structure, with nothing above or below the line of writing and there are no special representations for adding vowel "values" or for forming compound consonants. It is easily adapted for cursive writing (the ability to write without lifting the pen off the paper, except for dotting the 'i's and 'j's, crossing the 't's and adding diacritical marks).

The principles of Indian lipis make it nearly impossible to do cursive writing. One is often forced to resort to the use of diacritic marks to represent Indian words properly in the Roman script. If true cursive writing is the goal, the use of diacritical marks must be avoided.

Why should an expansion/modification of the 26-letter alphabet be tried when a similar attempt with ITA did not succeed? The purpose is arriving at a scientific script that combines the merits of both principles—juxtaposition, as in the Roman or Semitic script, with the legibility, transparency and exactitude of truly phonetic representation, possible with the Indian representations. It is easy to create new ASCII (computer) codes for the new extra, non-modifiable, symbols suitable for keyboards. The primary intention should be the easing of communication among the different linguistic regions of India, without the burden of having to learn different scripts. The Roman-based but expanded alphabet (Universal Indro-Roman) would be culturally, linguistically, religiously, regionally neutral.

A highly interesting and important purpose in new research is to compare the efficacy of the two principles of phoneme-formation mentioned above in mitigating the symptoms of dyslexia. The intention in proposing a new script can never be that scripts distinct to the various major Indian languages should be displaced. It should be to propagate the use of Universal Indro-Roman as a guide to correct pronunciation, an adjunct to the many different scripts in current use in India. A wider recognition of the ancient Indian contribution should be an aim. A widespread manifestation of dyslexia, compounding the already prevalent high rate of illiteracy, may yet be avoided.


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Back to basics: Reflections on refraction

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The first writings on the nature of light date back to Greek philosophers and mathematicians. The law of reflection of light was known to the Greeks.

Elementary textbooks of physics sometimes deal with a simple observation, related to a pencil of light incident on a glass tumbler. The pencil of transmitted light looks bent in a direction away from the incident light and the phenomenon is known as refraction. The behaviour of light that gives this image, depends on a property of the medium (water), namely its index of refraction. The higher a material's index, the slower light travels through it, and the more it 'bends'. A beam of light passing from air into a glass slab is deflected by a greater amount in the same direction, as the refractive index of glass is larger than that of water.

This puzzled the ancients for a long time. According to Feynman, Claudius Ptolemy (the Greek natural philosopher) made a table of the angles in water (from the normal to water surface) for each of a number of different angles in air. The table was made in 140 AD, but it was not until 1621 AD when finally Willebrord Snell, a Dutch mathematician, found a rule connecting the two angles, although he did not make it public. Referring to Figure 1, the rule is

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2, \tag{1} \]

where \( \theta_1 \) and \( \theta_2 \) are angles (made by the beam of light with respect to normal to the interface between the two media) in the first and in the second media, respectively. Snell’s law states that the sines of the incident and refracted angles \( \theta_1 \) and \( \theta_2 \), should be in the same ratio as the velocities of the light beam in the two media. In other words,

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = (n_2/n_1). \tag{2} \]

We define ‘an absolute refractive index’ \( n \) of a medium; it is the refractive index for refraction from vacuum into that medium. If \( n_1 \) and \( n_2 \) are absolute refractive indices of the two media, the ‘relative refractive index’ \( n_{12} \) is given by,

\[ n_{12} = n_2/n_1 = v_1/v_2, \tag{3} \]

If the speed of light in vacuum is denoted by \( c \), the speed of light in any material will be

\[ v = c/n. \tag{4} \]
where $n$ is the (absolute) index of refraction of that material.

Fermat, in 1650, thought of the way that this phenomenon takes place. His idea was that of all possible paths that light might take to get from one point to another, it takes the path which requires shortest time. It is called ‘principle of least time’ or Fermat’s principle. Feynman says, ‘...but the principle of least time is not quite correct. The more accurate statement is that light takes a path such that there are many other paths nearby which take almost exactly the same time.’

Two important developments in the field of optics are due to Fresnel and Maxwell. Fresnel’s laws govern the intensity and polarization of light rays produced by reflection and refraction. Maxwell summed up ‘all experiences in this field in a system of equations’. He conjectured that light waves are electromagnetic waves, propagating in space and associated with electric and magnetic fields.

According to Born and Wolf, ‘The state of excitation which is established in space by the presence of electric charges is said to constitute an electromagnetic field. It is represented by two vectors, $\mathbf{E}$ and $\mathbf{B}$ called the electric vector and magnetic induction, respectively. To describe the effect of the field on materials, it is necessary to introduce a second set of vectors, namely the electric current density $\mathbf{J}$, the electric displacement $\mathbf{D}$ and the magnetic vector $\mathbf{H}$. The space and time derivatives of the five vectors are related by Maxwell’s equations, which hold at every point in whose neighbourhood, the physical properties of the medium are continuous’. The equations are:

$$\text{curl} \, \mathbf{E} + \frac{1}{c} \frac{\partial \mathbf{B}}{\partial t} = 0,$$

$$\text{div} \, \mathbf{D} = 4\pi \rho; \text{div} \, \mathbf{B} = 0. \tag{5}$$

$p$ is electric charge density and $\mathbf{D}$ and $\mathbf{B}$ denote time derivatives of $\mathbf{D}$ and $\mathbf{B}$, respectively. In writing these equations, it may be noted that $\mathbf{E}$, $\mathbf{D}$, $\mathbf{J}$ and $\rho$ are in electrostatic units, $\mathbf{H}$ and $\mathbf{B}$ are in electromagnetic units and $c$ is velocity of light in vacuum ($= 3 \times 10^8$ cm/s). These equations must be supplemented by relations that describe the behaviour of substances under the influence of the field. These relations are known as material equations or constitutive equations.

If the field is time-harmonic, if the bodies are at rest or in slow motion and if the materials are isotropic, they take usually the relatively simple form:

$$\mathbf{j} = \sigma \mathbf{E}; \mathbf{D} = \varepsilon \mathbf{E} \text{ and } \mathbf{B} = \mu \mathbf{H}. \tag{6}$$

Here $\sigma$ is called the specific conductivity, $\varepsilon$ is known as dielectric constant (or permittivity) and $\mu$ is called the magnetic permeability. $\varepsilon$ is a measure of a material’s response to an applied electric field, while $\mu$ is a measure of the material’s response to an applied magnetic field.

Substances with $\sigma > 0$ are conductors and those with $\sigma = 0$, insulators or dielectrics. The electric and magnetic properties of the latter are completely determined by $\varepsilon$ and $\mu$. For most of the substances, magnetic permeability $\mu = 1$. If $\mu \neq 1$, the substance is magnetic; if $\mu > 1$, the material is paramagnetic and if $\mu < 1$, it is diamagnetic. When $\mu > 1$, the material is ferromagnetic and is associated with hysteresis effects due to fields.

If the medium is homogeneous, in addition to being isotropic, the equations for $\mathbf{E}$ and $\mathbf{H}$ are given by

$$\nabla \times \mathbf{E} - (\varepsilon \mu / c^2) \mathbf{H} = 0,$$

and

$$\nabla \times \mathbf{H} - (\varepsilon / c^2) \mathbf{E} = 0. \tag{7}$$

$\mathbf{E}$ and $\mathbf{H}$ are double derivatives of $\mathbf{E}$ and $\mathbf{H}$ with respect to time, respectively. These equations, being standard equations of wave motion, suggest existence of electromagnetic waves propagating with velocity

$$v = c / \sqrt{(\varepsilon \mu)}. \tag{8}$$

Since $\varepsilon$ is generally $> 1$ and $\mu = 1$ for transparent substances, $v$ is $< c$. $v$ is determined only relative to $c$ with the help of the law of refraction. Hereafter, we shall refer to absolute refractive index whenever we mention refractive index of any material. Comparison of eq. (4) with eq. (8) gives the Maxwell’s formula

$$n = \sqrt{(\varepsilon \mu)}. \tag{9}$$

It has been a convention to take the positive square root of $\varepsilon \mu$ to define $n$.

For non-magnetic systems $\mu = 1$ but $\varepsilon$ is generally a function of $\omega$, the frequency of the field. $\varepsilon(0)$ can be treated by taking into account the atomic structure and dynamics of matter.

Veselago in a paper entitled ‘The electrodynamics of substances with simultaneous negative values of $\varepsilon$ and $\mu$’ examined the nature of materials whose $\varepsilon$ and $\mu$ are negative. Although he stated that ‘there were no experiments in which a substance with $\varepsilon < 0$ and $\mu < 0$ should be observed’, he dwelt into ‘the arguments as to where and how one should look into such substances’. Independent of this realization, he was interested, per se, in the electrodynamics of such substances.

For a plane electromagnetic wave, the Maxwell’s equations and the constitutive equations reduce to

$$\mathbf{k} \times \mathbf{E} = (\omega / c) \mu \mathbf{H},$$

$$\mathbf{k} \times \mathbf{H} = -(\omega / c) \varepsilon \mathbf{E}, \tag{10}$$

where $\mathbf{k}$ is the wave-vector of the electromagnetic wave having frequency $\omega$. If $\varepsilon > 0$ and $\mu > 0$, then $\mathbf{E}$, $\mathbf{H}$ and $\mathbf{k}$ form a right-handed triplet of vectors and if $\varepsilon < 0$ and $\mu < 0$, they are a left-handed set.

The energy flux associated with the wave is denoted by the Poynting vector $\mathbf{S}$ given by $\mathbf{S} = (c / 4\pi) \mathbf{E} \times \mathbf{H}$. Since $\mathbf{S}$, $\mathbf{E}$ and $\mathbf{H}$ always form a right-handed set, two types of substances can be identified: right-handed substances with $\mathbf{S}$ parallel to $\mathbf{k}$ and left-handed substances with $\mathbf{S}$ anti-parallel to $\mathbf{k}$. Since $\mathbf{k}$ denotes the direction of phase velocity and $\mathbf{S}$ denotes the direction of group velocity, the left-handed substances have negative group velocity which occurs in anisotropic systems or when there is spectral dispersion.
In a left-handed medium, light propagates (or appears to move) in the opposite direction as energy flows.

Veselago, argued that in a left-handed material (that is a material with both negative $\varepsilon$ and negative $\mu$), passage of light results in several novel optical phenomena as listed below:

(a) Reversed Doppler effect: The Doppler shift is given by

$$\omega = \omega_0 [1 - p(v/u)],$$

where $v$ is velocity with which a detector of radiation is moving with respect to a source emitting radiation of frequency $\omega_0$, $v$ is taken to be positive when the detector is receding from the source, $u$ is the velocity of energy flux or group velocity of light, regarded as always positive. The parameter $p$ may be referred to as ‘handedness’. It is the determinant of the $3 \times 3$ matrix formed by the direction cosines of $E$, $H$, and $k$. $p$ is $+1$ for right-handed substances and is $-1$ for left-handed substances. Hence the frequency $\omega$ observed by the detector will be smaller than $\omega_0$ (not larger as in right-hand substances) in left-handed substances, that is, there will be blue-shift instead of red-shift in the observed frequency.

(b) The Vavilov–Cerenkov effect is also reversed. Cerenkov radiation is the light emitted when a charged particle passes through a medium, under certain conditions. In a normal material, the emitted light is in the forward direction, while ‘for left-handed media, the cone of radiation will be directed backward relative to the motion of the particle’.

(c) During the passage of light from one medium into another, the electric and magnetic vectors $E$ and $H$ ‘not only change magnitude owing to difference in $\varepsilon$ and $\mu$, but also undergo a refraction relative to the interface of the two media’. Specifically, when the first medium is right-handed (as say, air, glass, water or vacuum) and the second is left-handed, the refracted ray lies on the opposite side of the normal to the interface, that is, it undergoes negative refraction from its position in the case of right-handed second medium (see Figure 2). Conventionally observed refraction is denoted as positive refraction in the figure. It may be noted that the direction of the reflected ray is always the same independent of whether the second medium is right- or left-handed.

Hence Veselago noted that the usual Snell's law

$$\frac{\sin \theta_1 / \sin \theta_2}{n_{12}} = \sqrt{(\varepsilon_2/\mu_2)/(\varepsilon_1/\mu_1)},$$

has to be given a more precise form, if the nature of the handedness of media 1 and 2 is different. The correct way to write the formula now is

$$\frac{\sin \theta_1 / \sin \theta_2}{n_{12}} = \frac{p_2 / p_1}{\sqrt{[(\varepsilon_2/\mu_2)/(\varepsilon_1/\mu_1)]}},$$

where $p_2$ and $p_1$ define the ‘handedness’ of second and first media, respectively.

Figure 2. A beam of light through medium 1 (with refractive index $n_1$) falls on a second medium (with refractive index $n_2$). Depending on the relative refractive index $n_{12}$, one can observe positive or negative refraction at the interface, with respect to the normal to the interface.

Figure 3. a. Rays through convex and concave lenses made of left-handed substances; b. Rays of light diverging from a point converge to a focus after two negative refractions as the rays pass through a slab of negative refractive-index material.
If a ray is passing from a medium with \( \varepsilon_1 > 0 \) and \( \mu_1 > 0 \) into one with \( \varepsilon_2 = -\varepsilon_1 \) and \( \mu_2 = -\mu_1 \), the ray undergoes refraction at the interface, but there is no reflected ray.

Lenses and optics made from left-handed materials will produce unusual optics. As an example, if a lens made by a right-handed material were converging light, the one made from a left-handed material, would be diverging the light, and vice versa (see Figure 3a). Also, a thick flat plate (window) of left-handed materials can focus radiation from a point source back to a point (see Figure 3b). The flat plate, unlike a lens, 'will not focus at a point a bundle of rays coming from infinity'.

The radiation pressure, characteristic of ordinary right-handed substances is replaced in left-handed substances by radiation tension or attraction.

Recently, John Pendry and coworkers showed how negative-\( \varepsilon \) materials could be built from rows of wires. According to Wiltshire, 'If the materials are microstructured and all their constituents are much less than the wavelength of radiation that they interact with, they can be described accurately by their \( \varepsilon \) and \( \mu \). Structures built of fine wires mimic a plasma and have negative \( \varepsilon \) in the microwave region'. Pendry et al. also proposed the design of negative-\( \mu \) materials from arrays of tiny resonant rings.

Subsequently, Sheldon Schultz and David Smith from the University of California, San Diego (UCSD), reported at the American Physical Society meeting in Minneapolis that 'they had followed Pendry's prescriptions and succeeded in constructing a material with both a negative \( \mu \) and a negative \( \varepsilon \), at microwave frequencies'. The raw materials used, copper wires and copper rings, do not have unusual properties of their own and indeed are non-magnetic. But, when incoming microwaves fall upon alternating rows of the rings and wires, mounted on a playing-card-sized platform and set in a cavity, then a resonant reaction between the light and the whole of the ring-and-wire array sets up tiny induced currents, which contribute fields of their own'. The net result is a set of fields moving to the left, even as electromagnetic energy is moving to the right. This effective medium is therefore a left-handed material. The results were also published (see ref. 7). At a press conference, Schultz and Smith said that having demonstrated that their medium possessed a negative \( \mu \) and \( \varepsilon \), they were proceeding to explore the novel optical effects predicted by Veselago. Furthermore, they hoped to adapt their design to accommodate shorter wavelengths. As for applications in microwave communications, a medium which focuses waves when other materials would disperse them (and vice versa) ought to be useful in improving existing delay lines, antennas and filters.

Experimental verification of negative refraction has come through experiments reported by Shelby et al. They used a left-handed material consisting of a 2D periodic array of copper-split ring resonators and wires fabricated by microfabrication technique on a thin fibre-glass circuit-board material. The rings and wires are on opposite sides of the board. These boards were assembled in an interlocking lattice unit as shown in Figure 4. The material exhibits negative refractive index at around 10.5 GHz. A microwave beam was made to be incident on the prism-shaped section cut out of the assembled unit and on a similarly cut teflon prism. They demonstrated that microwaves were refracted to positive angles as expected in teflon, whereas to the opposite side (negative angles) of the normal from the left-handed sample (see Figure 5). From the measured angle, a refractive index of \(-2.7 \pm 0.1\) was derived.

Far from being a physical curiosity, Wiltshire et al. have created negative permeability material at RF region, based on the 'Swiss-role' structure. They state 'exploiting this class of materials could fundamentally change existing approaches to magnetic resonance imaging and spectroscopy'. Suggestions exist for synthesis of materials in the IR, although currently proposals for similar materials in the optic region do not seem to exist. However, Pendry has noted that at optical frequency, several metals behave like a perfect
plasma'; \( \varepsilon \) becomes negative for \( \omega < \omega_{pe} \), the electron-plasma frequency. He has discussed the circumstances under which one can examine the nature of transmission of light through such materials ‘without placing any conditions on \( \mu \)’. According to Pendry, a material with a negative refractive index could make a ‘perfect lens’. This is because such a lens would not be restricted by the diffraction limit. A slab of silver (with all dimensions of the order of a few nanometres, that is smaller than wavelength of light) is studied by simulation to see how well one can focus an image using a layer of silver. This concept may be realizable into a practical device.


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RANDOM SELECTION

FROM THE ARCHIVES

Scientists and war

‘There are three lusts which are present in the subconscious mind of man which lie at the basis of war, the lust of power, the lust of prestige, and the lust of possession’. These remarks were made by Dr Gilbert J. Fowler in the course of his presidential address at a discussion on ‘Moral responsibility of scientists in modern warfare’, held at Bangalore on 22 August, under the joint auspices of the Society of Biological Chemists, India, and the Institute of Chemistry.

In the course of a thoughtful address, Dr Fowler observed, ‘My scientific and professional work has brought me in contact with chemists and engineers all over the world including Moscow and Japan. I may, therefore, claim to be something of a citizen of the world and can have no desire to hate or destroy the many good friends I have made.

My experience will, in some degree no doubt, be that of many other scientists and therefore, the scientist is pre-eminently fitted to be a friend of all the world.

If, however, this worthy ambition is to be realized, it would seem necessary that certain commonly voiced statements and their implications should first be criticized.

One view which is gaining ground is that the discoveries of scientists are themselves largely the cause of war. The fallacy of this will be evident after a moment’s thinking.

It is often apparently assumed that poison gas or chemical warfare is due to the secret and devilish investigations of chemists. Actually I believe practically all the gaseous weapons, used in the war, had been discovered previously in the course of purely peaceful investigations.