

After many years of trial, the writer commends this method on account of its simplicity and accuracy; even the student with but little quantitative experience can use it with success. The ability to secure good results increases one's interest in quantitative work. The ordinary high school student who has access to a fairly good analytical balance would have no serious difficulty with this determination. In our laboratory we use this method in the analysis of Iceland spar, dolomite and siderite.

THE INDEX OF REFRACTION. (SNELL'S LAW.)

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In the March number of SCHOOL SCIENCE AND MATHEMATICS, Dr. Millikan, in an interesting article on "Tendencies in Physics," gives a list of "bugbears" which beset the pathway of the physics teacher. As bugbear No. 12 he mentions the presentation of the *index of refraction* as a *ratio of sines* instead of a *ratio of velocities*. Such a change as he suggests has somewhat to commend it and perhaps ought to be adopted were the teacher limited to a choice between the two.

It must be remembered, however, that definitions and laws, like the one under consideration, have a history that is as truly a part of the science of Physics as are the finished expressions themselves. Sometimes the definitions, in their wording, suggest this history and are an epitome of it, so that on reading them the mind casts a bird's-eye view backward over the sometimes tortuous, but always interesting, historical progress of the subject.

It would surely be a loss to lightly throw aside the historical content of the definition or law merely to make room for a more recent or even more salient expression of the same truth. Will it not better be to frame a second definition which expresses the same truth from the new viewpoint, thereby leaving unmarred the old, and enriching it by the new?

The law in question is one of this class—it bears the name of one of the early workers in Physics, and is in its wording, an epitome of the knowledge of optics up to the time of its framing. To the lover of Physics its story gives the opportunity of engaging the interest of the pupil and of making the subject a living

instead of a dead thing. It would indeed be a pity to lose such a landmark from the landscape of the science.

The better to illustrate my point let us for a moment look at the history of this law.

The bending or "refraction" of a beam of light as it passes from one medium to another must have been noted in the very earliest times. Claudius Ptolemy (A. D. 139) was the first to leave any record of observations. From him we have tables of what we now call the angles of incidence and refraction. Eleven centuries later Vitellio (A. D. 1278) also left similar tables. The law which lay hidden in these observations was not detected by even so keen a mind as Kepler's and was not discovered until four centuries later Willebrod Snellius "observed* that if the refracted ray and the incident ray continued through the point of incidence be intercepted by any line parallel to the normal to the surface at the point of incidence, the length of the intercepted portion of the refracted ray is in a constant ratio to the length of the intercepted portion of the incident ray." Snellius died without publishing his conclusions and the world first knew them from the pen of Descartes in 1637. Descartes is supposed to have had access to Snell's papers and if so found the following form of the law,† "For the same media the ratio of the cosecants of the angle of incidence and of refraction retain always the same value." He changed the wording and gave the law the form as we now have it as follows: "The incident and refracted rays are in the same plane with the normal to the surface; they lie on opposite sides of it, and the sines of their inclinations to it bear a constant ratio to one another." The wording of Descartes is a more comprehensive and better one than that of Snell, and perhaps he thus justified himself in omitting to give due credit to his predecessor. At all events the law was long known as Descartes' law and only in comparatively recent times has honor been given where honor was due.

Snell's law was published in 1637, and, as we have seen, relates only to the refraction or bending of the ray. It was fully developed fifty years before. Romer, in 1676 made his classic determination of the velocity of light in interplanetary space. It was not until nearly two centuries later (1850) that Foucault announced the experimental determination of the velocity of light

* Preston's *Theory of Light*, page 9.
† Cajori's *History of Physics*, page 76.

in water and the fact that the ratio of the velocity in air and water is the same as required by Snell's law. The history of the determination of the velocity of light is an intensely interesting, but an entirely distinct, story from that of the law of refraction, and is worthy of a monument of its own. Such a formula, summarizing the work of Arago and Foucault, would be a gain to scientific clearness and would stand in Physical Optics as the law of Snell does in Geometrical Optics. The question then arises, how can we express the so called law of refraction so as not to confuse it with Snell's law and yet bring out the law of velocities in two media?

My answer is as follows: The velocity of light in the free ether is the same for all wave-lengths and is taken as the standard velocity. It is found by experiment that the velocity in material media is less than in the free ether, and depends upon the wave-length. If now we construct a table of relative velocities we obtain what may be called *the coefficient of retardation* of the given medium. This coefficient is the term by which the velocity in the free ether must be multiplied to obtain the (generally) reduced velocity in the given medium. The fact that the coefficient of retardation is the reciprocal of the index of refraction at once shows its relation to Snell's law and keeps it distinct from it. The following is such a table:

Substance.	Index of Refractions.	Co-efficient of Retardation.
Water.....	1.336.....	0.748
Crown Glass.....	1.5	0.666
Flint Glass	1.585.....	0.632
Ice.....	1.31	0.764
Diamond	2.47 to 2.75	0.405 to 0.364

The index of refraction is expressed by the equation

$$n = \frac{\sin i}{\sin r},$$

while the coefficient of retardation is given by the equation

$$V_1 = KV_0 \text{ where } \begin{array}{l} V_1 = \text{velocity in given medium.} \\ V_0 = \text{ " " vacuum.} \end{array}$$

Since they represent different, though related, ideas, they should be taught as separate quantities. If the teacher cannot take the time to include both in his teaching I would agree with Dr. Millikan that the ideas involved in the Coefficient of Retardation are to be given precedence over those represented by the Index of Refraction.