CONSERVATION OF ENERGY AND FREQUENCY SHIFTS IN REFLECTION AND REFRACTION.

by

M. W. Evans, H. Eckardt, G. J. Evans, and T. Morris

Civil List, AIAS and UPITEC

ABSTRACT

The experimental observation of frequency shifts in reflection and refraction is explained straightforwardly with conservation of total energy and total momentum across the interface between two media. The two conservation equations can be solved to show that there must be frequency changes across the boundary, the frequencies of the refracted and reflected electromagnetic radiation must be different from that of the incoming beam. The standard physics asserts that the frequencies of all three beams are the same, but this is a trivial violation of conservation of total energy.

Keywords: ECE theory, Evans Morris frequency effects, conservation of total energy and total momentum.

UFT 278

1. INTRODUCTION

Snell's law of reflection and refraction was discovered several hundred years ago and may have been inferred in ancient times. Its theory is developed in the standard model of physics by asserting without proof that the frequencies of the incoming and refracted and reflected beams are equal. Over several years, Gareth J. Evans and Trevor Morris have collected a data bank of reproducible and repeatable experimental data which show that the standard dogma is completely wrong, not for the first time in the history of physics. They have shown that there are monochromatic frequency shifts, so these are true frequency shifts. They have reported that these shifts can be very pronounced. Many of their data have been posted on the diary or blog of www.aias.us in colour photographs.

In Section 2 the ECE theory of Compton scattering and related effects {1 - 10}, (UFT158 ff. on www.aias.us), is used straightforwardly to show that the standard model of physics trivially violates conservation of total energy in the equal frequency dogma of Snell's Law. A new theory of the experimental Snell Law is devloped in which there can be many different frequency shifts governed by the complex permittivity, power absorption coefficient and refractive index of the medium in which refraction takes place. There can be as many different types of frequency shift as there are different types of spectra. Evans and Morris have observed red shifts, blue shifts, multiple frequency shifts and many types of light bending effects due to refraction. They have produced these data with simple experiments that have been replicated as discussed on the blog or diary of www.aias.us in all detail.

In Section 3 the theory is graphed and analysed, and some theories of far infra red and microwave type absorption used to model the complex refractive index: the Debye theory of 1913 and the memory function theory by M. W. Evans and G. J. Evans of 1976.

2. CONSERVATION OF TOTAL ENERGY AND MOMENTUM

As usual this paper should be read in conjunction with its background notes on www.aias.us for UFT278. Note 278(1) deals with an adaptation of UFT49 and is developed in Note 278(2) with the ECE current density. These two notes suggest how frequency shifts could occur. This Section is based on Notes 278(3) to 278(5).

Consider Snell's law of reflection and refraction. It can be summarized as:

$$\theta = \theta_2 \qquad -(1)$$

and:

$$\frac{\sin\theta}{\sin\theta_1} = \frac{v}{v_1} = \frac{n_1}{n} \qquad -(2)$$

where θ is the angle of incidence and θ_2 is the angle of reflection. The angle of refraction is θ_1 .Here $\underline{v}$ is the initial velocity of the electromagnetic radiation such as a beam of light, $\underline{v_1}$ is its refracted velocity, n_1 is the refracted refractive index and n the initial refractive index.

By conservation of total energy of one photon:

$$\hbar\omega = \hbar\omega_1 + \hbar\omega_2 \qquad -(3)$$

and by conservation of total momentum of one photon:

$$\hbar\underline{k} = \hbar\underline{k_1} + \hbar\underline{k_2} \qquad -(4)$$

where $\underline{k}$ is the incoming wave-vector, $\underline{k_1}$ is the refracted wave vector, and $\underline{k_2}$ the reflected wave vector. These equations are universal and must be obeyed in any type of physics. They were used in UFT158 ff in a development of the Compton effect theory to include photon mass. The latter must also play a role in Snell's law and this will be developed in future work.

The obsolete standard physics trivially violates Eq. (3) because it asserts incorrectly that:

$$\omega \overset{?}{=} \omega_1 \overset{?}{=} \omega_2 . \quad -(5)$$

Gareth Evans and Trevor Morris have experimentally counter indicated the incorrect dogma (5) in many experiments over several years.

From Eq. (4):

$$\underline{\kappa}_1 = \underline{\kappa} - \underline{\kappa}_2 \quad -(6)$$

and

$$\kappa_1^2 = \kappa^2 + \kappa_2^2 - 2\kappa\kappa_2 \cos 2\theta \quad -(7).$$

where

$$2\theta = \theta + \theta_2 \quad -(8)$$

experimentally. Now use:

$$\kappa_1 = \frac{\omega_1}{v_1} \quad -(9)$$

and assume that the incoming beam travels in air with a velocity c for all practical purposes, so:

$$\kappa = \frac{\omega}{c}, \quad \kappa_2 = \frac{\omega_2}{c} . \quad -(10)$$

It follows that:

$$\omega_1^2 = \left(\frac{v_1}{c}\right)^2 \left(\omega^2 + \omega_2^2 - 2\omega\,\omega_2 \cos 2\theta\right) \quad -(11)$$

$$= \left(\frac{\epsilon_0 \mu_0}{\epsilon_1 \mu_1}\right)\left(\omega^2 + \omega_2^2 - 2\omega\,\omega_2 \cos 2\theta\right)$$

where:

$$n^2 = \mu_r \epsilon_r = \frac{\epsilon_1 \mu_1}{\epsilon_0 \mu_0} \quad -(12)$$

is the square of the refractive index of the medium in which refraction takes place. So:

$$n^2 \omega_1^2 = \omega^2 + \omega_2^2 - 2\omega\,\omega_2 \cos 2\theta \quad -(13)$$

and

$$\omega = \omega_1 + \omega_2 . \quad -(14)$$

The change of frequency due to refraction is:

$$\omega_2 = \omega - \omega_1 \quad -(15)$$

so:

$$n^2 \omega_1^2 = \omega^2 + (\omega - \omega_1)^2 - 2\omega(\omega - \omega_1) \cos 2\theta \quad -(16)$$

and the refracted frequency ω_1 can be expressed in terms of the incoming frequency ω and cos (2θ) by solving the equation:

$$\omega_1^2 (n^2 - 1) = 2\omega(\omega - \omega_1) \cos 2\theta \quad (17)$$

by computer algebra. Similarly the reflected frequency ω_2 can be expressed in terms of the incoming frequency and cos (2θ). This theory exactly parallels Compton effect theory in UFT158 ff. In these equations the vacuum permittivity and permeability are respectively ϵ_0 and μ_0 . The permittivity and permeability of the medium in which refraction takes place are ϵ_1 and μ_1 respectively. The relative permeability and permittivity are respectively:

$$\mu_r = \frac{\mu_1}{\mu_0} \qquad -(18)$$

and

$$\epsilon_r = \frac{\epsilon_1}{\epsilon_0} . \qquad -(19)$$

In general there is dispersion and loss so:

$$\mu_r = \mu_r' + i\mu_r'', \qquad -(20)$$

$$\epsilon_r = \epsilon_r' + i\epsilon_r''. \qquad -(21)$$

The magnetic permeability varies experimentally from about a million in some metallic materials to about unity in air and water and to zero in superconductors. In general the relative permittivity ϵ_r' and dielectric loss ϵ_r'' are spectra.

So in general there may be many different types of frequency shift as observed by Garteh J. Evans and Trevor Morris repeatably and reproducibly.

The refractive index is also complex valued in general:

$$n = n' + in''. \qquad -(22)$$

If a material such as water is chosen in which the permeability is about one, and is real valued, then:

$$(n' + in'')^2 = n'^2 + 2in'n'' - n''^2 = \epsilon_r' + i\epsilon_r''. \qquad -(23)$$

Therefore it follows by equating the real and imaginary parts of Eq. (23) that:

$$\epsilon_r' = n'^2 - n''^2 \qquad -(24)$$

and

$$2n'n'' = \epsilon_r'' . \quad - (25)$$

The real and imaginary parts of the refractive index are therefore:

$$n'^2 = \left(\frac{\epsilon_r''}{2n'}\right)^2 + \epsilon_r' \quad - (26)$$

and

$$n'' = \frac{\epsilon_r''}{2n'} . \quad - (27)$$

It follows that:

$$n' = \frac{1}{\sqrt{2}}\left(\epsilon' + \left(\epsilon'^2 + \epsilon''^2\right)^{1/2}\right)^{1/2} \quad - (28)$$

in general and that:

$$n'' = \frac{\epsilon''}{2n''} . \quad - (29)$$

The power absorption coefficient {11} is:

$$\alpha = \frac{\omega\epsilon''}{n'c} \quad - (30)$$

and is used in spectra from far infra red to the ultra violet. If it is assumed that the frequencies in Eq. (16) must be real valued, then n^2 in that equation must be real valued, so:

$$n^2 = \epsilon_r' \quad - (31)$$

so n^2 becomes the relative permittivity of the material in which refraction takes place.

In order to develop the theory of the Evans / Morris effects a theory of the relative permittivity ϵ_r' is needed for the medium in which refraction takes place. There are many such theories in the literature, from sub Hertzian to gamma ray frequencies. The effects reported by Gareth Evans and Trevor Morris are in the visible range. In order to give an idea of the nature of the dielectric permittivity the Debye theory of dielectric relaxation is used, together with the first explanation of the far infra red region {11, 12} using the memory function.

In the Debye theory of 1913:

$$\epsilon = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{1 - i\omega_1\tau} \qquad -(32)$$

where τ is the Debye relaxation time, so the dielectric permittivity is:

$$\epsilon' = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{1 + \omega_1^2\tau^2} \qquad -(33)$$

and the dielectric loss is:

$$\epsilon'' = \frac{(\epsilon_0 - \epsilon_\infty)\omega\tau}{1 + \omega_1^2\tau^2} \qquad -(34)$$

where ω_1 is the frequency in the medium of refraction. Therefore:

$$n^2 = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{1 + \omega_1^2\tau^2} \qquad -(35)$$

and Eq. (16) must be solved using computer algebra with this value of the refractive index. The results are graphed and discussed in Section 3, and they intended to give a qualitative idea of the visible frequency Evans Morris effects. A more quantitative theory would use the known visible frequency dispersion spectrum of the medium in which refraction takes place.

It is well known {11, 12} that the Debye theory fails qualitatively in the far infra red when expressed in terms of the power absorption coefficient using Eqs. (30) and (34).

The result is an unphysical plateau. In 1976 the memory function method of M. W. Evans and G. J. Evans {12} successfully explained the far infra red in terms of the continued fraction:

$$\tilde{C}(p) = \cfrac{C(0)}{p + \cfrac{K_0(0)}{p + \cfrac{K_1(0)}{\cdots}}} \qquad -(36)$$

where the Laplace variable p is related to the frequency in general by:

$$p = -i\omega \,. \qquad -(37)$$

Here K_0 and K_1 are frequency dependent memory functions. The dielectric dispersion and loss are given respectively by:

$$\epsilon' = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{\omega}\,\mathrm{Im}\,\tilde{C}(p) \qquad -(38)$$

and

$$\epsilon'' = (\epsilon_0 - \epsilon_\infty)\,\omega\,\mathrm{Re}\,\tilde{C}(p) \,. \qquad -(39)$$

With the availability of computer algebra any number of terms of the continued fraction may be used to build up any kind of spectrum. The far infra red was explained for the first time in 1976 {12} by using the memory function:

$$K_1(t) = K_1(0)\exp(-\gamma t) \qquad -(40)$$

so its Laplace transform is:

$$K_1(p) = \frac{K_1(0)}{p + \gamma} \,. \qquad -(41)$$

Therefore the Laplace transformed spectrum is:

$$\tilde{C}(p) = \frac{C(0)}{p + \frac{K_0(0)}{p + \frac{K_1(0)}{p+\gamma}}} \quad -(42)$$

$$= \frac{C(0)\left(p^2 + \gamma p + K_1(0)\right)}{p^3 + \left(K_0(0) + K_1(0)\right)p + \gamma p^2 + \gamma K_0(0)}$$

Using Eq. (37) produces:

$$\tilde{C}(\omega) = \frac{C(0)}{D}\left(A - i\gamma\omega\right)\left(B - i\omega C\right) \quad -(43)$$

where:

$$A = K_1(0) - \omega^2, \quad -(44)$$
$$B = \gamma\left(K_0(0) - \omega^2\right),$$
$$C = \omega^2 - \left(K_0(0) + K_1(0)\right)$$
$$D = \gamma^2\left(K_0(0) - \omega^2\right)^2 + \omega^2\left(\omega^2 - \left(K_0(0) + K_1(0)\right)^2\right)$$

so the dispersion is:

$$\epsilon'(\omega_1) = \epsilon_\infty - \frac{(\epsilon_0 - \epsilon_\infty)}{D(\omega_1)} C(0)\left(\omega_1 AC + \gamma B\right) \quad -(45)$$

and can be used in Eq. (17) to express the incoming frequency ω in terms of the refracted frequency ω_1. This expression can be inverted numerically to express ω_1 in terms of ω. It becomes obvious that the refracted frequency is a spectrum and contains a lot of new and original information.

SECTION 3: NUMERICAL RESULTS AND GRAPHICS

By Dr. Horst Eckardt

Conservation of energy and frequency shift in reflection and refraction

M. W. Evans[*], H. Eckardt[†], G. J. Evans, T. Morris
Civil List, A.I.A.S. and UPITEC

(www.webarchive.org.uk, www.aias.us,
www.atomicprecision.com, www.upitec.org)

3 Numerical results and graphics

From Eq.(16) the refracted frequency ω_1 can be expressed in terms of ω. The solution of this quadratic equation is

$$\omega_1 = \omega_0 \, \frac{\pm\sqrt{\cos\left(2\,\theta\right)^2 - 2\,n^2\cos\left(2\,\theta\right) + 2\,n^2 - 1} + \cos\left(2\,\theta\right) - 1}{n^2 - 1}. \tag{46}$$

Both solutions are graphed in Fig. 1 as functions of θ. Actually the solutions have been normalized to unity because the input frequency ω, here denoted by ω_0, appears as a common factor. The first solution is negative, therefore only the second solution is physical. The reflected frequency can be determined in the same way from Eq.(16) by replacing ω_1 by ω_2 via Eq.(14). The result is

$$\omega_2 = \omega_0 \, \frac{\pm\sqrt{\cos\left(2\,\theta\right)^2 - 2\,n^2\cos\left(2\,\theta\right) + 2\,n^2 - 1} - \cos\left(2\,\theta\right) + n^2}{n^2 - 1} \tag{47}$$

and differs from ω_1 only by the last two terms in the numerator. The graph of Fig. 2 shows two positive solutions. The second is always larger than unity, showing a probably unphysical increase in energy. It has been checked that the pairwise sum of normalized ω_1 and ω_2 is unity. This is a test for the energy conservation equation (14) which entered the calculation and must be valid also for the solutions.

The calculations so far were made with $n = 1.5$. There are artificial materials with $n < 1$ available nowadays. Figs. 1 and 2 have been recreated with $n = 0.5$ (see Figs. 3 and 4). There are some interesting findings. Refraction and reflection are only defined for the upper range of θ. The reflection is always negative, i.e. there is no reflected beam. The refraction frequency is greater than the incident frequency for both solutions in a certain range, indicating a blue-shift. Formally, energy is conserved because the reflected frequency is negative.

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[*] email: emyrone@aol.com
[†] email: mail@horst-eckardt.de

A complex valued refraction index is described as a function of the complex valued dielectric constant by Eqs.(22-29). Eq.(30) defines the power absorption coefficient α in dependence of permittivity ϵ' and absorption ϵ'':

$$\alpha = \frac{\omega_0 \ \epsilon''}{n' \ c} \tag{48}$$

where n' depends on ϵ' and ϵ'' via Eq.(28). The dependence of the normalized function $\alpha \ c/\omega_0$ is graphed in Fig. 5 for three parameter values of ϵ'. Obviously α grows continously with ϵ'' but decreases with ϵ'.

For the squared absolute value of the refraction index we obtain according to Eq.(31)

$$n^2 = \epsilon', \tag{49}$$

the absorption ϵ'' does not enter the law of refraction in the simplest case. By inserting Eq.(49) into (46) and (47) we obtain the dependence of refracted and reflected frequencies from ϵ'. This is shown in Figs. 6 and 7 for a fixed angle $\theta = \pi/4$. There is a frequency increase in refraction for $\epsilon' < 1$ as discussed above for specialized materials with $n < 1$.

A more realistic model – although valid only in a very restriced frequency range – is the Debye Theory, Eqs.(32-35). Inserting (35) into (16) leads to an equation of fourth order in ω_1. This quartic can be solved analytically but the solutions are highly complicated. Nevertheless the computer is able to graph the solutions as shown in Fig. 8 for $\omega_0 = 1 \cdot 10^{12}/s$, $\tau = 1 \cdot 10^{-12}s$, $\epsilon_\infty = 0$ and $\epsilon_0 = 2.25$. The latter value corresponds to $n = 1.5$. Only the third solution seems to be physical. This solution is graphed for three values of relaxation time τ in Fig. 9. For increased relaxation times the refracted frequency ω_1 is not defined in the complete angular range because it has a vertical asymptote and becomes imaginary. A blue shift is possible for increased τ values. The results indicate that the Evans-Morris effect can be expected and be explained in the infrared region, not only in the frequency range of visible light.

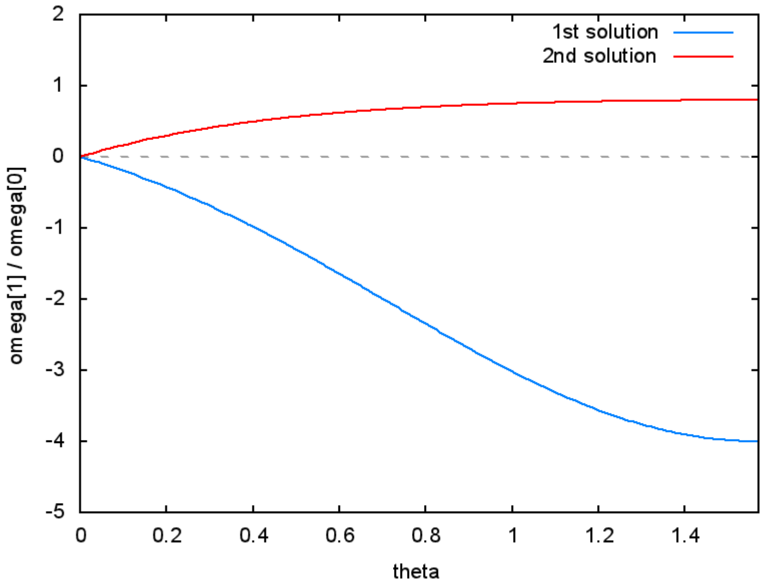

Figure 1: Normalized refracted frequency ω_1 for $n = 1.5$.

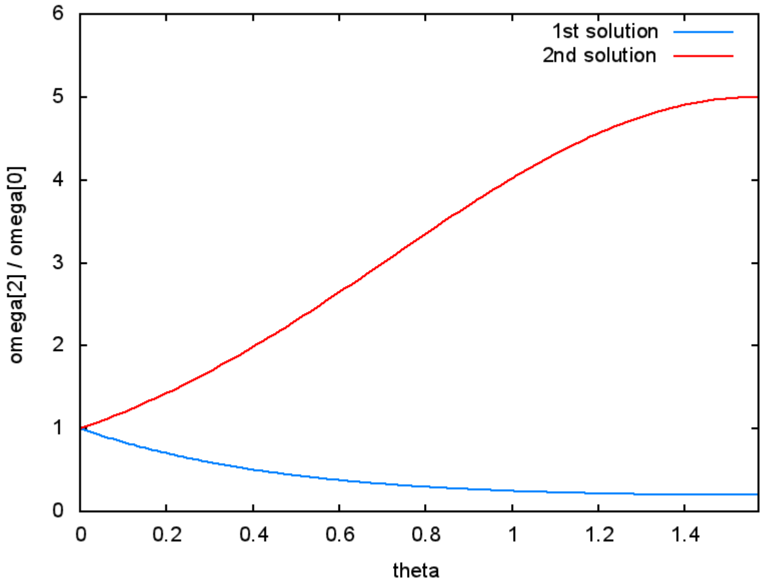

Figure 2: Normalized reflected frequency ω_2 for $n = 1.5$.

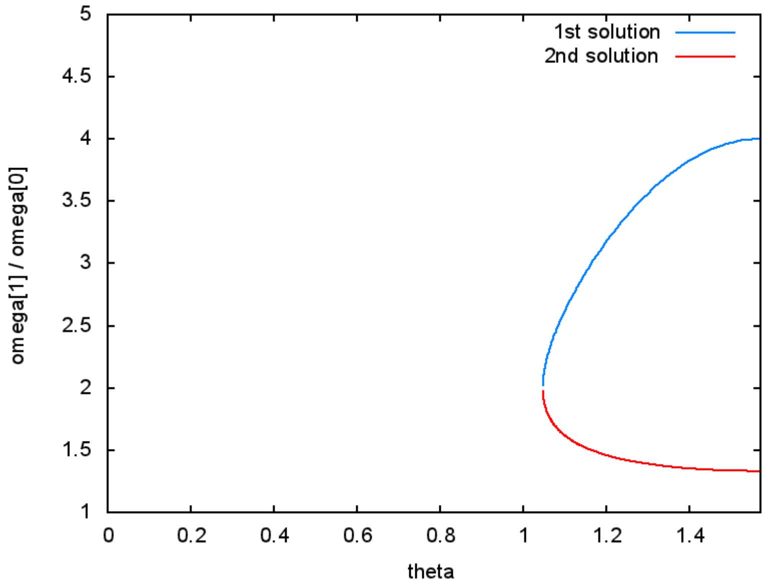

Figure 3: Normalized refracted frequency ω_1 for $n = 0.5$.

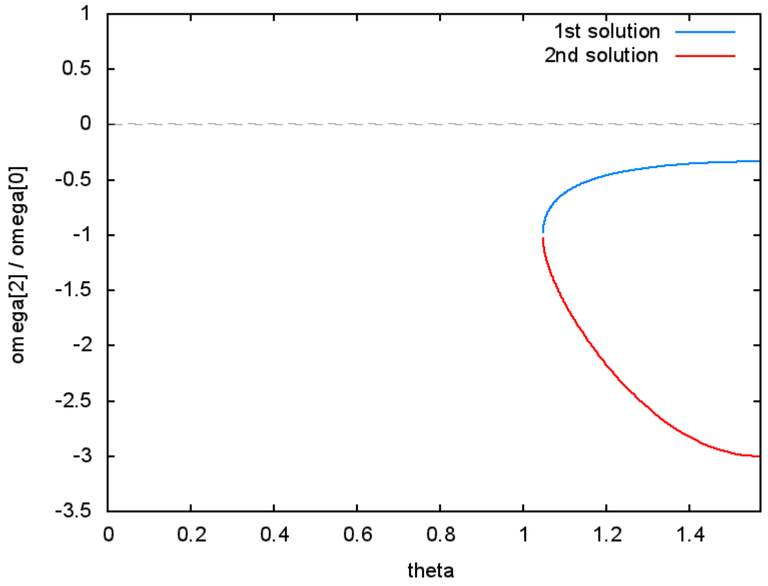

Figure 4: Normalized reflected frequency ω_2 for $n = 0.5$.

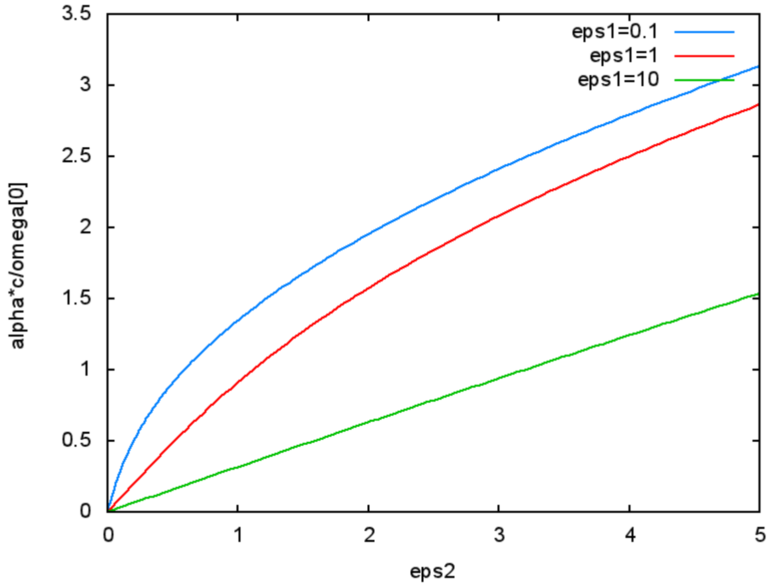

Figure 5: Absorption coefficient $\alpha c/\omega_0$ in dependence of dielectric absorption ϵ''.

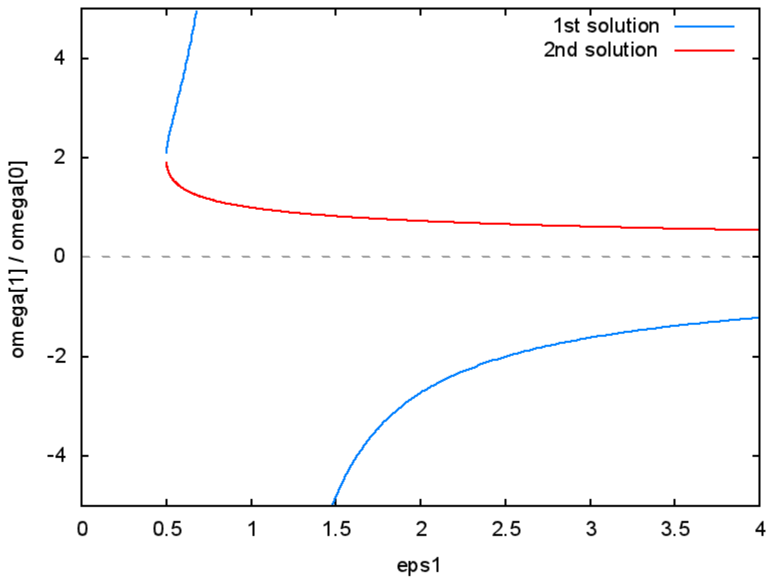

Figure 6: Normalized refracted frequency $\omega_1(\epsilon')$ at $\theta = \pi/4$.

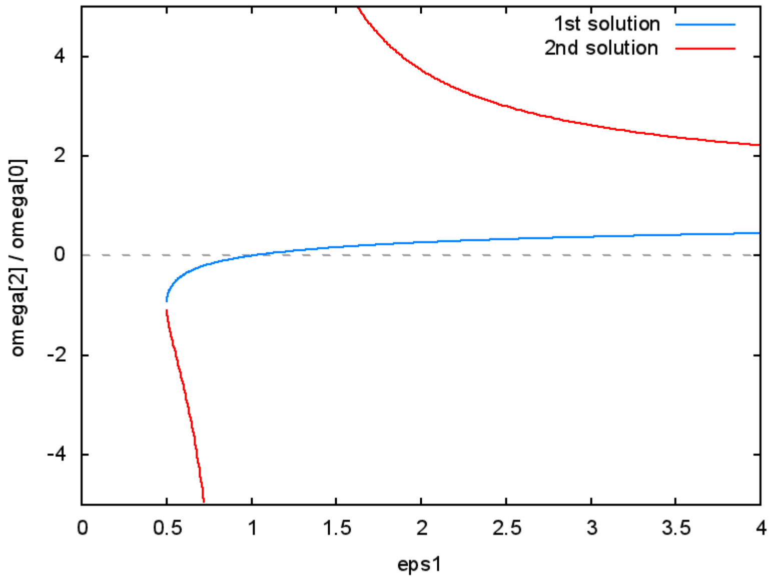

Figure 7: Normalized reflected frequency $\omega_2(\epsilon')$ at $\theta = \pi/4$.

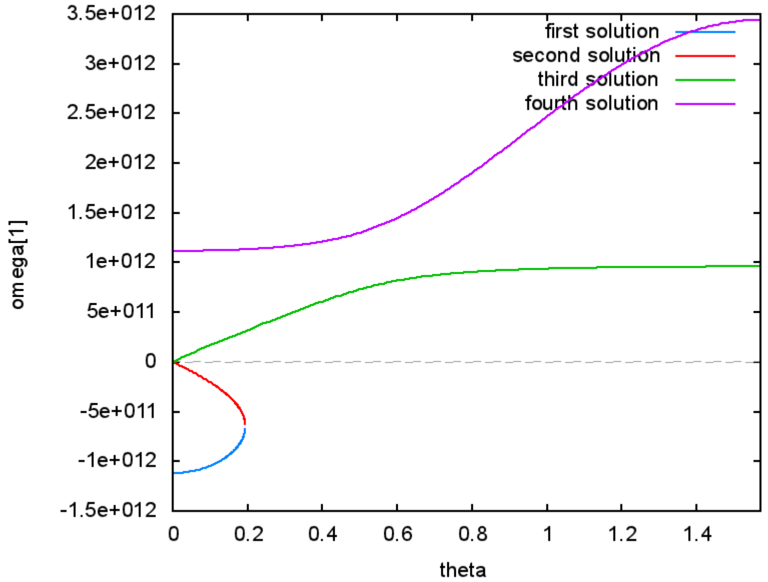

Figure 8: Four solutions of $\omega_1(\theta)$ for Debye theory with $\omega_0 = 1 \cdot 10^{12}/s$, $\tau = 1 \cdot 10^{-12}s$, $\epsilon_0 = 2.25$.

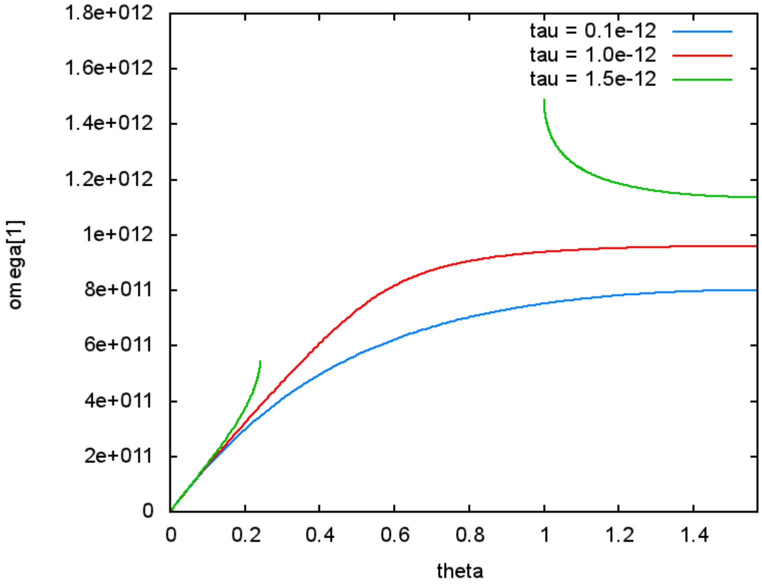

Figure 9: Third solution of Fig. 8 for three Debye relaxation times.

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