Chapter 3.

MATTER OPTICAL PROPERTIES

3.1. General remarks

When a light ray propagates along a medium and reaches the limit which separates it from the second one, it may return to it (reflection), it may strike it and become part of the second medium, where it will be converted into a different form of energy (absorption), and some will not change (transmission).

Out of these phenomena, two or three take place simultaneously. Following the fundamental principle of energy, the sum of reflected, absorbed and transmitted radiation must equal the incident radiation.

Therefore, the use of light in the most convenient way requires control and distribution achieved by modifying its characteristics through the physical phenomena of light reflection, absorption and transmission, without leaving aside the fourth factor known as *refraction.*

3.2. Reflection

When any type of waves strikes a flat surface like a mirror, for example, new waves that move away from the surface are generated. This phenomenon is known as reflection.

When light is returned by a surface, a certain amount of light is lost due to the absorption phenomenon. The ratio between the reflected flux and the incident flux is called surface *reflectance*

Any surface which is not completely dark may reflect light. The amount of reflected light is determined by the surface reflection properties. There are four kinds of reflection, namely: specular, composed, diffused and mixed. Reflector systems are based on these reflection properties.

Specular reflection (Fig. 1): It takes place when the reflecting surface is flat. This kind of reflection is based on two fundamental laws:

1. The incident ray, the reflected ray and the normal to the surface at the point of incidence lie in the same plane.
2. The angle of incidence (i) is the same as the angle of reflection (r).

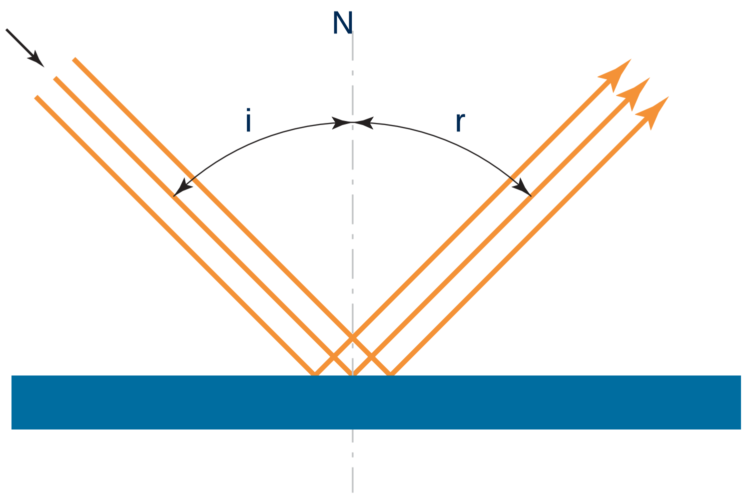

Figure 1. Specular reflection.

Composed reflection (Fig. 2): Contrary to specular reflection, there is no mirror image of the light source, but the maximum angle of reflected intensity is the same as the angle of incidence. This type of reflection takes place when the surface is irregular or rough.

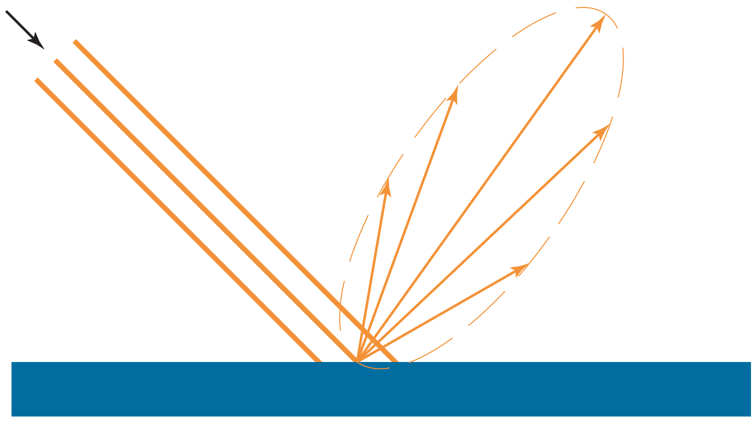

Figure 2. Composed reflection.

Diffused reflection (Fig. 3): This takes place when the light that strikes a surface is reflected in all directions, the normal ray to the surface being the most intense one.
This kind of reflection takes place on surfaces such as matt white paper, walls, plaster flat ceilings, snow, etc.

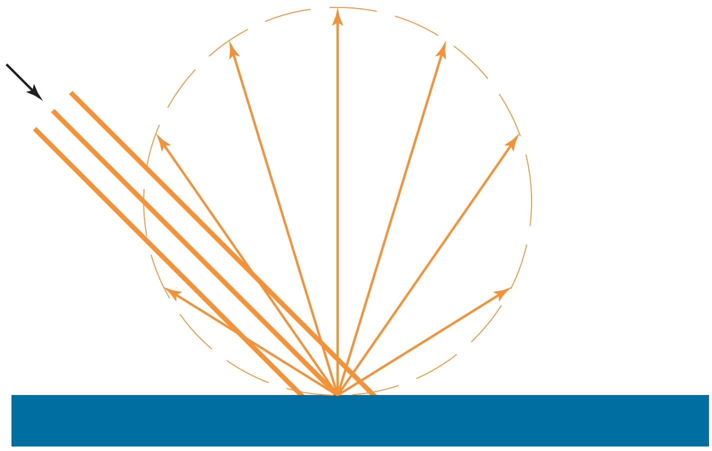

Figure 3. Diffused reflection.

Mixed reflection (Fig. 4): This is an intermediate kind of reflection between the specular and the diffused reflection, in which some of the incident beam is reflected and some, diffused. This kind of reflection takes place with non polished metals, glossy paper and barnished surfaces.

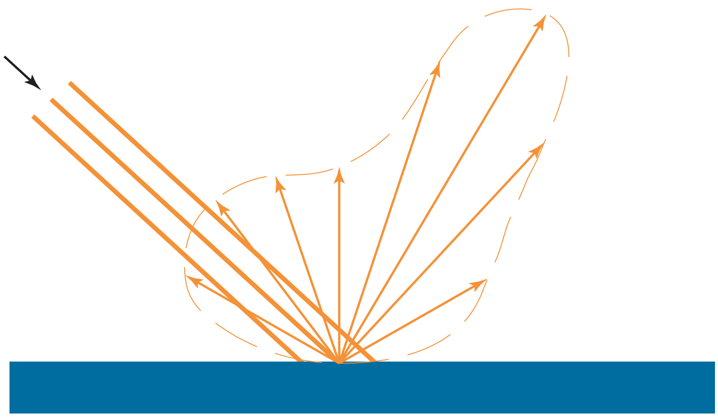

Figure 4. Mixed reflection.

Reflecting surface	% reflection index
Gloss silver	92 - 97
Gold	60 - 92
Matte silver	85 - 92
Polished nickel	60 - 65
Polished chrome	60 - 65
Polished aluminium	67 - 72
Electropolished aluminium	86 - 90
Vaporised aluminium	90 - 95
Copper	35 - 80
Iron	50 - 55
Enamelled porcelain	60 - 80
Mirrors	80 - 85
Matte white paint	70 - 80
Light beige	70 - 80
Yellow and light cream	60 - 75
Accoustic ceilings	60 - 75
Light green	70 - 80
Light green and pink	45 - 65
Light blue	45 - 55
Light grey	40 - 50
Light red	30 - 50
Light brown	30 - 40
Dark beige	25 - 35
Dark brown, green and blue	5 - 20
Black	3 - 4

Chart 1. Reflection coefficient for white daylight.

3.3. Transmmission

Radiation passes through a medium without a change in the frequency of monochromatic radiations. This phenomenon can be seen on certain kinds of glass, crystal, water and other liquids, and air, of course.

However, when passing through the material, some of the light is lost due to the reflection on the medium surface and through absorption. The relation between the transmitted light and the incident light is known as material *transmittance.*

Transmission falls into three categories: spread, diffused and mixed.

Spread transmission (Fig. 5): The beam strikes a medium and passes through it. The media which fulfill this property are called "transparent materials" and allow a sharp view of objects on the opposite side.

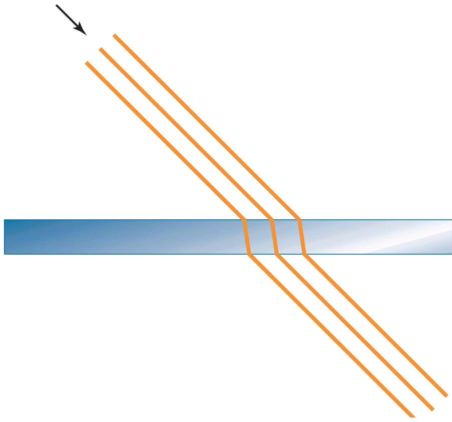

Figure 5. Spread transmission.

Diffused transmission (Fig. 6): The incident beam spreads through the medium, coming out of it in scattered directions. These transmitting media are called “translucent”. The most common ones are ground glass and opalized organic glass. Objects situated behind them appear blurred.

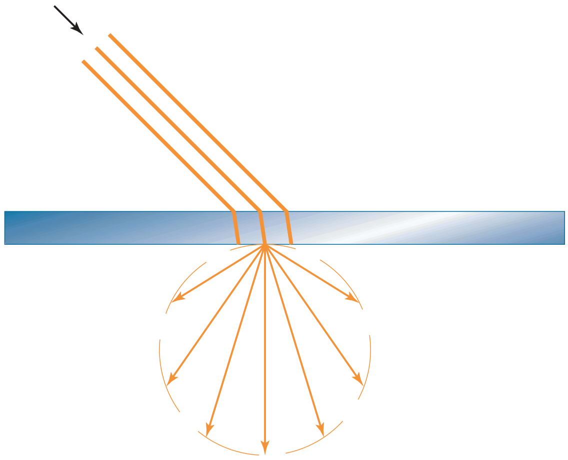

Figure 6. Diffused transmission.

Mixed transmission (Fig. 7): This is a kind of combination between spread and diffused transmission. It is produced with organic, polished and carved surface glass. Although beam spread is not complete, objects situated behind them appear blurred, but their position is relative.

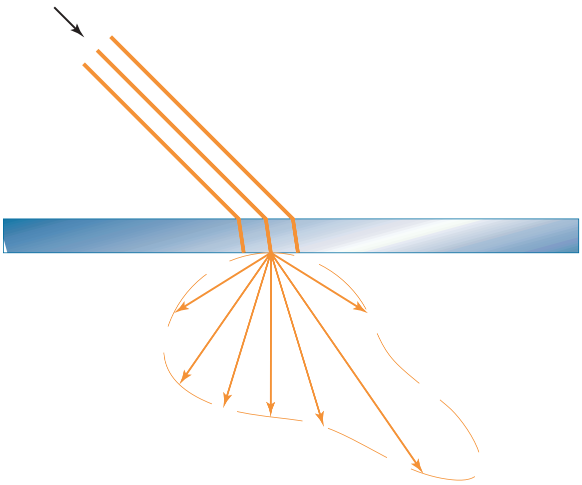

Figure 7. Mixed transmission.

3.4. Absorption

Process by which radiant energy is converted into a different form of energy, mainly in the form of heat. This phenomenon is characteristic both of all surfaces which are not completely reflective and of materials which are not totally transparent. The ratio between absorbed flux to incident flux is known as *absorptance*.

Absorption of certain light wavelengths is called selective absorption. Generally speaking, objects take their color from selective absorption.

3.5. Refraction

The direction of the light beam may change when passing from one medium to the other. This is a result of a change in the light speed of propagation. Speed decreases if the new media density is higher, and increases if it is lower. This change in speed and direction is known as refraction.

There are two laws of refraction:

1. When the wave goes from one medium to another, the incident ray, the reflected ray and the normal to the separating surface of the media on the incidence point, are on the same plane.
2. The ratio between the incidence angle sine and the refraction angle sine is a constant for the given pair of media.

The above mentioned constant is known as the index of refraction *n*, for the given media. The second law of refraction is usually known as *Snell's law*.

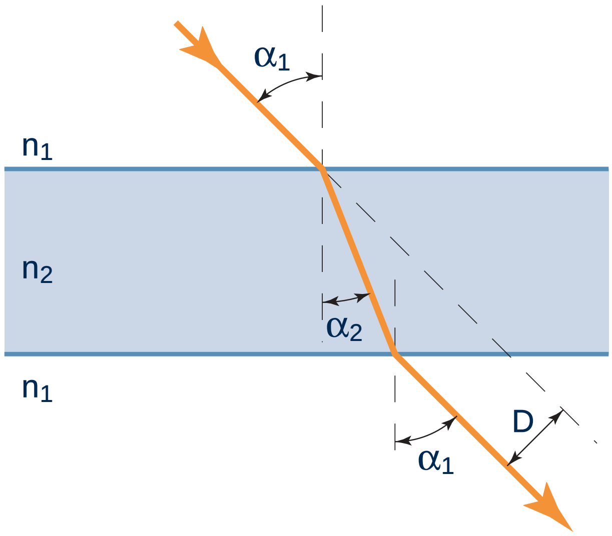

Figure 8. Refraction in the boundary bewtween two media.

$$n_1 \cdot \sin \alpha_1 = n_2 \cdot \sin \alpha_2 \Rightarrow \frac{\sin \alpha_1}{\sin \alpha_2} = \frac{n_2}{n_1} = n$$

n_1* = angle of refration for the first medium.

n_2* = angle of refraction for the second medium.

α_1 = angle of incidence.

α_2 = angle of refraction.

When the first medium is the air, $n_1 = 1$ and the formula is:

$$\sin \alpha_1 = n_2 \cdot \sin \alpha_2$$

The distance D in figure 8 is known as displacement. Such a displacemnt depends on the angle of incidence and on the index of refraction. When the incident ray is perpendicular to the surface, refraction and displacement equal zero.

Refraction varies according to wavelength. Short waves (like blue and violet) are transmitted better than long waves (for example red). This phenomenon is used to decompose white light into its component colours when passing through a refraction prism. The degree to which color is decomposed depends on the angle of incidence and the refraction properties of the prism material. This is called dispersion.

* "n_i" is calculated by the quotient between the speed of light in the air and the speed of light in the medium "i".