

# Understanding the Optical Properties of Glass

**SWIFT GLASS**

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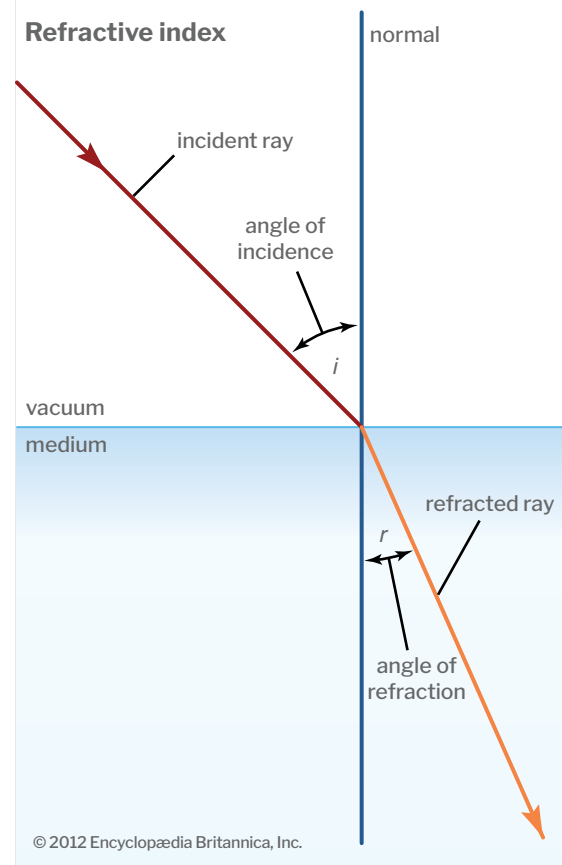
## Refractive Index

The refractive index ( $n$ ), also commonly referred to as the index of refraction, measures the bending of a ray of light as it passes out of one medium and into another.

Light's speed is reduced as it begins to travel through a material. This occurs as a result of the interaction between electrons and photons. The higher the density of the electrons, the lower the velocities, which explains why light moves quickly in glass, even quicker in water, and quickest of all when unobstructed in a vacuum.

So, to determine the refractive index of a given material, one must determine the ratio between the speed of light in a vacuum and the reduced speed the light travels through said material.

When light rays encounter a glass surface, some of the light gets reflected, and some continues onward and is transmitted through the material. The glass's refractive index will determine the amounts of transmitted and reflected light, as well as the angle of refraction within the glass.



Using Snell's law, it's possible to calculate the light's transmission angle:

$$n_{\text{air}} \sin \theta_1 = n_{\text{glass}} \sin \theta_t$$

The larger the index of refraction, the bigger the discrepancy between the light's transmission and the incidence angle. At this point, an immediate change occurs in the refractive index existing between the glass and the medium it is surrounded by.

For normal incidences ( $i = 0^\circ$ ), the amount of reflected light can be determined using the following formula:

$$R = 100 \times \left( \frac{n_{\text{air}} - n_{\text{glass}}}{n_{\text{air}} + n_{\text{glass}}} \right)^2$$

For the majority of glass materials that possess a 1.5 rating on the index of refraction, lost reflection from the glass surface will cause an average 4% reduction in the intensity of the light.

## Chromatic Dispersion

Chromatic dispersion refers to the change of index of refraction due to changes in wavelength. Typically, the index decreases as wavelength increases, as blue light travels slower than red light in the material. Dispersion refers to the phenomenon that creates color separation in a prism. Dispersion also causes (usually undesirable) chromatic aberration in lenses.

In most situations, the dispersion of a material is characterized by measuring the index at the blue F line of hydrogen (486.1 nm), the red hydrogen C line (656.3 nm), and the yellow sodium D line (589.3 nm). Dispersion is measured using the standard parameter of Abbe's number, or the V number or V value.

In transparent media, blue light travels slower than red light.

$$v = \frac{(n_D - 1)}{(n_F - n_C)}$$

hydrogen blue sodium yellow hydrogen red

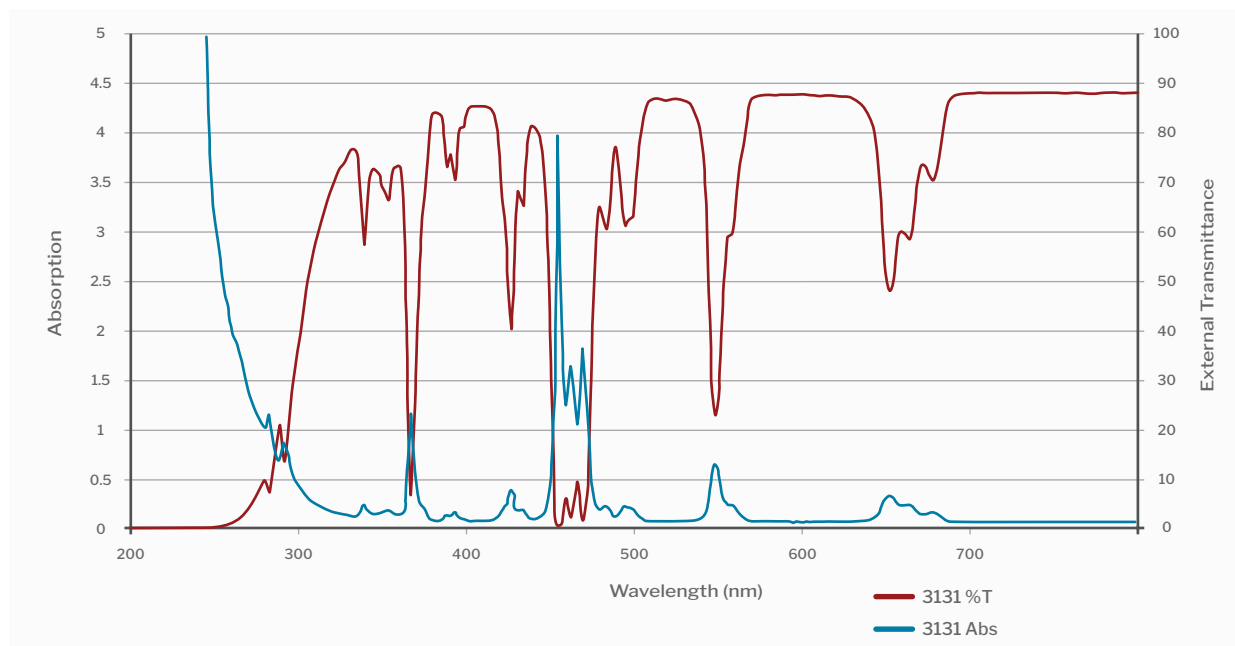
Glasses where  $v \geq 55$  (low dispersion) are called crowns

Glasses where  $v < 50$  (high dispersion) are called flints



## The Absorption Rate in Glass Materials

A beam of light's intensity is usually reduced as it travels through a glass. Absorption occurs when a photon contained within the light emits energy matching the amount required to excite the glass's electron to its higher-energy state. This causes the glass to absorb the photon



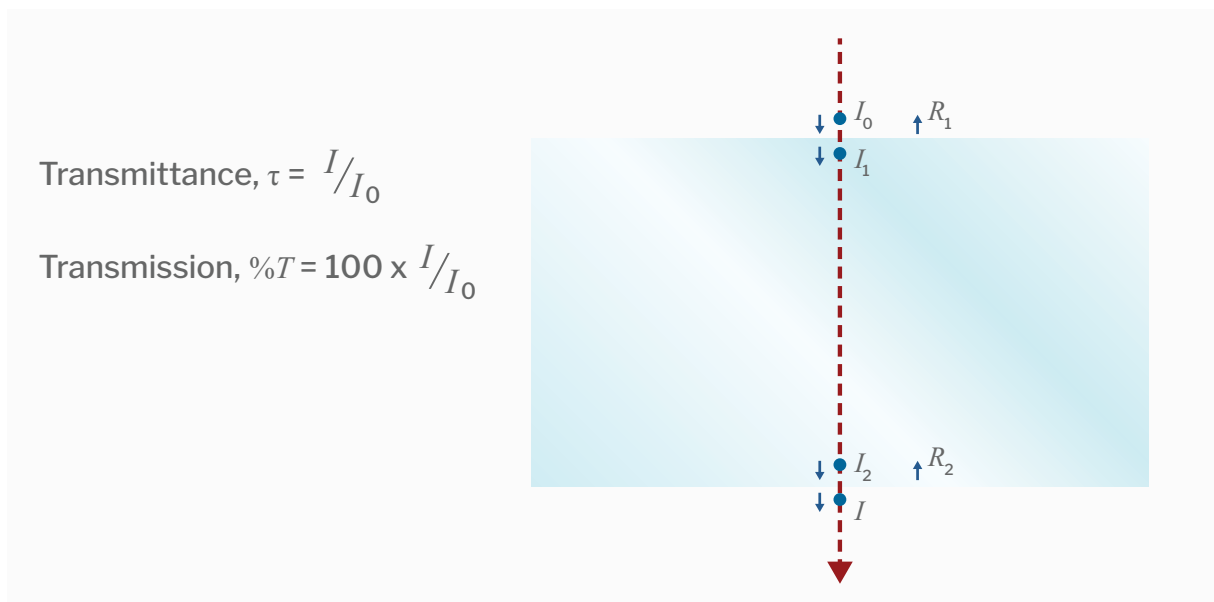
Depending upon the composition of a specific glass material, the absorption spectrum of a particular glass may differ.

Glass materials with standard composition display standard absorption peaks in the spectra. The glass plotted to the left (Kopp Glass' 3131 filter glass) is one such glass, and is used to reliably calibrate spectrophotometers. Large absorption peaks directly correlate with decreases in the transmission spectra

## Transmission/Transmittance

Any light not reflected at the glass's surface or absorbed by it ends up being transmitted into and through it. In many applications, it's crucial to determine the amount of light that passes through a particular glass material at a specific wavelength.

Glasses are often assessed and discussed based on their transmission or transmittance. Transmittance and transmission convey roughly the same information; the only difference being in the way the information is displayed. Transmission reporting is based on a percentage range of 0% to 100%, while transmittance is reported based on a decimal range of zero to 1.



External transmission may be calculated based on the intensity of the incident light ( $I_0$ ) and the light's intensity after exiting the glass ( $I$ ). This calculation accounts for reflection from the glass surface.

Internal transmission, however, excludes losses from reflection. Internal transmission is determined by the intensity of the light that has just entered the glass ( $I_1$ ) and its intensity as it leaves the glass ( $I_2$ ).

This method of internal transmission is frequently used to report transmittance, and may be determined as follows:

$$t_i = \frac{I_2}{I_1}$$



## About Swift Glass

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We're happy to offer our expertise and recommendations, ensuring customers receive the best possible glass solution for their specific needs.

To learn more about glass material and their optical properties, or to discuss the concepts outlined here in greater detail, reach out to Swift Glass today. As an ISO 9001:2015- certified, ITAR-registered, industry-leading fabricator of glass parts, we're proud to serve as the premier specialist in all aspects of glass fabrication.

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