Relativistic effect inside matter. Obtaining a relativistic dispersion formula.

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Research Article

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Relativistic effect inside matter.
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Content

Abstract.

The main prerequisite for this study was the external similarity of such physical processes as the refraction of light in a transparent substance and the deflection of light by the gravitational field of massive cosmic bodies. Based on the external similarity, the author put forward a hypothesis about the internal similarity of these two physical processes. This made it possible to integrate Einstein's well-known relativistic formula into the process of light propagation in electron clouds (fields) of a transparent substance. As a result of the transformations carried out, a new physical dispersion formula with a wide spectrum of action was obtained from the Einstein formula.

According to the new dispersion formula, **26** refractive indices of light were calculated in **5** transparent substances in **3** states of aggregation. Comparison of the obtained indicators with laboratory indicators showed the high accuracy of the new physical formula, which amounted **to** $\pm 10^{-7} - 10^{-5}$ in the calculated sections of the wave ranges **over 100 nm.**

The successful application of the relativistic formula to the process of light refraction in transparent substances indicates that relativistic effects are present at the atomic-molecular level.

Keywords. Relativistic effect inside matter, relativistic dispersion formula, new dispersion formula, empirical dispersion formulas, a formula for determining the total energy of a moving body, the energy density index of electron clouds, the calculation of the refractive indices of light, interaction of light with matter.

Introduction.

Before moving on to the main goal of this study - the presence of a relativistic effect in a transparent substance - let's give a brief information about the currently existing dispersion formulas. This is due to the fact that the proof of the existence of the relativistic effect at the atomic-molecular level is directly related to the derivation of a new physical dispersion formula.

Currently, there are no **physical dispersion formulas** that can be applied to a wide range of transparent substances. For example, the well-known physical formula of Lorentz-Lorentz, which is based on the dependence of the refractive index of light **on the density of a substance,** is valid only for isotropic media (gases, non-polar liquids, cubic crystals) and is not applicable for most transparent substances. Therefore, in practice, to calculate the refractive indices, empirical dispersion formulas (Cauchy, Hartmann, etc.) are used. These formulas are quite accurate, but at the same time they are not physical formulas.

Methods.

Let's start with the well-known formula, where the refractive index of light in a transparent substance is $\boldsymbol{n = c/v}$, where $\boldsymbol{c}$ is the speed of light in vacuum, $\boldsymbol{v}$ is the speed of light in matter.

In this work, it is hypothesized that the speed of propagation $\boldsymbol{v_\gamma}$ of photons in a transparent substance depends on the energy of electron clouds $\boldsymbol{Q_e}$ of atoms of the substance: the higher the density of the electron clouds, the lower the speed of the photons and vice versa. In this case, the greater the energy of the photons entering the substance, the more the electron clouds of the atoms of the substance are "condensed" by this energy. As a result of this circumstance, electromagnetic waves with different wavelengths propagate in the same transparent substance at different speeds. Thus, there is an inverse relationship between the energy density $\boldsymbol{Q_e}$ of electron clouds of atoms of matter and the speed of propagation $\boldsymbol{v_\gamma}$ of photons in matter. To determine this dependence and then obtain the dispersion formula, we use in this study the relativistic Einstein formula to determine the total energy of a moving body:

$$\boldsymbol{E_{total}} = \frac{\boldsymbol{m_0\, c^2}}{\sqrt{\boldsymbol{1-\frac{v^2}{c^2}}}} \quad \text{or} \quad \boldsymbol{E_{total}} = \frac{\boldsymbol{E_0}}{\sqrt{\boldsymbol{1-\frac{v^2}{c^2}}}} \quad \textbf{(1-1)}$$

Where $\boldsymbol{E_{total}}$ is the total energy of a moving body.

$\boldsymbol{E_0}$ – energy of a body at rest.

$\boldsymbol{v}$ is the speed of the body.

Let's transform the formula (1-1) and as a result we get:

$$\boldsymbol{v} = \boldsymbol{c}\sqrt{\boldsymbol{1} - \frac{\boldsymbol{E_0}^2}{\boldsymbol{E}^2_{\text{полн.}}}} \quad \text{или} \quad \boldsymbol{v} = \boldsymbol{c}\sqrt{\boldsymbol{1} - \boldsymbol{Q_b^2}} \quad \textbf{(1-2)}$$

Where $\boldsymbol{Q_b}$ is an indicator of the ratio of the energy of a body at rest to the total energy of a moving body, $\boldsymbol{0 < Q_b <} 1$.

Now we apply formula (1-2) to the speed of propagation of photons in a transparent substance:

$$\boldsymbol{v_\gamma} = \boldsymbol{c}\sqrt{\boldsymbol{1} - \boldsymbol{Q_e^2}} \quad \textbf{(1-3)}$$

Where $\boldsymbol{v_\gamma}$ is the speed of propagation of photons in the electron clouds of atoms of a transparent substance.

$\boldsymbol{Q_e}$ is a dimensionless indicator of the energy density of electron clouds of a transparent substance, $\mathbf{0} < \boldsymbol{Q_e} < 1$.

Let's transform the formula (1-3) and get:

$$\frac{c}{v_\gamma} = \frac{1}{\sqrt{1-Q_e^2}} \quad \text{or} \quad n = \frac{1}{\sqrt{1-Q_e^2}} \qquad \textbf{(1-4)}$$

Where $\boldsymbol{n}$ is the refractive index of light in the substance ($\boldsymbol{n} = \boldsymbol{c}/\boldsymbol{v_\gamma}$).

Let's reveal the value of $\boldsymbol{Q_e}$ in the formula (1-4):

$$n = \frac{1}{\sqrt{1-(Q_0+\Delta Q_\lambda)^2}} \qquad \textbf{(1-5)}$$

Where $\boldsymbol{Q_0}$ is a dimensionless basic indicator of the energy density of electron clouds of a transparent substance.

$\Delta\boldsymbol{Q_\lambda}$ is a dimensionless indicator of the increase in the energy density of electron clouds of a transparent substance.

The $\boldsymbol{Q_0}$ index is constant (at constant temperature and pressure). The exponent $\Delta\boldsymbol{Q_\lambda}$ is a variable. It depends on the energy $\boldsymbol{e}$ of the electromagnetic wave, where $\boldsymbol{e} = \boldsymbol{h\gamma} = \boldsymbol{h\,c/\lambda}$. From here we get the formula:

$$n = \frac{1}{\sqrt{1-(Q_0+k_\gamma h\,c/\lambda\ )^2}} \qquad \textbf{(1-6)}$$

Where $\boldsymbol{k_\gamma}$ is the coefficient of proportionality, J^{-1}.

Replace $\boldsymbol{k_\gamma}\ \boldsymbol{h}\ \boldsymbol{c}$ with a single coefficient $\boldsymbol{k_\lambda}$ and obtain a new dispersion formula:

$$n = \frac{1}{\sqrt{1-(Q_0+k_\lambda/\lambda)^2}} \qquad \textbf{(1-7)}$$

Where $\boldsymbol{k_\lambda}$ is the coefficient of proportionality, nm.

$\boldsymbol{\lambda}-$ wavelength, nm.

The coefficient $\boldsymbol{k_\lambda}$ is individual for each substance and depends on the absorption of electromagnetic waves by atoms. It is relatively stable in the visible range of the electromagnetic spectrum. But in the ultraviolet and infrared ranges, the coefficient $\boldsymbol{k_\lambda}$ can significantly change its value due to changes in the absorption of electromagnetic waves by matter. For this reason, according to f. (1-7), the value of the refractive index $\boldsymbol{n}$ can change sharply up to the adoption of anomalous values. This circumstance introduces a limitation on the use of formula (1-7) in these wave ranges.

Let us check the accuracy of the new dispersion formula. Table 1 presents 39 laboratory indices of light refraction in the visible range in five transparent substances in three states of aggregation. 13 conventionally known indices of refraction of light are highlighted in bold, 26 conventionally unknown indices, which must be determined using a new formula, knowing the wavelength, are highlighted in regular font. (These refractive indices are commonly known and readily available on the Internet. The datasets used and analysed during the current study are available from the corresponding author on reasonable request).

To be able to verify with the table data, they will be sent to the editor in a separate file). The first column of the table contains the basic indicators $\boldsymbol{Q_0}$ (they were determined by solving a system of equations and subsequent selection of the optimal value $\boldsymbol{Q_0}$). The wavelengths are highlighted in bold in the table, where the proportionality coefficients were calculated using the formula $\boldsymbol{k_{\lambda 1,2} = \lambda_n}$

$\left(\sqrt{\frac{n^2-1}{n^2}}-Q_0\right)$ **(1-8)**, which will be used for interpolation. As can be seen from the table, for an inert gas the number of such coefficients was unity for the entire wavelength range, for other substances - 3. (This is due to different amplitudes of fluctuations in the magnitude of the proportionality coefficients in these substances). Then, using the formula $k_\lambda = \frac{k_{\lambda 1}(\lambda_n-\lambda_2)+k_{\lambda 2}(\lambda_1-\lambda_n)}{(\lambda_1-\lambda_2)}$ **(1-9)**, the coefficients k_λ (they are presented in the table in regular font) and then the refractive indices of light are determined by the formula (1-7).

After that, the calculated indices were rounded off in accordance with the number of digits after the decimal point in laboratory refractive indices. Therefore, for an inert gas, the refractive indices of light were rounded up to 7 decimal places, for water - up to 5 decimal places, for solids - up to 4 decimal places. It should be noted that in those cases when the rounding of the numbers led to a complete coincidence of the refractive indices, then the accuracy was taken to be one order of magnitude greater than that of the other refractive indices. For example, in glass, after rounding, two refractive indices completely coincided for wavelengths of 670, 8, and 643.8 nm. The accuracy here was taken as $\mathbf{10^{-6}}$. An order of magnitude higher than the rest of the refractive indices in glass, where the accuracy was $\mathbf{10^{-5}}$. The same method was applied to the rest of the indicators in other substances. The author believes that this approach is the most correct, because the known laboratory parameters, after being obtained experimentally, were also rounded to a certain sign. From this it follows that when comparing the refractive indices, the equality of the commas after zero must be observed, because otherwise, the calculation accuracy indices may increase unreasonably or, conversely, decrease.

After rounding off the calculated indices, they were compared with laboratory refractive indices and the discrepancy between them was determined. The results were tabulated.

Results.

Table 1 shows the 26 calculated refractive indices of light in 5 transparent substances, which were calculated using the new physical formula. In this case, the calculated sections of the wave range were **more than 100 nm** (see Table 1). For comparison. The most accurate empirical Hartmann formula: $\boldsymbol{n = n_{\infty} + C/(\lambda - \lambda_0)^a}$, has **4** empirical constants ($\boldsymbol{n_{\infty}, C,\ \lambda_0, a}$). Using these constants, the refractive indices of light are determined with an accuracy of $\boldsymbol{\pm 10^{-6} - 10^{-5}}$ for the calculated sections of the wave ranges **not exceeding several tens of nm**, that is, (($\boldsymbol{\lambda - \lambda_0) < 30 - 40}$ nm. If this range is exceeded, it is necessary to recalculate the empirical constants, otherwise the accuracy of the formula is significantly reduced depending on the size of the calculated area and the type of substance.

If we compare the new formula with the Lorentz-Lorentz **physical** dispersion formula, then the advantage of the new physical formula is obvious. This is not only higher accuracy, but also a much wider range of action among transparent substances, which is not limited to isotropic media.

Conclusions.

In this study, based on the relativistic formula of Einstein, a new dispersion formula was obtained with an accuracy of $\boldsymbol{\pm 10^{-7} - 10^{-5}}$ in the calculated sections of the wavelength range **of more than 100 nm.** The new physical formula can be applied to the same wide range of transparent substances as well-known empirical formulas (Hartmann, Cauchy, etc.). At the same time, the resulting physical formula in identical transparent substances in wider calculated sections of the wave ranges should be more accurate than empirical formulas. Here it is necessary to emphasize that <u>the main goal of this study was to prove the presence of a relativistic effect inside the substance,</u> and not to comprehensively test the new dispersion formula. Therefore, in this study it is inappropriate (because of the large loss of time) to conduct a comparative analysis of the new physical formula with empirical formulas **on the example of many transparent substances.** The author believes that to confirm the main goal of this study, it will be more than enough to calculate 26 refractive indices in 5 transparent substances in 3 different states of aggregation. If you wish, you can independently calculate the refractive indices in other substances and then compare them with laboratory indicators (here you must initially correctly determine the value of $\boldsymbol{Q_0}$ in order for the comparison to be reliable).

Thus, on the basis of the foregoing, the main conclusion of this study can be drawn: **relativistic effects can occur inside matter at the atomic-molecular level.** The fact of successful application of the relativistic formula to the process of light refraction in matter confirms this conclusion.

Table 1

Substance	λ nm	k_λ nm	Calculated refractive index	Laboratory refractive index	Divergence
Krypton Q_0 **=0,0228741**	450,4		1,0002750	1,0002752	**10^{-7}**
	556,4	**0,2573906**	**-**	**1,0002724**	
	565,1		1,0002723	1,0002722	
	587,3		1,0002719	1,0002719	
	605,8		1,0002715	1,0002716	
	645,8		1,0002709	1,0002711	
Water Q_0 **= 0,648752** t= 20 °C	447,1	7,3594178	1,33931	1,33942	**$10^{-6} - 10^{-5}$**
	471,3	**7,3504891**	**-**	**1,33793**	
	486,1	7,3450358	1,33716	1,33712	
	501,6	7,3393246	1,33640	1,33635	
	546,1	**7,322928**	-	**1,33447**	
	577,0	7,3469439	1,33342	1,33338	
	587,6	7,3551824	1,33308	1,33304	
	656,3	**7,4085769**	**-**	**1,33115**	
	670,8	7,4198465	1,33080	1,33080	
	706,5	7,447593	1,32999	1,33002	
Sylvin Q_0 **= 0,727035** t= 18 °C	480,0	8,5850021	1,4989	1,4990	
	486,1	**8,5766026**	-	**1,4983**	**$10^{-6} - 10^{-5}$**
	508,6	8,5456209	1,4962	1,4961	
	546,1	**8,4939848**	-	**1,4931**	
	589,3	8,5471312	1,4905	1,4904	
	643,8	8,6141794	1,4876	1,4877	
	656,3	**8,6295574**	-	**1,4872**	
	670,8	8,6473959	1,4866	1,4866	
Light crown glass Q_0 **=0,741579** t=15 °C	480,0	6,1563048	1,5234	1,5235	
	486,1	**6,1545121**	-	**1,5230**	**$10^{-6} - 10^{-5}$**
	546,1	6,1372274	1,5192	1,5191	
	589,3	**6,1241824**	-	**1,5170**	
	643,8	6,1806235	1,5149	1,5149	
	656,3	**6,1935687**	-	**1,5145**	
	670,8	6,2085851	1,5140	1,5140	
Rock salt Q_0 **= 0,747572** t=18 °C	480,0	8,5940181	1,5541	1,5541	
	486,1	**8,5867621**	-	**1,5534**	**$10^{-6} - 10^{-5}$**
	508,6	8,5599976	1,5510	1,5509	
	546,1	**8,5153919**	-	**1,5475**	
	589,3	8,5653435	1,5445	1,5443	
	643,8	8,6283611	1,5413	1,5412	
	656,3	**8,6428147**	-	**1,5407**	
	670,8	8,6360523	1,5399	1,5400	

Declarations

1. **Availability of data and materials.**

All data obtained and analyzed in the course of this study is included in this article.

2. **Competing interests.** Not applicable (there are no competing interests).

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