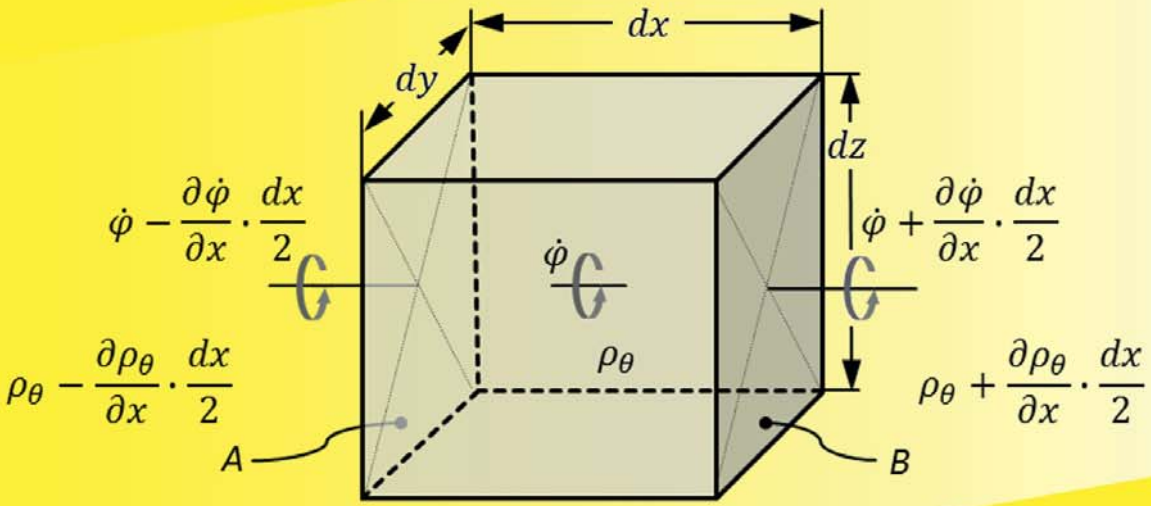
Raymond Freymann

About an Extended Field Theory based on an Energy Conservation Approach



Cuvillier Verlag Göttingen
Internationaler wissenschaftlicher Fachverlag

About an Extended Field Theory based on an Energy Conservation Approach

About an Extended Field Theory based on an Energy Conservation Approach

Raymond Freymann

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.
1. Aufl. - Göttingen: Cuvillier, 2018

Nonnenstieg 8, 37075 Göttingen
Telefon: 0551-54724-0
Telefax: 0551-54724-21
www.cuvillier.de

1. Auflage, 2018
Gedruckt auf umweltfreundlichem, säurefreiem Papier aus nachhaltiger Forstwirtschaft.

ISBN 978-3-7369-9752-3
eISBN 978-3-7369-8752-4

Preface

Having been involved for many years in diverse engineering fields, I never ever had imagined to be confronted real unexpectedly with rather fundamental considerations being related to the electromagnetic free-field. Working on the topic, I did detect in the scope of rather simple energy considerations, that there must exist a “missing part” in the actual description of the physical model being related to free-field considerations. Extending the existing model of a “longitudinal field” by a “rotational component” leads to a significantly changed view on the overall field dynamics. Rather surprising, but finally convincing and logical results are obtained by the extended approach, now allowing the energy conservation in the free-field at any location and at any time.

The aim of the publication is to provide the required information as to the need of an extended field model. A detailed physical and mathematical description of the model will be derived.

In the scope of the research work I did recognize that the many publications on “the Internet” are of a tremendously high value when asking for an answer to well-defined questions/assumptions. In so far, I need to address that the information being accessible via “the Internet” has significantly contributed to achieve this work in a still reasonable time frame. Many thanks to the authors.

Special thanks also to Philipp Linnebach for having provided a considerable support as to the preparation of the text and of the figures. Many thanks, Philipp.

Prof. Dr.-Ing. habil. Raymond Freymann

March 2018

Contents

List of Symbols

$\mathcal{B}$	tesla	magnetic field
E	N m	energy
$\mathcal{E}$	V/m	electric field
I	W/m²	(spectral) radiation intensity
I^*	W/m² m	specific spectral radiation density
M	kg/mole	molar mass
N		number of particles
N_A		Avogadro constant = 6,022 · 10^{23} 1/mole
$\mathcal{R}$		universal gas constant = 8,315 J/mole K
T	s	time period of a harmonic signal
V	m³	defined *fixed size* volume
c	m/s	propagation speed of sound/light
f	1/s	frequency of a harmonic signal
h		Planck action quantum = 6,63 · 10^{-34} Nm
i		imaginary unit = $\sqrt{-1}$
i_L	A	electric current related to the longitudinal field
i_R	A	electric current related to the rotational field
k	1/m	phase constant
k		Boltzmann constant = 1,38 · 10^{-23} Nm/K
m	kg	mass
n		number of moles
p	N/m²	pressure
t	s	time
v	m/s	translational speed of a source
θ	kg m²	inertia
γ	rad	phase shift angle
κ		adiabatic coefficient
λ	m	wavelength
μ		constant factor = 10^{-11} 1/s
$\dot{\xi}_x$	m/s	vibrational longitudinal particle celerity
ϑ	K	absolute temperature

$\dot{\varphi}$	rad/s	vibrational rotational particle celerity
ρ	kg/m³	mass density
ρ_θ	kg/m	inertia density
σ		Stefan-Boltzmann constant = 5,67 · 10^{-8} W/m²K⁴
ψ		constant factor = 3,03 · 10^{-17} mole/m³K³
ω	1/s	circular frequency

Indices

A	related to the wave penetration side A of a volume element
B	related to the wave leaving side B of a volume element
AB	related to the difference of values “A”-“B”
L	related to the longitudinal field
P	related to a particle
R	related to the rotational field
V	related to a volume element
avg	averaged value of
eff	effective value of
kin	related to the kinetic energy
max	maximum value of
min	minimum value of
pot	related to the potential energy
peak	related to a value at λ_{peak}
tot	total value of
0	related to the peak amplitude of a harmonic signal
$(\tilde{})$	related to a dynamic value
$(\bar{})$	related to a steady value
$(\dot{})$	first derivative of a variable with respect to time
$(\ddot{})$	second derivative of a variable with respect to time

1. Introduction

Yes, it´s all about curiosity! One day I was concentrating on the electromagnetic behavior of electrical (“50 Hz”) transformers. This was just to understand how the energy transfer is realized in the “iron”, the armature, to move the energy from the (externally excited) primary coil to the (energy receiving) secondary coil. I just wanted to know in detail what is going on in the “iron”.

I studied a lot of literature on the Internet and by doing so, just by pure incident and real unexpectedly, I was confronted with the wave propagation topic in an electromagnetic free-field. I really dived in into this topic with the expectation to get a deeper understanding about the energy content being related to an electromagnetic field. And, I need to admit, by digging deeper and deeper more and more questions were brought up. All of this first appeared as to finish in a so-called endless story.

When concentrating on the electromagnetic free-field, I was in some way surprised by the simplicity of the corresponding physical background when compared to the overall electromagnetic situation related to solid materials /1/. What struck me most was that in a propagating free-field there are just two fields existing, an electric $\mathscr{E}$ - field and a magnetic $\mathscr{B}$ - field, located in a vertical plane relative to the wave propagation direction. Both *fields, being in-phase* and vertically oriented to one another, may indeed create – in accordance with Lorentz´s law or Ampère´s force law - an environment allowing an electrically charged particle to be moved in the direction of the so-called pointing vector, which is the direction of the wave propagation. Yes, all in all it looks quite plausible, but the longer I was concentrating on the possible physical mechanisms involved, the more I got the impression that there must be “something” missing.

Just having an engineering background (in aeronautical sciences), I had to notice soon that it might not be easy to come up with a decent explanation/solution in context with the topic addressed. There were so many (additional) constraints existing which needed to be considered: the particle/wave properties of the electromagnetic field as well as the quantum theory. Accordingly, at a very first glance, all of this appeared to be of a “highly complicated matter” and – as is noted in so many publications – there is no way existing to explain this highly complex topic by an approach based on “classical physics”.

With this a priori information, I had to recognize that my starting position to tackle the topic was rather bad. I really have no deep insight into the physics on the particle level. On the other hand, I dare to say that I have a lot of experience as to deal with energy considerations on a more global level, say on the field level. Accordingly, I decided to analyze the electromagnetic field physics on an energy conservation approach.

Since the electromagnetic field does in many respects still lack transparency, I first went on looking at "possibly related analogies" in other technological fields. And … I did identify similar effects in acoustics, the acoustic wave propagation! The similarity is due to the fact, that in an acoustic free-field environment, the pressure and the acoustic celerity *fields are in-phase*, which is (at least superficially) similar to the $\mathcal{E}$ - and $\mathcal{B}$ - fields in an electromagnetic wave propagation field. Moreover, the acoustic free-field does feature both particle and wave characteristics, just in the same way as the electromagnetic field does.

To cope with this fact, a deeper focus will be pointed in Chapter 2 on the wave propagation in an acoustic free-field environment. Since both, the acoustic and electromagnetic fields – at least at a first glance – seem to have some commonalities, it appears to make sense to first concentrate on the more transparent acoustic free-field before addressing the more complex electromagnetic topic in Chapter 3. In the scope of related detailed analysis, the "missing part", being inherent both to the acoustic and electromagnetic fields, could be identified. The missing part is a "rotational field degree of freedom"!

Having set up the physical model of the electromagnetic field and having derived the related energy equations, the next task consisted in the verification/calibration of the derived extended model. It was considered that the black body radiation (Planck´s radiation spectra) was best suited to validate the elaborated theoretical model. In Chapter 3 we will focus on the validation process which finally proved to be successful. Thereby also an explanation about the so-called "ultraviolet catastrophe" will be given. A simple physical reasoning will indicate that this catastrophe cannot exist!

Moreover, in Chapter 3, characteristic values, being related to the medium on the particle and volume level, will be derived by introducing an extended formulation of the thermodynamic equations related to the perfect gas theory.

Having demonstrated that there is a significant evidence existing that the acoustic and electromagnetic fields are physically similar, some further considerations can be derived therefrom. These will be addressed in Chapter 4 with focus pointed on the topics of “superlight speed”, the photoelectric effect and an (assumed!) gravity mechanism.

Finally, it should be mentioned that the work outlined in *the publication is primarily focusing on the identification and explanation of physical phenomena* related to the dynamics in a sustained free-field environment. Thereby use will be made of an approach being completely based on classical physics/mechanics. In the scope of the investigations just a first order approximation is considered to mathematically describe the field dynamics. This is of no major significance as to the results/information obtained from the related physical considerations which appear as logical and convincing. This is among others due to the fact, that the (many) field energies involved are forming an overall completely balanced dynamic system, being at resonance at any location, at any time and at any frequency. The overall dynamic behavior and performance of the system is so remarkable, just absolutely (!) perfect.

2. Acoustic wave field

For the sake of simplification let´s concentrate first on the one-dimensional acoustic free-field, as depicted in **Fig. 1**. Thereby it is assumed that the field is propagating from a source to a sink. Let´s just focus on a *sustained harmonic* free-field existing between the source and the sink. The free-field is characterized by the fact that both the pressure and acoustic celerity fields are in-phase all along the propagation x-axis /2/. Accordingly, the pressure and celerity fields, p and $\dot{\xi}_x$ respectively, can be expressed in the form

(1) $p = p_0 \cos(\omega t - kx)$,

(2) $\dot{\xi}_x = \dot{\xi}_{x0} \cos(\omega t - kx)$.

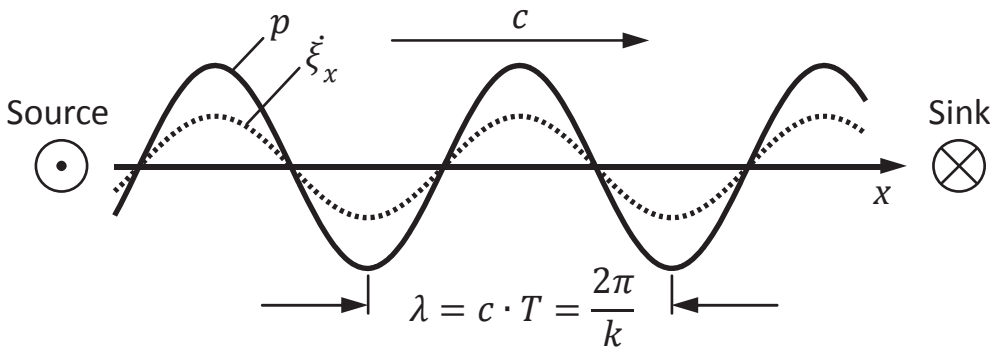


Figure 1: *One-dimensional acoustic free-field*

In Eqs. (1) and (2) p_0 and $\dot{\xi}_{x0}$ are denoting the amplitudes of both variables, ω defines the circular frequency of the time dependent harmonic signals and k the phase constant describing the harmonic wave pattern as a function of the x-location. With λ defining the wave length of the harmonic field, T its time period and c denoting the speed of sound in the medium, leads moreover to the following interrelation

(3) $\omega T = k \cdot \lambda = k \cdot c \cdot T = 2\pi$.

There is no need to say that Eqs. (1) and (2) are related to waves propagating in the positive x-direction. Accordingly, these waves are constantly transporting energy in the positive x-direction of the wave field.

But how about the energy content related to a defined *fixed size* volume element positioned at a *fixed* x-location (**Fig. 2**) within the field? Based on an energy conservation approach, we can write

(4) $$\frac{d}{dt}(E_A - E_B) = \frac{d}{dt}(E_{kin,V} + E_{pot,V}),$$

E_A, E_B denoting the acoustic input and output energies to the volume element, respectively, and $E_{kin,V}$, $E_{pot,V}$ defining the kinetic and potential energies inherent to the volume element itself.

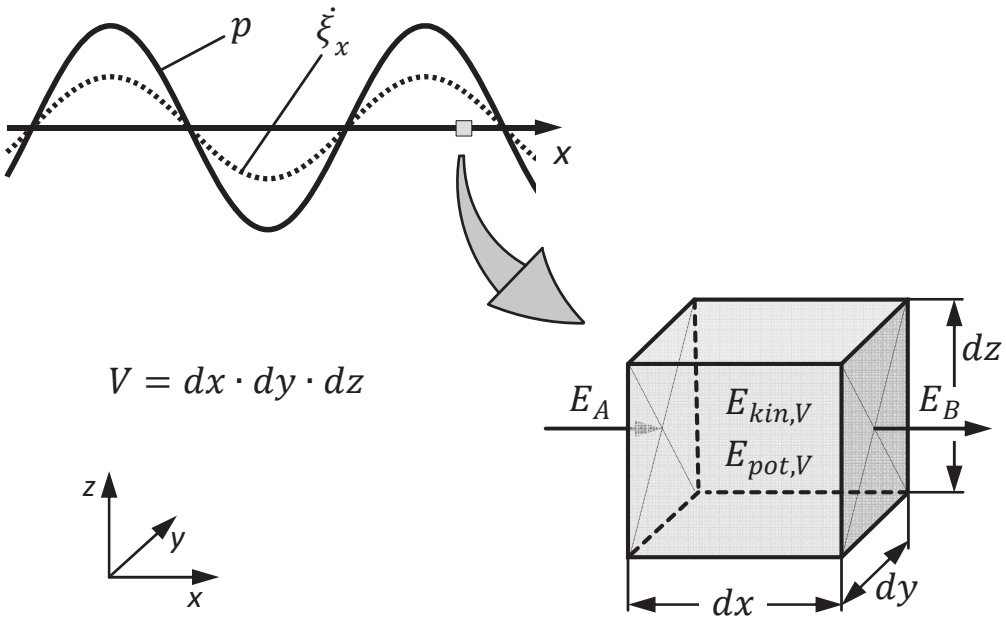


Figure 2: *Energies related to a volume element*

Eq. (4) leads to a significant finding. If the length (in the x-direction) of the fixed size volume element is identical to the wavelength λ or to an integral multiple of this wavelength, then – in case of a sustained harmonic acoustic field – its kinetic and potential energy content will not vary over time. It follows therefrom that $E_A = E_B$ in any time interval, say "what´s coming in is going out". The interesting story behind this is as follows: *neighboring elements can transfer energy to/among each other without changing their own energy content* (**Fig. 3**). Of course, this finding is resulting from a rather macroscopic approach, microscopic considerations would indicate that there is a lot "going on" in the volume element itself. Nevertheless, this is a highly interesting finding!

If we now focus on a fixed size volume element of length $dx << \lambda$, we need to consider the microscopic dynamics in the medium. In this context let´s just address the potential energy changes inherent to this real small volume

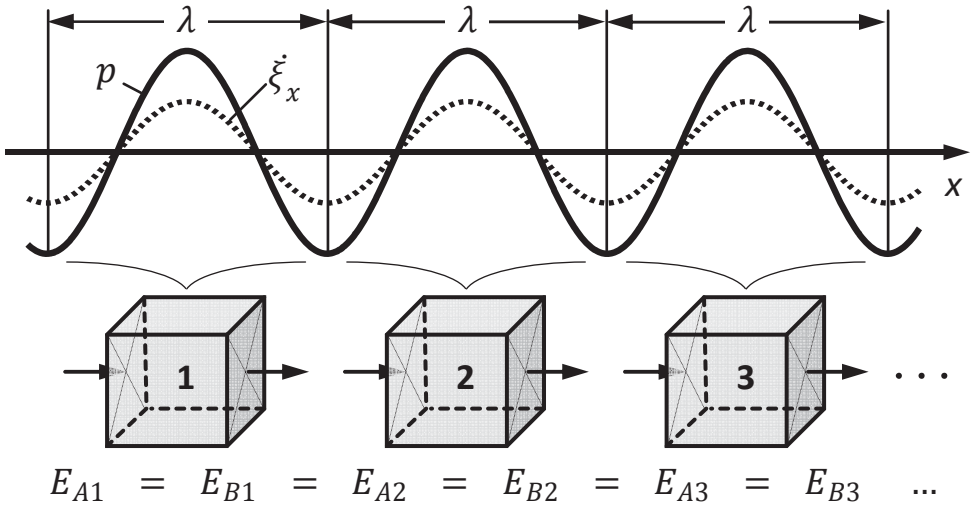


Figure 3: *Energy transfer between volume elements*

element resulting from the dynamic pressure fluctuations. Let´s focus on the narrow dx-slot being indicated in **Fig. 4.**

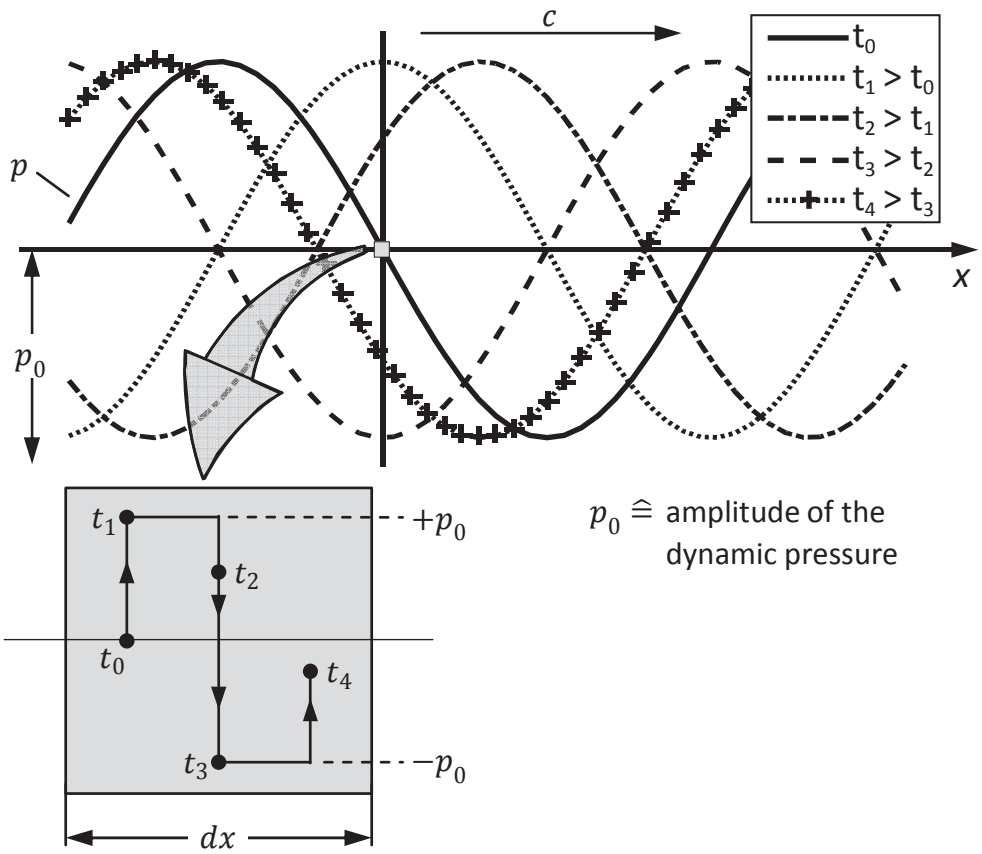


Figure 4: *Timely dependent pressure fluctuations in a volume element*

The dynamic pressure will increase in a first time interval (compression), will be reduced in a second time interval (expansion), will feature negative values in a third time interval (dilution), will increase again in a fourth time interval (compression) and this will be repeated all over time. At a first glance, all of this looks quite logical. Potential energy is built up in a first step, then recovered in a second step and so on and so on. And finally, the related energy variations will be longitudinally transferred to a next neighboring volume element in accordance with Eq. (4).

A second glance at the situation reveals that this compression and dilution work cannot really be performed in the scope of an efficient process. It all looks so “unbalanced”. It appears like moving up and down an elevator having no counterweights. There must be “something” missing.

To clear up the situation, let´s focus on the following *virtual* experiment. Let´s assume that, as is indicated in **Fig. 5**, a noise source (loudspeaker) is placed on a flat surface and is homogeneously radiating “noise” into a spherical half-room. This entails that sound pressure levels are equal on (half-) shell surfaces being equidistant from the noise source. Let´s further assume that the noise emitted by the source is harmonic with time and at a frequency of 1000 Hz. The excitation level of the noise generator is adjusted to produce - at a 1 m distance – a sound pressure level of 74 dB, which corresponds to an *effective*

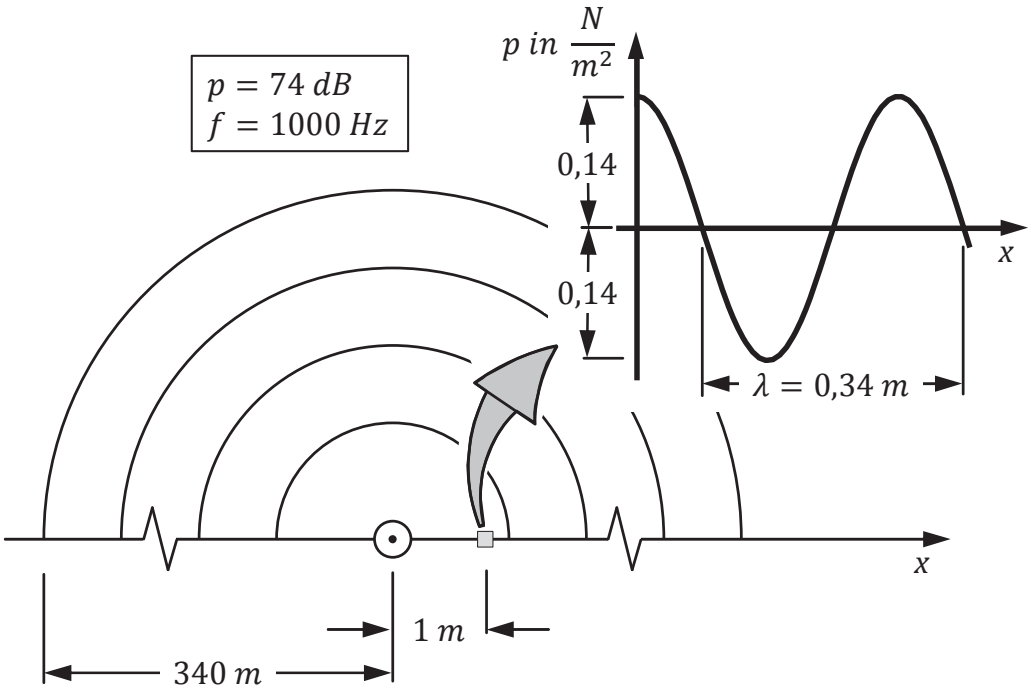


Figure 5: *Virtual experiment*

sound pressure of 0,1 N/m². This may be considered as a medium noise level as to the audible perception of human beings. This is for sure not “loud noise”.

Based on the test setup described, we now perform a *virtual* test run being defined by the following 3 states:

State 1: The noise source is not activated ... no ambient noise, just dead silence.

State 2: The noise source is switched on and noise is radiated into the spherical half-room. The noise propagation will occur at the speed of sound, say 340 m/s.

State 3: Just one second after having activated the noise source let´s (virtually) freeze the radiated noise field and switch off the noise source. At this statically frozen 1 sec. time point the noise has spread around the noise source, creating a half-spherical sound field ranging from 0 m to 340 m relative to the noise source location. Evaluating the acoustic energy inherent to this frozen acoustic field will allow to determine the required energy/power of the noise source to produce the noise field.

Evaluating the energy content of the (frozen) field we will just focus on its potential energy. The kinetic energy is negligible. Moreover, it is well-known that the acoustic energy in half-shell volume segments of equal thickness is of a constant value and thus independent of their corresponding distance relative to the noise source. This allows to just determine the acoustic energy content in one shell volume – e.g. being of 1 m thickness - and multiply this value by a factor of 340, 340 m being the extension of the frozen noise field.

Let´s now evaluate the potential energy being inherent to the shell volume segment ranging from 0,5 m to 1,5 m from the noise source. We defined the noise pressure level existing at a 1 m distance from the noise source: $p_{eff} = 0{,}1\, N/m^2$. In the volume considered there are areas of compression and dilution of the medium existing. Now it needs to be understood that both the compression and the dilution of the medium require the input of energy to the field. In this context, just let me note that it is not allowed to consider compression areas as “positive energy areas” and dilution areas as “negative energy areas”. This is not true. Positive and “negative” energy areas do not compensate! Both compression and dilution need *positive* (!) work to be performed.

In the scope of an energy approach this finally allows to take into account the (positive and "negative") dynamic pressure fluctuations over a wavelength by a static *averaged* positive pressure value p_{avg}, defined by the following equation:

$$(5) \qquad p_{avg} = \frac{1}{\lambda/2} \cdot p_0 \int_0^{\lambda/2} \sin(kx) \cdot dx = \frac{2}{\pi} \cdot p_0 = \frac{2}{\pi} \cdot \sqrt{2} \cdot p_{eff},$$

p_0 characterizing the (dynamic) peak pressure amplitude and p_{eff} the related effective pressure amplitude. The interrelation existing between both of these values is $p_0 = \sqrt{2} p_{eff}$.

Based on the considerations made above, the dynamic potential energy of a field volume can now be written as follows:

$$(6) \qquad E_{pot} = [V] \cdot [p_{avg}].$$

Concentrating on the half-shell volume between the radii $R_{inner} = 0{,}5\ m$ and $R_{outer} = 1{,}5\ m$ leads to

$$(7) \qquad E_{pot,1m} = \left[\frac{1}{2} \cdot \frac{4}{3} \pi \cdot \left(R_{outer}^3 - R_{inner}^3 \right) \right] \cdot \left[\frac{2}{\pi} \cdot \sqrt{2} \cdot p_{eff} \right]$$

$$\hat{=} \left[\frac{1}{2} \cdot \frac{4}{3} \pi \cdot \left(1{,}5^3 - 0{,}5^3 \right) \right] \cdot \left[\frac{2}{\pi} \cdot \sqrt{2} \cdot 0{,}1 \frac{N}{m^2} \right] = 0{,}62\ Nm.$$

Multiplying this value by a factor of 340 finally yields the total dynamic potential energy inherent to the acoustic field according to

$$(8) \qquad E_{pot,340m} = 0{,}62\ Nm \cdot 340 = 210\ Nm = 210\ Ws.$$

This *acoustic* energy has been provided by the noise source in a one-second time interval. Knowing that the electro-acoustical efficiency of a sound generator is rather poor, let´s assume an efficiency factor of 1% in case of a simple loudspeaker system, which can (easily) generate the 74 dB dynamic pressure level at a distance of 1 m from its location. This entails that the *electric* energy which needed to be provided to the loudspeaker system – in this 1 second time interval – is in the range of 20.000 Ws. The thus related *electric* power request amounts to 20 kW! Reality now shows that a battery powered "small device" can produce the sound levels considered with an

electric input in the range of a few Watts. Moreover, taking into account the inner energy consumption of “the sound generating device” indicates that *there is existing a non-correlation between theoretical analysis and practical evidence, being underlined by a discrepancy exceeding by far a factor of 1.000!*

We can now deliberate about some assumptions in context with the real rough derivation made above. We can discuss about the radiation characteristics of loudspeaker systems, their electro-acoustical efficiency and probably a lot more. But the difference between practical and theoretical realities cannot be denied. There will remain a significant gap between the two realities!

What´s missing? Let´s come back to the elevator already addressed above. As indicated, the counterweights seem to be missing in the description of the acoustic field. What´s forming this counterweight?

Due to the large difference really existing between the energy/power levels of the noise source and the related acoustic field it can definitively be concluded that the energy inherent to the acoustic field has not been produced by the noise source. This consequently entails that the energy related to the acoustic field must already exist in the field at ambient rest conditions, corresponding to “State 1” described above. Accordingly, the noise source is not producing but it is just transforming, say triggering or activating, the already existing energy in the field. In order that this can dynamically happen there needs to exist an “additional degree of freedom” in the medium. Based on some deeper reflections it was concluded that *this degree of freedom must be of a rotational nature*. It is forming the counterweight of the elevator.

Remark: The energy characteristics being allocated to the rotational degree of freedom are related to the so-called “inner energy” addressed in thermodynamics /3/,/4/. This topic, being related to highly complex physical/chemical phenomena on the particle/volume level, will not be further analyzed in the following.

As a result of these reflections, I dare to state the following:

In a sustained free-field environment energy conservation is realized at any time in any defined volume element regardless of its size and location.

In a sustained free-field, volume elements, independent of their size, just behave as volume elements of length λ, which finally entails that “what is going in is going out”. In case of the existence of a “rotational degree of freedom”, we will have to deal with the following 4 energy forms in the field:

a) kinetic energy related to the longitudinal field,
b) potential energy related to the longitudinal field,
c) kinetic energy related to the rotational field,
d) potential energy related to the rotational field.

In the following paragraphs a mathematical formulation of these 4 energies will be derived. This will lead to some rather surprising results!

2.1 Kinetic energy - longitudinal field

Considering the left side (area A) of the volume element, depicted in **Fig. 6**, we can formulate for the kinetic energy of a mass flow $\dot{m}_A$ entering the volume element in a time interval dt :

$$(9) \qquad dE_{kin,L,A,dt} = \frac{1}{2} \cdot \dot{m}_A \cdot dt \cdot \left(\dot{\xi}_x - \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} \right)^2 .$$

With

$$(10) \qquad \dot{m}_A = \left(\rho - \frac{\partial \rho}{\partial x} \cdot \frac{dx}{2} \right) \cdot dy \cdot dz \cdot \left(\dot{\xi}_x - \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} \right) ,$$

ρ denoting the volumetric density of the medium, finally yields with Eq. (9) if second order terms are neglected:

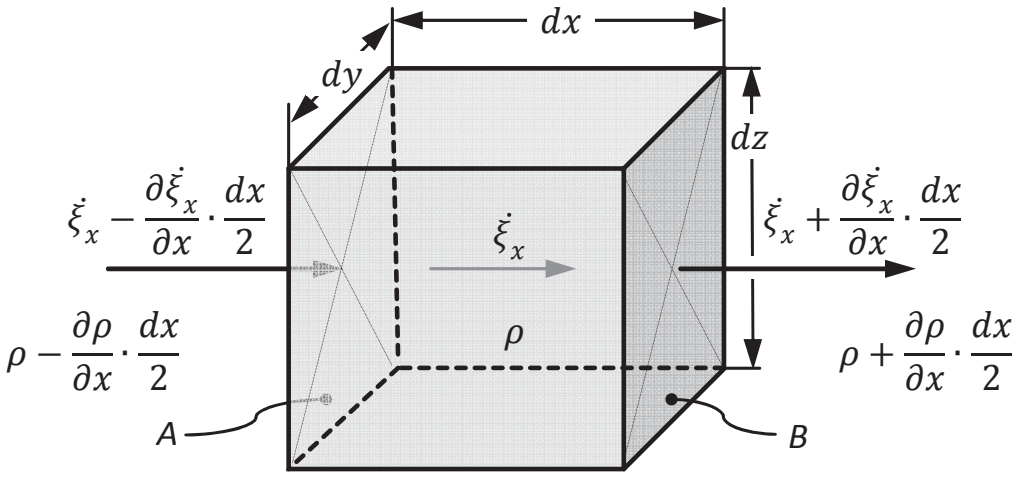


Figure 6: *Volume element – longitudinal energy model*

(11) $$dE_{kin,L,A,dt} = \frac{1}{2} \cdot dy \cdot dz \cdot \left(\rho \dot{\xi}_x^3 - 3\rho \dot{\xi}_x^2 \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} - \dot{\xi}_x^3 \frac{\partial \rho}{\partial x} \cdot \frac{dx}{2} \right) \cdot dt \,.$$

The same formalism applied to the right side (area B) of the volume element gives an indication of the kinetic energy leaving the volume element in a time interval dt. This leads to

(12) $$dE_{kin,L,B,dt} = \frac{1}{2} \cdot dy \cdot dz \cdot \left(\rho \dot{\xi}_x^3 + 3\rho \dot{\xi}_x^2 \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} + \dot{\xi}_x^3 \frac{\partial \rho}{\partial x} \cdot \frac{dx}{2} \right) \cdot dt \,.$$

The difference of the kinetic energy supplied to or evacuated from the volume element is defined by

(13) $$dE_{kin,L,V,dt} = dE_{kin,L,A,dt} - dE_{kin,L,B,dt}$$

$$= -\frac{1}{2} \cdot dy \cdot dz \cdot \left(6\rho \dot{\xi}_x^2 \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} + 2\dot{\xi}_x^3 \frac{\partial \rho}{\partial x} \cdot \frac{dx}{2} \right) \cdot dt \,,$$

finally leading to

(14) $$\frac{dE_{kin,L,V}}{dt} = -\frac{1}{2} \cdot \rho V \dot{\xi}_x^2 \cdot \left(3\frac{\partial \dot{\xi}_x}{\partial x} + \dot{\xi}_x \frac{1}{\rho} \cdot \frac{\partial \rho}{\partial x} \right).$$

Eq. (14) is formed by variables being a function of time t and location x. If just an information about energy variations at a defined location x is needed, then it makes sense to alter the form of Eq. (14) by making use of the following transformation rule for a variable (-):

(15) $$\frac{\partial(-)}{\partial x} = \frac{\partial(-)}{\partial t} \cdot \frac{\partial t}{\partial x} = \dot{(-)} \cdot \left(-\frac{1}{c} \right),$$

c denoting the propagation speed of the sound wave which is equal to the speed of sound. Applying this rule to Eq. (14) yields

(16) $$\frac{dE_{kin,L,V}}{dt} = \frac{3}{2} \cdot \rho V \cdot \frac{1}{c} \cdot \dot{\xi}_x^2 \cdot \ddot{\xi}_x + \frac{1}{2} \cdot V \cdot \frac{1}{c} \cdot \dot{\xi}_x^3 \cdot \dot{\rho} \,.$$

Let´s now focus on a harmonic free field with circular frequency ω. This allows to formulate the expressions for the pressure and density variables as follows in the complex plane:

(17) $p = \overline{p}_0 + \tilde{p}$ and $\rho = \overline{\rho}_0 + \tilde{\rho}$,

with

(18) $\tilde{p} = p_0 \cdot e^{i\omega t}$ and $\tilde{\rho} = \rho_0 \cdot e^{i\omega t}$,

which entails

(19) $\dot{p} = \dot{\tilde{p}} = (i\omega) \cdot p_0 \cdot e^{i\omega t}$ and $\dot{\rho} = \dot{\tilde{\rho}} = (i\omega) \cdot \rho_0 \cdot e^{i\omega t}$.

In Eq. (17) p, ρ characterize the total pressure and density (in a defined volume element), $\overline{p}_0$, $\overline{\rho}_0$ the corresponding steady values at ambient conditions and p_0, ρ_0 the amplitudes related to the unsteady (harmonic) fluctuations. For the celerity, being in-phase with the pressure, we can write

(20) $\dot{\xi}_x = \dot{\xi}_{x0} \cdot e^{i\omega t}$,

from which it follows:

(21) $\ddot{\xi}_x = (i\omega) \cdot \dot{\xi}_{x0} \cdot e^{i\omega t}$.

Moreover, making use of the interrelations /5/

(22) $\overline{p}_0 = \frac{1}{\kappa} \cdot c^2 \cdot \overline{\rho}_0$ and $\tilde{p} = c^2 \cdot \tilde{\rho}$,

κ defining the adiabatic coefficient of the medium, allows to reformulate Eq. (16) as follows:

(23) $$\frac{dE_{kin,L,V}}{dt} = (i\omega) \cdot \frac{3}{2} \cdot \kappa \cdot \overline{p}_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i3\omega t} + (i\omega) \cdot 2 \cdot p_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i4\omega t}.$$

The integration of Eq. (23) allows to determine the time dependent longitudinal kinetic energy content in a defined volume element of volume size V. The integration yields

(24) $$E_{kin,L,V} = \frac{1}{2} \cdot \kappa \cdot \overline{p}_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i3\omega t} + \frac{1}{2} \cdot p_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i4\omega t}.$$

There is no need to consider an integration constant in Eq. (24). This results from the fact that $E_{kin,L,V}$ is zero if $\dot{\xi}_{x0}$ is zero.

The back-transformation of Eq. (24) from the complex plane to the real domain allows to express the energy term related to the kinetic energy in the longitudinal field as follows:

$$(25) \quad E_{kin,L,V} = \frac{1}{2} \cdot \kappa \cdot \overline{p}_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot \cos(3\omega t) + \frac{1}{2} \cdot p_0 V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot \cos(4\omega t) .$$

This indicates that the expression of the kinetic energy related to a fixed size volume element is a time dependent function driven by $\cos(3\omega t)$ and $\cos(4\omega t)$.

2.2 Potential energy - longitudinal field

The potential energy content related to a defined fixed size volume element is expressed by the equation

$$(26) \quad E_{pot,L,V} = p \cdot V = (\overline{p}_0 + \tilde{p}) \cdot V = \overline{p}_0 \cdot V + \tilde{p} \cdot V ,$$

which leads to

$$(27) \quad \frac{dE_{pot,L,V}}{dt} = V \cdot \dot{\tilde{p}} = V \cdot \dot{p} .$$

In the scope of an adiabatic approach, based on Poisson´s law /6/

$$(28) \quad p \cdot V^{\kappa} = const. ,$$

the total pressure related to a *fixed size* volume element can be expressed as follows on the basis of a first order approximation

$$(29) \quad p = \overline{p}_0 \cdot \frac{V + \kappa \cdot V_{AB}}{V} = \overline{p}_0 + \kappa \cdot \overline{p}_0 \cdot \frac{V_{AB}}{V} ,$$

V characterizing the volume of the *fixed size* element considered and V_{AB} the volume displacement required to produce the pressure increase from $\overline{p}_0$ to p in the basic element. It follows therefrom

$$(30) \quad \tilde{p} = \kappa \cdot \overline{p}_0 \cdot \frac{V_{AB}}{V_V}$$

and accordingly

(31) $$\dot{p} = \kappa \cdot \overline{p}_0 \cdot \frac{\dot{V}_{AB}}{V} .$$

The time dependent rate of the total volume supply $\dot{V}_{AB}$ is formed by the difference of the rates $\dot{V}_A$ and $\dot{V}_B$ of the volume displacements being realized at the left side (area A) or right side (area B) of the element. With the consideration of Fig. 6 we can write:

(32) $$\dot{V}_A = \left(\dot{\xi}_x - \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} \right) \cdot dy \cdot dz ,$$

(33) $$\dot{V}_B = \left(\dot{\xi}_x + \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} \right) \cdot dy \cdot dz ,$$

leading to

(34) $$\dot{V}_{AB} = \dot{V}_A - \dot{V}_B = - \frac{\partial \dot{\xi}_x}{\partial x} \cdot V$$

With the consideration of Eq. (15) it follows therefrom:

(35) $$\dot{V}_{AB} = \frac{1}{c} \cdot \ddot{\xi}_x \cdot V .$$

This allows to reformulate Eq. (31) as follows:

(36) $$\dot{p} = \frac{1}{c} \cdot \kappa \cdot \overline{p}_0 \cdot \ddot{\xi}_x ,$$

leading to

(37) $$p_0 \cdot e^{i\omega t} = \kappa \cdot \overline{p}_0 \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot e^{i\omega t} \quad \text{and} \quad p_0 = \kappa \cdot \overline{p}_0 \left(\frac{\dot{\xi}_{x0}}{c} \right) .$$

Entering Eq. (37) into Eq. (26) leads with the consideration of Eq. (18) to:

(38) $$E_{pot,L,V} = \overline{p}_0 V + \kappa \overline{p}_0 V \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot e^{i\omega t}$$

and

(39) $$\frac{dE_{pot}}{dt} = (i\omega) \cdot \kappa \overline{p}_0 V \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot e^{i\omega t} .$$

The back-transformation of Eq. (38) to the real domain yields:

(40) $$E_{pot,L,V} = \overline{p}_0 V + \kappa \overline{p}_0 V \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot \cos(\omega t)$$

Since the "energy dynamics" in a fixed size volume element indicate a $\cos(\omega t)$ *dependence as to the potential energy content - Eq. (40) - and a* $\cos(3\omega t)$, $\cos(4\omega t)$ *dependence as to the kinetic energy content - Eq. (25) -, it is evident that there cannot exist an energy transfer between both of these energy forms!*

2.3 Acoustic celerity and speed of sound

Before focusing on the rotational (kinetic and potential) energy fields, let´s first concentrate on some relevant facts in context with the longitudinal field.

The acoustic celerity and the speed of sound need to be considered as parameters being of a noticeably different value. This is allocated to the fact that the speed of sound c is related to the high propagation speed of the wave field, whereas the celerity $\dot{\xi}_X$ is related to the physical material transport in the wave.

In textbooks related to the fundamentals of acoustics, often also dealing with ambient noise and hearing topics, reference is made to a so-called "medium noise level working point" /7/, characterized by a frequency of 1000 Hz of the acoustic field and a sound pressure level of 74 dB, which corresponds – at ambient conditions - to an effective sound pressure p_{eff} of 0,1 N/m² (Pa) and an effective celerity $\dot{\xi}_{x,eff}$ of $2{,}5 \cdot 10^{-4}$ m/s. This clearly indicates that - in the context of "ambient noise levels" - the celerity $\dot{\xi}_X$ in an acoustic free-field is *significantly* lower than the speed of sound c.

An interesting question relates to the maximum celerity $\dot{\xi}_{x,\max}$ which can theoretically be reached. To identify this celerity value, let´s concentrate on Eq. (37) which is setting a limit as to the dynamic pressure which can be realized in the medium. The limiting factor is defined by

(41) $p_0 = p_{0,\max} = \overline{p}_0$,

since p_0 can never exceed $\overline{p}_0$; $p_0 > \overline{p}_0$ would entail absolute negative pressure values which cannot be realized.

The dynamic peak pressure value can never exceed the value of the ambient pressure at rest!

Based on these considerations, Eq. (37) allows to define the theoretically highest possible celerity as

(42) $\dot{\xi}_{X0,\max} = c/\kappa$ at $p_{0,\max} = \overline{p}_0$.

Accordingly, the following can be stated:

In a free-field environment the maximum celerity which can (theoretically) be reached by the particles is c/κ. The maximum celerity is reached at a dynamic pressure level being identical to the ambient pressure level at rest.

2.4 Kinetic energy – rotational field

Having detected the necessity for the existence of a rotational field, focus will be placed in the following on the derivation of its rotational energy content. In the scope of the energy approach being outlined here, there is no need to concentrate in detail on the rotational behavior of the medium on the particle level. There is no need to have a deeper knowledge about all of this. The only relevant premise of the approach is based on the de facto existence of a rotational degree of freedom in the medium, whatever is forming it.

In the following we will denote by $\dot{\varphi}$ the angular rotational celerity related to this additional degree of freedom. There is no need – in the scope of an energy approach - to decide about the orientation of the rotational axis of this degree of freedom, e.g. to clear up if its orientation has a random distribution in the volume element or if there are any orientation preferences existing as to the x-, y-, z- axes.

Let´s now derive the equation describing the kinetic energy related to the rotational degree of freedom. The considerations will be based on **Fig. 7**. The approach being applied is similar to the fundamentals already addressed in Para. 2.1. In this context, an inertia flow $\dot{\theta}$ is defined. This flow relates to the

rotational inertia characteristics of the medium, just in the same way as the mass flow $\dot{m}$ is characterizing its translational inertia properties.

This allows to express the rotational kinetic energy, supplied to the volume element (Fig. 7) on the left side (area A) in a time interval dt, as follows:

$$(43) \quad dE_{kin,R,A,dt} = \frac{1}{2}\dot{\theta}_A \cdot dt \cdot \left(\dot{\varphi} - \frac{\partial \dot{\varphi}}{\partial x} \cdot \frac{dx}{2} \right)^2 ,$$

with

$$(44) \quad \dot{\theta}_A = \left(\rho_\theta - \frac{\partial \rho_\theta}{\partial x} \cdot \frac{dx}{2} \right) \cdot dy \cdot dz \cdot \left(\dot{\xi}_x - \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} \right) ,$$

ρ_θ defining the volumetric inertia density. According to this definition it can be stated that the ratio between the volumetric mass density ρ and the volumetric inertia density ρ_θ needs to be of a constant value being a characteristic to a defined medium.

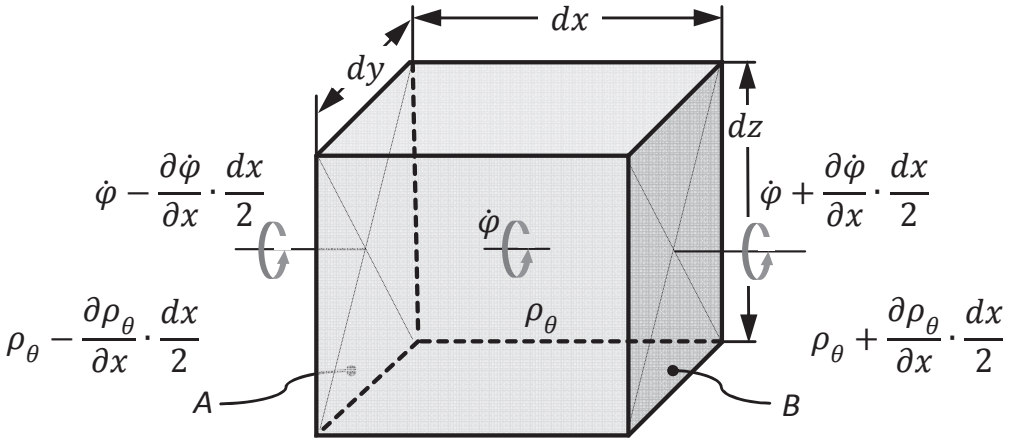


Figure 7: *Volume element – rotational energy model*

Entering Eq. (44) into (43) finally leads to the following expression if second order terms are neglected:

$$(45) \quad dE_{kin,R,A,dt} = \frac{1}{2} \cdot dy \cdot dz \cdot \left(\rho_\theta \cdot \dot{\xi}_x \cdot \dot{\varphi}^2 - 2\rho_\theta \cdot \dot{\xi}_x \cdot \dot{\varphi} \cdot \frac{\partial \dot{\varphi}}{\partial x} \cdot \frac{dx}{2} - \right.$$

$$\left. - \rho_\theta \cdot \dot{\varphi}^2 \cdot \frac{\partial \dot{\xi}_x}{\partial x} \cdot \frac{dx}{2} - \dot{\xi}_x \cdot \dot{\varphi}^2 \frac{\partial \rho_\theta}{\partial x} \cdot \frac{dx}{2} \right) \cdot dt .$$

The kinetic energy content leaving the right side (area B) of the volume element can be derived in a similar way, which yields

$$(46)\quad dE_{kin,R,B,dt} = \frac{1}{2}\cdot dy\cdot dz\cdot\left(\rho_\theta\cdot\dot{\xi}_x\cdot\dot{\varphi}^2 + 2\rho_\theta\cdot\dot{\xi}_x\cdot\dot{\varphi}\cdot\frac{\partial\dot{\varphi}}{\partial x}\cdot\frac{dx}{2} + \rho_\theta\cdot\dot{\varphi}^2\cdot\frac{\partial\dot{\xi}_x}{\partial x}\cdot\frac{dx}{2} + \dot{\xi}_x\cdot\dot{\varphi}^2\cdot\frac{\partial\rho_\theta}{\partial x}\cdot\frac{dx}{2}\right)\cdot dt\,.$$

Accordingly, the kinetic energy content provided to the volume element in a time interval dt is defined by

$$(47)\quad dE_{kin,R,V,dt} = dE_{kin,R,A,dt} - dE_{kin,R,B,dt}$$

$$= -\frac{1}{2}\rho_\theta\cdot V\cdot\dot{\varphi}^2\cdot\left[\frac{\partial\dot{\xi}_x}{\partial x} + \dot{\xi}_x\cdot\left(\frac{2}{\dot{\varphi}}\cdot\frac{\partial\dot{\varphi}}{\partial x} + \frac{1}{\rho_\theta}\cdot\frac{\partial\rho_\theta}{\partial x}\right)\right],$$

also leading to

$$(48)\quad \frac{dE_{kin,R,V}}{dt} = -\frac{1}{2}\rho_\theta\cdot V\cdot\dot{\varphi}^2\cdot\left[\frac{\partial\dot{\xi}_x}{\partial x} + \dot{\xi}_x\cdot\left(\frac{2}{\dot{\varphi}}\cdot\frac{\partial\dot{\varphi}}{\partial x} + \frac{1}{\rho_\theta}\cdot\frac{\partial\rho_\theta}{\partial x}\right)\right].$$

Considering Eq. (15) allows to reformulate Eq. (48) as follows:

$$(49)\quad \frac{dE_{kin,R,V}}{dt} = \frac{1}{2}\rho_\theta\cdot V\cdot\frac{1}{c}\cdot\dot{\varphi}^2\cdot\left[\ddot{\xi}_x + \dot{\xi}_x\cdot\left(\frac{2}{\dot{\varphi}}\cdot\ddot{\varphi} + \frac{1}{\rho_\theta}\cdot\dot{\rho}_\theta\right)\right].$$

Assuming a harmonic acoustic free-field with circular frequency ω, we can write for the variables related to the density terms:

$$(50)\quad \rho_\theta = \overline{\rho}_{\theta 0} + \tilde{\rho}_\theta\,,$$

$\overline{\rho}_{\theta 0}$ characterizing the inertia density at ambient conditions at rest and $\tilde{\rho}_\theta$ the corresponding density fluctuations in the harmonic field, which are expressed by

$$(51)\quad \tilde{\rho}_\theta = \rho_{\theta 0}\cdot e^{i\omega t}\,,$$

also leading to

$$(52)\quad \dot{\rho}_\theta = \dot{\tilde{\rho}}_\theta = (i\omega)\cdot\rho_{\theta 0}\cdot e^{i\omega t}\,.$$

For the expression of the rotational celerity term we write

(53) $\dot{\varphi} = \dot{\varphi}_0 \cdot e^{i(\omega t + \gamma)}$,

which entails

(54) $\ddot{\varphi} = (i\omega) \cdot \dot{\varphi}_0 \cdot e^{i(\omega t + \gamma)}$.

Eqs. (51) and (18) indicate that the rotational inertia density $\tilde{\rho}_\theta$ is considered as being in phase with the volumetric mass density $\tilde{\rho}$. This makes sense since both parameters are directly related to the number of particles enclosed in a defined volume. On the other side, it is considered that the rotational celerity $\dot{\varphi}$ of particles might not be in phase with the longitudinal celerity $\dot{\xi}_x$. This effect is respected by the phase shift angle γ indicated in Eqs. (53) and (54).

Introducing Eqs. (50) to (54) as well as (20) and (21) into Eq. (49) yields for the time dependent energy gradient related to a defined fixed size volume element

(55) $$\frac{dE_{kin,R,V}}{dt} = (i\omega) \cdot \frac{3}{2} \overline{\rho}_{\theta 0} \cdot V \cdot \frac{1}{c} \cdot \dot{\varphi}_0^2 \cdot \dot{\xi}_{x0} \cdot e^{i3\omega t} \cdot e^{i2\gamma}$$

$$+ (i\omega) \cdot 2\rho_{\theta 0} \cdot V \cdot \frac{1}{c} \cdot \dot{\varphi}_0^2 \cdot \dot{\xi}_{x0} \cdot e^{i4\omega t} \cdot e^{i2\gamma}.$$

The rotational kinetic energy content can be derived therefrom by an integration over time which leads to

(56) $$E_{kin,R,V} = \frac{1}{2} \overline{\rho}_{\theta 0} \cdot V \cdot \frac{1}{c} \cdot \dot{\varphi}_0^2 \cdot \dot{\xi}_{x0} \cdot e^{i3\omega t} \cdot e^{i2\gamma}$$

$$+ \frac{1}{2} \rho_{\theta 0} \cdot V \cdot \frac{1}{c} \cdot \dot{\varphi}_0^2 \cdot \dot{\xi}_{x0} \cdot e^{i4\omega t} \cdot e^{i2\gamma} + E_{kin,R,V,0}.$$

Eq. (56) considers an integration constant $E_{kin,R,V,0}$. This constant energy term is related to the rotational kinetic energy content in the volume element “at rest”, say at ambient stationary conditions.

2.5 Potential energy – rotational field

To address this topic requires a deeper detailed knowledge about the medium on the particle level. What is the physical mechanism forming the rotational field? Since the mechanism, related to the different terms forming the thermodynamic "inner energy", cannot be conclusively described at the present time, the rotational field will be considered in the following just in form of the notations $E_{pot,R,V}$ and $dE_{pot,R,V}/dt$, $E_{pot,R,V}$ describing the rotational potential energy content inherent to a defined fixed size volume element within the medium, and $dE_{pot,R,V}/dt$ denoting the related energy variations with regard to time t.

As will be shown in the next Para., these variables can be determined despite of the fact that the "hidden" physical mechanism creating the rotational potential field has not been defined.

2.6 Energy equilibrium

Let´s come back to the introductory part of Chapter 2. The reflections outlined in the corresponding text did lead to the following statement:

"In a sustained free-field environment energy conservation is realized at any time in any defined volume element regardless of its size and location."

This finally allows to reformulate Eq. (4) in the form of the two following separated equations:

(57) $$\frac{d}{dt}(E_A - E_B) = 0,$$

(58) $$\frac{d}{dt}\left(E_{kin,V} + E_{pot,V}\right) = 0.$$

With the consideration of Fig. 2, Eq. (57) entails that "what is coming in is going out". This means that – in the case of a sustained free-field – the energies entering and leaving a defined fixed size volume element in a time interval dt are of an identical value. This, however, does not require the energies to be of an identical form. The energies E_A and E_B may be related to the longitudinal or rotational fields or in a mixed form to both of them!

Eq. (58) describes the energy conservation in the volume element itself. Thereby we need to consider all 4 energies related to the longitudinal and rotational fields, say the longitudinal kinetic energy, the longitudinal potential energy, the rotational kinetic energy and the rotational potential energy. The total energy in a fixed size volume element, being formed by these 4 energies, will be of a constant value at any time and at any location in the case of a sustained free-field!

It is evident that there will at any time occur an energy exchange between different energy forms being inherent to a volume element. Thereby it needs to be recognized that an energy transformation between kinetic and potential energies cannot take place. This is due to the fact, that according to Eqs. (25) and (40), the time dependent variations of the (longitudinal) energies are characterized by different circular frequencies, being $3\omega t$, $4\omega t$ and ωt, respectively. Despite the missing formulation of the rotational potential energy term, it can be concluded that the overall situation is identical in case of the rotational field: no transformation between rotational kinetic and rotational potential energies will occur.

These reflections allow to state:

In a sustained free-field environment any energy transformation in a defined fixed size volume element is based on a conversion of the kinetic energies related to the longitudinal and rotational fields as well as on a conversion of the potential energies related to these fields. A conversion between kinetic and potential field energies does not take place.

This statement entails a decoupled reformulation of Eq. (58) leading to

$$\frac{d}{dt}\left(E_{kin,V}\right)=\frac{dE_{kin,L,V}}{dt}+\frac{dE_{kin,R,V}}{dt}=0 \tag{59}$$

and

$$\frac{d}{dt}\left(E_{pot,V}\right)=\frac{dE_{pot,L,V}}{dt}+\frac{dE_{pot,R,V}}{dt}=0\,. \tag{60}$$

We will now concentrate on the energy transformation taking place in the volume element between the *kinetic energies* related to the longitudinal and rotational fields. This kinetic energy exchange can be expressed as follows by Eq. (59), when considering $dE_{kin,L,V}/dt$ as defined in Eq. (23) and $dE_{kin,R,V}/dt$ as

expressed by Eq. (55). Solving Eq. (59) will finally lead - after some calculation steps - to the following interrelations:

(61) $e^{i2\gamma} = -1$ leading to $\gamma = \pm\frac{\pi}{2}$,

(62) $\overline{\rho}_{\theta 0} = \overline{\rho}_0 \cdot \left(\frac{\dot{\xi}_{x0}}{\dot{\varphi}_0} \right)^2$,

(63) $\rho_{\theta 0} = \rho_0 \cdot \left(\frac{\dot{\xi}_{x0}}{\dot{\varphi}_0} \right)^2$.

Eq. (61) indicates that the longitudinal and rotational velocities are phase-shifted by $\pi/2$ or 90 degrees relative to each other. Entering Eqs. (61) to (63) into Eq. (56) and by further considering Eq. (22) will allow to express the *rotational* kinetic energy content inherent to the volume element by

(64) $E_{kin,R,V} = -\frac{1}{2}\kappa \cdot \overline{p}_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i3\omega t} - \frac{1}{2} p_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i4\omega t} + E_{kin,R,V,0}$.

The back-transformation to the real domain leads to

(65) $E_{kin,R,V} = -\frac{1}{2}\kappa \cdot \overline{p}_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cos(3\omega t) - \frac{1}{2} p_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cos(4\omega t) + E_{kin,R,V,0}$.

Comparing Eq. (65) to Eq. (25) indicates that the mathematical expressions related to the longitudinal and rotational kinetic energies are quite similar. A first difference consists in their (plus or minus) sign, which indicates that these energy terms are phase-opposed. A second difference is due to the integration constant in Eq. (65). At rest, the longitudinal kinetic energy in the medium is zero. This does not apply to the rotational kinetic energy.

In a next step focus is pointed on the relationship existing in the volume element between the *potential energies* related to the longitudinal and rotational fields. Based on the reasoning outlined above, it is evident that the expression of the time dependent variation of the rotational potential energy can be expressed as follows with the consideration of Eq. (39):

(66) $\frac{dE_{pot,R,V}}{dt} = -(i\omega) \cdot \kappa \cdot \overline{p}_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot e^{i\omega t}$,

leading to

$$(67) \quad E_{pot,R,V} = -\kappa \cdot \overline{p}_0 \cdot V \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right) \cdot \cos(\omega t) + E_{pot,R,V,0} \,.$$

Eq. (67) indicates the opposed sign and the integration constant when compared to Eq. (40). Both potential fields are phase-opposed and fitted with energy at ambient rest conditions.

Eq. (58) indicates that the total energy content of a defined fixed size volume element within a sustained field in the medium is not changing over time. This entails that the total energy content is not depending upon the (dynamic) amplitude level of the variables characterizing the field. At least at a first glance this may appear strange. But, now having understood that an increase in the longitudinal energy level is flanked by a corresponding decrease in the rotational energy level, does explain the overall situation.

2.7 Comments

I. The *total* energy content related to a fixed size volume element is *at any time* equal to its energy content at rest. According to Eqs. (40), (65) and (67) the *total* energy content is defined by

$$(68) \quad E_{tot,V} = \overline{p}_0 \cdot V + E_{kin,R,V,0} + E_{pot,R,V,0} = \overline{p}_0 \cdot V + E_{V,0} \,.$$

It is evident that the energy content of the volume element is related at any time to the thermodynamic inner energy at rest of the particle compound enclosed. To allow the particles to reach higher celerity values does require the particle to be fitted with the thus required basic energy content.

II. Eqs. (25)/(65) and (40)/(67), related to the kinetic and potential energies of the field, respectively, indicate that at low celerity values ($\dot{\xi}_{x0} << c$) the potential energies in the field, proportional to ($\dot{\xi}_{x0} / c$), are by far larger than the kinetic energies, being proportional to $(\dot{\xi}_{x0} / c)^3$.

III. A highly interesting topic relates to the acoustic power of the source. What´s the source power required to sustain the field? To answer this question does require to consider the acoustic field as being in a perfect dynamic balance, the longitudinal and related rotational energy components being

phase-opposed at any time. This entails that the system is always at resonance! Based on these considerations it is now rather easy to allocate a value to the acoustic energy which needs to be provided by the source. In a resonant (mechanical) system the energy of the source is just providing the energy required to compensate for the energy losses in the field. It is compensating for the "damping losses". Source energy and damping energy are phase-opposed and phase-shifted by 90 degrees relative to the potential energies. In this context, it also needs also to be recognized that the energy/power level of the source is directly influencing the amplitude level of the variables in the field.

In mechanics, the damping inherent to a dynamic system is often taken into account by a so-called loss angle factor, defining the ratio existing between the potential and damping energies in a system. As to our virtual experiment, related to Fig. 5, a damping loss factor angle being lower than 10^{-4} can be determined. The low value of this factor appears to agree with the damping characteristics of acoustic fields, being outlined in /2/ and /5/. These references also indicate a significant increase of the factor with increasing frequencies.

This explains why the celerity does not reach the velocity of c/κ in an acoustic free-field. There is too much damping existing. There is no power source existing to provide the thus required energy. Even near field noise levels produced by jet aircraft (140 dB) are so far below the theoretically maximum noise pressure level ranging at 197 dB. Accordingly, the celerity, which can be reached by the particles in the field, is not solely depending on their (basic) energy content but also on the damping energy inherent to the field which needs to be provided by the source.

IV. It can be estimated that what "we" perceive/detect in a volume element is just the (dynamic) energy related to the longitudinal field. We, as human beings, perceive/hear the longitudinal (dynamic) component of an acoustic field but not its rotational component. Moreover, acoustic sensor equipment does not allow to detect the rotational component. But, considering the facts outlined above, this (non-perceived/non-detected) rotational component must exist!

Having analyzed the acoustic free-field in detail and by having now already accumulated a deeper overall insight into the dynamics of a sustained propagating free-field allows to approach the electromagnetic field a in the next Chapter on a "higher level".

3. Electromagnetic wave field

Is there any problem existing to admit that the acoustic and electromagnetic fields do not differ so much from one another as to their physical behavior? It really appears that there are so many similarities existing between both fields. In this context, it is worthwhile to address the mass (impulse) and wave (interference) characteristics of the electromagnetic medium. Let´s accept in the following that the medium does possess *at any time* both mass and wave properties. And now we are real close to the physical properties of the acoustic medium.

3.1 Fundamental considerations

To be fully aligned with the physics of the acoustic field, there is a need to allow for the following:

a) The existence of “electromagnetic particles with mass”.

b) The existence of an *ambient* pressure field in the electromagnetic environment.

c) The existence of both a longitudinal and a rotational degree of freedom in the electromagnetic field.

If all of this is existing, then there is a significant similarity, a fundamental coincidence (!), existing between the free-fields in acoustics and electromagnetics.

On the other hand, due to the difference in the wavelength allocated to both fields, it must be recognized, that all energy exchange mechanisms, as outlined in Chapter 2, are taking place in an extremely small volume of the electromagnetic field, if compared to the acoustic field. Just to give an indication of what we are talking about, let´s give (a real rough) estimate about the wavelength relation existing between an acoustic and an optical electromagnetic field. It appears that the wavelength in the visible optical field is roughly 100.000 times shorter when compared to the audible acoustic field. Accordingly, the *fixed size* volume element, so often addressed in Chapter 2, will feature a (virtual) edge length of (far) less than 100 nm if wavelengths in the optical range are considered. Geometrically speaking, the electromagnetic

field must be considered as being reduced in size by a factor of 100.000 when compared to the acoustic field. This also entails that the particles in an electromagnetic field must be of an extremely small size when compared to the particles/molecules forming the medium of an acoustic field.

Having in mind the physical similarity between both the acoustic and electromagnetic free-fields, does allow to stick at the mathematical formulations outlined in Chapter 2 when addressing the electromagnetic field. There is a priori no need for a change. This consequently leads (among others) to the following statement:

In an electromagnetic environment the physical significance of the speed of light is identical to the speed of sound in an acoustic environment.

Let´s now focus on the 3 assumptions a), b), and c), mentioned at the top of this Para.

Assumption c) (longitudinal/rotational degree of freedom) is easy to accept since it is forming the basis of the considerations outlined here.

Assumption a) (particle mass) proves to be rather difficult to discuss, since this appears to be in full-contrast with the photon characteristics … and much more! (Just as a preliminary remark: the mass of the particle will be derived in Para. 3.3)

Assumption b) (*ambient* electromagnetic pressure) is confirmed by a publication /8/, in which the black body radiation was approached from a thermodynamics point of view. The report gives a hint, a clear indication, to an *ambient* radiation pressure, termed “Strahlungsdruck”. Based on some deeper reflections it was concluded that this radiation pressure must be identical to the assumed/expected “*ambient* electromagnetic field pressure”. As will be shown in Para. 3.2, the “Strahlungsdruck”, as defined in the scope of this publication, will finally allow to validate and calibrate the complete mathematical model.

Before addressing the validation and calibration tasks, let´s first concentrate on some already available results, which can be derived from the fundamentals formulated in Chapter 2 and being now adopted to the electromagnetic field. In the scope of the approach it is assumed that the electromagnetic particle is fitted with mass *and* an electric charge. It is true that this is in contrast to the actually existing definitions characterizing the particle, clearly saying: no mass, no electric charge … just a massless energy bundle /9/. Despite of these

contradictions, let´s go on and focus on the validation of the assumptions expressed.

Based on the considerations outlined in Chapter 2 we need to deal with two fields, a longitudinal and a rotational field. The particle celerity values associated to the longitudinal and rotational fields are $\dot{\xi}_x$ and $\dot{\varphi}$, respectively, both being phase-shifted by 90 degrees relative to one another. This celerity of the particles is generating the corresponding longitudinal and rotational electric currents i_L and i_R. With the further consideration of the longitudinal field, being a capacitor field, and of the rotational field, being a coil field, leads to the following /10/:

a) The $\mathcal{E}_L$ - field corresponding to the longitudinal current is phase shifted by - 90 degrees relative to the electric current i_L.

b) The $\mathcal{E}_R$ - field related to the rotational current is phase shifted by + 90 degrees relative to the electric current i_R.

c) The $\mathcal{B}_L$ - field (magnetic longitudinal field induced by i_R) is in-phase with the rotational electric current i_R.

Remark: This requires a preferred orientation of the rotational axis of "the spin" in the medium. The corresponding rotational axis is oriented along the wave propagation direction (x-direction according to Fig. 1). This "synchronized spin" orientation in the electromagnetic medium may be compared to the well-known oriented spin of eddy currents in solid conductor materials /1/.

d) The $\mathcal{B}_R$ - field (magnetic rotational field induced by i_L) is in-phase with the longitudinal electric current i_L.

e) And not to forget, the dynamic pressure $\tilde{p}$ is in-phase with the longitudinal particle celerity $\dot{\xi}_x$ and correspondingly in-phase with the electric current i_L.

As an overview related to these findings, the various dynamic field variables are depicted in **Fig. 8** in the complex plane. Thereby it was assumed that the longitudinal electric current is preceding the rotational electric current by 90 degrees. This corresponds to $\gamma = -\pi/2$ in context with Eq. (53). The decision for $\gamma = -\pi/2$ is based on the *sole* fact that this choice leads to a situation where $\mathcal{E}_L$ and $\mathcal{B}_L$ are in-phase, which is in alignment with the standard

electromagnetic field theory. If $\gamma = +\pi/2$, then both fields would appear as phase-opposed. When considering the energies associated to the $\mathcal{E}_L$ - and $\mathcal{B}_L$ - fields, being a quadratic function of the corresponding field amplitudes /11/, both the consideration of $\gamma = -\pi/2$ or of $\gamma = +\pi/2$ will lead to an identical overall well-balanced electric and magnetic energy distribution existing at any time between the longitudinal and rotational fields!

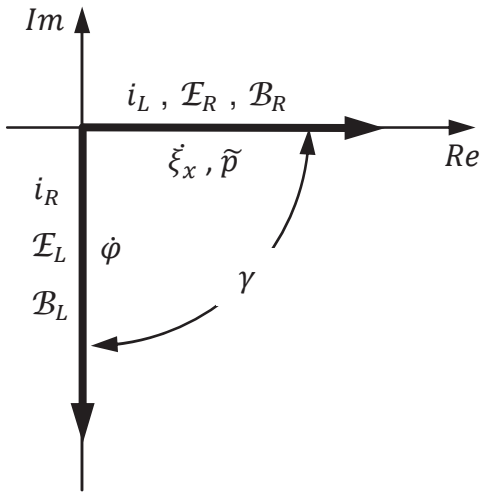


Figure 8: *Representation of the field variables in the complex plane*

Based on the phasing information now allows to generate the corresponding (qualitative) time plots related to the $\mathcal{E}$ - and $\mathcal{B}$ - fields, as depicted in **Fig. 9**.

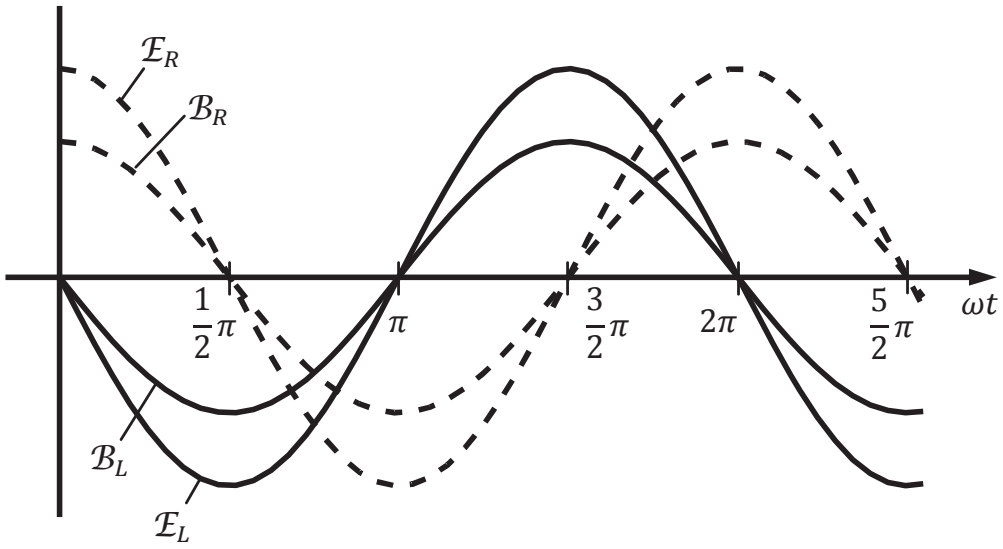


Figure 9: *Qualitative time plot of field variables ($\gamma = -\pi/2$)*

Remark: Fig. 9 indicates the existence of four fields in the electromagnetic medium which is in contrast to the two-field representation in the standard literature. The existence of the four fields indicated does not contradict Maxwell´s equations, since the fields are related, two by two, to longitudinal and rotational degrees of freedom being orthogonal to one another.

From the phasing of the different variables, outlined in Fig. 8, it follows that the different field energies are completely balanced when considering the longitudinal and rotational fields. In this context, completely balanced means that the related energies are phase-opposed (180-degree phase shift) to one another. This leads to the following statement:

The electromagnetic free-field system is at a perfect resonance at any time at any location and at any frequency.

This means in detail that the following dynamic energy forms, as listed below, are in a complete energy balance to one another.

In the mechanical system:

$E_{kin,L,V}$ is balanced by $E_{kin,R,V}$,

$E_{pot,L,V}$ is balanced by $E_{pot,R,V}$.

In the electric system:

$E(\mathcal{E}_{L,V})$ is balanced by $E(\mathcal{E}_{R,V})$,

$E(\mathcal{B}_{L,V})$ is balanced by $E(\mathcal{B}_{R,V})$.

Thereby $E(\mathcal{E}_{L,V})$, $E(\mathcal{E}_{R,V})$ and $E(\mathcal{B}_{L,V})$, $E(\mathcal{B}_{R,V})$ are characterizing the dynamic energies related to the corresponding longitudinal and rotational $\mathcal{E}$- and $\mathcal{B}$-fields.

Remark: concentrating on the mechanical and electric energies - in the scope of the many investigations performed - brought up a variety of fundamental questions. This interesting topic will be separately addressed in Chapter 5.

With the information outlined in this Para. time has come to focus on the validation and calibration process of the developed mathematical model.

3.2 Validation of the mathematical model

It took some time to come up with an idea of how to validate the developed mathematical model. After many, many reflections it was considered that the black body radiation, as defined by Max Planck, offered a realistic best possibility to deal with this. In this context, it needs to be addressed that *the black body radiation spectra must be considered as time-averaged spectra.*

Let´s again refer to reference /8/. The publication provides a concentrated information related to the so-called Planck-radiation-spectra. It gives a clear information as to the following characteristics:

a) The *specific* spectral radiation density $I^*_{\vartheta,\lambda}$, being a function of the absolute temperature ϑ and of the wavelength λ of the field, is defined by

(69) $$I^*_{\vartheta,\lambda} = \frac{2\pi \cdot h \cdot c^2}{\lambda^5} \cdot \frac{1}{e^{\frac{h \cdot c}{\bar{k} \cdot \lambda \cdot \vartheta}} - 1},$$

with $h = 6{,}63 \cdot 10^{-34} N \cdot m \cdot s$, characterizing the Planck action quantum and $\bar{k} = 1{,}38 \cdot 10^{-23} N \cdot m / K$ the Boltzmann constant. As a *specific* value, the dimension of $I^*_{\vartheta,\lambda}$ is $W/(m^2 \cdot m)$ or, as is often used in the literature, $W/(m^2 \cdot \mu m)$.

b) The wavelength λ_{peak}, at which the maximum of radiation is reached as a function of the temperature, is defined according to

(70) $$\lambda_{peak,\vartheta} = \frac{1}{4{,}965} \cdot \frac{h \cdot c}{\bar{k} \cdot \vartheta}.$$

c) The total spectral intensity at a defined temperature ϑ is defined by

(71) $$I_{tot,\vartheta} = \int_0^\infty I^*_{\vartheta,\lambda} \cdot d\lambda,$$

which results in

(72) $$I_{tot,\vartheta} = \sigma \cdot \vartheta^4,$$

with $\sigma = 5{,}67 \cdot 10^{-8} W/(m^2 \cdot K^4)$, defining the Stefan-Boltzmann constant.

d) The so-called “Strahlungsdruck”, say the *ambient* radiation pressure, is defined by

(73) $$p_{r,\vartheta} = \frac{4}{3}\frac{\sigma}{c}\cdot\vartheta^4 .$$

Let´s concentrate in a next step on the *specific* spectral density distribution, as described by Eq. (69). If we draw the plot in a linear format, as depicted in **Fig. 10**, it will indicate an exponential increase of the radiation intensity if, for a defined temperature, the wavelength λ is reduced from a high value down to λ_{peak}. This exponential magnification to the vicinity of λ_{peak}, standard theoretical approaches do/did predict an infinite (!) increase of the intensity at further reduced wavelengths, is related to the so-called “ultraviolet catastrophe” /12/. But, as reality shows, this catastrophe is not existing. A rather simple explanation as to the reason of the non-existence, say to the non-possible existence of this catastrophe, will be given in the following.

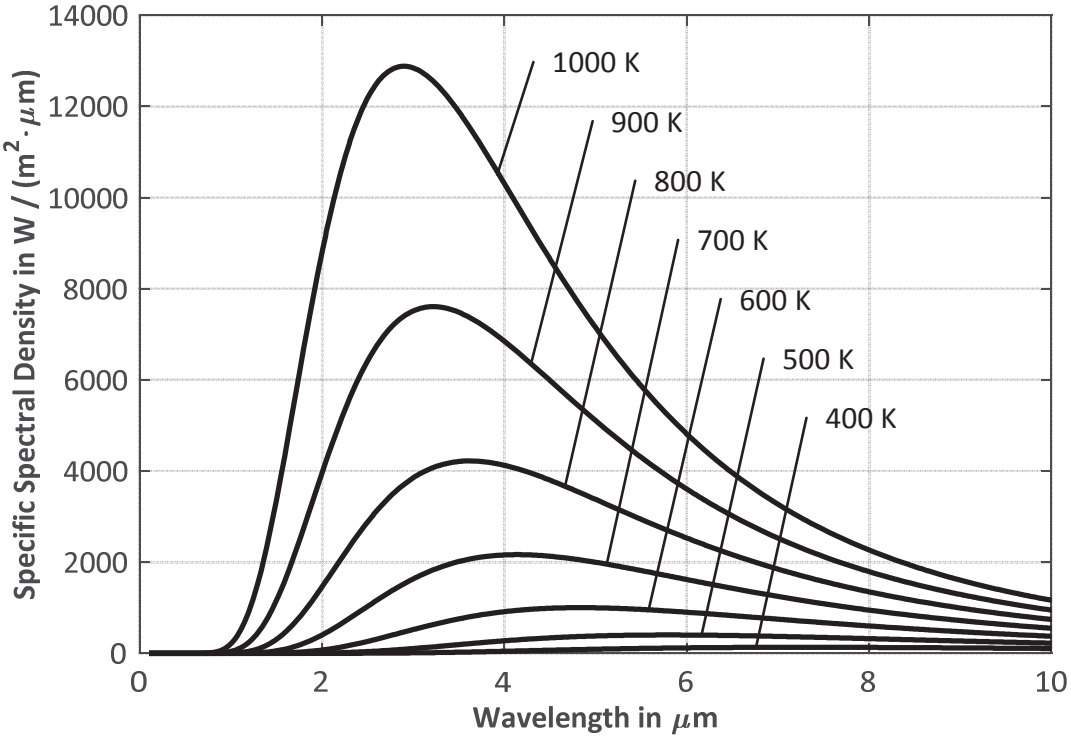


Figure 10: *Linear plot of the specific spectral density*

A first and also a second glance at Fig. 10 reveals, that beyond a rough indication of the ultraviolet catastrophe, there is no valuable further information that can be extracted from the plot. This impression changes completely if the graph is drawn in a double-logarithmic format, as shown in

Fig. 11. In this context, it needs to be mentioned that the initial idea to generate this "double-log-graph" was triggered by a similar representation being outlined in /13/.

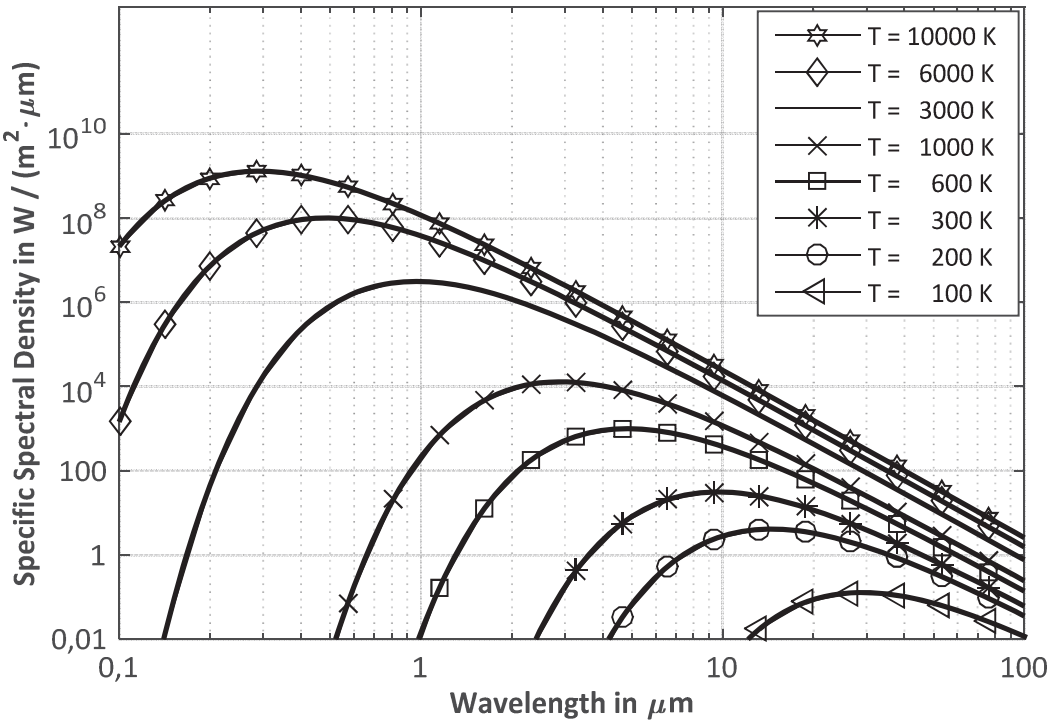


Figure 11: *Double-log plot of the specific spectral density*

The curves appear impressive, indicating, for a defined temperature, an approximate 40 dB/decade positive slope of the intensity when reducing wavelengths down to λ_{peak} and a real sharp negative slope of more than 100 dB/decade at wavelengths $\lambda << \lambda_{peak}$. But, it was recognized soon that the plot is not ideally suited to be used as a basis for the validation process. This is due to the fact that the ordinate in Fig. 11 is indicating the intensity in form of a "*specific* spectral density" with dimension W/(m²·µm). This "normalization" of the spectral density may offer advantages in some applications, but it may also lead to a lot of confusion. Studying many of the publications related to this topic (on the Internet) will indicate that occasionally it is not real clear if the authors are referring to "specific" or "non-specific" values.

To avoid this confusion it was considered to be advantageous to transform the "normalized graph" in a "standard graph", say to convert the "*specific* spectral density curves $I^*_{\vartheta,\lambda}$" with dimension W/(m²·µm) to "spectral intensity curves $I_{\vartheta,\lambda}$" with dimension W/m². The result of this effort is depicted in **Fig. 12**. The

plot reveals that the curves allocated to the different temperatures, now being of a flatter form, indicate a 30 dB/decade slope in the longer wavelength range. As we will see in the following, the complete information needed in the scope of the validation process is hidden in Fig. 12.

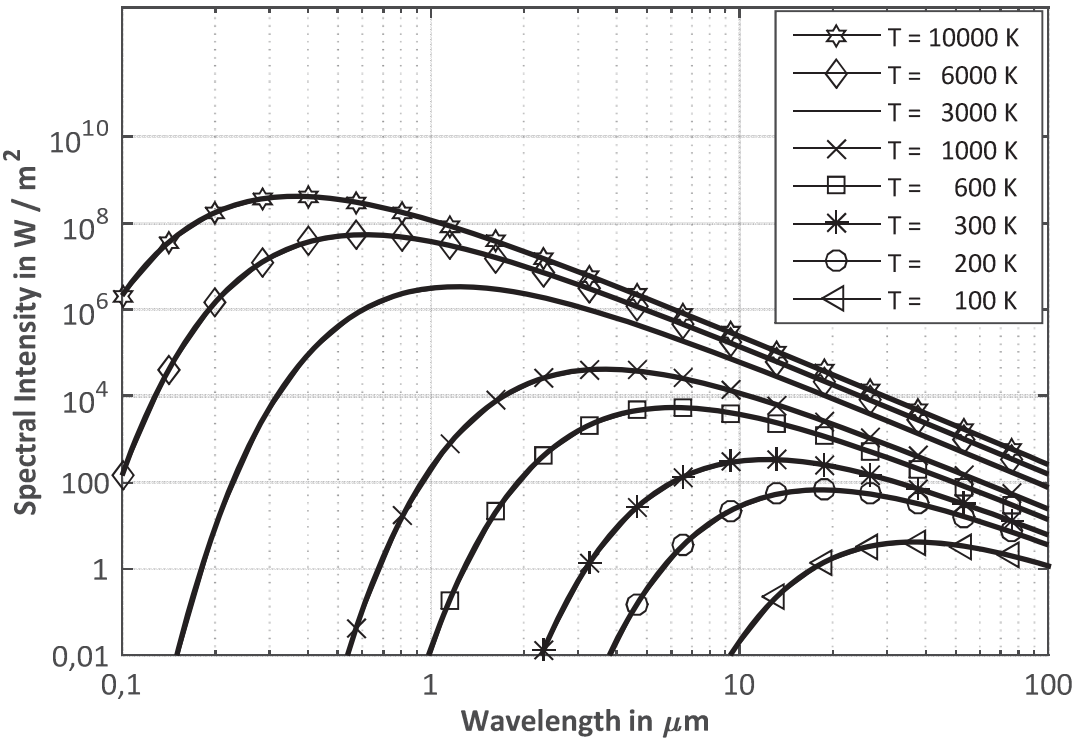


Figure 12: *Double-log plot of the spectral intensity*

Before going on let´s first concentrate on "the what" being represented in Fig. 12. "What" is forming the indicated intensity I ? The electric/electromagnetic model indicates that both, the electric $\mathcal{E}_L$ - field and the magnetic $\mathcal{B}_L$ - field do contribute, each by one half, to the total intensity /11/. Based on our findings we can state the following:

In an electromagnetic field, the energy inherent to a volume element of the electric $\mathcal{E}_L$ - field is directly related to the mechanical longitudinal kinetic energy, say $E(\mathcal{E}_{L,V})=E_{kin,L,V}$. The energy inherent to a volume of the magnetic $\mathcal{B}_L$ - field is directly related to the mechanical rotational field kinetic energy, say $E(\mathcal{B}_{L,V})=E_{kin,R,V}$.

This also allows to conclude:

The potential energy inherent to the field is not contributing to the intensity of the field.

Moreover, this entails that *the longitudinal kinetic energy is contributing to half of the total intensity of the electromagnetic field.* To deal with this fact, let´s focus on the interrelation existing between the longitudinal field kinetic energy and the thus related field intensity being defined by

$$(74) \quad I_{kin,L} = \frac{dE_{kin,L,V}}{dt} \cdot \frac{1}{A}, \qquad (V = A \cdot dx,\ dx \to 0),$$

$A = dy \cdot dz$ characterizing the surface area of the volume element as depicted in Fig. 6. With the consideration of

$$(75) \quad dt = \frac{1}{c} \cdot dx$$

in Eq. (74) leads to

$$(76) \quad I_{kin,L} = c \cdot \frac{dE_{kin,L,V}}{dV}.$$

With the consideration of Eqs. (24) and (37) we obtain

$$(77) \quad I_{kin,L} = c \cdot \left[\frac{1}{2} \kappa \cdot \overline{p}_0 \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^3 \cdot e^{i3\omega t} + \frac{1}{2} \kappa \cdot \overline{p}_0 \cdot \left(\frac{\dot{\xi}_{x0}}{c} \right)^4 \cdot e^{i4\omega t} \right].$$

This allows to write for the *timely averaged* intensity due to $E_{kin,L,V}$:

$$(78) \quad I_{kin,L,avg} = \frac{2}{\pi} \cdot I_{kin,L} = \frac{1}{\pi} \cdot c \cdot \kappa \cdot \overline{p}_0 \cdot \left[\left(\frac{\dot{\xi}_{x0}}{c} \right)^3 + \left(\frac{\dot{\xi}_{x0}}{c} \right)^4 \right],$$

the factor of $2/\pi$ resulting from

$$(79) \quad \frac{1}{T/2} \int_{-T/4}^{T/4} e^{i\omega t} dt = \frac{2}{\pi},$$

which applies to a harmonic signal at any circular frequency ω.

Having cleared up the interrelation existing between the longitudinal kinetic volume energy and the field intensity now allows to proceed to next steps. In this scope let´s repeat that the intensity $I_{kin,L,avg}$, as formulated in Eq. (78), is just forming half of the total intensity $I_{\vartheta,\lambda}$, as indicated in Fig. 12, according to

(80) $$I_{kin,L,avg} = \frac{1}{2} I_{\vartheta,\lambda}.$$

Let´s investigate about possible commonalities existing between the spectral radiation intensity $I_{\vartheta,\lambda}$, as depicted in Fig. 12, and the radiation intensity $I_{kin,L,avg}$, as defined by Eq. (78). Thereby it needs to be well-understood that the plotted curves are related to the broad-band spectra of a rather stochastic real world environment, whereas Eq. (78) is related to line-spectra of an analytically perfect harmonic environment. Despite of the difference existing let´s give it a try to correlate these two inputs to one another.

First it appears highly promising that Eq. (78) is indicating a (-)³ dependence as to the longitudinal particle celerity. It can be estimated that this correlates to the 30 dB/decade-slope in the longer wavelength range of constant temperature $I_{\vartheta,\lambda}$ - curves in Fig. 12. This entails that *the particle celerity is increasing when the wavelength is decreasing*. In the scope of a first estimate, neglecting the 4th-order term in Eq. (78), we can write

(81) $$\frac{\dot{\xi}_{x0,\lambda}}{\dot{\xi}_{x0,\lambda_{peak}}} = \frac{\lambda_{peak}}{\lambda}.$$

Let´s further concentrate on the 3rd- order term in Eq. (78) and let´s draw the related 30 dB/decade slope-curve. This is exemplarily indicated in **Fig. 13** by a line X-X, corresponding to the 3000 K intensity curve.

A next question needs to address the deviations existing between the 3000 K broadband intensity curve and the harmonic spectrum, as defined by line X-X. What is causing the difference between these curves in the shorter wavelength range? To clear up the situation, let´s (virtually) follow the 3000 K-curve, starting from large wavelengths and proceeding to shorter wavelengths.

When ramping up the 30 dB/decade slope-curve the particle celerity (and the intensity) will continuously increase. But, as indicated in the Fig., the deviations between real world and analytical curves are increasing. This is due to the fact, that not all particles can follow this increase in celerity. They do lack the thus required basic energy, as defined by Eq. (68). In the real world stochastic environment the particles do interfere with one another, say exchange energy among one another. This entails that not all particles in the field are fitted with the same (basic) energy level at a defined time point. Some particles will be poor in energy, others will be rich in energy, some may even have been

provided with a temporary “overshoot of energy”. The particles being low in energy cannot ramp up the 30 dB/decade slope-curve. These particles will not contribute to the intensity in the shorter wavelength range.

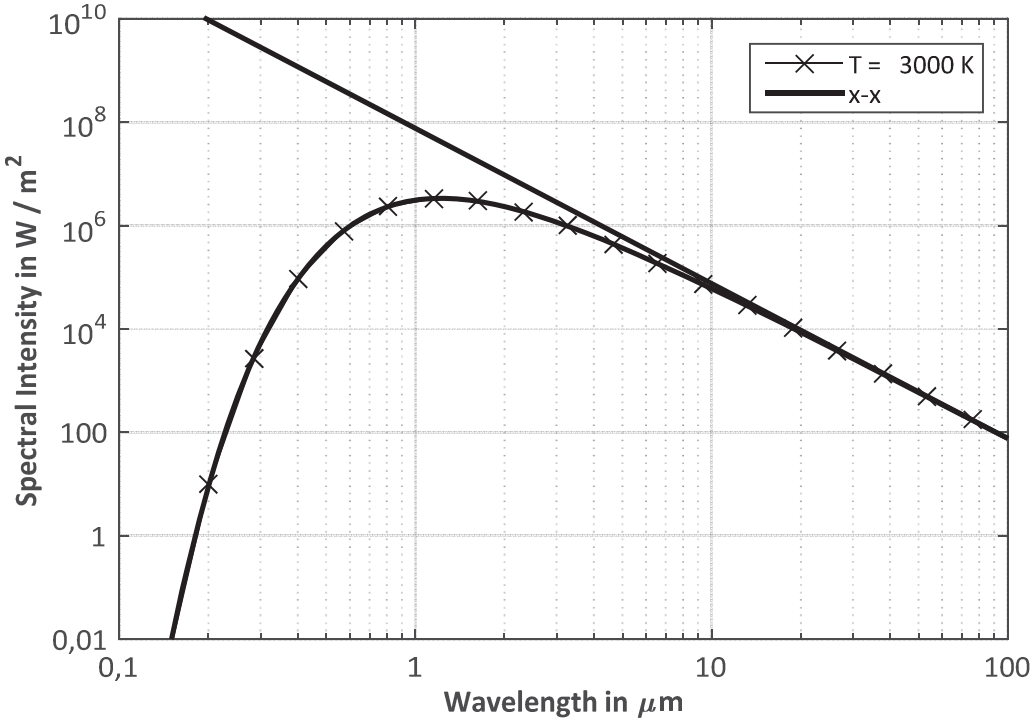


Figure 13: *30 dB/decade-line corresponding to the 3000 K spectrum*

Ramping up the spectral intensity curve further ends when reaching the λ_{peak}-wavelength point. Why is this happening? Based on the previously made considerations, it can be estimated that the particle celerity may be equal or real close to the maximum theoretically obtainable velocity c/κ, as defined by Eq. (42), when reaching λ_{peak}. This must be considered as an absolute celerity limit, due to the limitation imposed to the dynamic pressure in the field. And now we are back to Para. 2.3, where the following was stated:

The dynamic peak pressure value p_0 can never exceed the value of the ambient pressure $\overline{p}_0$ at rest!

It is this restriction which places a strict limitation as to a further increase of the spectral intensity levels at wavelengths $\lambda << \lambda_{peak}$.

This explains why the so-called “ultraviolet catastrophe” cannot happen!

It may now be argued that this is not real true, since there is some residual intensity existing at wavelengths $\lambda << \lambda_{peak}$. How can these shorter wavelengths be reached by any particle? This effect can be explained by the superposition of short and long wavelength fields in the existing broadband frequency environment. This does allow particles, being fitted with a high basic energy, to penetrate this short wavelength field, just for a short time duration, due to a temporarily favorable pressure environment created by the superposition of long wavelength pressure fields. In the scope of this reasoning it needs to be addressed that all of this can be realized with full respect of the fundamental pressure condition, stating that the *overall* dynamic pressure, inherent to any volume element of the total broadband field, cannot exceed at any time the ambient radiation pressure level.

With this information, now being available, let´s focus next in more detail on the λ_{peak} - point. How about the celerity $\dot{\xi}_{x0}$ of the particles being reached at this operating point? To deal with this, let´s once again consider the 3000 K intensity curve and the thus related intensity at λ_{peak}. From Eq. (69) we obtain

$$(82) \quad I^*_{3000K,\lambda_{peak}} = 3{,}11 \cdot 10^6 \frac{W}{m^2 \cdot \mu m} .$$

This leads, with $\lambda_{peak} \approx 1\,\mu m$ (!) at 3000 K, also to

$$(83) \quad I_{3000K,\lambda_{peak}} \approx 3{,}11 \cdot 10^6 \frac{W}{m^2} .$$

Moreover, Eq. (73) allows to determine the radiation pressure related to the broadband field at 3000 K. It results therefrom:

$$(84) \quad p_{r,3000K} = 2{,}04 \cdot 10^{-2} \frac{N}{m^2} .$$

Let´s now determine the particle velocity which is related to this spectral intensity *line*. Eqs. (78) and (80) lead to the following interrelation:

$$(85) \quad \left[\left(\frac{\dot{\xi}_{x0}}{c} \right)^3 + \left(\frac{\dot{\xi}_{x0}}{c} \right)^4 \right] = \frac{\pi}{2} \cdot \frac{I_{\vartheta,\lambda}}{c \cdot \kappa \cdot \overline{p}_0} .$$

With the consideration of (83) and (84) yields for a value of $\kappa = 4/3$, as defined in /14/ for a “photon gas”:

(86) $$\left[\left(\frac{\dot{\xi}_{x0}}{c}\right)^3+\left(\frac{\dot{\xi}_{x0}}{c}\right)^4\right]=0{,}60,$$

leading to

(87) $$\left(\frac{\dot{\xi}_{x0}}{c}\right)=0{,}71.$$

This indicates that the particle celerity is 0,71·c at the λ_{peak} - spectral *line*. Referring to Eq. (42) reveals that the maximum celerity which can be reached is $\left(\dot{\xi}_{x0}/c\right)=1/\kappa=3/4=0{,}75$. This is in a surprisingly good agreement with the result outlined in (87) when considering that the related mathematical formulations are all based just on a first order approach. This also may be considered as an indication as to the consistency of the theoretical fundamentals outlined in the previous Paras. Finally, it needs to be mentioned that this result is not restricted to the 3000 K intensity curve. Identical results will be obtained when concentrating on the intensity curves related to other temperatures.

An interesting question relates to the percentage of particles being fitted with the basic energy required to reach the shorter wavelength range. This can be answered when comparing, at a defined wavelength, the broadband intensity to the corresponding analytically determined intensity. A *highly rough* comparison between both intensities indicates the following: 45% of the particles reach the required velocity to contribute to the intensity at $5\lambda_{peak}$, 15% of the particles contribute at $2\lambda_{peak}$ and just about 4% of the particles contribute at λ_{peak} and can, assuming that their basic energy content is high enough, penetrate the wavelength range $\lambda<\lambda_{peak}$, if a favorable pressure environment does allow to do so. This entails that the *average* particle celerity in an electromagnetic field, related to the black body radiation, is (significantly) lower than the speed of light c.

Remark: It needs to be noted that, if *all* particles in the volume element were following the X-X line in Fig. 13, it would entail/require a dramatic increase of the radiation pressure at ambient conditions.

Another interesting topic relates to the vibrational amplitude levels being realized by the particles in an electromagnetic field. With the consideration of

(88) $\lambda = c \cdot T = c \cdot \frac{1}{f}$

and

(89) $\dot{\xi}_{x0} = \omega \cdot \xi_{x0} = 2\pi \cdot f \cdot \xi_{x0}$

allows to determine the vibrational amplitude of particles as follows:

(90) $\xi_{x0} = \frac{\dot{\xi}_{x0} \cdot \lambda}{2\pi \cdot c}$,

which yields at λ_{peak}, characterized by a celerity of $\dot{\xi}_{x0} = 0{,}71c$:

(91) $\xi_{x0,\lambda_{peak}} = 0{,}113 \cdot \lambda$

Focusing on $\lambda_{peak} = 1\,\mu m$ at $\vartheta = 3000\,K$ leads to the following results: $\xi_{x0} = 0{,}11\,\mu m$ and $f = 3 \cdot 10^{14}\,1/s$. Let´s repeat this finding: the particle is vibrating at a frequency of $3 \cdot 10^{14}$ per second with an amplitude ranging at $0{,}11\,\mu m$ entailing that the particle celerity (vibrational velocity!) is reaching 71% of light speed c. And, not to forget, the particle is achieving this "dynamic performance" - in a super-imposed manner - in the entire broadband wavelength/frequency range! Considering the 300 K peak point will reveal a pretty similar situation, characterized by $\xi_{x0} = 1{,}1\,\mu m$ and $f = 3 \cdot 10^{13}\,1/s$.

All of this sounds unbelievable. But finally, it is so plausible. No need to say that the related "dynamic performance" of the particle must be considered as outstanding. It requires the particle to be of an extremely small mass and being enclosed within an extremely balanced resonant environment. The situation of the perfectly balanced/resonant system has already been addressed above. The mass topic will be addressed in the next Para.

3.3 Particle properties

A primary question relates to the properties of the electromagnetic particle. Why has the particle not been detected yet? There are two possibilities existing to identify the particle, by its mass and/or by its electromagnetic properties. In this context, let´s first concentrate on the particle mass.

To do so, we will refer to the “fundamentals of thermodynamics”. Considering the perfect gas theory /3/, /15/ allows to write for a fixed size volume element:

(92) $$\overline{p}_0 \cdot V = c^2 \cdot \frac{1}{\kappa} \cdot \overline{\rho}_0 \cdot V = n \cdot \mathcal{R} \cdot \vartheta,$$

with $\mathcal{R} = 8{,}315\ J/(mole \cdot K)$ denoting the universal gas constant and n the number of moles enclosed in a (defined) volume V. Eq. (92) allows to determine the mass m_V related to the volume V of the medium according to

(93) $$m_V = \overline{\rho}_0 \cdot V = \frac{\kappa}{c^2} \cdot n \cdot \mathcal{R} \cdot \vartheta.$$

This mass term can also be expressed by

(94) $$m_V = n \cdot N_A \cdot m_P,$$

m_P defining the particle mass, n the number of moles enclosed in the volume V and $N_A = 6{,}022 \cdot 10^{23}\, 1/mole$ the so-called Avogadro-number, defining the number of particles enclosed in one mole volume of the medium.

Eqs. (93) and (94) lead to

(95) $$m_P = \frac{\kappa \cdot \mathcal{R} \cdot \vartheta}{c^2 \cdot N_A}.$$

Eq. (95) suggests that the particle mass is proportionally depending on the temperature of the environment. This does not appear to make sense. Accordingly, the next question relates to “the what” producing this erroneous result. Why is this result obtained?

Some deeper reflections lead to the understanding that classical thermodynamics cannot completely handle the electromagnetic topic. This is due to the fact, that thermodynamics are not explicitly considering frequency effects, frequency is an unknown parameter in thermodynamics! This is in contradiction with the situation in electromagnetics, clearly indicating, as depicted in Figs. 11 and 12, a wavelength/frequency shift in the spectra as a function of the temperature.

If the temperature is increased by a factor 10, then the wavelength is reduced by a factor 10, being coupled to a related frequency increase by a factor 10.

Moreover, due to the interrelation

(96) $$c^2 = \kappa \cdot \frac{\mathcal{R}}{M} \cdot \vartheta,$$

M defining the mass per mole volume of the medium, it is considered in thermodynamics that the wave propagation speed in a medium is depending on the temperature. This also is in contrast to the fundamentals of electromagnetics, considering the speed of light c as being a constant factor. First, all of this appears like “a mess” and suggests that there is no physical relationship existing between thermodynamics and electromagnetics.

To deal with this, let´s reformulate Eq. (92) according to

(97) $$\left(\frac{n}{V}\right) = \frac{\overline{p}_0}{\mathcal{R} \cdot \vartheta},$$

(n/V) defining the volumetric molar density (number of moles per volume V) in the medium.

With the consideration of Eq. (73), Eq. (97) leads to

(98) $$\left(\frac{n}{V}\right) = \psi \cdot \vartheta^3,$$

with

(99) $$\psi = \frac{4}{3}\frac{\sigma}{c} \cdot \frac{1}{\mathcal{R}} = 3{,}03 \cdot 10^{-17} \frac{mole}{m^3 \cdot K^3}.$$

Eq. (98) indicates that a temperature increase by a factor 10 in the field will entail an increase of the molar density by a factor 10^3. This is in contrast to the real situation existing in an electromagnetic field, revealing a 10^4 - molar density increase if the temperature is raised by a factor 10. This finding is based on Eqs. (73) and (22), indicating that – *at a constant wave propagation speed c not depending on the temperature* – both the ambient pressure *and the density* are a function of ϑ^4. The identified deviation between thermodynamics and electromagnetics is related to the frequency shift in the electromagnetic spectra being aligned to temperature shifts. To respect the influence of frequency shifts, it is proposed to extend Eq. (98) as follows:

(100) $$\left(\frac{n}{V}\right) = \psi \cdot \vartheta^3 \cdot \mu \cdot f.$$

Considering the intensity spectra in Fig. 12 allows to write for correlated points related to different temperature curves:

(101) $$f = \left(\frac{\partial f}{\partial \vartheta} \right) \cdot \vartheta .$$

This leads with Eq. (100) to

(102) $$\left(\frac{n}{V} \right) = \psi \cdot \vartheta^4 \cdot \left[\mu \cdot \frac{\partial f}{\partial \vartheta} \right] .$$

In the scope of the overall approach it makes sense to allocate to the term enclosed in square brackets the value of "1" *with dimension 1/K*. In this context, reference is made to point **I** of Para. 3.4. This entails

(103) $$\mu = [1] \cdot \frac{\partial \vartheta}{\partial f} = 10^{-11} s$$

and

(104) $$\left(\frac{n}{V} \right) = \psi \cdot \vartheta^4 \cdot [1].$$

This being said, let´s come back to the particle mass topic and formulate for the mass of the volume element

(105) $$m_V = \overline{\rho}_0 \cdot V = \frac{1}{c^2} \cdot \overline{p}_0 \cdot V = \frac{1}{c^2} \cdot \psi \cdot \kappa \cdot \mathcal{R} \cdot \vartheta^4 \cdot V$$

and

(106) $$m_V = \left(\frac{n}{V} \right) \cdot V \cdot N_A \cdot m_P = \psi \cdot \vartheta^4 \cdot [1] \cdot V \cdot N_A \cdot m_P .$$

Eqs. (111) and (112) finally lead to

(107) $$m_P = \frac{\kappa \cdot \mathcal{R} / [1]}{c^2 \cdot N_A} = \frac{(4/3) \cdot 8{,}315}{\left(3 \cdot 10^8\right)^2 \cdot 6{,}022 \cdot 10^{23}} = 2{,}04 \cdot 10^{-40} kg .$$

The particle mass is 2,04·10^{-40} kg.

The molar mass of the medium is 12,28·10^{-17} kg/mole or 12,28·10^{-14} g/mole.

Eq. (104) allows to determine the particle density according to

(108) $$\left(\frac{N}{V}\right)=\left(\frac{n}{V}\right)\cdot N_A,$$

N defining the number of particles enclosed in a volume V. We obtain at

3000 K: $N=1{,}48\cdot 10^{21}\,1/m^3$

300 K: $N=1{,}48\cdot 10^{17}\,1/m^3$

30 K: $N=1{,}48\cdot 10^{13}\,1/m^3$

3 K: $N=1{,}48\cdot 10^{9}\,1/m^3 \approx 1500\ particles/cm^3$!

Finally, it should be mentioned that the wave propagation speed in the electromagnetic medium is defined by

(109) $$c^2=\frac{\kappa\cdot\mathcal{R}/[1]}{M}=\frac{(4/3)\cdot 8{,}315}{12{,}28\cdot 10^{-17}}=9\cdot 10^{16}\ \frac{m^2}{s^2},$$

which leads to $c=3\cdot 10^8\ m/s$.

Comparing Eq. (100) to Eq. (104) reveals the effect of a frequency shift in the electromagnetic medium**.**

Frequency shifts are coupled to molar density changes in a fixed size volume element of the medium.

Eq. (107) indicates the real small mass value of the particle. But, this small mass is required when considering the dynamic performance of the particle in the field, as addressed at the end of Para. 3.2. And finally, this small mass might be the reason why the particle has not been detected yet.

Are there any other possibilities existing as to a possible particle detection? Yes, the electric and magnetic properties. But this topic too, might be difficult to experimentally address. There are so many possibilities existing for the particle to hide, at least at ambient rest conditions. This might be related to a more or less random orientation of the particles in the field at rest conditions not allowing to really deploy a noticeable magnetic field. And, who knows, if the particle is formed by just one single electrically charged element or by at least two (rotating) sub-particles with different charge, allowing to also electrically hide at rest conditions. There are for sure a lot of further questions remaining as to the particle structure and its electromagnetic properties.

3.4 Comments

I. The thermodynamic reflections made in the scope of Para. 3.3 reveal that the molar density in the electromagnetic medium is depending both on the temperature and on the frequency.

If the temperature in an electromagnetic medium is increased by a factor of 10, the molar density is increasing by a factor of 10^4. Thereby a factor 10^3 of the density increase is related to classical thermodynamic effects and a factor 10 to the frequency shift of the spectrum by a factor of 10.

In this context it can be assumed that the particles are featuring an "apparent volume" being related to their vibrational amplitude (not velocity). This finally entails that the "apparent volume" increase of particles with raising temperatures is compensated by a corresponding "apparent volume" reduction due to the related spectral frequency shift. Both "apparent volume" changes are a linear function of the driving parameters, being the temperature and the frequency, respectively.

II. Another interesting and relevant topic is addressing the experimental work being performed in the scope of radiation experiments. Thereby it needs to be recognized that the measurements are not taken "at the source" but "in the neighborhood" of the source, being normally characterized by a different ambient radiation pressure. "We do not measure inside a light bulb, but outside the bulb" or "we are measuring the spectrum of the sun on our globe or in space". All of this is coupled to a real interesting further topic, being related to field/particle dynamic response investigations, an action point, which has not been addressed in the scope of the previous chapters.

III. The virtual experiment, indicated in Fig. 5 in concern with an acoustic field, was investigated in context with an electromagnetic field, where a light bulb was considered as the source exciting the field. Just to mention: the results are similar if compared to the acoustic case. The light bulb cannot produce the light energy being inherent to the surrounding field. In this context, reference is made to Point **III** of Para. 2.7.

IV. In the scope of Chapter 2 it was stated:

"In a sustained free-field environment energy conservation is realized at any time in any defined volume element regardless of its size and location",

which entailed – in concern with any defined volume element – "what is going

in is going out". Now, just imagine that two neighboring volume elements are related to different media, being characterized by different values of their light propagation speed and/or of a different molar particle density. Let´s assume that the medium with the lower values is located "behind" the medium with the corresponding high values as to the light propagation direction. How can this medium deal with the incoming energy it must "absorb"? According to Eqs. (25) and (40) there is at least "one degree of freedom" existing to handle the problem: just increase $\dot{\xi}_{x0}/c$ in the "behind" medium, accepting to even generate celerity values exceeding c in the propagation direction of the field. This cannot be realized in the opposite direction since it would violate the absolute pressure condition formulated in Eq. (42). In this context, reference is made to se so-called "clipping of (harmonic) signals". It may be assumed that these reflections are aligned with the so-called Tscherenkow effect /16/.

V. From Eq. (108) a particle density of about 1500 particles/cm³ was determined at a temperature of 3 K, which is recognized as "the ambient temperature in space". Referring to Eq. (90) now indicates that the vibrational amplitudes, related to the majority of the particles, will range in the 100 µm domain at this temperature level. How can these tiny particles interact to allow for the propagation of an electromagnetic (communication) signal? In this context, it can be assumed that the particles do not necessarily need to physically collide with one another to transmit "the signal". They can exchange the corresponding information via the longitudinal magnetic field being directly related to the rotational electric field.

4. Further considerations

Due to the non-deniable physical similarities existing between acoustic and electromagnetic fields does at least allow to address additional topics, not being directly related to the basic field investigations outlined in the preceding chapters.

4.1 Superlight speed

There is no doubt, that the celerity of particles in an acoustic or electromagnetic environment is ranging *far* below the speed of sound c and that in the electromagnetic medium the celerity of the particles is also ranging below the speed of light c.

But this does in no way entail that a "solid mass" cannot reach steady translational speeds in the medium exceeding c! Just remember in this context that supersonic flight is a reality. This is due to the fact, that *the acoustic wave propagation speed and the flight speed are parameters being related to two completely different physical phenomena.* Acoustics /2/, /5/ and aerodynamics /17/ are based on different physical considerations! Theoretical acoustics clearly indicate that the vibrational particle celerity in the acoustic field can (at its ultimate theoretical limit) just reach c/κ, as formulated in Eq. (42). On the other side, aerodynamics clearly indicate that supersonic flight is possible and there is clear evidence that a "solid mass (airplane)" can go supersonic.

Particle vibrational celerity and "solid mass" steady translational velocity are not linked to one another!

But, not to forget, to go supersonic needs a lot of power to be provided by a propulsion system.

Based on these reflections and with the consideration of a previous statement, saying that

"In an electromagnetic environment the physical significance of the speed of light is identical to the speed of sound in an acoustic environment",

directly entails that

Superlight and hyperlight speed of a "solid mass" is possible!

Is there any objection existing to contradict to this? Let´s go into more details to underline this statement.

First, let´s consider a passenger car being powered to 100 km/h within 10 sec. The corresponding averaged acceleration will roughly be at 3 m/s², say 0,3 g, with g = 9,81 m/s². Let´s consider a (fighter) aircraft reaching a speed of 300 m/s within 100 sec. Again, we will obtain 0,3 g as an averaged acceleration. These accelerations can be considered as “high”, since it needs a powerful propulsion system to allow to do so.

Now, let´s assume that we are going to accelerate these “solid masses” to the speed of light, considering the same acceleration factor of 0,3 g. How long does it take to do so? The result to this can easily be formulated: just about 3 years.

This finally means that it takes for a “solid mass”
3 years at 0,3 g to reach the speed of light c, which roughly equivalates to
10^1 years at 10^{-1} g to reach c, or
10^3 years at 10^{-3} g to reach c, or
10^6 years at 10^{-6} g to reach c, or
10^9 years at 10^{-9} g to reach c.

Now, just imagine that in the stellar system a “solid mass” is subjected for a longer time to an even smallest continuous gravitational acceleration. There cannot exist a doubt that this “solid mass” can reach superlight or even hyperlight speeds. It just takes a long, long time to reach the corresponding velocity levels. It would appear rather strange if this would/could not happen in the universe. Accordingly, the gravitational forces need to be recognized as the driving force to allow for the corresponding acceleration and the thus resulting velocities.

What is happening if the “mass” is reaching the speed of light c? In the air medium the transition from sub- to supersonic is coupled to the so-called “acoustic boom”. The transition is *mathematically* expressed by a significant change in the related so-called “potential function”, describing the velocity flow field existing around the “solid mass”, turning from an elliptical to a hyperbolic expression /17/ when going from sub- to supersonic flight speed.

Aligned to this it may be assumed that the transition from sub- to superlight speed is coupled to a “light boom”, induced by the interference of the “solid mass” with the electromagnetic particle environment. Having crossed the light barrier entails that the “mass” is no longer “visible”. Its emitted radiation,

coupled to the propagation speed c *relative to the "solid mass"*, can no longer be perceived by a detector being placed "behind" the "mass" as to its flight direction. The "solid mass" has optically gone, but, no need to say, it is still influencing its surrounding gravitational field. It really makes sense to think about "solid masses" at superlight speed in the universe which cannot be electromagnetically perceived/detected but which nevertheless do deploy their gravitational potential.

Remark: It needs to be addressed that the radiation spectrum, emitted by a "solid mass", being subjected to an evading speed v<c relative to a fixed observer, will be perceived at the observers location in form of a frequency shifted spectrum, with frequency band <f´> = <f> (1-v/c) , <f> defining the frequency band of the radiation at v=0 of the "solid mass". This entails that the radiation spectrum, perceived at the location of the observer, is coupled to lowest frequency values if the evading speed of the "solid mass" is approaching the speed of light c.

4.2 Photoelectric effect

The (external) photoelectric effect /18/ is characterized by the fact that a solid material surface can emit electrons if subjected to the radiation of an electromagnetic field. Experimental investigations now indicate that this is not happening in a low frequency radiation field whatever is its intensity level. On the other side, it is recognized that a high frequency radiation field does allow for the emission of the electrons from the material. What´s the reason of this effect? Why does a "low" intensity radiation field in the high frequency range induce the electron emission whereas a "high" intensity field in the low frequency range cannot do so?

To explain this effect, let´s came back – once again – to acoustics. Testing facilities in acoustics are (among others) characterized by two typical "testing rooms", the so-called reverberation chamber and the anechoic chamber /2/.

The reverberation chamber is a "hard-wall" chamber, reflecting (at nearly 100%) the incoming acoustic waves reaching the walls. The acoustic noise level can be increased in the chamber to any value, the chamber wall does not absorb "any" of this energy, it is just reflecting it. In this context, it needs to be understood that at the hard wall surface, the dynamic field pressure is doubling whereas the particle celerity in the acoustic medium is zero.

Accordingly, there cannot exist a transfer of *kinetic* acoustic energy from the acoustic field to the wall!

The anechoic chamber is a “soft-wall” chamber. Its walls are covered with sound absorbing material. This allows the acoustic waves to penetrate the wall surface, say to be (at least partially) absorbed. This absorption is coupled to a conversion of the *kinetic* acoustic energy, penetrating the wall surface, into heat energy. The sound absorbing material is heating up. Accordingly, there is an energy transmission existing from the acoustic field to the wall material. But, as is well-known, these anechoic chambers are characterized by a so-called cutoff frequency, depending (among others) on the properties of the sound absorbing material installed (e.g. thickness, surface shape, material used). Below this cutoff frequency, the acoustic field energy is poorly absorbed, whereas at frequencies exceeding the cutoff frequency the absorption performance is significant.

Transferring this existing knowledge to the electromagnetic field explains the photoelectric effect. At low frequencies, the radiation wave field is reflected from the material surface. It cannot penetrate the material, the field celerity at the surface is zero. At high frequencies, the wave field is (partially) absorbed. It can transmit its *kinetic* energy to the solid material and, if powerful enough, can reach and exceed the binding energy of the electrons in the atomic configuration existing and thus liberate the electrons. The exceeding energy is converted into heat energy.

These considerations finally allow to state:

To efficiently “crack” a (solid) material needs high frequency (and high temperature?) levels in the electromagnetic field.

In this context, it can be assumed that any material will become “transparent”, say absorbing, at highest frequency levels.

4.3 Gravity

Please, just consider the following as a “mental input”. *There are no real facts existing as to the reflections made in the following*!

The many considerations performed in the scope of this publication have indicated at several occasions that it might (!) be, and it would from a physical

point of view make sense, if the gravity topic was coupled to the rotational degree of freedom addressed in the foregoing Paras. Once again, *there is no proof as to all of this*!

The related question is easy to formulate: is gravity *directly* related to the rotational degree of freedom in the medium?

The following *virtual experiment* should provide an answer to the question.

Just consider a pressurized bottle filled with a “gaseous medium”. Assume the bottle to be tight, no leakage! The molecules inside the bottle will interact among one another and the inner bottle surface. All of this does create heat! This heat is (continuously) removed from the bottle at its outer surface. Accordingly, the total energy inside the bottle will decrease as a function of time. The basic inner energy content of the particles will weaken over time. Finally, there will be no more energy left in the bottle, the pressure has gone … but, all molecules are still enclosed in the tight bottle. Question: What is finally remaining in the bottle? How about the remaining “dead mass” of the gas? Is there any gravitational difference existing between “dead mass” and “active mass”?

5. Scientific observations

Working on the highly special electromagnetic topic, I was confronted with diverse fields of engineering: mechanics, acoustics, electrotechnology, thermodynamics, electromagnetics, aerodynamics. No need to talk about the high level of expertise existing in these fields. On the other side, I was amazed by the "diversity" of the approaches being used to deal with technical issues in the distinct engineering fields.

Why is this diversity existing? It is probably due to the historical background of these scientific fields, which fundamentals have been elaborated (independently from one another) far more than 100 years ago. All of this must be recognized as a "tremendously great work" having been performed and having been continuously developed "over centuries". Our today´s amazing technology level is the result of all of this!

On the other side, this "diversity", at a today´s view, may lead to some questions:
"Why do the basic equations (of motion) in mechanics differ so much from those in electrotechnology?"
"Why does the *formulation* of the energy conservation laws in thermodynamics differ so much from the corresponding *formulation* in mechanics?"
"Is there an energy conservation law at all existing in electrotechnology?"

This diversity can be explained or argued. But let´s come back to the real basics. *All* engineering sciences are dealing with the transformation and conversion of energies, be it in thermodynamics, electrotechnology or in acoustics. *It´s all about the transformation and conversion of energies!* And, all these energy transformations have their origin on the particle/volume level.

If all these energy conversions could be explained on the particle level, or at least on the volume (or component) level, would entail a far better insight into our technical world. It would also allow to create "a common basis" and would create synergies between the different engineering fields. In this context, please allow me to refer to a major content of my habilitation thesis, approaching vibro-acoustics on an energy consideration level /19/, being *completely* aligned to structural-dynamics considerations. This convincingly indicates that a common energy approach is possible, also in a priori highly different engineering fields. And finally, this "common basis" would entail that

the many “empirical constant factors” existing in our engineering fields, could finally be explained. Wouldn´t it be nice to know more about “the what” hiding behind some of these factors?

Leaving the particle/volume level, say working on a higher level of abstraction, *may* entail to lose control on the de facto existing physical phenomena related to a technical environment. In this context, I really doubt that even a most sophisticated analysis of the electromagnetic field, based on the *dynamics* of $\mathcal{E}$ - and $\mathcal{B}$ - fields, can deliver an explanation as to the ultraviolet catastrophe, being related a rather fundamental *static* factor, the ambient radiation pressure at rest.

This being said, and with the consideration of my 40 years of engineering experience, I dare to formulate the following recommendations to generate a further push to engineering sciences in the future.

1. Clear up the energy situation/interrelations existing on the particle/volume level.

2. Formulate the fundamentals, related to the diverse engineering fields, on the basis of a *common* energy conservation approach.

3. Proceed to a further detailing of the physical phenomena and interrelations existing in a defined technical field based on the formulation of the corresponding energy conservation fundamentals.

A corresponding approach, at least on the energy level, would allow the engineering sciences “to merge/synergize” on *common* de facto existing fundamentals. This again would allow engineering students from one faculty to handle far more easily topics being related to another faculty in the scope of a more or less changed teaching process. Cross-engineering field knowledge “in one brain” could be significantly amplified without requiring an additional effort by the persons involved. This gain in brain-skills, focusing on the interdisciplinary qualification required to address emerging new technologies, would open a new and more modern world to engineering sciences, being of a high attractivity to engineering students, and would finally allow for another future boost of our overall technology level.

6. Conclusion

No need to say that the outcome of the analysis performed in the scope of this publication did lead to some rather surprising results. But, finally, the intensive work performed does now allow to perceive the electromagnetic free-field in a far more transparent form. The good news is that the electromagnetic field has revealed to be of a “normal kind” comparable to the acoustic field. This finally allows to approach the dynamics in the electromagnetic environment on a classical mechanics approach.

However, it was detected in the scope of the analysis, that both the acoustic and electromagnetic (conventional) field descriptions do lack the consideration of a rotational field being inherent to the medium. Energy conservation considerations indicate that this field must exist!

This finally leads to the situation of an energy conservation in any volume element located in the free-field at any time and being independent of its location.

In the scope of the energy conservation analysis it was further detected that there is no energy exchange taking place between kinetic and potential energies in the field.

On the other hand, due to the fact, that the longitudinal and rotational fields are exchanging their corresponding energies among one another in the form of a kinetic to kinetic and a potential to potential energy exchange, leads to the situation of a perfectly balanced dynamic system being at resonance at any frequency.

The perfectly balanced resonant system entails that the energy, to be provided by a source to excite the field, just needs to compensate for the energy losses, “the damping” in the field.

Accordingly, it is evident that the energy to be provided by a source is *by far* lower than the energy being inherent to the field. This field energy is already present “at rest”, say at ambient steady field conditions, and is formed by the rotational energy in the field “at rest”. The rotational energy is related to the so-called “inner energy” considered in thermodynamics. The source is just triggering/activating this already existing energy to a change from a rotational to a longitudinal orientation.

Based on these fundamental findings, it was possible to mathematically address the electromagnetic field in more detail and to finally validate the elaborated mathematical model by the radiation spectra, as defined by Max-Planck.

The *vibrational* celerity of the particle in the field is quite impressive but lower than the speed of light c. Just to remember: the propagation velocity of the field c is not identical to the (vibrational) particle celerity, being related to the physical material transport in the wave. The particle celerity is definitively not related to a sustained steady translational velocity c. The particles are vibrating!

In the scope of an extended thermodynamic approach the particle mass, being $2{,}04 \cdot 10^{-40}$ kg, and the molar mass of the medium, being $12{,}28 \cdot 10^{-14}$ g/mole, were identified.

The thermodynamic investigations also indicate that the temperature related frequency shift of the Planck-spectra is coupled to a molar density change in the electromagnetic field. Thereby the “apparent volume” changes of particles related to temperature and frequency effects are compensating one another.

For sure, a lot of results were produced in the scope of the research work performed. But, working on the many different topics, related to the different technical fields which needed to be addressed in the scope of the investigations performed, “a dozen” of highly interesting new topics did “pop-up”. In so far, this publication needs to be considered just as a first contribution to the topic addressed.

There is a lot of a highly interesting and real challenging work remaining!

Just to mention a few of the “remaining challenges”:

- What is “the particle”, how is it formed, how is it generated?
- The “dynamic response behavior” in an electromagnetic field.
- The “inner energy” content inherent to an electromagnetic field at rest conditions.
- The energy effort being required on the particle/volume level to allow for the longitudinal/rotational energy transformation/triggering in a free-field.
- The particle/volume (longitudinal and rotational) energy situation in concern with a “gaseous medium” in a “cavity volume”, which is not forming a free-field.

- The dynamic particle/volume energy situation existing in fluid and solid materials.
- Explanation for the discrepancy actually existing in the periodicity of the electric and magnetic field energies, resulting from the standard formulation in electrotechnology /11/, when compared to the kinetic field energies, as defined by Eqs. (25) and (56) in mechanics.
- Describe the physical mechanism creating a magnetic field on the particle/volume level.
- The importance of frequency considerations in thermodynamics.

There are still a lot of open questions remaining!

7. References

/1/ Cessac, J.; Tréherne, G.: Physique - 1ère C
Fernand Nathan, Paris, 1966

/2/ Henn, H.; Sinambari, G.R.; Fallen, M.: Ingenieurakustik
Friedrich Vieweg & Sohn Verlagsgesellschaft, Braunschweig, 1999

/3/ Löffler, H.J.: Thermodynamik – Erster Band
Springer-Verlag Berlin, 1969

/4/ Innere Energie
https://de.m.wikipedia.org/wiki/Innere_Energie

/5/ Meyer, E.; Neumann, E.-G.; Physikalische und Technische Akustik
Friedrich Vieweg & Sohn Verlagsgesellschaft, Braunschweig, 1979

/6/ Adiabatische Zustandsänderung
https://de.m.wikipedia.org/wiki/Adiabatische_Zustandsänderung

/7/ Cremer, L.; Hubert, M.: Vorlesungen über Technische Akustik
(3. Auflage), Springer Verlag Berlin, 1985

/8/ Binninger B.: Vorlesungsumdruck Thermodynamik II - Kapitel 5, Institut für Technische Verbrennung der RWTH Aachen
https://itv.rwth-aachen.de/index.php
> Lehre > Thermodynamik II

/9/ Photon
https://de.m.wikipedia.org/wiki/Photon

/10/ Cessac, J.; Tréherne, G.: Physique - classe terminale C
Fernand Nathan, Paris, 1967

/11/ Energy in Electromagnetic Waves
farside.ph.utexas.edu/teaching/302l/lectures/node119.html

/12/ Rayleigh-Jeans-Gesetz
https://de.m.wikipedia.org/wiki/Rayleigh-Jeans-Gesetz

/13/ Planckscches Strahlungsgesetz
https://de.m.wikipedia.org/wiki/Plankscches_Strahlungsgesetz

/14/ Heintz, A.: Gleichgewichtsthermodynamik
Springer Verlag Berlin, 2011

/15/ Thermische Zustandsgleichung idealer Gase
https://de.m.wikipedia.org/wiki/Thermische_Zustandsgleichung_idealer_Gase

/16/ Tscherenkow-Strahlung
https://de.m.wikipedia.org/wiki/Tscherenkow-Strahlung

/17/ Schlichting, H.; Truckenbrodt, E.: Aerodynamik des Flugzeugs – Erster Band, Springer-Verlag Berlin, 1967

/18/ Photoelektrischer Effekt
https://de.m.wikipedia.org/wiki/Photoelektrischer_Effekt

/19/ Freymann, R.; Advanced Numerical and Experimental Methods in the Field of Vehicle Structural-Acoustics
Hieronymus Buchreproduktions GmbH, München, 2000
ISBN 3-89791-172-8