rays contained in light. If an object does not reflect any of these rays then it is considered to be black.

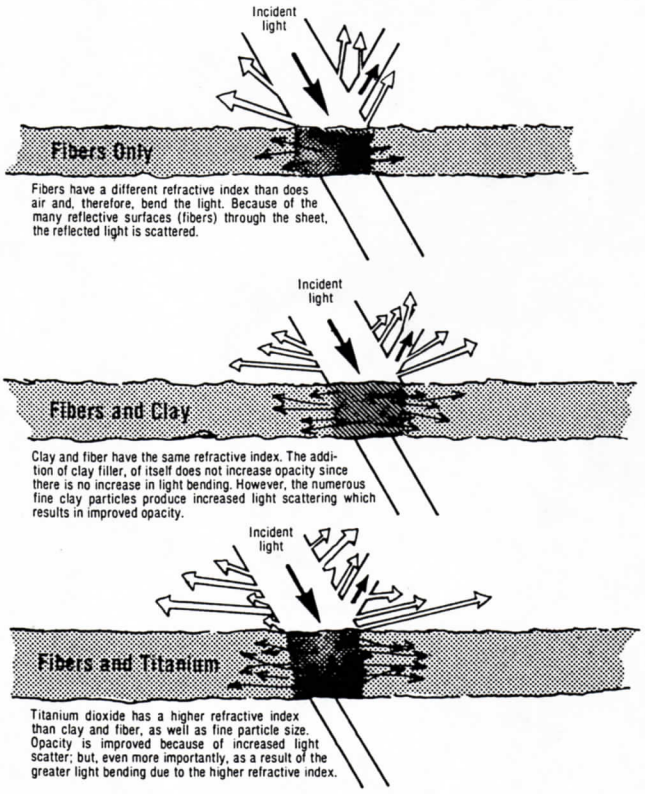
How Different Papers Absorb and Reflect. A black cover paper is not really black in itself. It is black because it absorbs all of the colored rays in light and reflects none of them. A blue cover appears blue only because it reflects the blue rays in light while absorbing the others. Grass absorbs all of the colored light rays except the green rays which are reflected to the eye and cause the grass to appear green.

Reflectance Requirements of a Pure White Paper. A paper that would reflect the complete combination of colors as they are contained in sunlight would be a white paper. Therefore, in order to make a paper that is a pure white the papermaker must find materials that are chemically and physically constituted so that they will reflect all of the colors that are contained in light. To date, no papermaker has been able to do this. Any combination of known materials will either reflect a surplus of blue rays and cause the paper to appear blue-white, or it will reflect a surplus of the orange rays, in which case the paper will appear cream-white in color. However, some progress has been made in the use of colorings with the result that the color of white papers has been brought nearer to the true pure white.

Brightness. The degree of brightness that can be captured in paper is proportionate to: (1) "whiteness;" and (2) directness of reflection.

Pure white light reflections are brightest, therefore as the papermaker approaches pure white he improves the brightness of the paper.

Directness of reflection preserves brightness. If a pigment bounces the white light rays directly back to the eye, brightness is retained. If a pigment is so constituted that the light rays scatter along its surface or reflect to one side, there is a loss of brightness.



How refraction of light effects brightness of paper.

Refractive Index and Its Importance. Scientists measure the reflecting qualities of different materials and give each a rating which is called the "refractive index." A material that bounces the reflection back to the eye and thus preserves brightness is given a high index. A material that bends the reflection to one side causing a loss of brightness is given a lower index.

The refractive indices of pulp fibers and most coating materials or filler materials are about the same. Titanium dioxide, as previously noted, and zinc pigments are exceptions.

Carbonate has a better color and a higher reflecting quality than clay and these are maintained through manufacture so that carbonate used as a filler in uncoated paper, or as a coating pigment, produces a brighter white color than clay. Fine particle carbonate, zinc sulphide, and titanium dioxide are all whiter than clay and have a higher reflective index than clay and, therefore, produce bright color when used as fillers or as coating materials.

Complementary Colors. Artists, physicists, and experienced users of colors describe opposite colors with the word complementary. They know that when complementary or opposite colors are combined the resulting color will be grayed—its brightness will be reduced.

Relation of Brightness, Color, and Opacity. High reflecting quality (a high refractive index) contributes to opacity. Thus pulps or pigments, which bounce light rays back to the eye, develop opacity because the light rays are reflected and not transmitted through the paper. Therefore, pigments such as carbonate, titanium dioxide and zinc sulphide enhance opacity because they possess high reflecting qualities which are combined with a high degree of basic "whiteness."

There are, however, pigments that have high reflecting qualities but inferior color. Carbon, for example, has a high refractive index and therefore it reduces light transmission and makes for opacity in paper though at the same time dimming or dirtying the color. Old paper pulps that have been imperfectly de-inked are opaque because they contain a residue of carbon ink pigment. Yet, because of the carbon residue, these papers cannot have bright color.

So, peculiarly, the highest degree of opacity can be secured with the two extremes in brightness, i.e. the maximum brightness when carbonate, titanium dioxide or zinc sulphide are used for fillers, and the minimum of brightness with pulps that contain carbon and similar pigments which lack purity of color or "whiteness."

BUILDING STIFFNESS AND HARDNESS INTO PAPER

There is an erroneous belief that a paper can be made stiff, rigid, hard and snappy by sizing. But these characteristics are not secured with sizing. As was discussed in the sections on formation and additives, internal rosin sizing, added to the pulp at the beater, helps to prevent the tendency of cellulose fibers to absorb water or liquid. External sizing increases strength and water resistance to some degree, but decreases