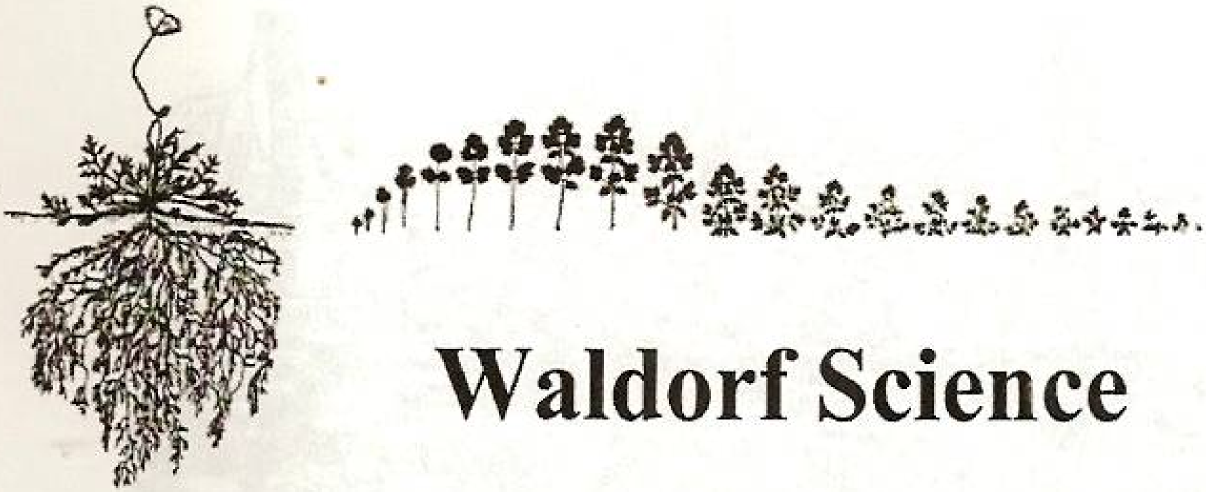

Waldorf Science

Explorations in Phenomenology as Practiced in Waldorf Schools

A Science News Roundletter

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NOTE FROM THE EDITORS

Because of the intense work on the High School Chemistry Colloquium the editors missed their self-imposed, Spring, deadline. We apologize for this.

Our next newsletter will be devoted to mathematics. As always, we ask that you please send us stories, ideas, and questions, or gather them from your colleagues. Please let us know your needs and what you would like to see us concentrate on.

OBTAINING BACK ISSUES

There has been a demand for back issues of the Waldorf Science Newsletter, so we have, for a nominal fee, made all back issues available through AWSNA Publications, 3911 Bannister Road, Fair Oaks, CA 95628.

"Wonders are many in the world, and none is more wonderful than the human being.

– Sophocles

MATHEMATICS COLLOQUIUM

In October 2000 a colloquium will be held to work through and develop further the mathematics curriculum for Waldorf high schools. This project is supported by the High School Research Group of AWSNA and will include the following participants:

Marty Levin, Washington Waldorf School
David Mitchell, AWSNA High School Research Project
David Booth, Austin Waldorf School
Harry Kretz, Harlemville, New York
Connie Gerwin, High Mowing School
Marisha Plotnik, Rudolf Steiner School, Manhattan
Cynthia Bennett, Betheda, Maryland
Erik Marstrander, Rudolf Steinerskole, Oslo, Norway
Ron Jarmon, Great Britain
Ernst Schuberth, Mannheim, Germany
Bonnie River, Remedial expert

The goal is to unveil the way in which the Waldorf mathematics curriculum exercises and develops different thinking capacities in the adolescent.

Three Worlds

Light and Darkness in 6th Grade Physics

by Thor Keller
From "Erziehungskunst"
issue 6/1989 (slightly edited by Author)

Based on his all encompassing knowledge of the growing child Rudolf Steiner proposed as early as 1919 that the teaching of physics start with the sixth grade.

Around the 12th year of life, during the last third of the second seven-year epoch, the children have completed a further step of grasping and knowing the earth as the forces of causal thinking start to awaken within them. The boys especially want to understand their earthly surrounding with all its important and interesting manifestations of daily life, technical matters, its commerce and business. If Rudolf Steiner's curriculum proposals were revolutionary in 1919, today they appear antiquated—to superficial examination. After all, public schools confront the children as early as second or third grade with the basics of our technical surroundings in social studies. Yet this is premature, a brutalizing of the still-dreaming soul of the child, still fully immersed in the domain of myths and in need of the images of myths, legends and fables for its development. At this age the spiritual forces needed for thinking are still devoted to building up the body. Only gradually do they free themselves, and only then are they free to grasp the world intellectually. The Waldorf curriculum from the first to the fourth grade takes this development into account. But if one fails to exercise and train these liberated forces in the sixth grade, they lie fallow and become stunted, or else grow rampant unless the children exercise them in extracurricular activities. In this case, one would give up on their pedagogical development and indeed prevent it. Besides one would create the vague, often unconscious feeling on the part of the student that one does not learn "anything proper" in the Waldorf school, i.e. nothing one now requires. Rudolf Steiner defines immersing the young people into the given surrounding social world as a task, equal in importance to that of the cultivation of all capabilities.

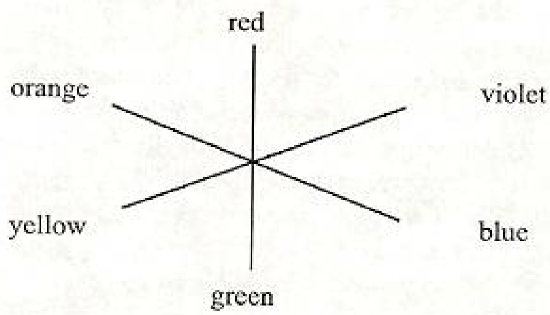
In issue 7-8/1986 of ***Erziehungskunst*** we reported on acoustics work done in the first physics main lesson in 6th grade. Here we report on Optics. The author has quite consciously taken a different approach than that taken by Manfred von Mackensen. This will be justified in the following discussions.

Sense perceptions awaken the child to its first "consciousness" when it first recognizes the world in the person of the mother, the father, the siblings and the first toys. Thus, the child step by step conquers the world for itself. It is the ear and the eye above all that are involved in this process. If nothing sounds, nothing shines, then no sensory stimulus occurs and consciousness ceases. This is why we put children to sleep in a dark quiet room. Thus, it is a serious and important question, whether one should start teaching optics with the experience of darkness (quite apart from the fact that modern school buildings often have no possibility to totally darken any rooms. The author found himself in this situation, when the entire side of a classroom consisted of only windows and all optical experiments up to eighth grade had to be carried out in daylight. It worked very well). Darkness also leads to all sorts of horseplay. This makes it hard to establish an earnest mood. Even during a nighttime or early morning walk, a class is hard put to remain quiet and listen for any length of time. Yet in spite of this, if it is at all possible every class should experience a sunrise as a group.

Only after presenting the first class on acoustics with experiments pertaining to sound transmission and velocity as well as those pertaining to resonance (apart from the experiments described in the above noted essay), only then did we start with color optics. We also first discussed other sound phenomena: the colossi of Memnon sounding at sunrise in ancient Egypt, "the ear of Dionysos" in Sicily which magnified a whisper at the end of the cave to loud sounds at the entrance, the "wall of echoes" in the Temple of Heaven in Beijing, where one can hear every word whispered in the courtyard, the acoustic phenomena in antique theaters, and the acoustic sound vessels in Roman churches (see "Goetheanum" No. 7/1977)

We began optics by having a slide projector shine through a glass tank, and slowly poured in previously prepared soapy water. The light changed color from a yellowish, through yellow, to orange, and finally red. If we placed a black board behind the vat and allowed the light to shine in from the side, a delicate blue appeared when dimming the solution slightly.[1] These phenomena, primarily the creation of pastel colors, can also be well shown using parchment paper and small transparent plastic boards of milky-turbid "Goethe glass." On the basis of experiencing these phenomena, we discussed the miracle of various natural phenomena—some of which we had marveled at since the first grade: the orange coloring of the sun at dawn, its yellowish coloring during the day, and its reddish cast in the evening or before it rains, the blue mid-day sky, deep violet to black at extreme altitudes, the bluish tint of light smoke against dark woods and its orange color against the light sky; rings around sun and moon, colored patterns on windows with condensation at dawn and dusk; the bluish cast of mountains and yellow tinge of icebergs when viewed from a distance, the blue grotto at Capri, the reddish light at great ocean depths. All these phenomena are physically understandable with the aid of these experiments.

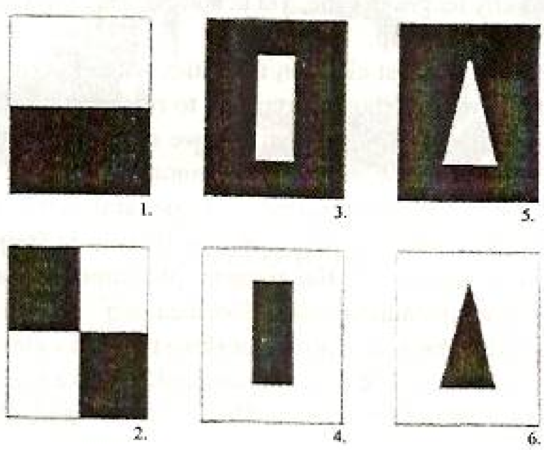
Based on these experiments, the children can also experience how colors are created by the interplay of light and darkness and can further understand Goethe's statement: "Colors are the deeds and sufferings of light". In his research, Goethe has developed the six-part color circle. If one calls yellow and blue the two archetypal colors, one can call red and yellow-blue the three basic colors. In the color circle two basic colors join to mixed colors, located in between them, the counter- or complementary color is always on the opposite side.



The children have already become acquainted with these colors in the painting lessons.

The experiments with colored shadows provide the next series. The light source may be daylight or bright lamplight. We created the colored light with colored glass squares, in a slide projector. The shadows are cast from one object by two projectors (one with the filter), and the complementary colors appearing in one shadow for various filters are beautiful to behold. The same phenomenon appears if one places a black figure on top of white cardboard and tracing or parchment-paper over this.

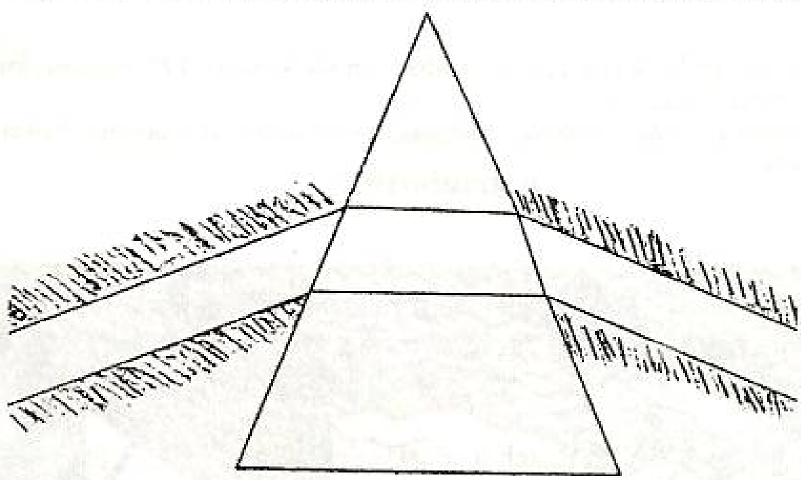
The experiments were followed by those involving the prism. It is best if one can give each child a glass prism, failing this, one lets them look at the various black and white boards through a large water prism. The children discover that their direction of view is being shifted.[2]



In addition, they also notice that wherever there are edges where dark areas meets bright ones, either warm or else cool (or dark) colors appear. One usually finds that if white comes first in the direction of the diversion, (darkness shifted into brightness) the warm colors appear, if black comes first (brightness shifted into darkness), the cool colors. A look through the prism at the room shows the same phenomenon everywhere light and dark border each other.

In the next series of experiments, we placed a penny at the bottom of a water filled tank, and slowly filled it with water. The penny and the bottom seemed to rise. Then we held a rod at an angle in the water, it appeared to have a kink at the surface of the water. Finally we allowed a light beam to fall at an angle into a water-filled glass tank. At the surface of the water, it was clearly diverted downward. We then discussed the laws and looked where these phenomena are to be found in daily life, namely wherever we look into the water.

Both phenomena express the same law: our direction of view (or the light beam) is being "shifted," and considering a thinner to a denser medium (air to water), shifts toward the denser one. The denser medium provides, as it were, more resistance and thus diverts vision and light. The diversion caused by the prism is based on the same law.



To conclude optics, one demonstrates how, by means of an iris diaphragm (a small hole in a larger cardboard) the image of a candle can be created on a screen of tracing paper, or else the image of the classroom window and perhaps even the landscape outside can be created on the screen. The children can then continue to build a "camera obscura" for themselves from a paper box.

The children have entered the experiments in their exercise books along with the texts summarizing the laws, provided by the teacher. In this way they have created their own textbook, just as Rudolf Steiner has recommended. This *supports and promotes understanding* and memorization of the physical laws.

Actual instruction was invariably carried out along the three steps, prescribed by Rudolf Steiner: observing experiments, descriptive review, and the next day, discussion of the laws.

The author has taught physics in the sixth grade, not just during the prescribed four weeks, but in two three-week blocks. This was done to allow enough time to work out the description of the experiments. Every experiment received two, three, or even four, descriptions by pupils. In the course of this mistakes were being corrected, what was missing was completed, what was superfluous was cut out. The emphasis was on extreme conciseness. This because I am of the opinion that detailed description of events should be practiced in composition lessons, not in Physics. In Physics I aimed at concise description of the experimental procedures and their results. Doing it the other way would make understanding of the physical events more difficult.

"We made a slide projector shine through a glass tank and slowly poured soapy water into it. As the water got progressively dimmer, the light turned first slightly yellow, then orange, red and finally deeply red."

"We held a rod in the water at an angle. It appeared to have a kink at the surface of the water."

If descriptions of experiments are thus well-practiced, the children know how to do it in the next grades and one has more time for the experiments and the necessary description. Observing a good schedule during the period makes it possible to work through the essentials in the remaining physical areas in about twelve to fourteen experiments each (theory of heat, magnetism, static electricity). The pupils exercise their thinking in the process and begin to understand the phenomena of the world. This gives them the needed assurance in life, particularly so if one succeeds—although this is quite challenging in Physics—in constantly connecting the subject to the human being, or at least to what happens in our daily life.

Endnotes:

[1] Another sequence puts this in the 8th grade. See Op 2, p.11, Manfred von Mackensen, "*A Phenomena-Based Physics,*" *Vol III (Grade 8)*, translated by AWSNA Publications, 1997.
[2] see: Experiment 8V1, p.104, in Michael D'Aleo & Steven Edelglass, "*Sensible Physics Teaching*," Parker-Courtney Press, 1999; also Op 1, "*Phenomena-Based Physics*."

The Relation of "Optical Elevation" to Binocular Vision

by Günter Altehage
Waldorf Pedagogical Research Institute, Germany
Translated by Thomas Forman

Introduction

Although a common experience of refraction, where objects under water appear from air in a different location than where we find them by touch, the quantitative details of this phenomena of lifting or "elevation" are rarely discussed, even in physics texts. [1] Usually they mention only the formula for the simple case of perpendicular view:

$$\frac{\text{apparent}}{\text{tangible.}} = \frac{-1}{n}$$

where n is the index of refraction of the lower media (usually $1/n = 1.33$ for air-water)

(The subtleties of situations for diagonal view, or the effects of viewing with two eyes (binocular vision) are rarely discussed. This essay discusses finer aspects that could be work for a 12th grade optics class, and uses an apparatus that could even be utilized in 7th or 8th grade Physics: optics of refraction (albeit qualitatively). —Eds.)

Optical Elevation and Perspective

If one observes objects located under the surface of the water from a point above the water's surface, they do not appear in their "real" shape, but distorted. Objects above water are seen in their familiar perspective arrangement and perspective form. By and large things under water are ordered in size and number as is expected according the laws of perspective. Yet, additional distortions appear, ones not understandable according to the laws of perspective. This failure of the laws of perspective shows itself in practice for example in the fact that we cannot grasp objects under water in the right way. Evidently, we have wrong ideas of distance under water. (South Sea islanders correct their error in spearfishing only by constant practice). And these false ideas are our *ideas* of the laws of perspective, tacitly applied to our perceptions. But actually, these laws are valid only when the observer and the object are both in the same medium. Yet in the situation considered here, this is *not* the case; the conditions which determine the visually seen image are that the eye which views the object being observed, is within a medium optically *different* (specifically optically less dense or refractive) than the object itself; and, both media meet in a flat interface.

In addition to the distortion, a change in colors usually takes place as well. This 'discoloration' can be completely eliminated by observing black and white objects. This makes the distortions appear in their pure form (it is common knowledge that colors appear only where boundaries of different brightness collide). In the case of multicolored objects, we can start by ignoring the discoloration and later account for the "coloration faults". This is standard procedure in the theory of optical depiction. We could also avoid discoloration by observing with monochromatic light.

Our skill in dealing with the laws of perspective is evident when we know how to correctly coordinate our touch-perceptions with our visual ones. But, now in our "situation of enlarged perspective," how can we grasp the laws of relationship between tangible and visual perceptions?

Experience has shown that the simplest way of defining the underlying law is to consider the point as basic element of touch and visual perceptions. If we align our pair of eyes such that both are at about the same distance from the surface of the water, the apparent location of the point of touch, seen by our eyes will be determined firstly by the fact that it is on a line vertical to the surface of the water and going to the point of touch. Secondly, it is located on a backward projection of the ray of light, emanating from the surface of the water with its origin at the point of touch and ending at the eye. That is, every point is lifted at right angles to the water's surface. The magnitude of its elevation is determined by the law of refraction and the location of the "point of the eye". (We define the "point of the eye" as the center of a line connecting the pupils of both eyes). The location where a point of touch is being seen in accordance with this "law of optical elevation" we call "Point of elevation" for short (see fig. 1). - In the context of this essay we use the concept of "light ray": naively in the sense of conventional geometrical optics.

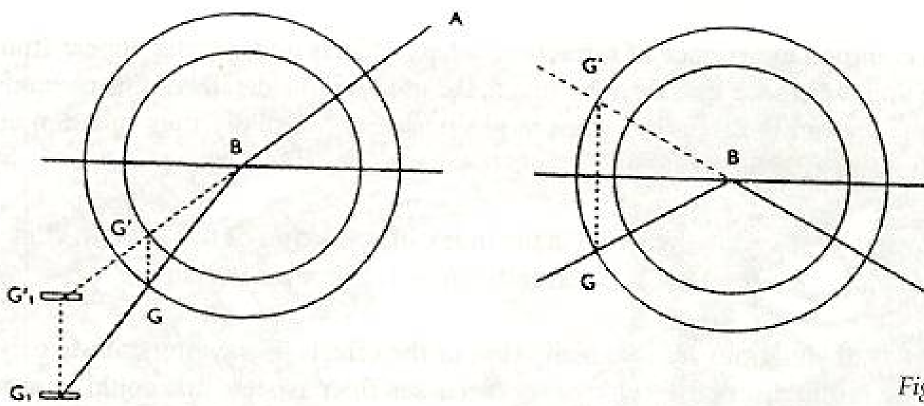


Fig. 1a, b

The objects, deformed according to the law of elevation are then seen in perspective by the eye. The optically perceived image is thus created from an object of touch by means of elevation and perspective.

The Problem of Optical Elevation ("Lifting") - Literature Review

The question for the reason for the phenomena of elevation as seen through a water surface was formulated perhaps for the first time by the emperor Frederick II (1212 - 1250), in a questionnaire directed at the Egyptian savant Schihab al Din Ahmed Ibn al Qarafi. There we read: "Why does one see rudders, spears, and all straight bodies that are partly submerged in clear water as bent toward the surface?" (Kurt Pfister, "Friedrich II," Munich 1941, pg. 208).

An early 20th century physicist, Arnold Brass,[2] writes about this beginning of a scientific treatment of elevation: "The brilliant Willebrord Snell, who, sadly died only too soon, worked on this question as early as the second decade of the 17th century. His contemporary, the Jesuit pupil Descartes, included Snell's unpublished accounts in his work, and Christian Huyghens (an equally famous contemporary of Descartes) in turn, tells of these accounts. They both neglected *elevation of images* because it did not agree at all with their hypotheses and calculations, and reformulated the law of refraction into a form still used today, as a ratio of the sine of the incident and sine of the refracted ray[3] along with the hypothesis of the wavelike propagation of light. Isaac Vossius also reports that Snell has omitted the computation of the elevation curve."[4] Brass defines the "elevation curve" as the curve appearing to the eye when it observes a straight line located below it in water. He also notes that Huyghens "...declared elevation to be only apparent, created by observing with two eyes."

Huyghens then correctly investigated this further, because when looking into water with only one eye, vertical elevation could still be observed. Goethe pointed out that " Huygens, through whom Snell's discovery was actually made known, protested against an alteration of the perpendicular ray, and led all his successors into this error."[5] Goethe notes further that Isaac Vossius "... had read Willebrord Snell's three optical books in manuscript form, and had acquired the latter's point of view. Vossius was of the opinion that elevation could be observed, even when looking vertically into the water, yet he was incapable of penetrating this phenomena. "[6]

Goethe apparently originated the term "elevation" for this phenomenon: "Pour water into a vessel and the eye will now see part of the bottom, and surely this occurs in such a manner that we believe we still see in a straight line; because the bottom appears raised, therefore we call this subjective phenomenon elevation (lifting)."[7] Elsewhere Goethe formulated this more precisely: "... every parallel medium displaces the object and moves it toward the eye, even when it is viewed perpendicularly."

Based on what we know about Snell and Vossius, and based on what we can deduce from Goethe's opinions, it appears doubtful at times that these authors were of the opinion that, a point would be raised perpendicularly, even for a diagonal view. This opinion was only definitively expressed by the other authors we discuss below. Yet, preceding the work of these authors, comes the development of a concept, thus far neglected by Descartes and Huygens, namely of the imaging point in the sense of geometrical optics: the basic element of optical space is the point as a bundle of rays. And the latter's imaging points are the places where the rays or their rearward extensions are gathered again after refraction at the first approach.[8] Based on this concept of the imaging point, a way of looking at elevation phenomena arose. One can see how this has condensed in Fig. 1a and 1b from Bergmann-Schaefer, "Lehrbuch der Experimentalphysik", III Band, 1. Teil. These figures have been chosen as typical examples from the descriptions in many tutorials and school books.

Arnold Brass takes issue with this way of treating the phenomena of elevation. He rejects "the attempts at explanation of curvelike image elevation along so-called caustic surfaces"[9] [see Fig. 2, the so-called di-caustic curve is a planar section through the rotationally symmetric caustic surface.] In the same way, he opposes Huygens' explanation of elevation as apparent (illusory) and caused by observation with two eyes. "I prefer not to mention what one should think of such an idea, which falls aside when one observes with one eye." The fact of *vertical* elevation is the only one that can explain the phenomena.[10]

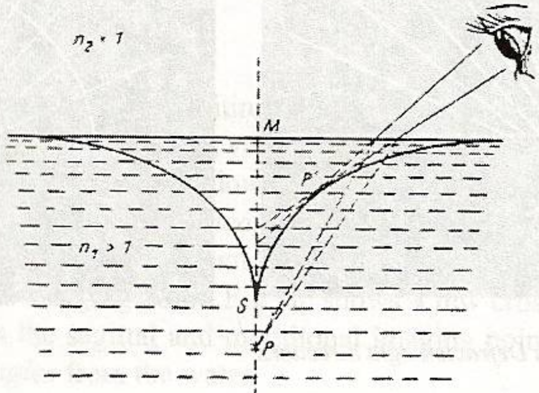


Fig. 2

In a similar vein, Hermann von Baravalle and E.A.Karl Stockmeyer also investigated optical elevation. For vertical elevation, Stockmeyer has specified a geometrical construction, and with its help has drawn several "elevation curves" for straight lines seen in water.[11] Later, von Baravalle has thoroughly investigated the conventional construction (Fig. 2, previous page). He constructed the images of a rod lying horizontally in water, as well as one immersed vertically, both according to the law of elevation (see Figures 3 and 4) as well as according to the conventional construction. After comparing the experience he came to the conclusion that only the construction of the vertical elevation was capable of correctly reproducing the phenomena. Figures 3, 4, 5 and 6 are from Dr. Herman von Baravalle, "Erweiterung der Perspective, Krümmung des Sehraumes" [The widening of perspective, curvature of the visual space], Stuttgart.

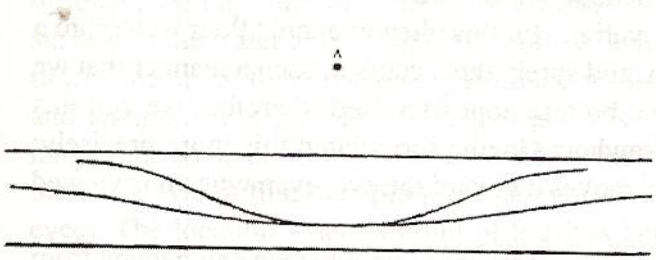


Fig. 3

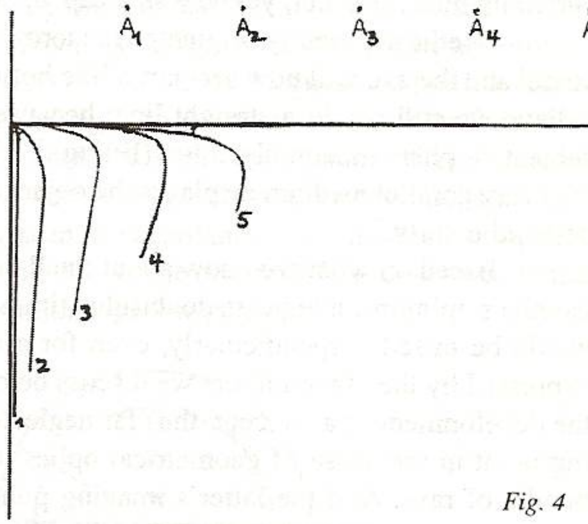


Fig. 4

This publication contains references to further essays of E.A.K. Stockmeyer and H. von Baravalle on the subject of optical elevation. A brief description of elevation may also be found in "Physik als reine Phänomenologie", Bern 1951, Band III, page 130 ff. by von Baravalle (Fig. 5 and 6).

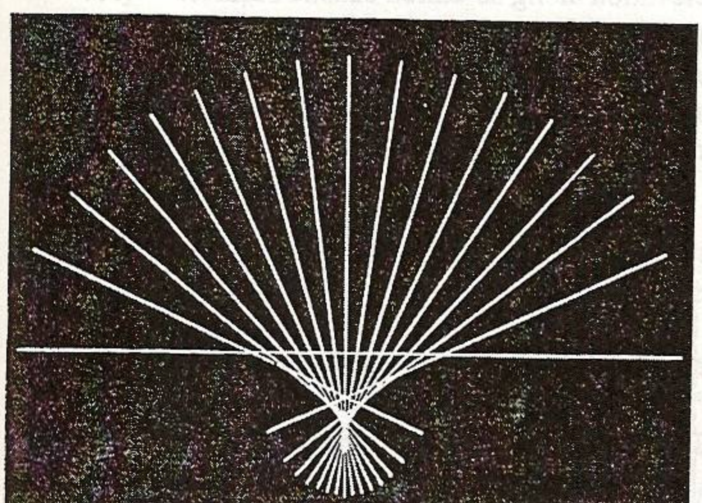


Fig. 5a Defracted light directions

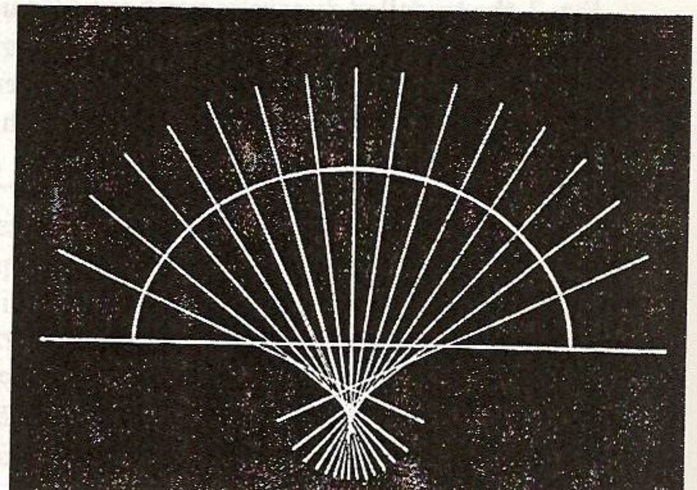


Fig 5b Evolute of an ellipse

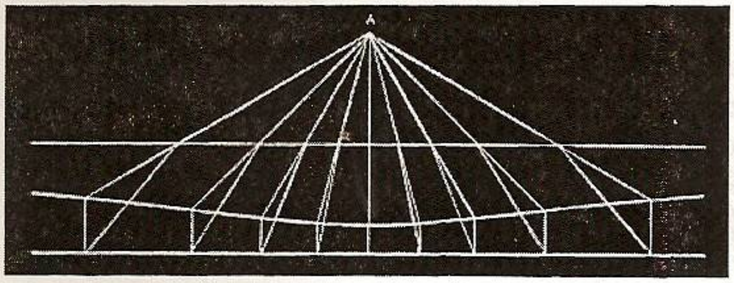


Fig. 6a The apparent lifting and the curvature of the plane

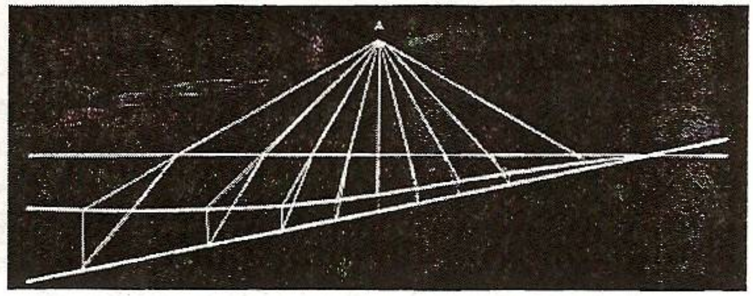


Fig. 6b Optical apparent curvature of a diagonal view into water.

Additionally Fritz Lobeck has expressed the fact of vertical elevation for all directions of observation in "Erfahrungen mit Goethes Farbenlehre an Iris, Halo, Hof" Strassburg 1937, page 32.

Robert Wichard Pohl briefly mentions vertical elevation in "Einführung in die Optik" Springer - Verlag 1948, page 42, Abb. 100. Pohl, like Huygens, explains optical elevation as a phenomenon of binocular vision.

This brings us to the end of our overview of literature regarding optical elevation as far as we know it.

Binocular Vision and the Sagittal or Meridional Image-Point

Referring to "conventional" representations of refraction of the type shown in Fig. 7, it has to be stated that firstly they incorrectly reproduce the phenomena and, secondly, that they are in contradiction to the construction (Fig. 7) meant to explain these drawings. In Fig. 7 the elevated point M^1 is located to *the left of* the tangible point (M), but in the Fig. 7b construction, *to the right*. One needs to note that the construction given in Fig 7 is incomplete in itself, in that it fails to fully take into account the astigmatism created by a fractured level plane.

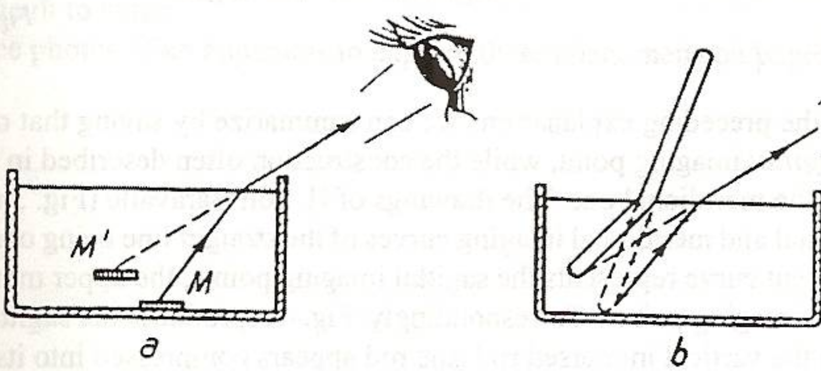


Fig. 7

Ignoring bonocular vision, and arbitrarily limiting itself to consider only the so-called "meridional imaging point" H_m(in the vertical plane) it overlooks the fact that the bent cone of light in its rearward projection shows a second choked-down area, the so-called "sagittal imaging point" H_s. And this sagittal imaging point lies on a *vertical* line through the tangible point. Figure 8a schematically shows the construction of the virtual *meridional* imaging points, Fig. 8b clarifies the location of the virtual sagittal imaging point, Fig. 8c shows a few cross sections of the refracted bundle of rays. We note that the sagittal and meridional imaging point coincide *only* for a light bundle emanating *at right angles* from the water.

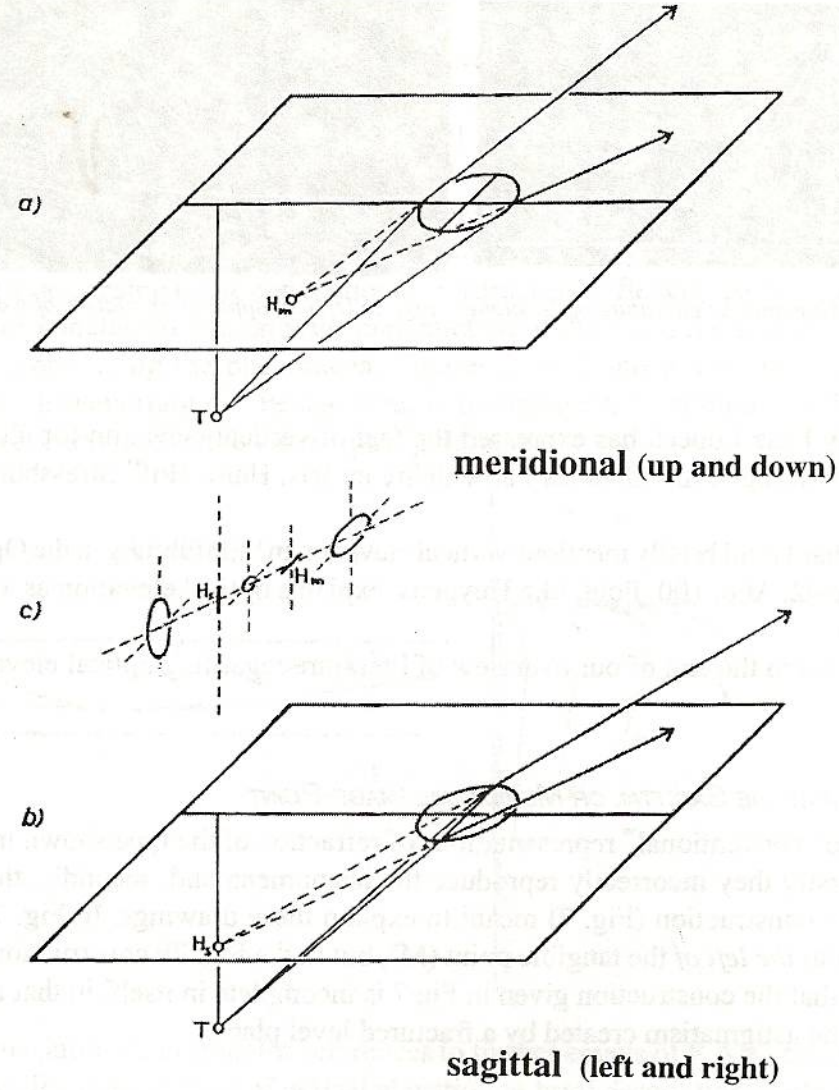


Fig. 8

Looking back at the preceding explanations we can summarize by saying that optical "el-evation" produces the *sagittal* imaging point, while the construction often described in text books (Fig. 2, again) produces the meridional one. The drawings of H. von Baravalle (Fig. 3 and Fig. 4, again) reproduce the sagittal and meridional imaging curves of the straight line being observed. On Fig. 3 the lower slightly bent curve represents the sagittal imaging points, the upper more strongly bent curve the meridional imaging points. Correspondingly, Fig. 4 reproduces the sagittal imaging points that coincide with the vertical immersed rod (the rod appears compressed into itself toward the top), and the family of bent curves 1 to 5 represents the respective meridional imaging curves for the corresponding points of observation A1 to A5.

One can easily convince oneself of the existence of both imaging curves, constructed by Hermann von Baravalle, both in case of the horizontal rod and of the vertically immersed rod. This is done in the following way. By observing with both one's pair of eyes, if one has a sufficiently large basin of water (a large aquarium of a swimming pool) you perceive the sagittal imaging curve when the axis connecting both pupils is oriented *parallel* to the surface of the water, the meridional one when the pupil axis is *vertical* to the water's surface, provided your distance from the object is large enough to allow the right and the left eye images to coincide.

If you wish to observe under laboratory conditions you can conduct Experiment 1 at the end of this Newsletter.

Synopsis

Normal human vision is binocular. Through accommodation we achieve a sharp focused image, and by crossing the direction of view, we are able to localize the image in space. Monocular vision is a case of degeneration of human vision.

The laws for binocular vision are simple. If the connecting line between the pupils is oriented *parallel* to the surface of the water, the law of optical elevation prevails (see Fig. 3 and 4). We can understand this law as a simplified construction of the virtual sagittal points of imaging. This elevating construction is clearer with one refracted ray of light leading from the point of touch to the point of the eye (see Fig. 3 and 4, again) instead of two rays leading to the pupils (see Fig. 2 or 8a). This leads to practically the same result.

Now, if we turn our two eyes *diagonally* out of the horizontal position, so that the pupils have unequal distances from the water's surface, then the perceived image generally separates into *two* images. The backward projections of the refracted rays do not intersect—they are askew of each other.

Lastly, if we turn our pair of eyes so far that the connecting axis is vertical to the surface of the water, i.e. in one and the same plane with the point of touch which is vertical to the surface of the water, again we see *one* perceived image. The backward projections of the rays leading to the point of touch intersect because they are again on the same plane. One finds the imaging point in this case in the construction of the virtual *meridional* imaging point (according to Fig. 8a). It lies in the vicinity of the dia-caustic (Fig. 2, again) if the light rays leading to the eyes diverge only very little. A simplified construction, as in the case of the virtual sagittal imaging point is not possible, one has to make do with approximations.

This may have clarified the connections between optical elevation, binocular and monocular vision and the concepts used in conventional optics of sagittal and meridional imaging points. From a pedagogical point of view, we might recommend introducing the sagittal and meridional imaging point with the help of binocular vision [perhaps in Grade 12 Optics – Eds.]. Corresponding considerations can be carried out for the case of the imaging point located in optically denser media and the point of touch in optically thinner media. However, the observations in this case are more difficult to make.

(See photos of an apparatus to explore these phenomena on pages 17-22.)

Description of Curves in Connection with Elevation Phenomenon

Fig. 9

The observer from the air looks vertically down (perpendicular) to a horizontal straight line in the water, at depth y = –d. From point 3 he sees the curve 3. As he approaches the surface of the water the curve increasingly conforms from below to the ellipse 0 at the surface of the water. If the observes moves away to infinity the curve increasingly conforms to the straight line from above.

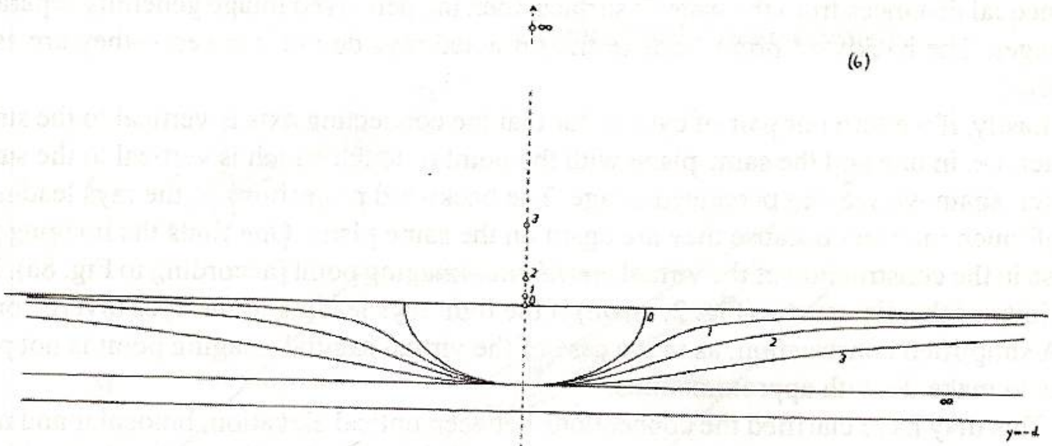


Fig 10 (The labels are upside down)

From the water the observer looks up at a straight line located in the air at altitude y = -d. From point 3 he sees the curve 3. If he gets up closer to the surface of the water, then the curve will increasingly approach the hyperbolic curve. If he moves deeper, to infinity, the curve will increasingly approach the straight line, above.

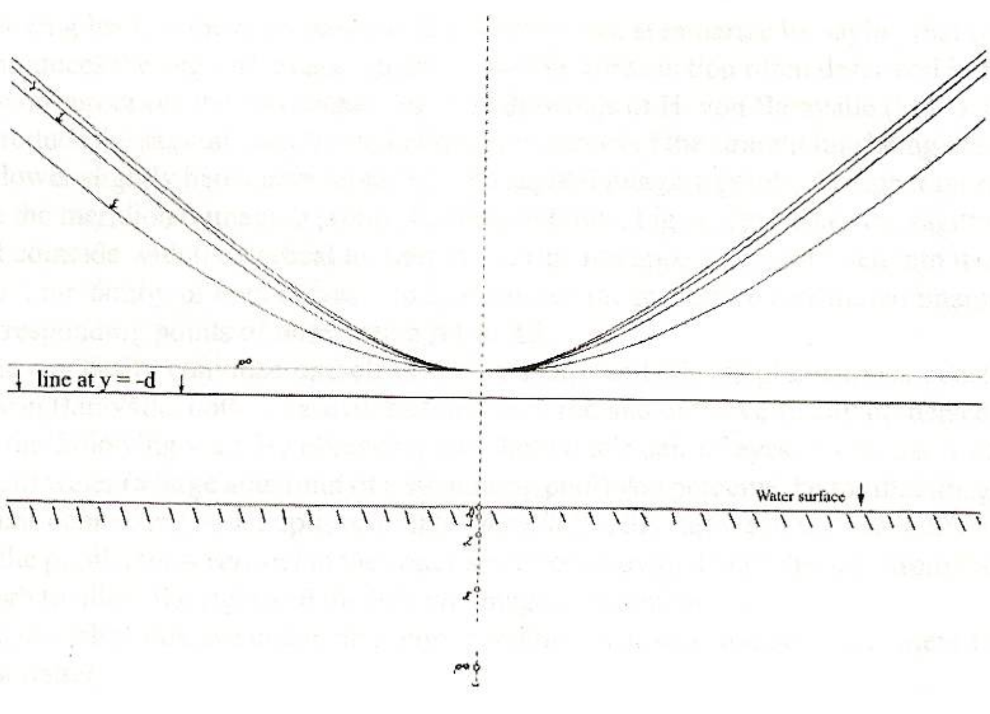


Fig 11

The observer from the air A looks at the array of straight horizontal, lines 1, 2, 3, 4, 5 lying in the water, and sees these as the array of curves 1, 2, 3, 4, 5 lying crosswise in the water.

The other branches of curves lying in the air which form one mathematical curve with the curves in the water are of significance in connection with the embryonic development of the eye. (One can call these conchoidal elliptical curves).

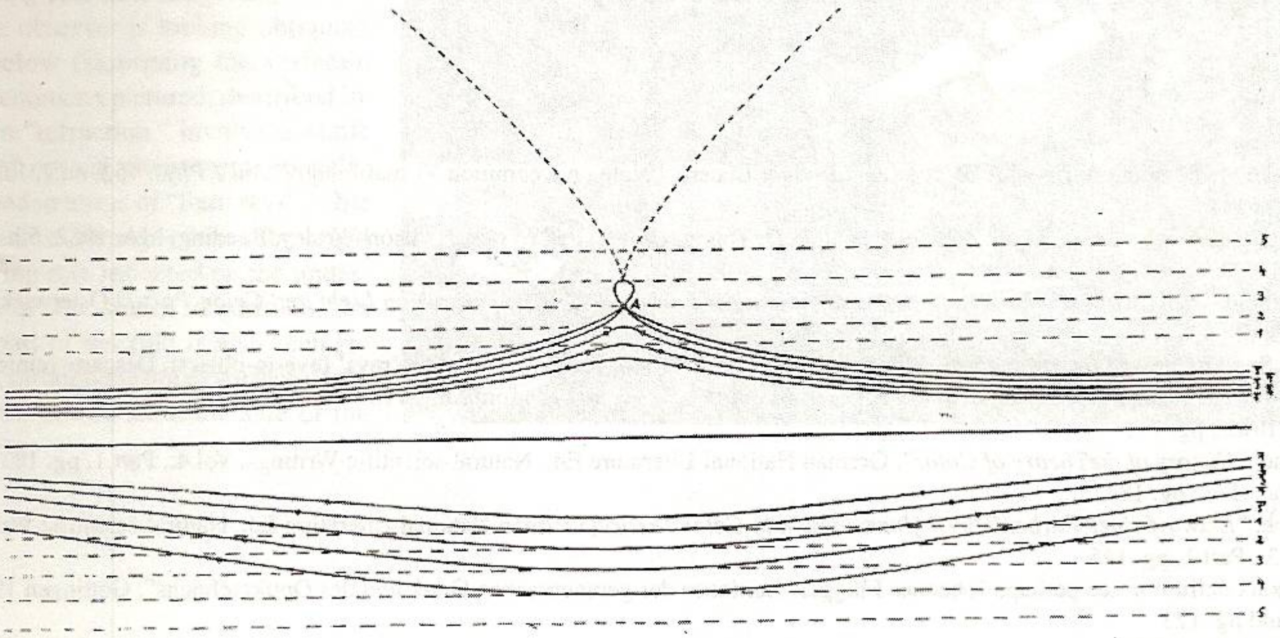
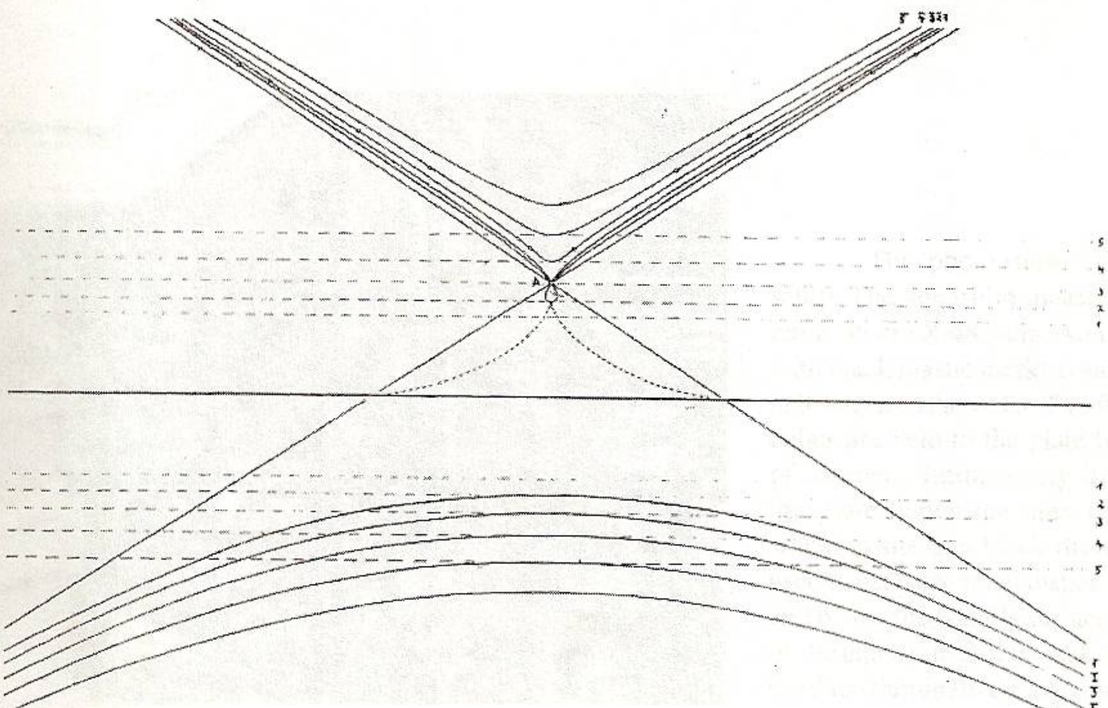


Fig.12

From the water observer A looks at he array of horizontal straight lines 1, 2, 3, 4, 5 and sees them as an array of crosswise curves lying in the air.

The other branches of curves, lying in the water which form one mathematical curve with those lying in the air are of significance in connection with the embryonic development of the eye. (One can call these conchoidal hyperbolic curves).



(4')

About the calculations

These curves may be analytically compared with inversions of representational equations, such as, for instance, the ones that were deduced for the situation "eye in air/points of contact in water."

Endnotes:

[1] For a detailed exploration, see: A. Bartlett and Rodger Lucero, "Note on a common Virtual Image," *Am.J.Phys.* v52, no.7, July 1984, p640-643.
compare also F.W. Sears, M.W. Zemansky, and H.D. Young, *University Physics*, Addison-Wesley, Reading, MA, 1982, 6th Ed., p744.

[2] Dr. Arnold Brass, "*Untersuchungen über das Licht und die Farben, 1. Teil*" [*Research on Light and Color, Part 1*] Osterwiek/Harz, 1906, pg. 130

[3] Note: Snell expressed the law geometrically as ratio of the length of the visible/tangible'rays' (eye-to-object); Descarte reinterpreted this into the mathematically equivalent, but experientially opaque, modern form of the formula Sin *i*/Sin *r*.

[4] *ibid.*, Brass, pg. 141

[5] Goethe, "*History of theTheory of Color*", German National-Literature Ed., Natural-scientific Writings, Vol.4., Part 1, pg. 183

[6] Goethe, *ibid.*, pg. 184

[7] Goethe, "*Entwurf einer Farbenlehre*," [*Introduction to Color Theory*] German National-Literature Ed., Natural-scientific Writings, Vol.3., Part 1, pg. 145

[8] For exact definition see perhaps Johannes Flügge, "Leitfaden der geometrischen Optik und des Optikrechnens", Göttingen 1954, pg. 20 und pg. 123

[9] Brass, *ibid.*, pg. 166

[10] Brass, *ibid.*, pg. 166

[11] E.A.K. Stockmeyer, "Die Erscheinung der optischen Hebung" [the Phenomenon of optical elevation] in the journal "Rudolf Steiner's Pedagogy" III annual edition 1929/30, issue 3/4 pg. 227

[12] See investigations of monocular and binocular vision on mirroring and refracting surfaces by H.W. Dove in "*Darstellung der Farbenlehre und optische Studien*" [*Presentation of the theory of colors and optical studies*], Berlin 1853

This photo shows an aluminum measuring rule held diagonally in water. The observer is looking obliquely from below (skimming the surface). The phenomena pictured, described by the term "refraction," involve a whole realm of optical phenomena –usually described in terms of "light rays". One sees the mirror image of the submerged measuring rule reflected on the under-surface of the water. In addition, the upper part of the rule is also seen refracted, through the upper surface of the water, as viewed from the side of the aquarium.

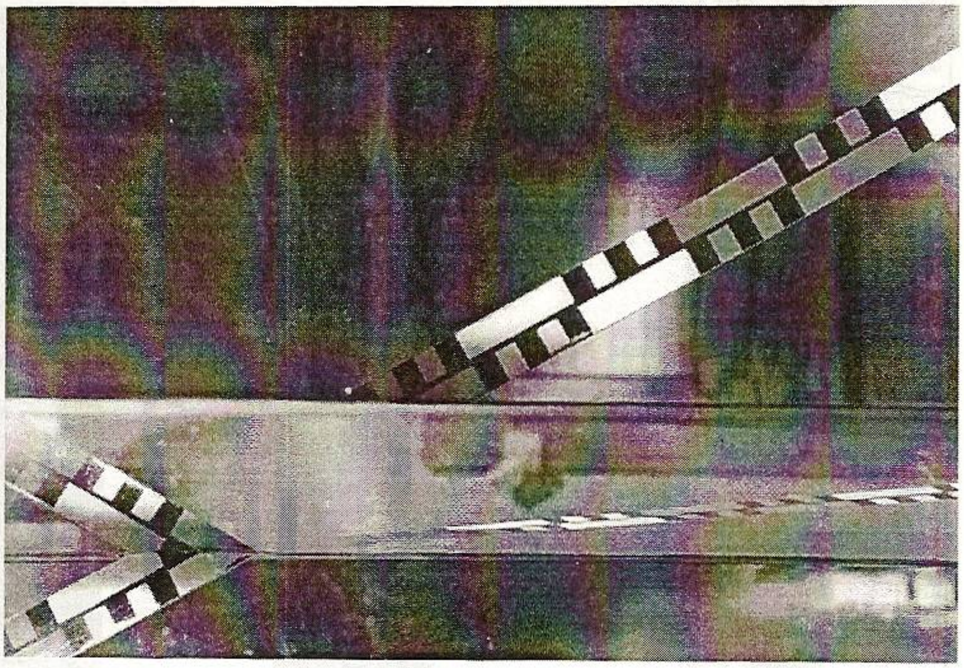
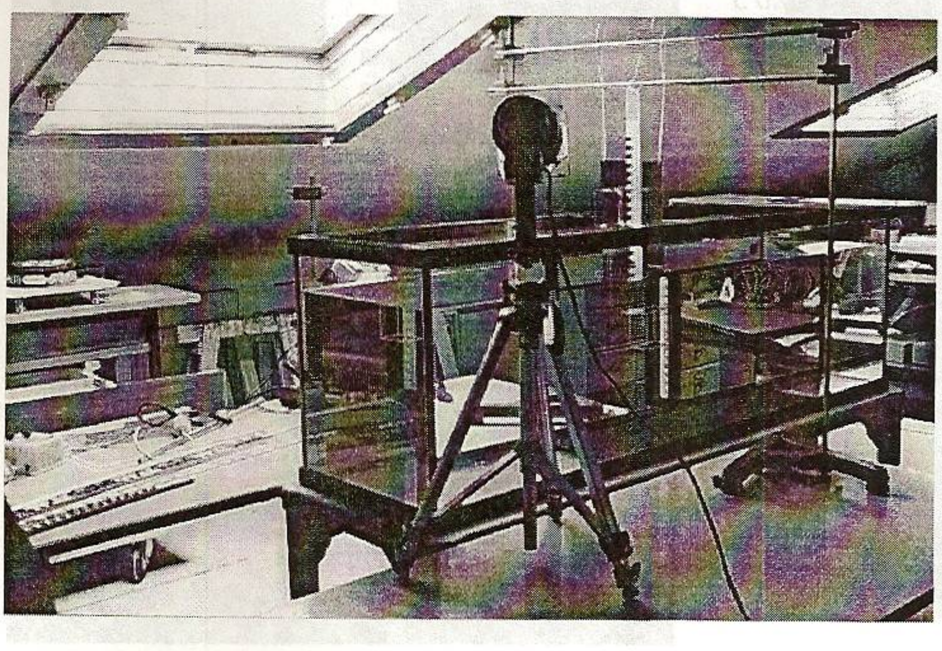
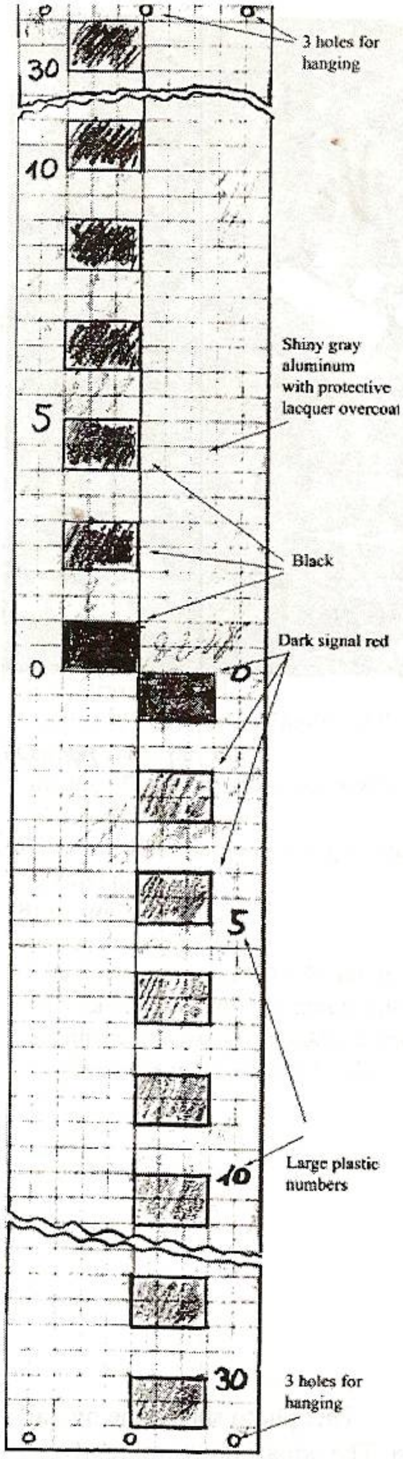


Photo 1



This photo shows the overall setup. The aquarium measures 165.5 cm X 39 cm X 48.3 cm. An iron plate with black plastic marks is submerged half-way into the water. Two 8 cm wire cubes are held to the plate by means of magnets. Immediately in front of the plate hangs the measuring rule whose white and black divisions are used to measure equal distances above and below the water's surface. In front of the aquarium and in back are lights used to illuminate the apparatus.

Photo 2



This photo shows an aluminum measuring rule which hung vertically on a wooded rod graduated in centimeters (the rod is 70 cm X 4 cm X 0.4 cm). The black scale will be seen reflected unchanged in size and the red scale will appear lifted and shortened. The red scale should be on the opposite side of the ruler than the black, as illustrated.

Photo 3

This photo shows a half-submerged aluminum measuring ruler mounted on a black metal plate. The black scale on the left is reflected on the water's surface, upside down but the lineal scale is unchanged. Notice the faint black reflected scale overlaying left side of the bright aluminum measuring stick. The red scale underwater is lifted and compressed; its 30 cm mark appears to match the 18 cm mark of the black scale.

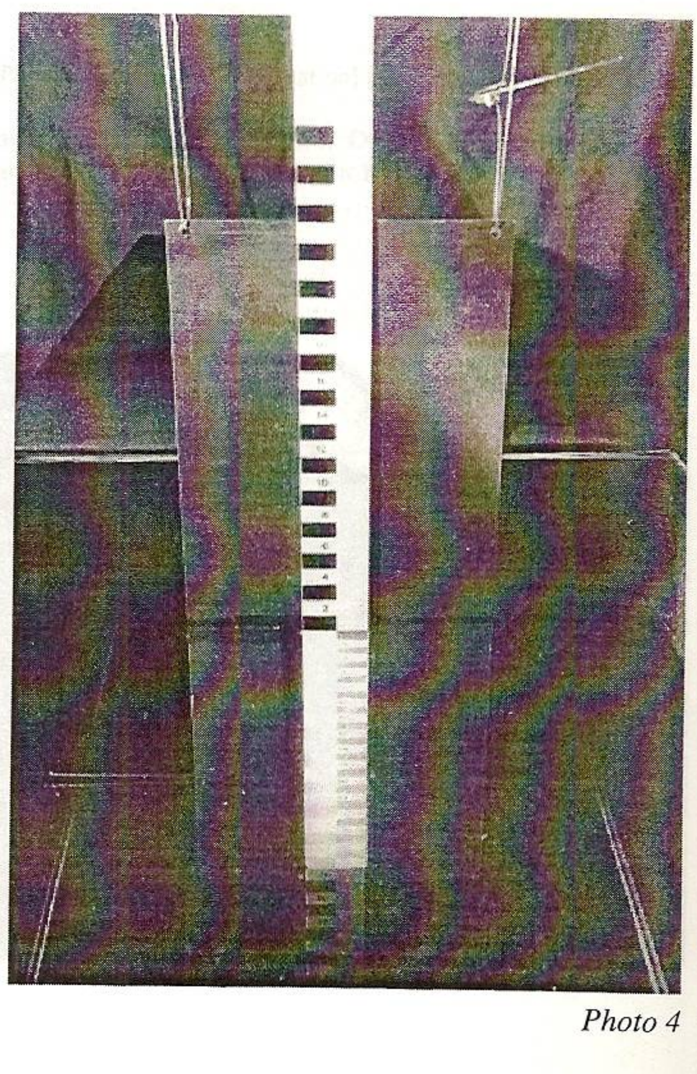


Photo 4

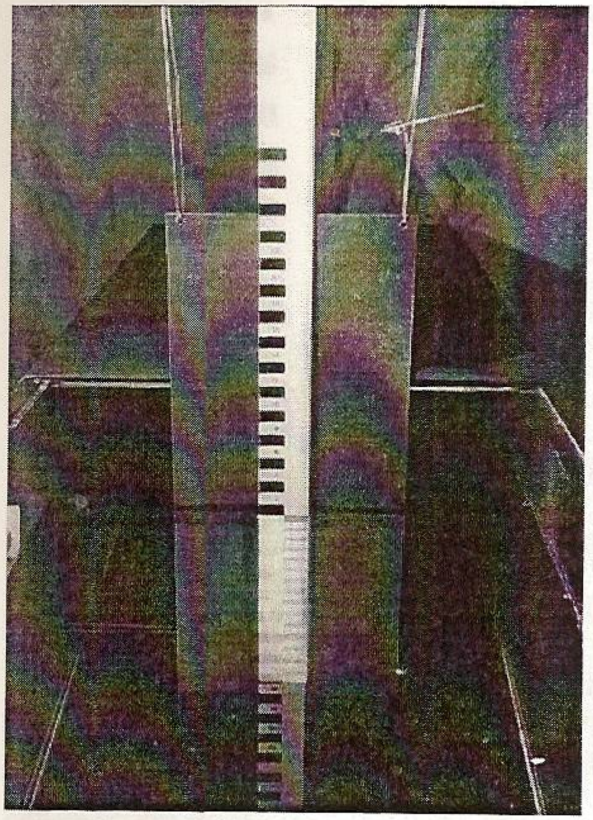


Photo 5

This photo shows a view looking lower, slightly closer to the rod and more oblique to the water. The phenomena of compression of the red scale due to lifting is increased; the 30 cm mark of the red scale appears at the same depth as the 15 cm mark of the mirrored black scale.

This photo shows a view closer to the surface of the water. The lifting is still stronger; the 30 cm mark of the red scale appears at the same depth as the 12 cm mark of the reflected black scale.

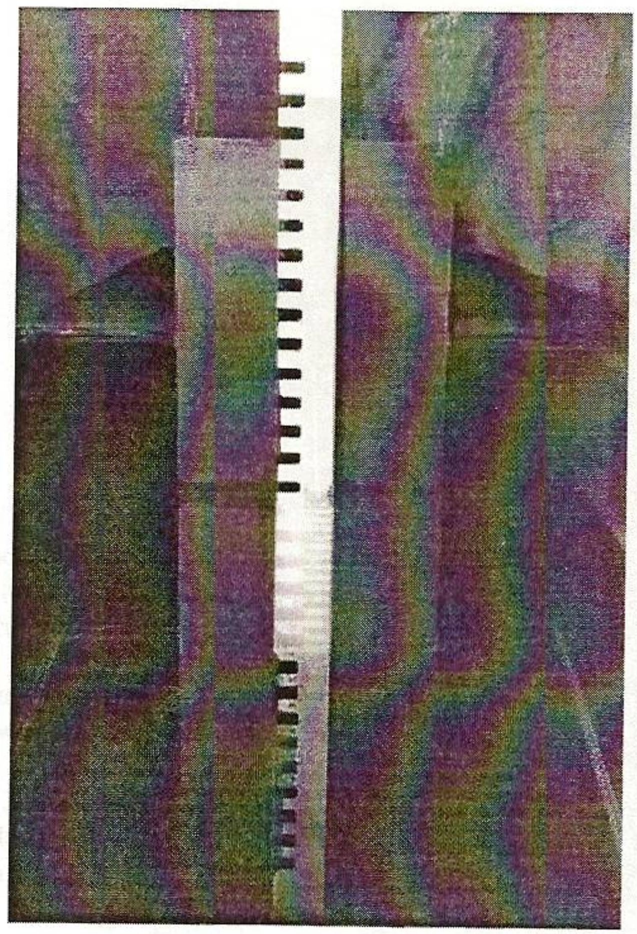


Photo 6

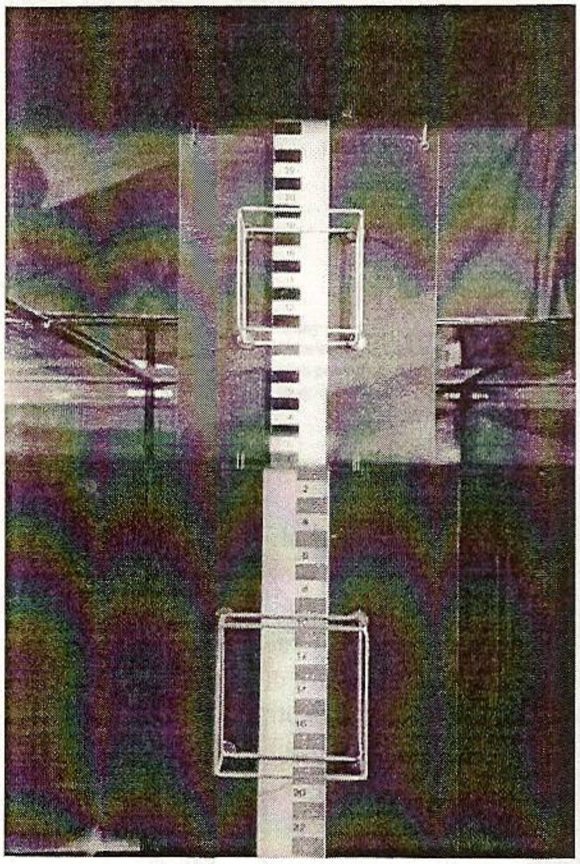


Photo 7

This photo shows two identical cubes viewed perpendicular to the aquarium wall. One is above and the other is below the surface of the water. They are positioned equidistant above and below the water despite the fact that the submerged scale is distorted.

The red cube and black mounting plate appear larger under water since they appear lifted vertically to the water's surface (side wall of the aquarium). Note how wide the iron plate appears wider under water.

This photo shows two identical cubes as above. Now the observer orients both eyes until the inter-pupillary line (connecting both eyes) is parallel to the surface of the water.

The mirror image of the white cube appears in true perspective size, and at equal depth under the water surface as the original is above the water's surface. The red cube appears completely lifted and compressed. The red 30 cm mark lies adjacent to the reflected black 19 cm mark. The red cube is lifted so far as to overlap only part of the reflected white cube.

Photo 8

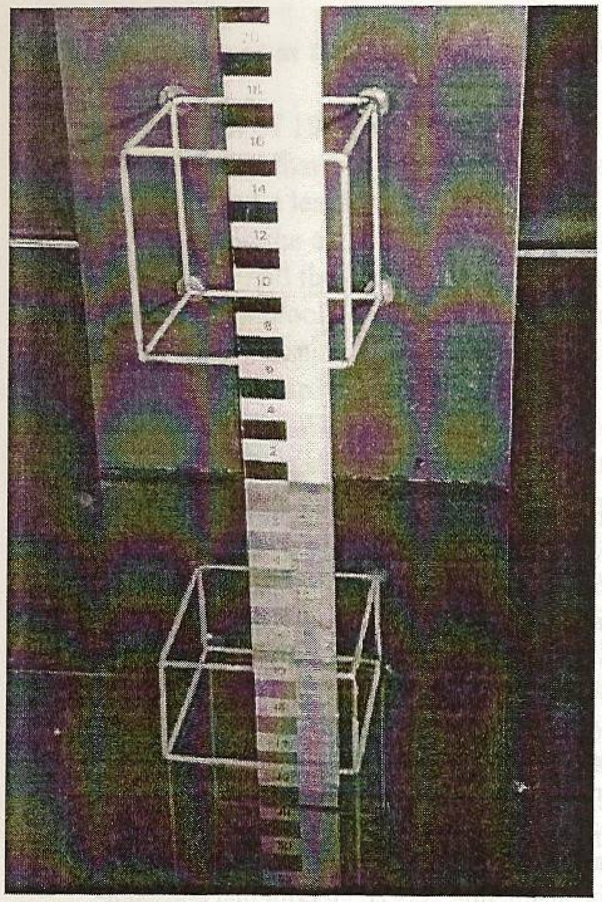


Photo 9

This photo shows a view even closer to the water's surface (and unfortunately for technical reasons, also closer to the cubes and therefore they are larger here then in preceding photos). The red cube is so strongly lifted that its lower edge matches the upper edge of the reflected white cube. The red 30 cm mark lies adjacent to the reflected <u>16.6 cm</u> black mark.

This photo shows a view still closer to the water's surface. The red cube appears to float above the mirrored white cube. The red 30 cm mark is adjacent to the black <u>11 cm mark</u>. (The red scale appears very weak since only a tiny portion of its light escapes the water's surface.) With these last three pictures of cube pairs the red cube appears progressively lifted vertically–provided that the observer's's interpupillary line is parallel to the water's surface and that both eyes are at the same distance from the water's surface.

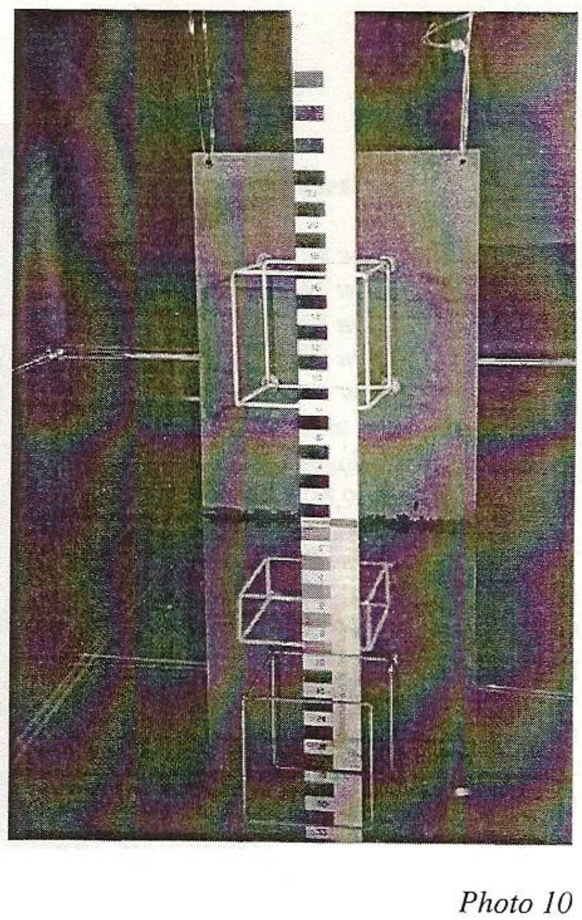


Photo 10

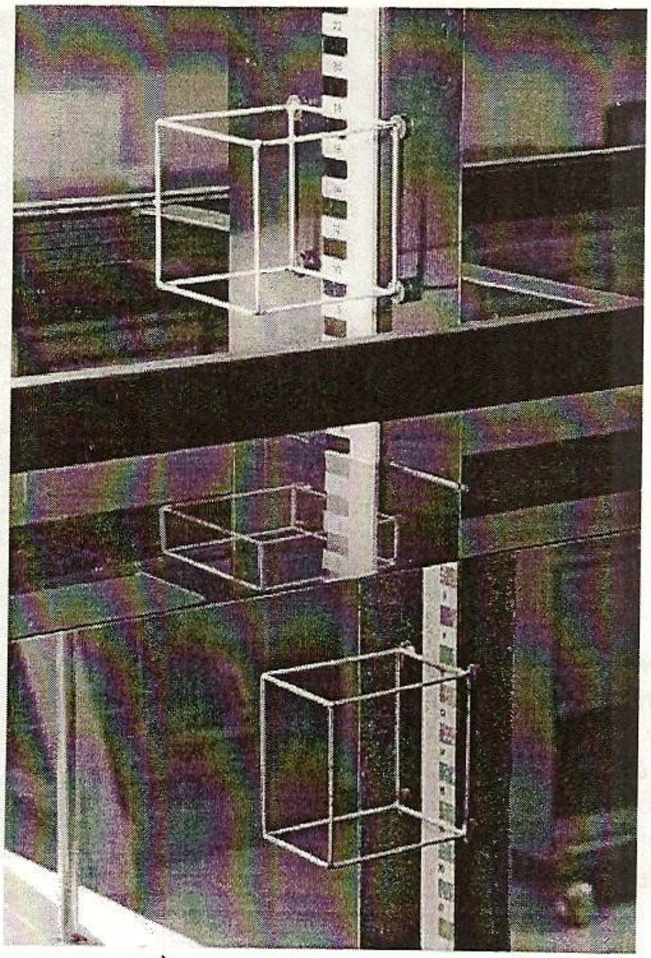


Photo 11

This photo is a closeup from the overall setup. The observer's view skims the water's surface and sees the submerged red cube, which appears strongly lifted and compressed.

Simultaneously, the observer looks diagonally through the side wall of the aquarium to the submerged red cube. Here it appears less compressed vertically and displaced somewhat, perpendicular to the vertical wall (essentially horizontal). Its image does not line up vertically anymore under its twin cube, since the distance of each eye is not the same to the aquarium wall. (This is the distinction between meridional and sagittal viewpoints as explained in the text).

This photo shows Dieter Wolf and Günter Altehage experimenting together with the "lifting" tank located at the Stuttgart Waldorf teacher training Seminar.

Photo 12

Water Treatment at the Toronto Waldorf School

In the fall of 1998, it became apparent to the school community that our septic system consisting of septic tanks and a leaching bed was, after 25 years of service, nearing the end of its useful life. Residential development and the services it would bring was approaching our school but not in a time frame that would help us in the near future. A new septic field built to current standards would be a large and expensive project as well. We began to look at alternative solutions to our sewage problems. We hoped that we could provide some environmental leadership and build a system that worked for us and the ecosystem we live in. The system we eventually selected was the Eco Rem process built by EcoWerks of Woodbridge Ontario. The EcoWerks process which is built upon the work of Dr. John Todd into the concept of the ìLiving Machineî. It treats sewage and gray water onsite without chemicals, using natural systems to produce ìswimming gradeî quality water. This water can be safely put back into the environment or re-cycled.

The process takes place in aerobic and anaerobic tanks surrounded by a filtering wetland inside a greenhouse. At the Toronto Waldorf School this greenhouse is about 600 square feet with an 18-foot high, sloped wall of glass facing solar south. As I write this in late winter, we have had an almost flawless ramp up to full capacity and are waiting for our first water quality test to come back. We are testing for nitrogen, phosphorus, suspended solids and biological oxygen demand. A complementary addition to this custom design is the inclusion of five flowforms whose water cascades into a plant filled pond. The greenhouse is odor- free and slowly filling with plants soon to be growing in the wetland. Potting benches in this heated space will also house the seedlings for the schoolís new gardening program.

An added feature of the system is that we will reuse our treated water over and over again in our toilets and urinals. This will result in a water consumption saving of between 60% and 75%. Even in winter, the greenhouse is a sunny, vegetation filled room echoing with the sound of running water and suitable for small groups of students to sit and study the complex interaction between sun, plants and water. Interest from the students has been high, beginning with the grade oneís who contributed a gold fish to the pond, to the high school students who are having the engineer who designed the project, come and speak to them. The school is also hoping that the project will have an aspect of outreach to the larger community as we continue to provide alternatives to the environmental challenges that surround us.

– Paul Sheardown

❋ ❋ ❋ ❋

A Little Perspective

Pythagorean theorem:	24 words
The Lord's prayer:	66 words
Archimedes' Principle:	67 words
The 10 Commandments:	179 words
The Gettysburg address:	286 words
The Declaration of Independence:	1,300 words
The US Government's recent regulations on the sale of cabbage:	26,911 words

A Lime Kiln That Can Be Assembled and Disassembled

John C. Hoffman

An important modern industry with a history older than that of the smelting of metals is the heating of time (calcium carbonate - CaCO3) to produce burned lime or quicklime (calcium oxide - CaO). Quicklime is used in mortars, cements, iron and glass making, and in neutralizing acid soils. Lime is obtained in the form of limestone, chalk, coral, shells, and marble, marble being the least desirable because of impurities. The chemistry of the lime cycle for mortar is simple. When heated to about 1000')C (1800 “F) in a kiln for a period of time, lime breaks down releasing carbonic acid (carbon dioxide - C02) leaving quicklime. The quicklime is mixed with sand and water to make a fluid mortar. Quicklime and water produce slaked lime (calcium hydroxide - Ca(OH)2) which hardens by releasing water and reabsorbing carbon dioxide from the air to produce lime. The process comes full circle from lime to quicklime to slaked lime to lime (see Fig. 1).

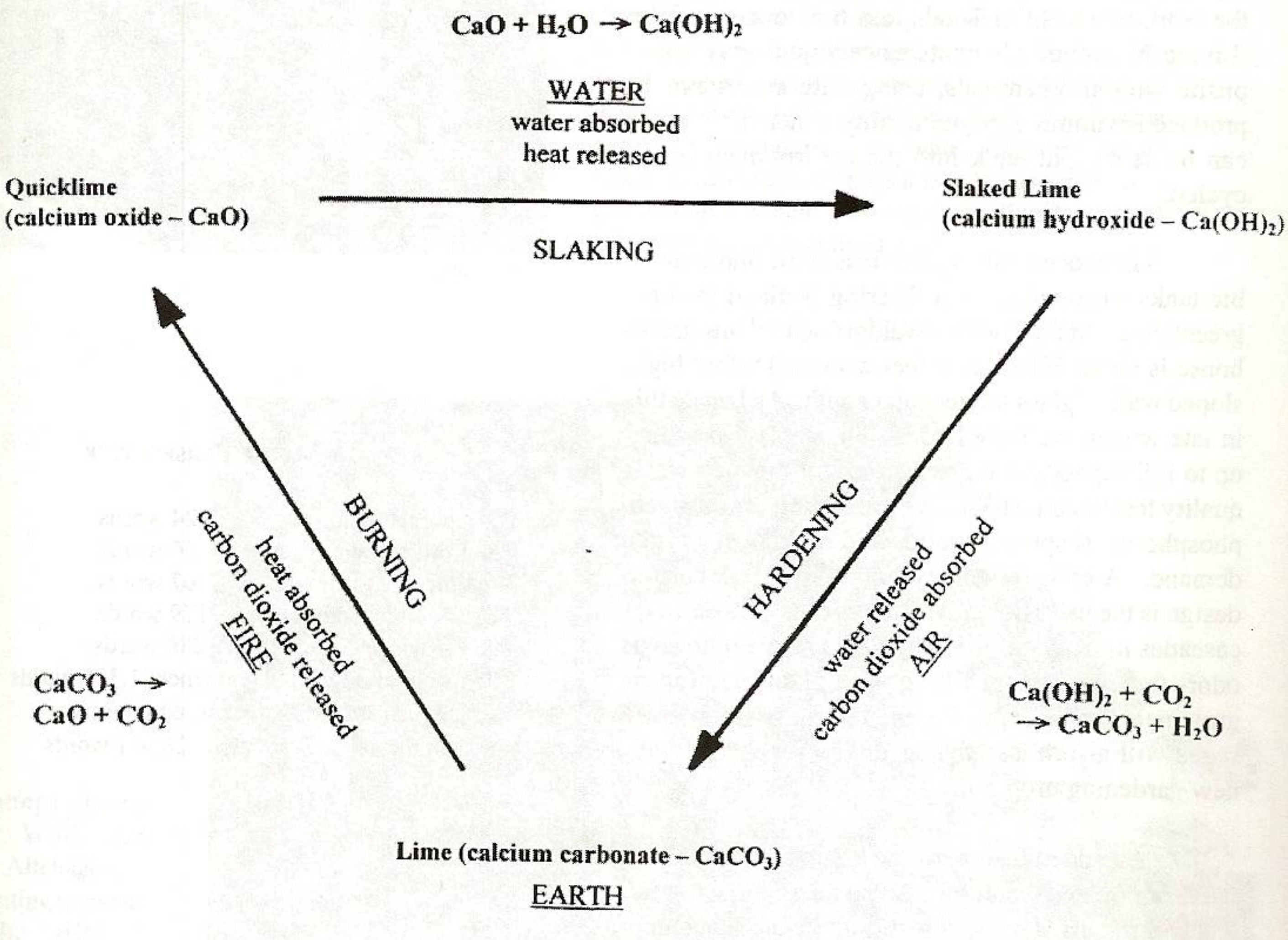


Fig. I The Lime Cycle

Today students have very little opportunity to observe actual industrial processes. Almost everything comes magically ready-made and packaged. Manufacturers, fearing accidents and lawsuits, have all but closed their doors to public tours. Nevertheless, the lime cycle studied in seventh grade chemistry offers an opportunity for the students not only to observe an important industrial process, but to build and fire the kiln used in the process. The construction, loading and firing, experimenting with the quicklime, and disassembly of the kiln is a three to four day project. It requires firebrick, a metal stack cover, a source of lime (limestone or marble), charcoal, a fan or bellows, and some digging. The cost of the metal stack cover and firebricks should be about $110, and the cost of firing and lime about $40. The kiln can be refired as many times as desired and then disassembled, the trench filled, and the bricks and steel stack cover stored for another class. If the grass at the kiln site is carefully removed, it can be replaced and the site healed. The kiln is simple to build and has been tested, but the instructions must be carefully followed. You are working with a quarter ton of firebrick and very high temperatures. An unstable structure could be dangerous. An excellent adjunct to the project would be a field trip to collect pieces of limestone or marble.

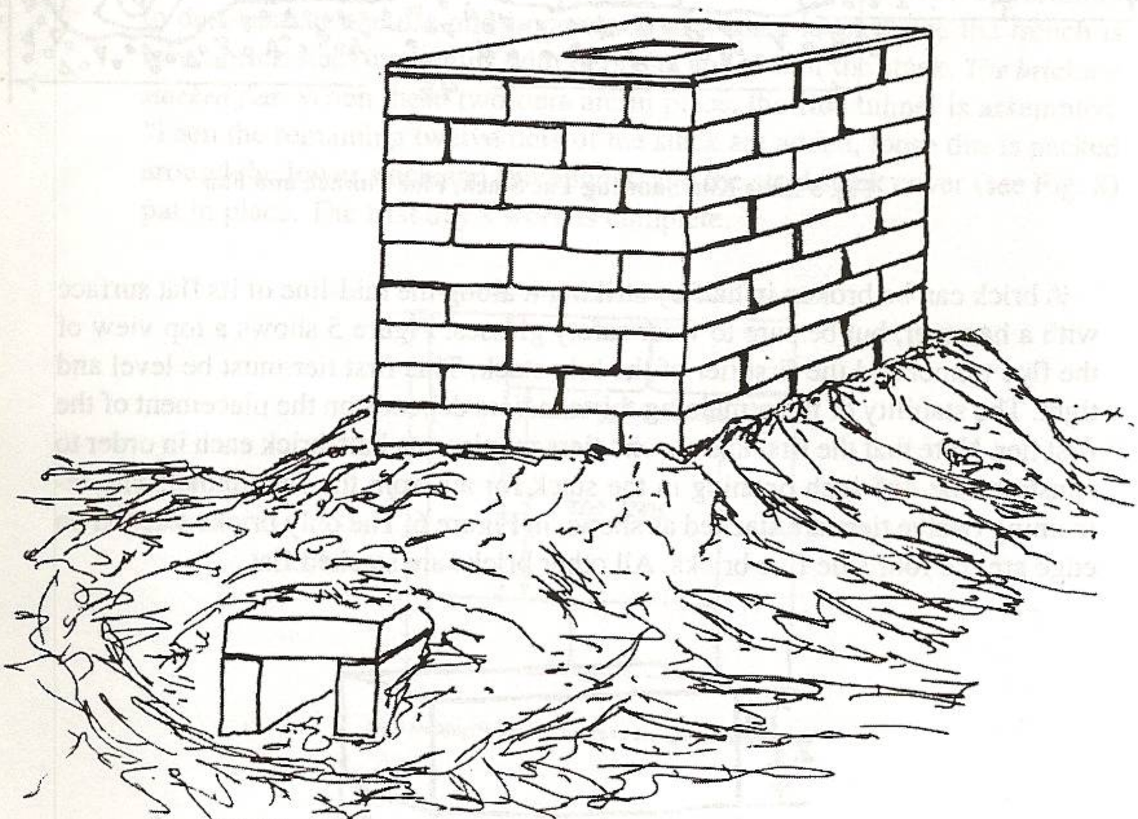


Fig.2 Lime Kiln Showing The Upper Stack and Flue Opening

Figure 2 shows an assembled kiln and its flue tunnel opening. Figure 3 shows a cutaway side view of the kiln and flue tunnel. Loose dirt from the trench is packed around the stack and flue tunnel to help hold in heat and reduce air leakage. The kiln stack stand,, about 35 inches in height and 20 inches square. It has 14 tiers and requires 110 whole firebricks and 2 half-bricks (see Fig. 4).

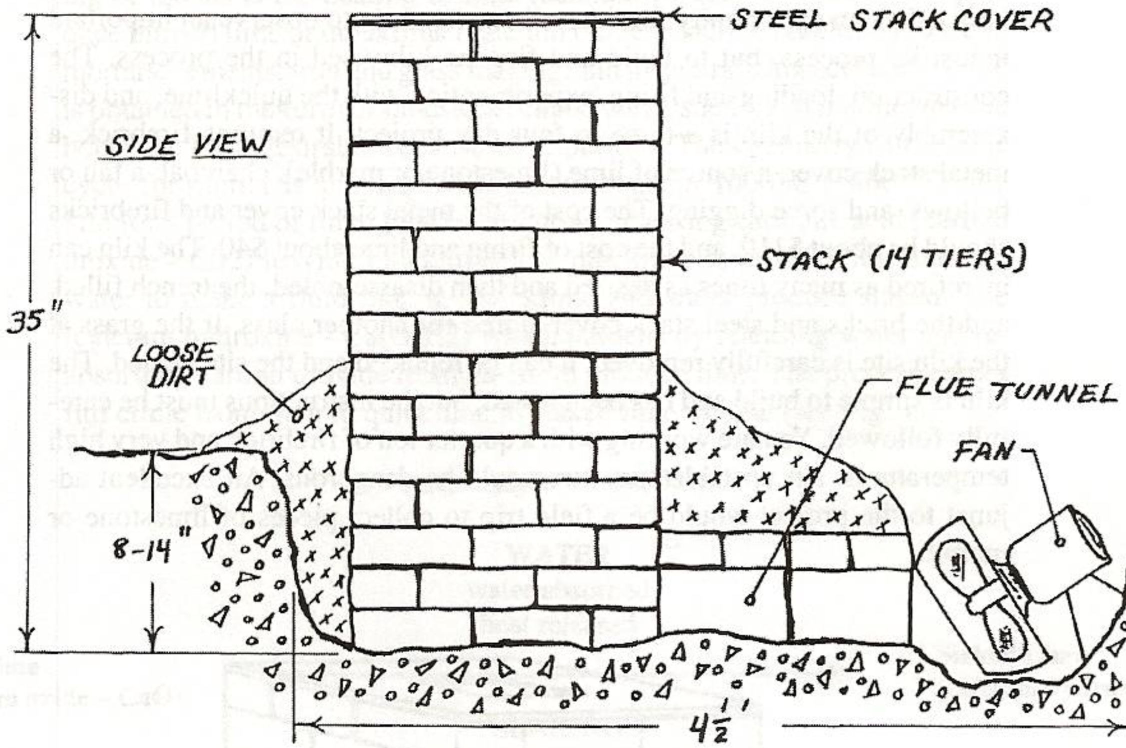


Fig. 3 Lime Kiln Showing The Stack, Flue Tunnel, and Fan

A brick can be broken in half by striking it along the mid-line of its flat surface with a hammer, but be sure to wear safety glasses. Figure 5 shows a top view of the flue tunnel and the first tier of the kiln stack. This first tier must be level and tight. The stability of the remaining thirteen tiers depends on the placement of the first tier. Note that the first and second tiers require one half-brick each in order to construct the 4x5 inch opening in the stack for air from the flue tunnel. The remaining twelve tiers are stacked as shown in Figure 6. The only bricks stacked on edge are the four side flue bricks. All other bricks are stacked flat.

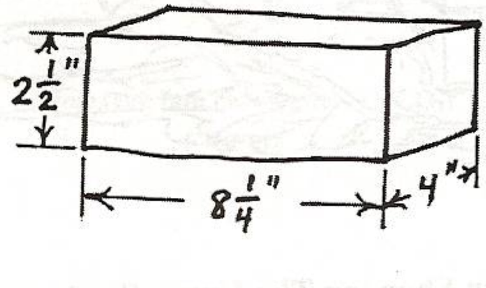


Fig. 4 Firebrick

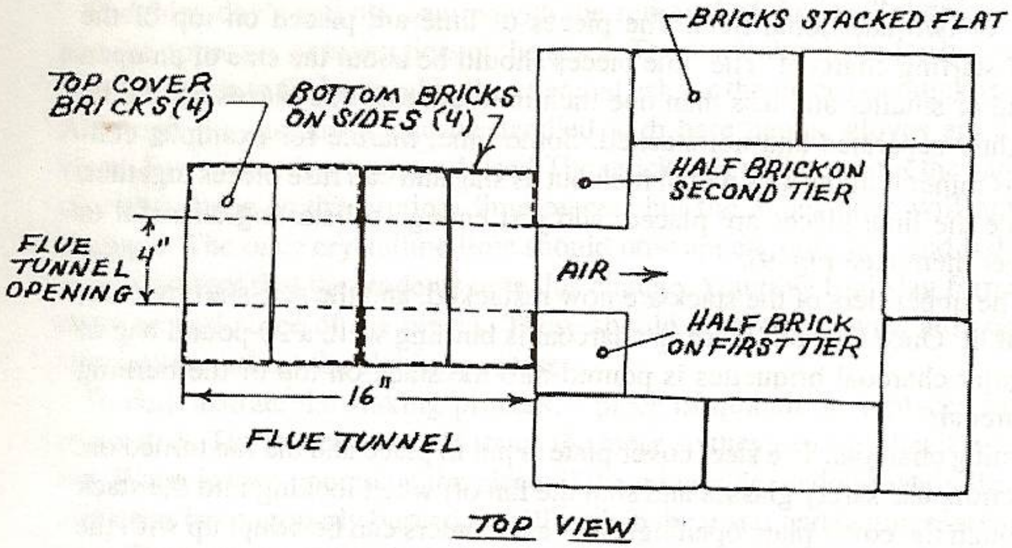


Fig. 5 Brick Stacking Pattern For The Flue Tunnel And First Two Stack Tiers

Kiln construction should take three to four hours. It begins with the digging of a trench to the approximate dimensions shown in Figure 7. Trench depth depends on how difficult the earth is to dig and how much effort the students are willing to put into digging. After the trench is dug, the bottom needs to be leveled, especially the surface under the stack. It is an excellent opportunity to demonstrate the use and importance of a spirit level. Once the trench is level, brick stacking begins with tiers one and two of the stack. *The brick.are stacked flat.* When these two tiers are in place, the flue tunnel is assembled. 'Then the remaining twelve tiers of the stack are added, loose dirt is packed around the lower stack and flue tunnel, and the steel stack cover (see Fig. 8) put in place. The first day's work is complete.

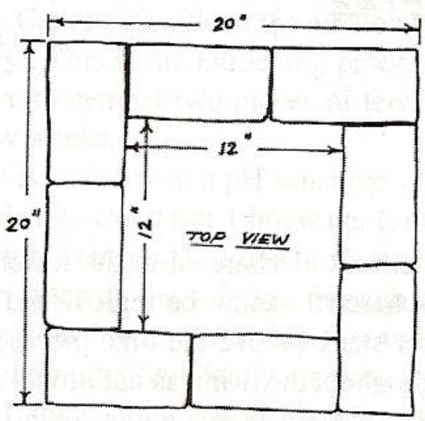


Fig. 6 Stacking Pattern For The Third Through Fourteenth Tiers

Loading and firing of the kiln on the second day begins with the removal of the steel stack cover and the upper six or seven tiers of the stack. This should go quickly and give dnv students who might have been left out of the first day's activity an opportunity to unstack and restack the bricks. Once the upper stack tiers are removed, one and a half 20 pound bags of charcoal briquettes (30 pounds total) are poured into the stack. Eight pounds of self-starting charcoal are poured on top of this. If the stack is not high enough, then add one or two additional tiers. The pieces of lime are placed on top of the self-starting charcoal. The lime pieces should be about the size of an open hand or smaller and less than one inch in thickness. The pieces should be slightly separated and not stacked. Some lime, marble for example, contains mineral impurities which melt out as slag and can fuse pieces together. Once the lime pieces are placed, add just enough selfstarting charcoal to cover them (see Fig. 9).

The upper tiers of the stack are now restacked, and the self-starting charcoal lit. Once the self- starting charcoal is burning well, a 20 pound bag of regular charcoal briquettes is poured into the stack on top of the burning charcoal

burning charcoal. The steel cover plate is put in place and the fan turned on. Caution: use safety glasses and shut the fan off when looking into the stack through the cover plate opening. Dust and cinders can be swept up with the hot air flow. Do not remove the steel stack cover when firing. It will be very hot! Also, the stack heat will cause the cover to warp. This is normal. Do not try to press it down.

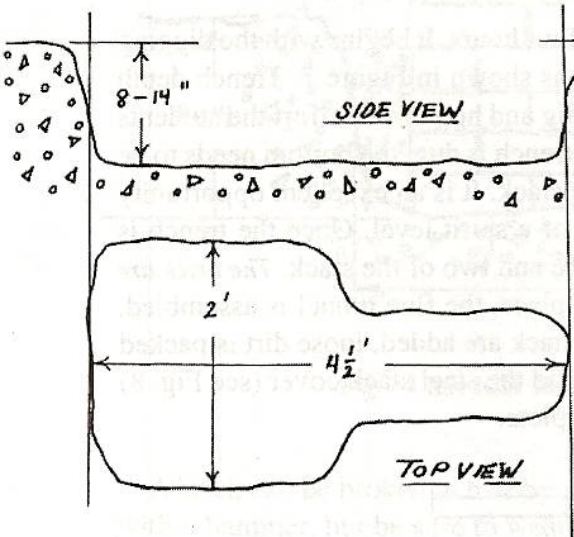


Fig. 7 Kiln Trench

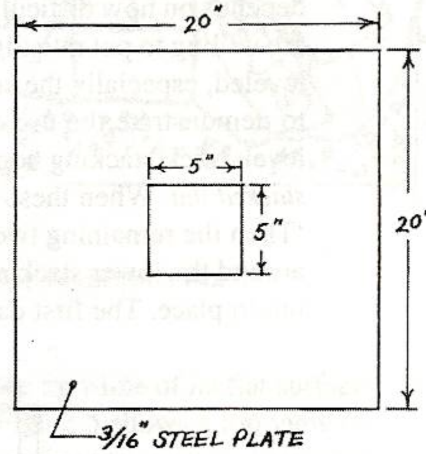


Fig. 8 Steel Stack Cover

The importance of an excess of charcoal in the lower stack (below the lime pieces) is that this charcoal cannot be replenished whereas charcoal can be added to the upper stack (above the lime pieces) through the steel cover plate opening. Throughout the firing an additional 10 to 20 pounds of briquettes should be added as the charcoal burns down.

The firing time for the kiln is five to six hours. If you start firing at 9 a.m., the kiln should be dying down by 2 or 3 p.m. The fan speed should be adjusted for a moderate flow of air. A too high fan speed will burn the charcoal too quickly and blow off the heat. When the kiln starts dying down, turn the fan off and leave the kiln overnight to cool. Be sure there is no rain in the forecast. If water gets into the kiln, it will start slaking the lime and cause a mess.

The third day's activity begins with the removal of the steel plate cover and the upper six or seven tiers ot the stack. The stack should be fairly cool. You will have to feel around in the charcoal ash for the pieces of quicklime. Although the quicklime can be handled with bare hands, gloves are advised. Eye protection is also advised.The quicklime will be about the same size and shape as the original lime pieces, but the appearance will have changed. The once crystalline lime should now appear dull, dry, and flaky. It is important that the students note this change. You may find slag formations around some of the pieces. These should be broken away, although slag will not affect the slaking process.

To demonstrate the slaking process, a piece of quicklime is placed in a pyrex dish. The students should touch the piece so they can feel that it is not hot. Water is then poured on the piece. If the mineral is predominately lime, and it has been properly burned, it will suck in the water and begin releasing heat. The students should hold their hands over the quicklime to experience this heat. As more water is added, the quicklime will swell and hiss and steam. Care should be taken that the students do not get their faces too close. Hot slaking lime will burn. If a student were to get quicklime in his or her eye, the eye should be immediately flushed with water. To emphasize that heat is released, a pea-sized piece of quicklime can be placed in a student's palm and water added. The student will quickly drop the piece. If the staking lime is held too long, it will burn the skin.

In order to make mortar, enough water is added to the slaked lime to create a paste. Sand is then added to the paste in the ratio of about two parts sand to one part paste, and the two are mixed. The mortar can be used to cement rocks, terra cotta, or bricks together, or it can be spread over wood sticks (lath) or metal screen as plaster. The mortar should set up overnight. However, the students will find it very fragile. It takes weeks and sometimes years for lime mortar to properly cure or harden back into lime. As water evaporates, microscopic channels are left in the slaked lime through which air can enter. Carbon dioxide in the air slowly reacts with the slaked lime to produce lime. This is the hardening process shown in Figure 1. It would be instructive to cement two pieces of terra cotta together and put them aside for a few weeks.

If the slaked lime is tested with a pH sensitive solution such as cabbage juice, it will test basic like wood ash. Limewater for testing for carbon dioxide is made by stirring a teaspoon of quicklime or fresh slaked lime into a glass of water, then filtering the solution through filter paper or a coffee filter. If you bubble your breath through a few milliliters of this solution using a straw, the solution will gradually turn cloudy. This is a positive test for carbon dioxide. If this cloudy solution is left overnight, a white precipitate will be found at the bottom of the test tube the next day. The precipitate is calcium carbonate.

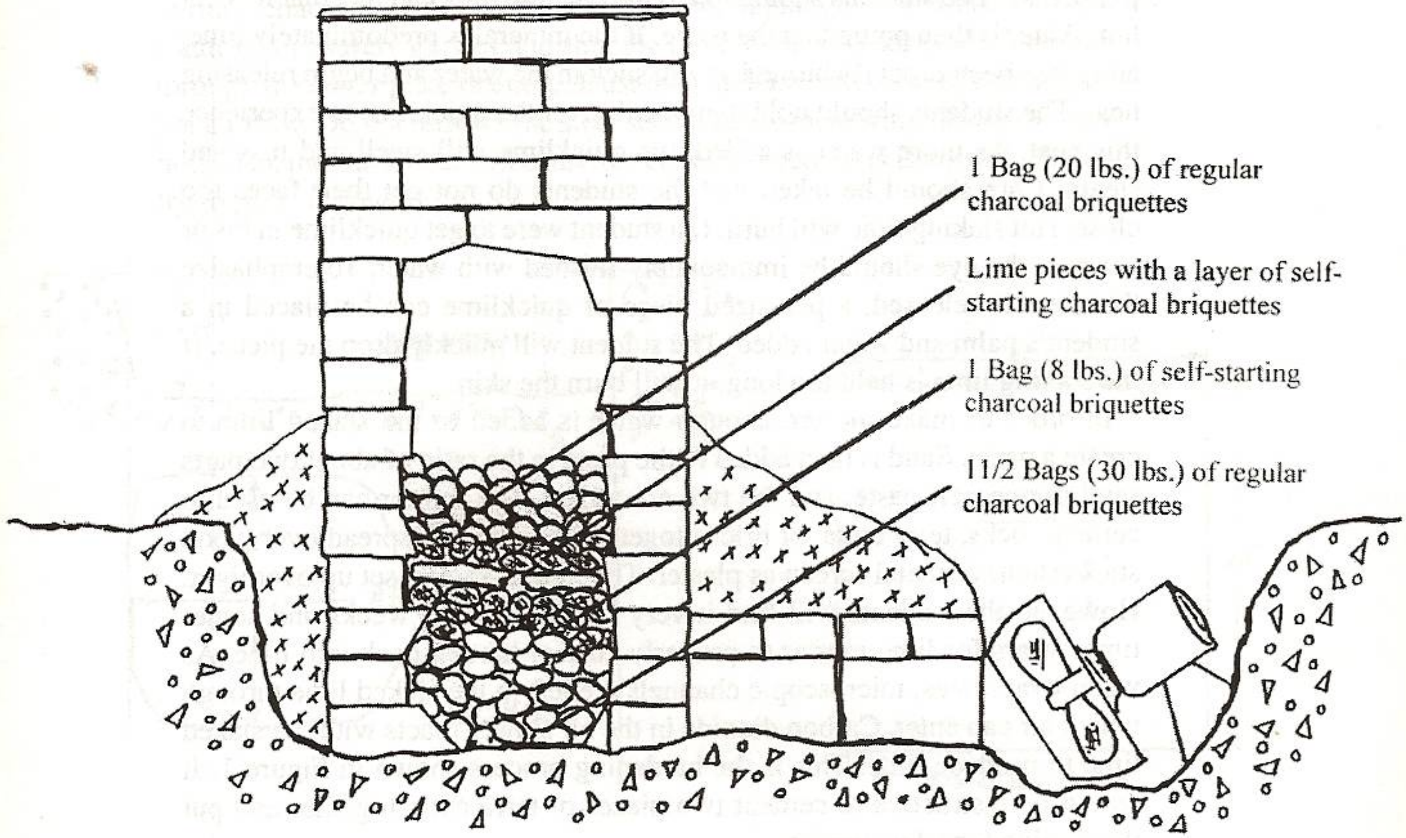


Fig. 9 Loading The Stack For Firing

Experiment 1

Optical Lifting

1. On a microscope stage, place a piece of millimeter paper and adjust into sharp focus. On top of the millimeter paper place a plane-parallel glass plate, with a thickness of d cm. and finds the focusing position. This second focusing position is higher than the first by d-(d - d/*n*) [where *n* is the refractive index of glass-air]: both imaging curves of a horizontal straight line of the depth of d cm under the refracted plane intersect at their deepest point the vertical at the depth of d/n cm (see fig. 19, sheet 2).

2. Replace the glass plate with a small flat prism with its breaking edge is oriented parallel to one of the system of lines on the millimeter paper. Two "in-focus" adjustments are found: at the deeper one you see the system of lines orthogonal to the breaking edge of the prism; at the higher one, the system of lines parallel to the edge. In principle, this agrees with pictures 19 and 20 if one takes fig c) sheet 3 into account.

3. If one carries out the above observations with millimeter paper beneath a large block of glass or a surface of water with the eyes, using both eyes (and provided that both pupils are at approximately the same distance from the broken plane) you can see things as prescribed by the law of optical elevation (meridional imaging points).

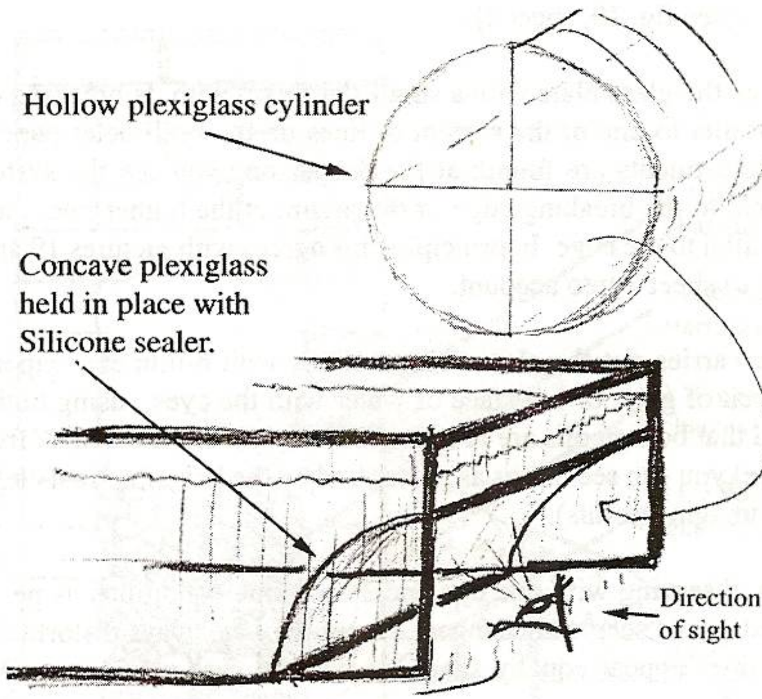
4. When observing with one eye under the same conditions as per step 3, the perceived image seems unchanged, except for a sideways distortion. Both systems of lines appear equally sharp, as was the case with binocular seeing in step 3.

But one must consider that it is hard to localize one point with monocular vision. Accomodation and turning of the head have only limited success. It is only by crossing the directions of seeing that we can succeed to determine the position of a point with accuracy. The following experiment draws attention to the difficulties of the situation.

5. Allow a string with a small weight at its end to hang deeply into the water. Both binocular (with the axis between pupils parallel to the water), as well as monocular vision give the impression that the string continues in the water in a straight vertical line, since the string in the water appears as a mirror image of string above the water. Now, run the string through a long glass tube (5 cm long, 5 mm diameter) immediately above the water, arranged so that the string hangs freely. With binocular vision one sees the string under the water freely run through the mirror image of the glass tube. (Using comparison with mirror images one can make an impressive demonstration of vertical elevation in such cases!) With monocular vision one can no longer unequivocally say whether the string comes out of the mirror image of the glass tube in front or behind or whether it lies inside the mirror image of the tube.[12] (see article)

Experiment 2

The apparatus drawn below can assist in observations in the "lifting " phenomena.



How to observe the "lifting" phenomena under the water, without getting wet!