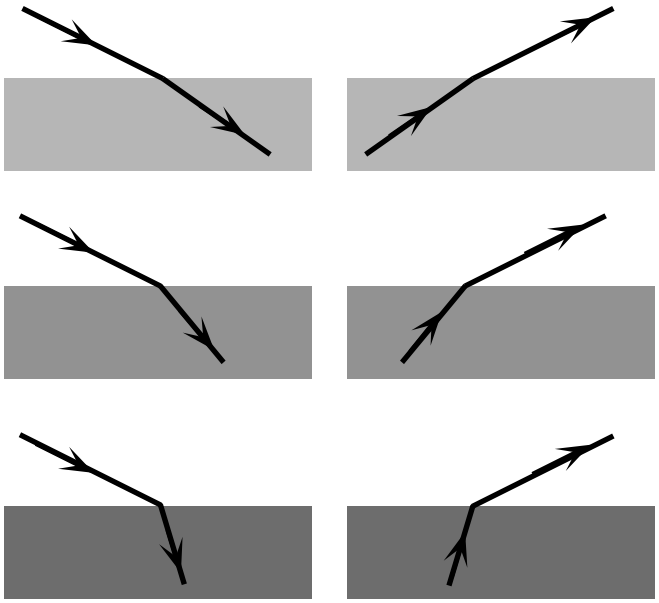
$$n = c/v$$

n is the index of refraction for a given material with respect to a vacuum
c is the speed of light in a vacuum: c = 299,792,458 m/s (exactly)
v is the effective speed of light in the material

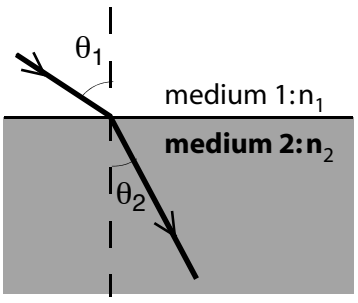
Indices of Refraction for Various Substances*

Substance	*n*
Air	**1.0003**
Ice	**1.31**
Water	**1.33**
Ethyl Alcohol	**1.36**
Quartz	**1.46**
Glycerin	**1.47**
Polystyrene (plastic)	**1.49**
Benzene	**1.50**
Glass, crown/lime/regular	**1.52**
Glass, flint	**1.63**
Carbon disulfide	**1.63**
Zircon	**1.92**
Fabulite	**2.41**
Diamond	**2.42**
Gallium Phosphide	**3.50**

*all values relative to a vacuum; λ = 589 nm yellow light



from low index material to high index material



θ_1 = angle of incidence
θ_2 = angle of refraction

from high index material to low index material