

# **OPTICAL PROPERTIES OF GEMS**

**Properties related to the behavior of light on, or in, a gemstone. Some of these can be seen, and even quantified, with the naked eye alone.**

# **OPTICAL PROPERTIES OF GEMS**

**Related to interaction of light with gemstones**

# Categories

## Visually observed

- Color
- Luster
- Transparency

## Measured by special instruments

- Refractive index
- Optical character
- Birefringence
- Pleochroism
- Dispersion
- Reaction to ultraviolet light
- Selective absorption

# Properties of Light

- Light- a form of energy which can be transmitted from one place to another at finite velocity
- Visible light part of a continuous spectrum of radiation ranging from cosmic rays to radio waves

# Properties of light

## Particle theory

- release of a small amount of energy as a photon when an atom is excited

## Wave theory

- radiant energy travels as a wave from one point to another.
- Waves have electrical and magnetic properties
  
- Wave theory explains
  - Polarization
  - Reflection
  - Refraction
  - interference
  - Components of a Light Ray

# OPTICAL PROPERTIES OF GEMS

Other characteristics are revealed, or measured, only through the use of special instruments. Some of these include: refractive index, optical character, birefringence, pleochroism, dispersion, reaction to ultraviolet light and selective absorption. When these properties of gems are analyzed and measured, one is engaging in *laboratory gemology*.

# 1. Luster

The luster of a gemstone is comprised of the *quantity and quality* of the light reflected from its surface. There is an inherent, potential luster possible for each species and variety of gemstone. The actual luster, on any individual piece, however; may be less than this, due to the skill level of the lapidary or faceter, the presence of inclusions, or various chemical or physical changes, such as oxidation or abrasion, that can affect the surface.

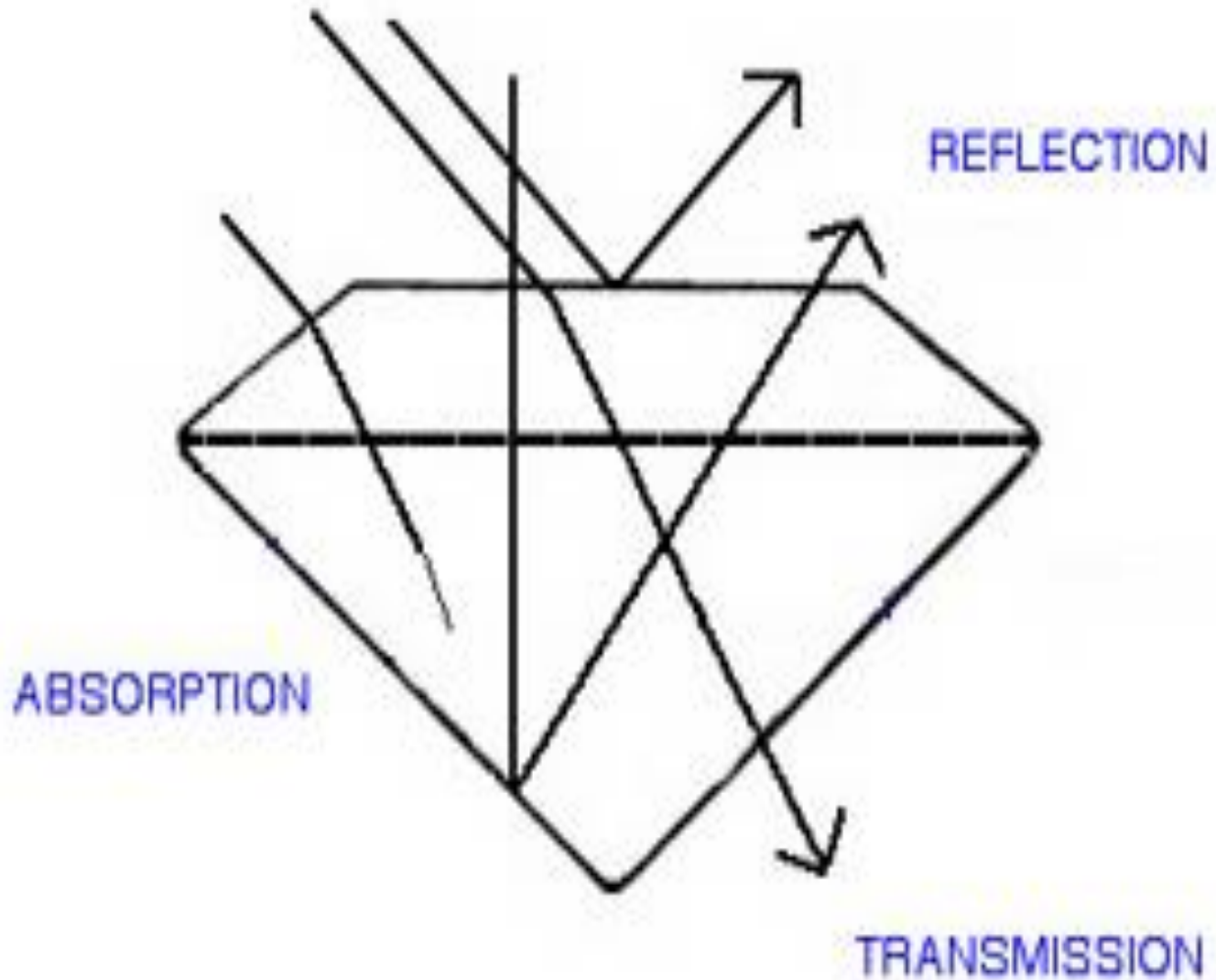
# Transparency

**Technically known as "diaphaneity", is the degree of transparency of a gemstone.**

**Transparency (or lack of it) is dependent on how much light gets through the gem, and is affected not only by the chemical and crystalline nature of the gem, but also by its thickness and, as in the case of luster, by inclusions, and its surface condition.**

# Transparency

When light hits the surface of a gem, there are only three fates for it (with respect to transparency). Various portions of the total amount of light will be reflected, absorbed or transmitted. The proportion in each category will determine the transparency of that gem.



# FATE OF LIGHT

**Reflection:** Light is reflected when it hits an exterior or interior surface of the gem and is bounced back off, or out of, the gem, in the direction of the observer.

**Absorption:** When light enters a gem and does not exit, we say it has been absorbed. Light is a form of energy, and energy does not just disappear, instead the visible light has been converted to a non-visible form of energy, in most cases, heat.

# FATE OF LIGHT

**Transmission:** Light that travels through the gem and exits in a direction other than that of the observer, is said to have been transmitted.

# Transparency

The issue of transparency (with the factors of reflection, absorption and transmission) is intimately linked with the color characteristics of a gem.

For the time being, however; we can be satisfied with the following descriptions:

***Opaque:*** No light is transmitted.

***Translucent:*** Some light is transmitted.

***Transparent:*** A high proportion of the light is transmitted.

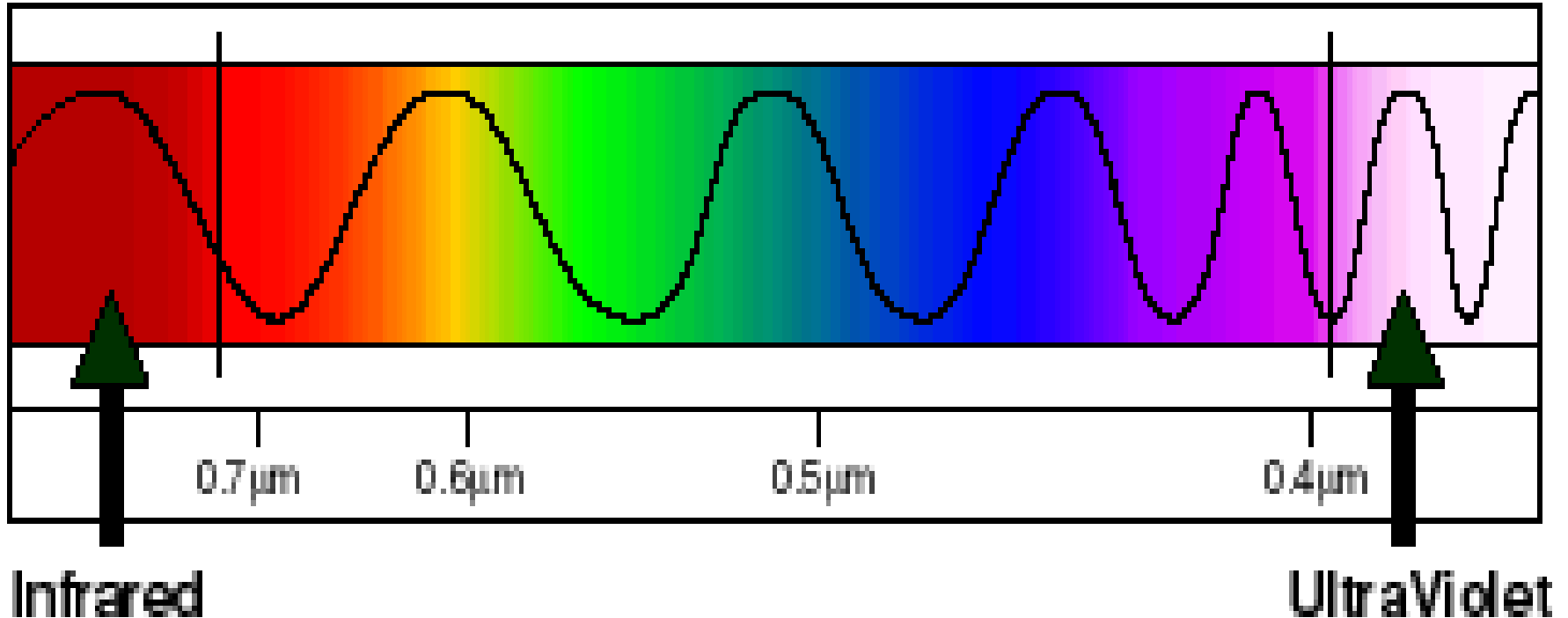
# Transparency

***Within any particular species of gem, it is often the most transparent pieces which are the most valuable.***

# Color

The color of a gem is determined by selective absorption of some of the wavelengths of light. We know that what appears to us as white (or colorless) light is actually made up of light of various colors. Issac Newton was the first to demonstrate this back in the 17th century.

# Visible Light Region of the Electromagnetic Spectrum



**The color of light is a function of its wavelength**

# Visible Light Spectrum (nm)

*infrared, microwaves and radiowaves*

- **700 - 630 = red**
- **630 - 590 = orange**
- **590 - 550 = yellow**
- **550 - 490 = green**
- **490 - 440 = blue**
- **440 - 400 = violet**

*ultraviolet, xrays and gamma rays*

*light of shorter wavelength is more energetic than light of longer wavelength.*

# Selective Absorption

The color of most objects, gems included, is a result of a process called "selective absorption".

With opaque objects it is the color of *reflected* light that we see, with transparent and translucent ones, the color we see consists of a mix of both their reflected and transmitted wavelengths.

# Transparency and Color

***Transparency* will depend on the relative proportion of light reflected, transmitted and absorbed by a gem. The *color* of the gem will depend on what is reflected or transmitted after selective absorption has removed some portion of the spectrum.**

- If none of the wavelengths are absorbed: the gem will be colorless if it is transparent, or white if opaque.
- If equal amounts of each wavelength are absorbed: the gem will be grey.
- If all wavelengths are absorbed equally and completely: the gem will be black.
- In colored gems: we will see a mix of wavelengths which were not absorbed and which (depending on reflectance vs transmittance) will give us a colored transparent, translucent or opaque gem.

# Chromophores

**The atoms (or ions) which create color in a gem are called "*chromophores*". Some of the most common chromophores in gemstones are: atoms of titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, nitrogen, and boron and their various ions.**

# Idiochromatic and Allochromatic Gems

With regard to the source of their color, gems fall into two categories: *idiochromatic* and *allochromatic*.

# Idiochromatic Gems

**Idiochromatic gems derive their color simply from the chemistry of their basic formula. Due to this fact, such gems will always occur in various shades of the same basic color.**

# Idiochromatic Gems



*Cuprite ( $\text{Cu}^{+1}$ )*



*Rhodocrosite ( $\text{Mn}$ )*



*Malachite ( $\text{Cu}^{+2}$ )*



*Peridot ( $\text{Fe}^{+2}$ )*

**Cuprite is red, malachite is green, and both contain copper! What gives the color?**

**Each gem's color is determined by an interplay between its chemical makeup (including the ionic state of its chromophores) and its structure.**

# Allochromatic

The more common group are the allochromatic gems. The chemistry of their basic formula does *not* cause any selective absorption so in the pure state, they are white or colorless. In gems of this sort it is tiny, trace amounts of impurities that act as the chromophores. Such gems occur in colorless forms as well as in a variety of other colors depending on the nature and amount of the "contaminants" in them.

# Allochromatic Gems

Some examples of allochromatic gems are: beryl, corundum, quartz, grossular garnet, tourmaline, topaz, spinel and nephrite jade. In some cases the "pure" material is the most common and therefore the lowest in value (corundum, quartz, beryl and topaz are in this category); but in others, the pure form is so rare as to be a high value collector's item. This is especially true in the case of grossular garnet, tourmaline and nephrite jade. Colorless spinel is so rare that it literally has not been found in Nature; we know it can exist, though, because colorless synthetic spinel is made in labs.

A good example of an allochromatic gem species is corundum. Pure  $\text{Al}_2\text{O}_3$  is colorless, as in white sapphire, but if we add just a tiny bit of iron to the mix then we get yellow or orange fancy sapphire, pair the iron with a bit of titanium, and the gem is the familiar blue, and if chromium is the chromophore, then the corundum is red and called ruby.

**To further pursue this point: some emeralds are green due to chromium content, while some get their green color from vanadium. So, iron (as in peridot), copper, chromium or vanadium can each be responsible for "greenness" in a gem. But on the other hand, chromium in corundum makes red rubies, and iron in chalcedony, makes orangey carnelian, but in sapphires gives us yellow. Furthermore, green zircons and green diamonds get their color not from chromophores, but from crystal defects.**

# Allochromatic Gems (in their pure state)



*"white" sapphire*



*colorless quartz (rock crystal)*



*Colorless beryl (Goshenite)*



*colorless grossular garnet (leucogarnet)]*

# Allochromatic Gems (in their impure state)



*Beryl: emerald (chromium or vanadium)*



*Corundum: sapphire (titanium and iron)*



*Quartz: carnelian (iron)*



*Garnet: Spessartite (manganese)*

# Other Sources of Color

**Some gems get their color (or apparent color) from visible to microscopic inclusions of other minerals within them.**

**One of the most beautiful of all the chalcedonies, often called "gem silica" but more properly termed "chrysocolla chalcedony" has a vivid blue-green color. The minute quartz crystals are actually colorless, but in amongst them are tiny crystals of the blue green (very soft) mineral, chrysocolla.**

# Patterns in color

## Banding/zoning

One of the most common features of some of the aggregate gems is the presence of patterning. Since these gems are formed from very tiny single crystals, we can easily envision conditions where differently colored pools or batches of tiny crystals mix and intermesh creating bands, dots or other patterns. Agates and jaspers are the most commonly seen gems with strong patterns.

# Patterns in color

It frequently happens that single crystal gems subjected to changing conditions during their growth can also show bands or zones of different colors or shades of the same color. When these are dramatic and attractive, they are desirable, but far more commonly, gems of this type have nondescript, patchy, or zoned coloration, and are considered inferior to more evenly colored pieces.

# Aggregates With Patterns



*Zebra agate*



*Picture jasper*



*Mookaite jasper*



*Carnelian*



*lavendar agate,*



*Dalmation jasper*



*Rain forest jasper*

# Single Crystal Gems with Attractive Color Zoning



*multi-color tourmaline,*



*Ametrine*



*watermelon tourmaline*

# Refraction and Birefringence

When a ray of light passes from air into a denser medium, such as a gemstone, part is reflected from the surface and part enters the gem material. Light entering the gem is slowed and bent, with the amount of bending dependent upon the angle with which it hit the surface and velocity of light in the two media.

Higher angles and greater velocity difference between air and the gem will result in greater refraction. This refraction or bending of light can be measured and this number is termed the refractive index. ***This index is a constant in different types of gems and is used in identification..***

# Refraction and Birefringence

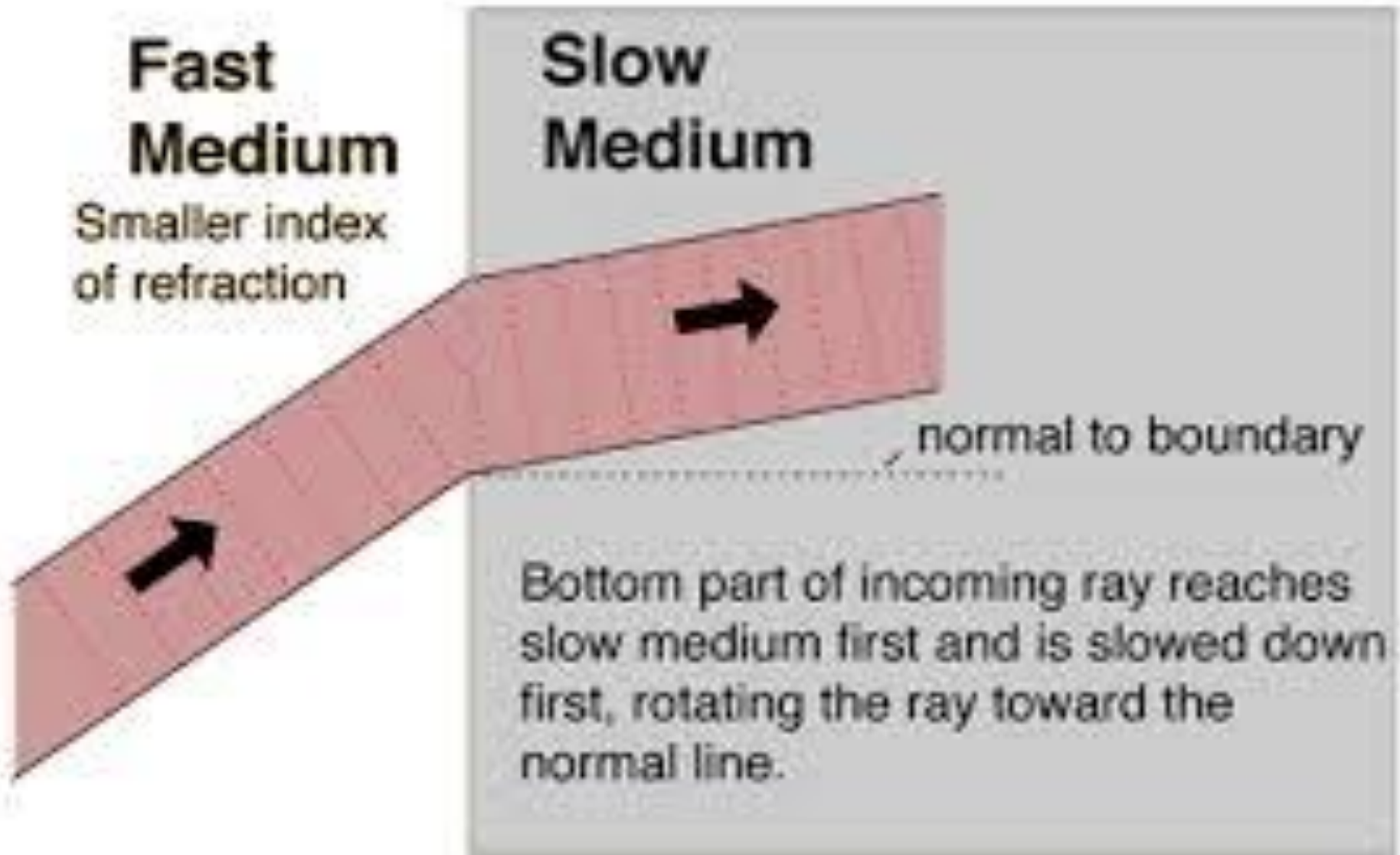
Higher angles and greater velocity difference between air and the gem will result in greater refraction.

# ***birefringence***

When light hitting a gemstone splits into two rays travelling through the stone at different speeds and in different directions, ***the reaction is called birefringence or double refraction***. This is seen uncommonly and in a variety of calcite called Iceland Spar as well as zircon, rutile, and sphene.

# Behavior of Light - Refraction

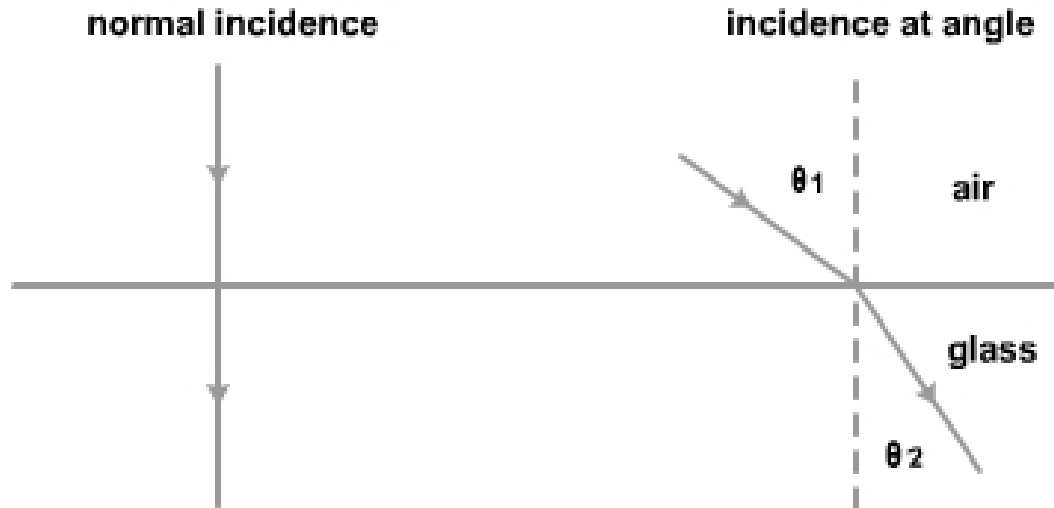
The ratio of the speed of light in air, to the speed of light in a gem, is called the gem's *refractive index* or RI. It differs, sometimes dramatically, between gem species, and is one of the most useful gem identification criteria. In natural gems it ranges from about 1.2 to 2.6. and can, in most cases, be measured by an instrument called a refractometer.



# Refraction and Birefringence

The refractive index is defined as a ratio of the speed of light in air to the speed of light in the stone. That is, if the speed of light in air is 300,000 km/sec and speed of light in diamond, 125,000 km/sec, then dividing 300,000 by 125,000 is 2.4 or the refractive index of diamond is 2.4. Light in air is 2.4 times faster than the speed of light in diamond

When a ray of light is incident at normal incidence, (at right angles), to the surface between two optical materials, the ray travels in a straight line.



When the ray is incident at any other angle, the ray changes direction as it refracts.

The dotted line is the normal (perpendicular) to the surface. In refraction, calculation angles are always measured between rays and the normal.

The change in direction of a ray depends on the change in speed of the light and can be used to calculate refractive index.

For the example above the refractive index  $n$  of the glass is given by:

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

When you use this relationship, angle must always be the angle in a vacuum (or air).

# Refractive index

The speed of light is determined by the **medium** (material) through which the light is travelling. Light travels faster in a vacuum than it does in any other medium.

Light changes speed as it passes from one medium to another. This is called **refraction**.

The frequency of light does not change as it refracts.

Refractive index of a material is a measure of the change in speed of light as it passes from a vacuum (or air as an approximation) into the material.

$$n = \frac{v_1}{v_2}$$

In the equation above,  $v_1$  is the speed of light in a vacuum. The bigger the refractive index the slower the light travels in that material - i.e. the smaller  $v_2$  is.



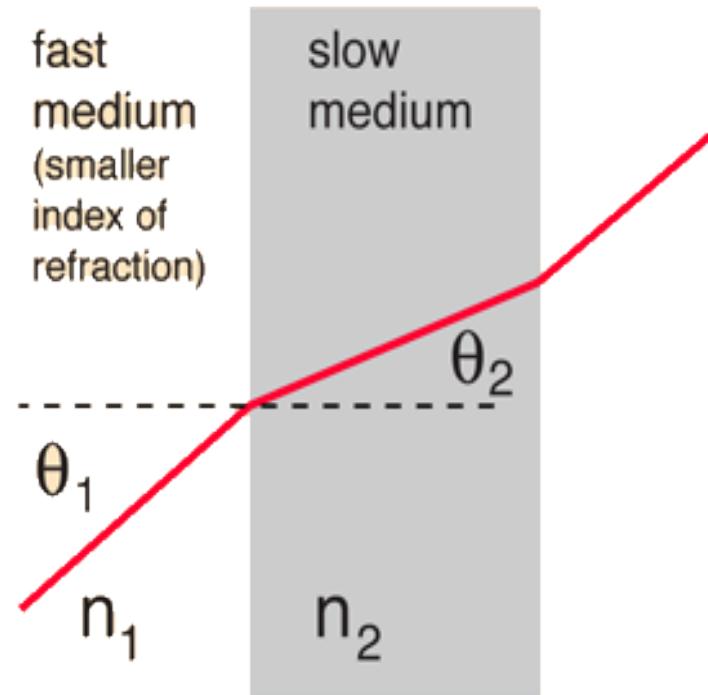
Diamonds have a very high refractive index of 2.42

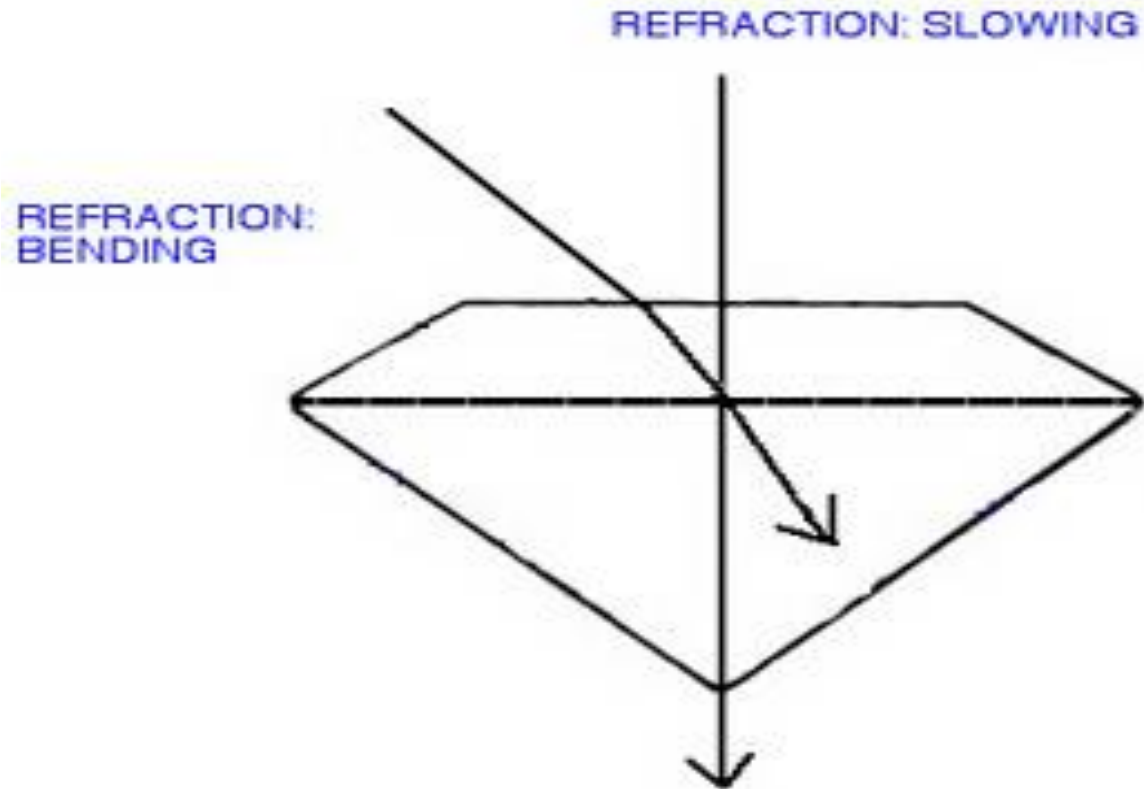
# Snell's Law

Snell's Law relates the [indices of refraction](#)  $n$  of the two media to the directions of propagation in terms of the angles to the normal. Snell's law can be derived from [Fermat's Principle](#) or from the Fresnel Equations.

## Snell's Law

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



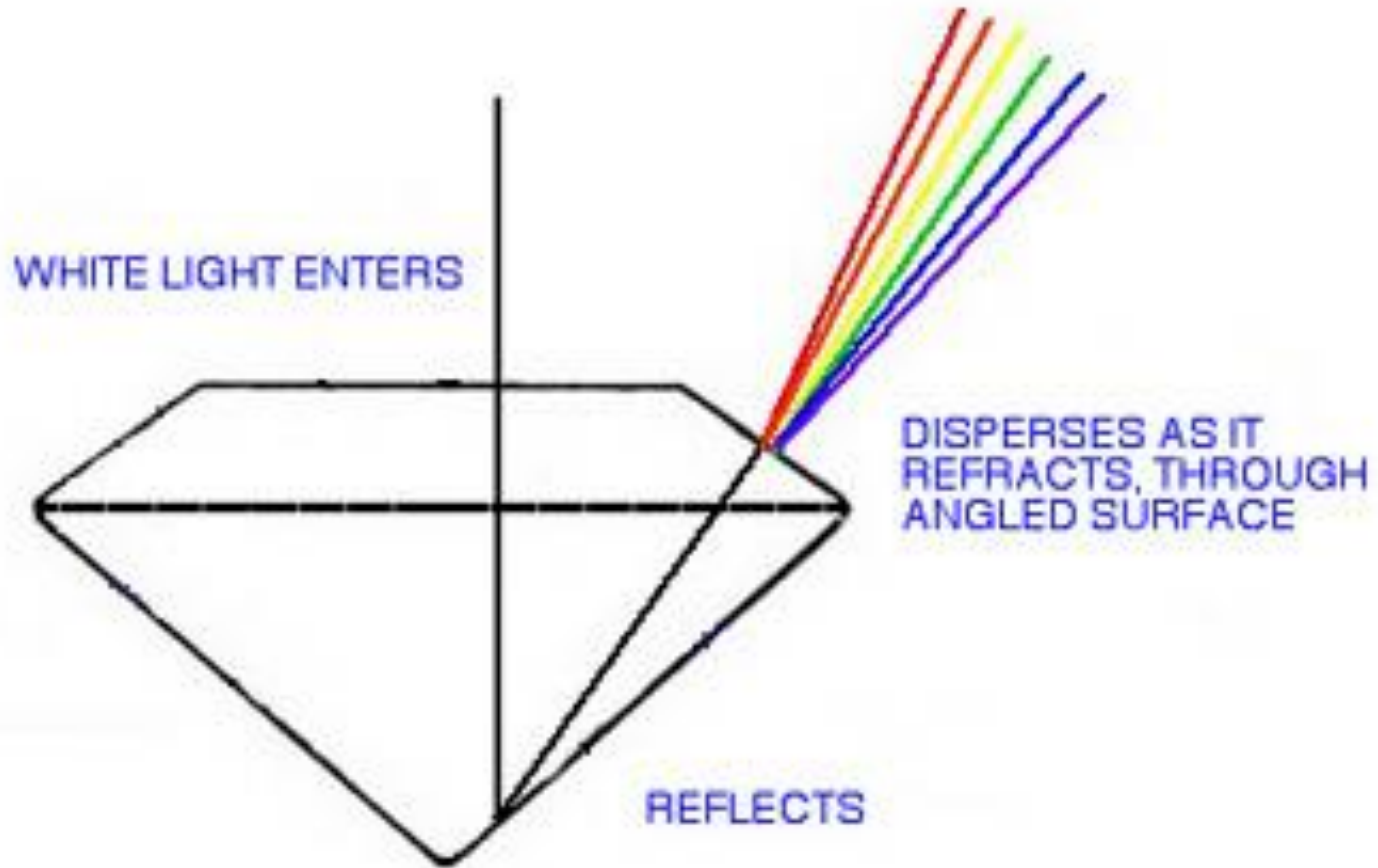


**Refraction includes the slowing and the (usually) consequent bending of light as it enters a gem**

# Behavior of Light - Dispersion

Light is slowed and refracted or bent upon entering a denser medium. A characteristic refraction or bending is associated with each different wavelength of light and this separation of white light into ***component colors is called dispersion.*** In other words, dispersion is the separation of light into its separate spectral colors.

White light is in fact a combination of ***red, blue, and green wavelengths of light.*** Recognition of this was credited to Sir Isaac Newton in 1666 when he observed a dispersed spectrum through a glass prism.



## Dispersion of white light as it leaves a gem

# Behavior of Light - Dispersion

The cause of this phenomenon is the differential refraction (bending) of the various wavelengths of light as they travel through a gem. Red (long wavelength) bends less, violet (shorter wavelength) bends more. *This causes the colors to become separated.* Although dispersion, theoretically, occurs in all gems, the degree depends on the RI of the gem material, and only those gems with sufficiently high RIs, have dispersion which is pronounced enough to be actually visible.

# Isotropic or Anisotropic

All transparent substances can be classified as either isotropic or anisotropic. Isotropic includes amorphous mineraloids and minerals in the isometric crystal system. Light entering isotropic gems moves in all directions with equal velocity, *creating only one index of refraction*. That is, a single refractive index results when light is considered moving in a wave motion with vibrations in all directions at right angles to the direction of propagation.

# Isotropic or Anisotropic

In contrast, when light enters anisotropic gem materials the light is split into two polarizing rays, vibrating in mutually perpendicular planes. *Thus in a given orientation, two refractive indices, one associated with each polarized ray, is detected and the specimen is termed doubly refractive.* Double refraction occurs in specimens from five of the six crystal systems, including tetragonal, orthorhombic, hexagonal, monoclinic, and triclinic. These anisotropic minerals possess the power to polarize light or confine the light wave to vibrate in only one direction, blocking all other waves and splitting light into two rays that travel at different speeds at right angles to one another.

# Light Refraction

**There are two groups of gems with regard to light refraction, each is said to have a different "optic character": SR or DR.**

**SR = Singly refractive**

**DR = Doubly refractive**

# Singly Refractive Gems

In such gems, each beam of light entering the gem stays as a single beam which has a single refractive index (travels at the same speed), regardless of the direction from which it enters. In this group we find all *amorphous* gem materials, such as opal, glass, amber, etc. as well as all crystalline gems belonging to the *cubic* (isometric) system. The most commonly encountered gems of the cubic system are: diamond, garnet and spinel.

# Doubly Refractive Gems

In such gems, single beams of light upon entering the gem, are split into two separate beams, which then travel perpendicularly to each other. Each of the resultant beams takes a different path through the crystal and, consequently, has its own speed. Such gems, then, have two RIs, one for each half of the original beam. In this group are all the gems of the non-cubic crystal systems

# Optic Axis

***Each DR gem, based on details of its crystal structure, has either one or two directions in which the light entering it behaves as if the gem is SR. These directions are known as "optic axes". Those species with a single optic axis are known as "uniaxial" and those with two are, logically, called "biaxial***

# Birefringence

**Birefringence, a property of DR gems only, is measured as the difference between the high and low RIs of the split beams. It ranges from a low of .003 to a high of .287.**

# Birefringence

**When a transparent gem with high BR is faceted, and the view through the table direction of that gem is not in an optic axis direction, the slightly "out of sync" light beams can create an appearance of interior "fuzziness" or in larger stones, can show up as two distinct images of each facet edge. This is known as "facet doubling" and it can be a pain in the neck to a faceter who, in trying to prevent it, must find an optic axis direction for the table of the stone. But it can also be a valuable identifying characteristic that can often be seen with the naked eye or a simple 10x loupe.**

***Food for thought:* The newest diamond simulant on the market is called Moissanite. Moissanite is markedly birefringent; diamond, being SR, has no birefringence.**

# **Behavior of Light - Pleochroism**

**DR gems split light into two perpendicular rays, each taking different paths through the crystal: one ramification of this is birefringence, another is pleochroism.**

**Pleochroism is the property of DR gems which results in their showing different colors, or different shades of the same color, when viewed in different crystal axis directions.**

**How can this be? Think again of the crystal lattice of a DR gem, made of carefully laid out atoms of the gem's component elements (and the trace chromophore elements), with fixed distances and densities that can **vary** depending on direction.**

**If two beams of light take a different path through this lattice, they may then be affected differently by selective absorption and emerge with different colors.**

# Dichroic and Trichroic Gems

Dichroic gems (like corundum) show two different colors while trichroic gems (like iolite) show three.

Pleochroism will *not* be observed in SR gems, nor in DR gems when looking through an *optic axis* direction

In most cases, pleochroism can best be observed using an instrument called a dichroscope

# Testing Refractive Index

**The refractive index (RI) of a gem is one of the most important characteristics determining its appearance, and is also a very useful piece of data for purposes of determining the species of an unidentified gem.**

**One must view the gem being tested with the dichroscope from several different directions because:**

- 1) Some directions will be optic axis directions, in which there would be no pleochroism shown, even if the gem were pleochroic. So, if you based your conclusion on one direction only, there would be a large chance for error.**
- 2) Only two colors show at a time, so, although dichroism might be detected from a single directional view, it would take more than one to see all three colors in a trichroic stone.**

**When strong, pleochroism may complicate the orientation process for a cutter and/or create setting issues for a jeweler.**

**The cutter is going to want the most desirable or attractive color to be that seen when looking through the gem's table. For example, iolite has a lovely blue-violet axis, one that is grey, and a third that is a near colorless light yellow. Few buyers are interested in a grey or nearly colorless iolite.**

**A large number of tourmaline stones have one axis that is an opaque black! The other directions may show a lovely green or pink, but if the gem is not cut so as to prevent light bouncing from the black direction into the green or pink, the color in the finished stone will look terrible a muddy brown. To prevent this, a special "tourmaline cut" has been devised whereby the sides of the offending axis are cut so steep (approximately 70 degrees) that light from it is prevented from reflecting back into the gem. This leaves a gem with proportions that do not fit into standard prong or bezel mounts. Jewelers have had to devise a special "tourmaline mount" to accomodate such gems.**

**Tanzanite gems, which in the rough are trichroic, but after their standard heating process become dichroic, have a blue and a purple axis. Blue stones have a higher per carat value than purple ones, but, unfortunately, the shape of this gem's crystals dictate that the *greatest yield* comes from cutting a purple gem.**

**The cutter, then, must balance these two factors and try to orient the stone so as to give the largest, best colored, and most valuable stone from an individual piece of rough.**

**In some gems, most notably Andalusite, all the colors are attractive (brownish shades of green, red and yellow) and the mix of them in the finished gem is considered desirable**

# Luminescence/ Fluorescence

Gems that emit visible light after exposure to short wave or long-wave ultraviolet radiation, they are said to be luminescent, or more specifically, fluorescent. A gem is phosphorescent if the luminescence continues after the UV light source has been removed. The fluorescence can be a bold green, orangish-red, or whitish blue, and vary in intensity. Fluorescence may be unpredictable because some gems will have no reaction to the UV light source

## **Fluorescence**

**You may recall from the topic of selective absorption, that gems may absorb parts of the visible light spectrum and convert them to heat. It is also the case that gems (due to the specifics of their chemical makeup or crystal lattices) may absorb other types of electromagnetic radiation (UV, Xrays) and convert them to visible light. This phenomenon is known as *photoluminescence*.**

**UV, or ultraviolet radiation is that part of the electromagnetic spectrum that has wavelengths just shorter than those of visible light. We divide the UV spectrum into two parts: longwave starting at 365 nm (LW), and shortwave starting at 254 nm (SW).**

*Remembering that wavelength and energy content have an inverse relationship, this tells us that SW is the more energetic type.*

**Although there are several expressions of the photoluminescence phenomenon that can be tested for in big gem labs, the type which is most useful to the average gemologist is fluorescence testing.**

**Fluorescence:** When a gem absorbs either SW or LW UV, or both, and immediately emits visible light, the phenomenon is called *fluorescence*. In order to test for fluorescence it is necessary to have a controlled source of SW and/or LW and a darkened viewing chamber.

It is also prudent to have UV protective eyewear as exposure to these rays can be damaging. The specifics of the color and intensity of fluorescence can sometimes be a useful diagnostic test in identifying gems.

**A typical UV test lamp, as seen below, usually consists of a light source which produces the UV with a pair of filters covering it. On one side a filter blocks SW and permits LW to pass, and on the other end LW is blocked passing the SW.**

**In a simple model, a simple metal slider mechanism is moved from one side to the other to block out the undesired wavelengths. The test would be performed inside a viewing chamber that blocks out all visible light.**

**The gem to be tested must be very clean as skin oil and dust particles often fluoresce brightly.**

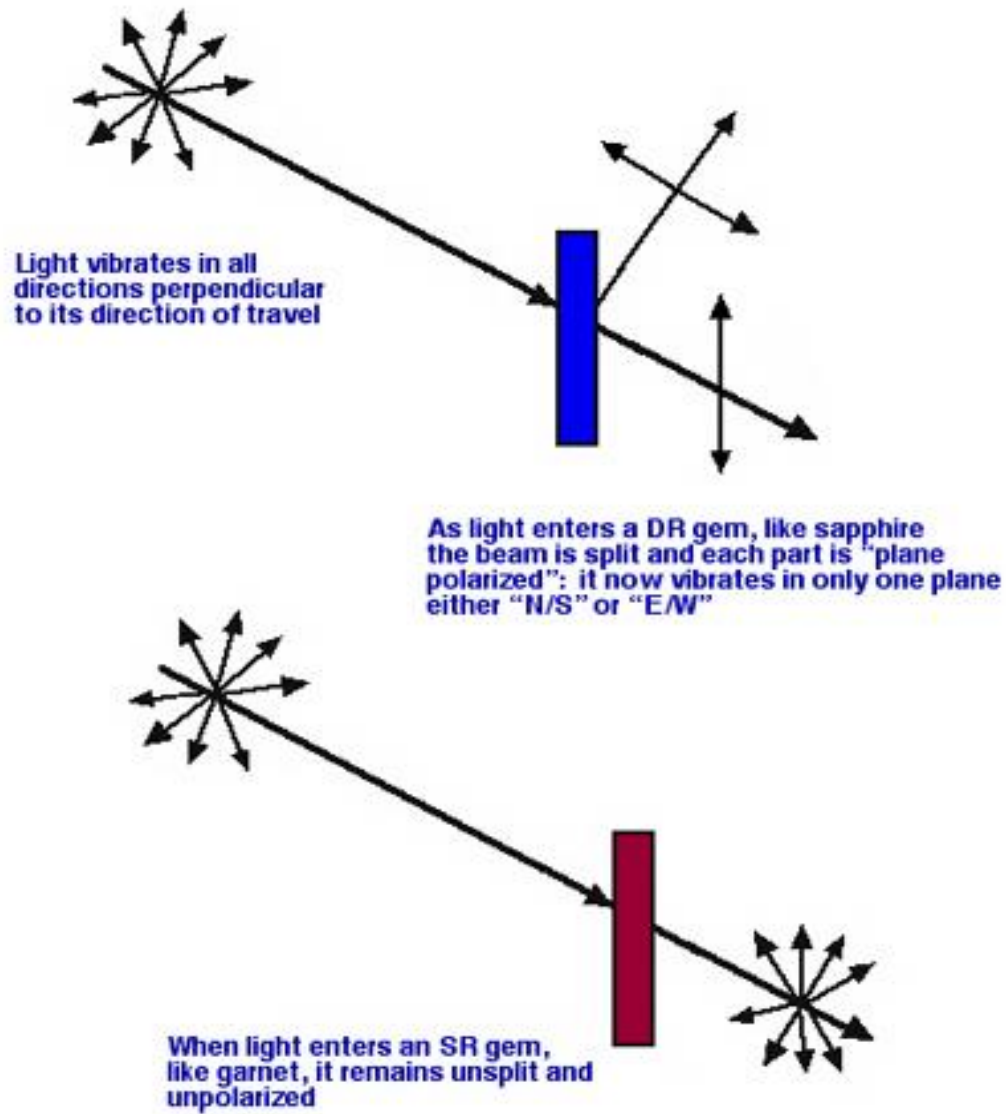
# Polarity of Light and the Optic Character of Gems

The rays of light from the environment or from standard man-made sources are vibrating in all directions perpendicular to their individual directions of propagation. They are said to be **non-polarized**. With respect to this vibration, light is affected by the gem materials it enters in two possible ways:

With DR materials, each of the two light rays that result from the splitting of an original beam, now vibrates in only one plane: it is said to be "plane polarized". Light goes into the gem non-polarized and comes out polarized. (The exception is light that travels through such a gem in an optic axis direction.) When we talk about such a pair of polarized rays, it is convenient to call one the E/W ray (East/West) and the other the N/S ray (North/South).

SR materials have no such effect, the light remains non-polarized as it travels through the gem. That is, light goes in and comes out of the gem non-polarized. We can also picture this by saying that light comes into the gem vibrating in all directions and exits the same way.

This property is one that is useful in gem identification and can be readily detected with an instrument called a polariscope.



*[The effect of optic character on the polarization of light]*

## Testing for Optic Character

*[A polariscope]*



**The easiest way to test a gem for optic character is by using a polariscope. It is composed of two polarizing lenses with a light source below them. Each lens transmits only light that vibrates in single plane, either N/S or E/W.**

**When the light in the base is turned on, normal, unpolarized light is produced, which becomes polarized, let's say N/S, as it passes through the lower polarizer on the base of the unit. The upper lens can be rotated freely. If the upper lens is parallel to the lower one (also N/S), then the light travels through it, and we see a lighted field. The picture below is a photo taken looking into the upper lens as just described.**

# Brief Review of SR -vs- DR Gems

*In singly refractive (SR) gems, light which enters remains as non-polarized beams, and travels through all crystal directions at the same speed. There is one refractive index (RI), no birefringence and no pleochroism. The SR gems can be amorphous or those of the cubic crystal system.*

*In doubly refractive (DR) gems, light which enters splits into two perpendicular polarized beams. Each beam travels at its own speed and has a separate RI which depends on direction. Such gems have birefringence and may show pleochroism. A DR gem can belong to any crystal system, other than cubic. All DR gems have either one (uniaxial) or two (biaxial) optic axis directions in which they will behave as SR.*

# Color Descriptions in Colored Gemstones

**There are three aspects to a formal colored stone color description: *hue, tone, and saturation*. Using these three descriptors, very detailed and nuanced color discriminations can be made, and communicated, between gemologists, jewelers and gem buyers. Let's take them each in turn:**

**Hue:** The hue of a gem is its basic position in the color spectrum: red, orange, yellow, green, blue or violet- but it also includes all the possible intermediates like slightly yellowish orange, or moderately bluish green.

**Tone:** The tone of a gem, basically how light or dark the color, is independent of its hue and ranges from so light as to appear virtually colorless, to so dark as to look black.

**Saturation:** The least commonly quantified aspect of gem color is "saturation", which is a measure of the purity of color, that is, the relative presence or absence of modifying grey or brown hues. It turns out that in most cases, as long as the hue and tone are reasonably nice, it is the degree of saturation of color that is the prime value setter in gemstones.

# HUE



*Gia's 31 basic gem hues]*

**You might ask, why does color description need to be so formalized? The main reasons are listed below:**

- Small color differences mean big dollars!: in the rarified world of gem and jewelry connoisseurs, zeros can be added to prices based on what look like small differences in color to the rest of us.**
- Commonly used adjectives are subjective, and culturally based: Without some system of regularizing color descriptions it is very difficult to communicate color information efficiently.**
- Color memory is notoriously unreliable. Without a system whereby precise color coordinates can be recorded, there is little chance of doing a good job matching a new piece to an existing one.**

# **GIA Color Description/Grading System**

**One well done, and widely used, system for color description is that developed and taught by GIA (Gemological Institute of America). Although not universal, it is familiar world-wide, and the basis for most formal gem description and evaluation in the US and Europe.**

**Since the wavelengths and light colors grade into one another in infinitesimal changes, there are an essentially infinite number of hues which could potentially be described. Most of these hues would be indistinguishable from each other to our eyes, so GIA has settled on a group of 31 which humans with normal color vision (and some training) can discriminate.**

## **TONE**

**Each of the 31 hues exists in a range of tones from almost colorless to almost black. GIA labels the tones as 0 - 10. {0 ( appears colorless), 1 (extremely light,) 2 (very light), 3 (light), 4 (medium light), 5 (medium), 6 (medium dark), 7 (dark), 8 (very dark), 9 (extremely dark), 10 (appears black).**

**For most species the most valuable tones are in the 5-6 range.**

# Color Grading in Diamonds

Within the gem industry, there are separate systems for marketing, grading, and describing colored gemstones and diamonds. For virtually all natural diamonds, discernable color is a negative attribute. The closer it is to an absolutely colorless condition, the more highly valued is the gem.

In the case of what are called "fancy" diamonds, whose color is both intense enough, and attractive enough, to be desirable, color is described and evaluated in a similar manner to that used for colored stones. There is sort of a "U" shaped value curve for diamonds, whereby the highest values accrue to only the whitest, and then, again, to the most vividly colored specimens, with value bottoming out in the central ranges where there is just a bit, to a moderate amount, of color.

Although most of the diamonds you might see on a day-to-day basis are called "white" and appear so, a little study and comparison will verify that a truly colorless diamond is a thing of great rarity, and the vast majority of diamond gems are actually tinted with small but noticeable amounts of yellow or brown.

**Before the GIA system was developed (beginning in the 1930's), there were as many diamond color descriptions as there were diamond sellers. Many of them used A, B, C and A+, AA, AAA etc. while others used adjectives like "river" and "cape". It is easy to see how difficult it would be to have a reliable system for trade under those conditions.**

**GIA's scale did away with A, B and C because of their long histories and diverse usages, and developed a system based on color grades from D-Z for "colorless" stones, plus the term "fancy" to indicate those whose strong color made them more, rather than less, valuable.**

## **What the Letters Mean**

**D, E, F:** gems in this range appear colorless even in larger sizes, only a highly trained diamond grader can tell the differences between them.

**G, H, I:** these grades describe gems that look colorless to most viewers in smaller sizes and if mounted.

**J, K, L:** small and mounted stones of these grades look near colorless, but larger and unset gems begin to have noticeable color

**M-Z:** gems in this range are worth much less than higher color grades and range from some color noticeable to distinctly light yellow (or brown).

**Z+:** beyond Z is the range of the "fancy" diamonds whose value is based on their hue tone and saturation, as in colored stones. In general browns are least valuable with yellow, orange, and green worth considerably more. The pinnacle of value for naturally colored diamonds is occupied by purple, blue, pink, and at the very tip-top, red.