Sound as a Transverse Wave

Armando. T. Canero
Departamento de Física, Facultad de Ingeniería, Universidad de Buenos Aires
armandotcanero@yahoo.com.ar

ABSTRACT

This paper presents sound propagation based on a transverse wave model which does not collide with the interpretation of physical events based on the longitudinal wave model, but responds to the correspondence principle and allows interpreting a significant number of scientific experiments that do not follow the longitudinal wave model. Among the problems that are solved are: the interpretation of the location of nodes and antinodes in a Kundt tube of classical mechanics, the traslation of phonons in the vacuum interparticle of quantum mechanics and gravitational waves in relativistic mechanics.

Indexing terms/Keywords

Sound, transversewave,mechanical waves, phonons, electromagnetism.

Academic Discipline And Sub-Disciplines

Physics; Theoretical Physics.

SUBJECT CLASSIFICATION

Physics Classification.

TYPE (METHOD/APPROACH)

Theoretical Analysis.

Introduction

Sound is studied from the wave equation, and is modeled through a wave of longitudinal propagation (Coombs, 2007)[2], this interpretation imposes a series of concepts and considerations that are erroneous and generate drawbacks in the analysis of different situations, which is counterproductive in research and in the practical application, as it will be explained below in the section "Drawbacks of the old model". This model of a single parameter reduces the chances of variations in the analysis; therefore it limits the richness of the results (in terms of the range of alternatives) that this kind of perturbations may present. It is worth mentioning that this concept of longitudinal wave is not accepted by a large number of students, since it is difficult for them to see it as a valid option [2] and this is because it does not correspond to the reality perceived by the observer.

This study provides a different solution based on a transverse wave model, which meets the conditions supported by the old model, thus responding to the principle of correspondence, and it gives a more correct answer to various problems that have arisen so far. Although this work is mainly based on a problem classical analysis approach, the proposed solution is able to support a thorough analysis from the point of view of quantum mechanics and relativity. Some results in such areas are presented. A study in greater depth considering quantum mechanics and relativity will be documented in a next publication.

In this paper, it is demonstrated that there is a significant number of experiences that impose the need for a nomological study of the characteristics of the sound propagation model. Although this paper presents an ontological proposition, it is clear that practical arguments obtained prove its importance. It is also demonstrated that a more advanced physical-mathematical knowledge than the one taught at the first year university is necessary for understand this topic at its full extent, as it is explained by Vergnaud in the Theory of Conceptual Fields (Moreira, 1997) [12], but this does not prevent it from should be explained correctly as a transverse wave.

THEORETICAL FRAMEWORK

For many years the study of electromagnetism was driven by ideas extracted from fluid mechanics (hydrodynamics), with Maxwell's equations this discipline gained acceptance and got separated from the original path which was to copy solutions from other branches of physics. In 1996, this idea was raised again with a theory that proposed the treatment of non-viscous hydrodynamics with the formalisms of Maxwell's equations. These studies were carried out by Marmanis (1996) [11], Liu (1998)[10], Rousseaux (2001; 2003)[13][15], Rousseaux and Gouyon (2002)[14], and Dmitriyev (2004) [6], which presented a system of equations identical to those of electromagnetism with the parameters for fluids or elasticity, therefore the comparison with other disciplines is again stimulated.

It is possible to measure sound velocity by different methods with high accuracy. The formula has been deducted through thermodynamic analysis (García, 1981) [8], and experiments confirm the validity of these deductions.

It was demonstrated, at subatomic level, that matter is not possible to be define as a wave or a particle (De Broglie, 1924;1925)[3][4], generating the so-called wave particle duality. That is to say, both light and matter responds similarly when they are exposed to different experiments. At macroscopic level, the equations used are those applied in the treatment of light and mechanics, thus equating the treatment of both as the Hamilton-Jacobi equation (Torres del Castillo, 1990)[18]. In order to analyze the concepts of geometrical optics and mechanics contrasted, was resorted to contrast on Arnold (1980) [1] (see Table 6).

DEVELOPMENT

Valid experimentation with both models

Some examples of experiments in which interpretation is valid for both models are: refraction, reflection, interference and Doppler Effect. These experiences that are admitted for both light and sound cannot validate the conditions of one of the two models since they are applicable to both. Therefore, these experiences are not treated in the present work.

Drawbacks of the old model

In the conceptual analysis of the interpretations of sound propagation from the perspective of different disciplines, it can be deducted that:

a.-In classical physics, the conventional model of pressure wave causes the following main difficulties:

a.1.- The pressure is considered a process based on random collisions, therefore, information cannot be transmitted coherently without distortion or losses in terms of distance.

a.2.- Time and distance relationship in the wave equations should depend on the cube of velocity, due to the movement in three dimensions and not on the square of it as it actually happens and is reflected in the wave equation (eq. 7). This affirmation is deducted from the fact that space is three-dimensional and there are three independent dimensions whose velocities can take any value, thus the existence of a lower number of dimensions in the velocity space will indicate that there is certain dependency among some of the velocities which shouldn't exist because they are random.

b.- In seismic, where it works with elastic waves, the strain tensor arises and the normal stresses get separated from cutting stresses for longitudinal and trasverse waves respectively, ie, attributing changes in volume to the longitudinal waves and changes in form to transverse waves, (Landau and Lifshitz, 1969) [9]and this is extrapolated to anisotropic contexts. Thus, two different constants are introduced for the propagation velocity. For brevity, only isotropic media will be analyzed regardless of surface changes, so waves to be studied are reduced only to P (and within them only the ones of the first type) and S waves. When the wave velocity is expressed for both perturbations, these are represented by Lamé coefficients (λ y μ).

In the case of the longitudinal wave P, $c_l = \sqrt{\frac{3k+4\mu}{\rho}}$(1)

In the case of the shear wave S, $c_t = \sqrt{\frac{\mu}{\rho}}$ (2)

where: C_l: longitudinal wave velocity,C_t: transverse wave velocity,*k*: compressibility module,*μ*: shearing or rigidity module and *ρ*: density.

It can be seen that expressions (1) and (2) contain K and μ, which eliminates the concept of volume change in P waves without transverse waves, since if they were not present, the shearing module should not appear. Even if the seismic justifies the existence of two types of waves with different velocities, both consider shearing in their expressions, which should be interpreted as a clear sign that the wave is transverse. Furthermore, volume variation does not support the idea ofthe longitudinal wave since volume varies in three dimensions and therefore it is not longitudinal; instead it supports the idea of the transverse wave because when the wave moves, one transverse deformation generates a volumetric deformation. Hence, although this seismic is defining P waves as longitudinal, they really are transverse waves of different velocities of response to those defined as transverse or S waves; they are definitely transverse ones.

It is worth highlighting that velocity is a constant in this equation and therefore doesn't mold the wave, it does not give any shape to the perturbation, since its only function is to determine the propagation time and it does not provide any argument to define the wave as longitudinal or transverse. However, it does allow identifying that the conditions imposed for each model are met, and particularly in this case within the expression selected for the wave equation, shearing parameters are included which generate a torsion field indicating a transverse perturbation and consequently it is not longitudinal.

c.- In mathematics, the argument that sound is a pressure wave and therefore it propagates in the same direction as perturbation occurs, collides with the meaning of pressure, since a scalar has no direction or sense. In order to have direction and sense, Mathematics imposes that the magnitude must be a vector or an antisymmetric tensor of second order.

d.- In thermodynamics, the calculation of sound velocity follows a adiabatic process that is also isentropic, indicating that it is theoretically reversible [8]. This eliminates any intention to consider random processes, or collisions between particles, as the cause of propagation, since it is the model of energy dissipation for any process. At this point, it must be recognized that physics is based on conservative non-dissipative processes. However, it is worth mentioning that random processes are always related to energy dissipation mechanisms, being this a topic that must be further developed by physics.

e.- In acoustics, sound propagation in the air is presented as a clear process, without leaving a remaining oscillation or reverberation in the place of propagation what indicates that the oscillation was not around a balance point. If so, propagation should have permanence in time, except for the case of critical damping and as the wave propagates for different materials, at different pressures, densities, temperature and even varying other conditions, this implies that it is a standard/common and therefore there is not critical damping, which means that there is not perturbation around the balance point. This eliminates the idea of an oscillation due to restitution forces of the environment, because if this happens they should last in time and therefore part of the energy carried by the wave will be absorbed; this energy is represented by the aforementioned remaining vibration. This speaks about disturbance that in order to keep it requires of an outside force and not of free oscillation.

f.- In quantum mechanics, the material medium is formed by a vacuum with particles that are distributed uniformly (for simplicity), the distant among them is several orders of magnitude of the particles, so it can still be considered vacuum in the case of solids. For the previous model the propagation of sound waves is only in material means, what makes impossible that the wave propagates in the vacuum between the particles and therefore in material means this concept is opposed to the idea that sound, and therefore mechanical waves cannot propagate in vacuum.

The concept that a solid body with particle links made by covalent bonds or by any other kind of electrical bonds may behave as a body in which wave propagation is performed on the basis of those links, seems to refute the argument that sound waves have to propagate in the vacuum between particles. However, this reasoning indicates that propagation is done through a photon, since an electric field perturbation is an electromagnetic wave between interacting bodies, what indicates that covalent bonds cannot be taken to give continuity to the material.

g.-In a gravitational wave, the signal is produced by the action of the moving masses, thus it is a mechanical wave, and its propagation through the Earth-Moon vacuum prevents the wave from being considered a longitudinal perturbation. This conclusion agrees with the transverse wave model for mechanical waves and more precisely with this model for sound.

In relativistic mechanics, signals do not propagate instantaneously. This can be seen in the gravitational action exerted by the Moon on the Earth, where the delay of the tide with respect to the axis Earth-Moon is in the order of 3°, approximately 12 minutes of time. It is worth highlighting that the delay of tides in reference to the axis Earth-Moon is attributed to the inertial effects of the ocean masses. However, relativistic mechanics states that the principle of inertia does not exist and therefore cannot be used to justify the delay of tides. This argument shows that experiments considering that mechanical waves are not longitudinal waves are not taken into account so as to avoid questioning how sound propagates in the air.

Experimentation

It will be demonstrated that in many experiences, significant discrepancies are present between what can be predicted by the longitudinal wave model and what can be seen in practice. However, this model is traditionally used by providing a superficial analysis that does not give an appropriate answer to problems and evades discussing the existing differences.

For example:

α.- Explosions: two kinds of energy propagate in a detonation, the so-called pressure wave and another called thermal wave (Diaz Alonso, 2006)[5]. The former is the one that generates sound and has that velocity; the latter has lower velocity and scope. Although the concept of sound is properly associated to the former wave, the concept of pressure is not entirely correct since it is associated with static pressure and this kind of force per unit area is the second form of energy transmission. The static pressure in thermodynamic balance is related to body temperature, its internal energy. Therefore, the higher its maximum value, the higher is the force exerted on the walls of the container per unit area. Thus, in an explosion, when temperature increases, its static pressure also increases, which is a random process of collision between particles in a three-dimensional space and therefore velocity has three separate components and its magnitude is related to the third power of velocity.For this reason, the damping ratio is higher than sound´s which as it is not a random process has a relationship with the square of the velocity shown in (eq.7). The velocity squared in a three-dimensional space indicates that there is a link between two velocities, this reduces in one degree the velocity system independence, thus implies that they are not random. At this point, we can see that there are two different ways of transmitting energy and since they do not have a very clear designation and they lead to misinterpretations, in this paper those concepts will be redefined in order to clarify both processes.

β.-Kundt Tube: In this experiment, the formation of stationary waves is clearly observed, however the location of its nodes and antinodes does not match the site where the longitudinal wave model locates them. In the longitudinal wave model, a node of movement must be generated in the fixed wall, however it can be seen that the number of particles is increased because this is a site of lower pressure, for this reason dust moves there due to the force exerted by the air. This indicates that there is not a pressure drop in the space between the two nodes and there is not an increase in the next internodal space, but that nodes in movement are low pressure antinodes. Therefore, Kundt tube shows the existence of waves in the propagation of sound but these weren't predicted in this form by the longitudinal wave model. It is interesting to see how this experience is usually shown to speak of sound as a wave, but is avoided to interpret the process, since a slightly deeper analysis allows deducing the inconsistency of the model used.

γ.-Wind Instruments: According to the longitudinal wave model, nodes of pressure (must have the external pressure) should be situated in the holes (of a flute for example) and those antinodes of high and low pressure are generated depending on the density variation in interspaces, alternating each other. However, nodes cannot maintain external pressure if an air mass circulates through them varying the density of the antinodes (interspaces between two holes).

$$\frac{u^2}{2}\rho + p + \rho h z = 0 \quad (3)$$

This indicates that nodes must be a decrease in pressure with respect to the external environment. Therefore it would not be a node, or if it were it must not match the external pressure, given that at a constant height, pressure drop is directly proportional to the increase of the square of the velocity. This way, the condition of keeping the pressure in the holes of the instrument cannot be preserved. On the other hand, the concept that an average pressure increase on the entire system is due to the internal energy increase (collision velocity between particles) should be discarded because this implies heat transfer, and since the process is adiabatic such transfer does not exist.

δ.- The Crystal Glass: When a finger is passed around the edge of a glass, a sound is produced and varies depending on the level of water contained. In this process, the glass is exposed to torsional forces which when released generate an oscillatory movement that produce no pressure or density variation in the medium. For this reason, it is not possible to justify that sound is produced by a wave pressure or density, which eliminates the longitudinal wave perturbation in order to interpret the experience. It is a consequence of the symmetry of the body, that torsional forces in a body of revolution do not generate changes in volume or form, since deformation exists only when asymmetrical forces are present, volume change exists when radial forces are present, and neither of them are found in a body of revolution that is subjected to torsion on its axis of symmetry, see[9].

ε.-Strings: A violin generates sound by an arc thatwrithes and releases a rope, in this movement as in the case of the crystal glass there are no variations in pressure or air density. For this reason, it is said that they are in the previous point condition. In a guitar or a piano, the blow or stretching is transverse to the rope, however it should be considered that the rope surface is very thin and therefore it does not generate a pressure area but rather a shearing area, which does not match the kind of perturbation predicted by the longitudinal wave model. The shearing is noticeable when moving a rod in the air; the thinner is the rod, the clearer is the sound, and the lower is the velocity imposed to the rod.

METHODOLOGY

In this section, the focus will be on oscillations following the path of the publications mentioned in the previous section. It is deducted that mechanical waves, which resort to the same basic equations of electromagnetism, are transverse propagation waves due to the mode of displacement. This point will be studied in the present paper.

Initial considerations about fluid conditions under study

1.- Sound waves propagate in the same way in gases, liquids and solids; this implies that the formulas must be the same for compressible and incompressible media. Although the simplification of considering the fluid as incompressible will be avoided, the independence of the characteristics of the wave in relation to pressure and density will be highlighted. When deducting the sound velocity formula, it is found that the variation of any of the parameters (pressure, density, temperature) modifies only the propagation velocity, not its form or its effects and further the parameter in question is taken as a constant which implies a variation in the environment pressure that does not alter what you hear or how you hear. See (eq.4) the relationship between pressure, velocity and density, wave velocity equation. See [8].

$$C = (P/\rho)^{1/2} \quad (4)$$

where: C is sound velocity, P is pressure and ρ is density.

The parameter velocity can be written as a function of a unique variable, the temperature, becoming independent of pressure and density as eq (5):

$$C = (kRT)^{1/2} \quad (5)$$

where:C is sound velocity, k isC_p/C_v (6)

(C_p and $C_v$are heat capacity at constant pressure and at constant volume respectively),

R is particular constant of gases and T is temperature.

It is to be noted that temperature is taken as the particles velocity in each of the three dimensions (kinetic energy of the particles or internal energy of the system), and from here arises its relationship with pressure.

Given that the rate of heat transfer by conduction is very low in relation to the velocity of vibration transmission, it is must be taken into account that there is not heat flow between the signal and the medium, therefore the sound velocity can be calculated as an adiabatic process. According to [8]we find the (7) equation:

$\frac{\partial^2 x}{\partial t^2} - c^2 \Delta \boldsymbol{x} = 0$ (7)

where: $\boldsymbol{x}$ is the position vector

It is to be noted that while we imagine particles in the medium with a random motion, this effect is not taken into account in the equation that we use to calculate the sound velocity. So we can say that the random motion does not disturb the wave propagation therefore they must be considered independent from each other.

2.- Sound waves are damped strongly in viscous media, so propagation will only be analyzed in non-viscous media.

Development

Although, the analysis is valid for solids or fluids, we only work with fluids because the longitudinal wave for sound is considered part of it's the propagation in the air.

Firstly, the equation of continuity is considered since it expresses that the addition of incoming and outgoing masses per unit volume in one unit of time are equal to the density variation per unit time. Therefore, for non-stationary movement of a compressible fluid is:

$\partial_t \rho + \partial_j (\rho \mathbf{u}_i) = 0$ (8)

and the dynamics equation (Fundamental Law of mechanics where force is proportional to the product of mass by acceleration) is:

$\rho \mathrm{D} \mathbf{u}_i = \boldsymbol{F} + \boldsymbol{P}$ (9)

where:$\boldsymbol{u}$ velocity per mass unit, ***F*** is force per mass unit,***P*** is force of a surface unit, *D* is substantial derivation (displaced with the particle).

Expressed (9) in index forms

$\rho\, \partial_t \boldsymbol{u}_i + \rho \boldsymbol{u}_j\, \partial_j \boldsymbol{u}_i = \mathbf{F}_i + \partial_i \boldsymbol{\sigma}_{ij}$ (10)

where:$\boldsymbol{\sigma}_{ij}$ is tensor of tensions.

Observe that force per surface unit is not considered a scalar but a second order tensor. In the analysis, it can be observed a separation of models, the longitudinal wave model takes as mean value the main diagonal (scalar) and the transverse wave model represents it with the cross product of two normal fields, shearing and transverse acceleration, which product is an anti-symmetric second order tensor as the one introduced in$\boldsymbol{\sigma}_{ij}$ (eq.10)

being$\boldsymbol{\sigma}_{ij} = -p + \mu \partial_i \boldsymbol{u}_j + \mu \partial_j \boldsymbol{u}_i - (2/3)\mu(\partial_i \boldsymbol{u}_i)$ (11)

From (9), (10) and (11) we obtain (12):

$\rho \partial_t \boldsymbol{u}_i + \rho \boldsymbol{u}_j \partial_j \boldsymbol{u}_i = \boldsymbol{F}_i - \partial_i p + \mu(\partial_i(\partial_i \boldsymbol{u}_j + \partial_j \boldsymbol{u}_i - (2/3)\partial_i \boldsymbol{u}_i))$ (12)

From algebraic relationships, it can be demonstrated that:

$\boldsymbol{u}_j \partial_j \boldsymbol{u}_i = (\nabla \times \boldsymbol{u}) \times \boldsymbol{u} + \frac{(\partial_j \boldsymbol{u}_i)^2}{2} = \nabla \times \boldsymbol{u} - \nabla \frac{\boldsymbol{u}^2}{2}$ (13)

By replacing (13) in (12) Navier Stokes vectorialequationisobtained (14):

$\partial \boldsymbol{u} / \partial t = -(\boldsymbol{w} \times \boldsymbol{u}) - \nabla\left(\frac{\mathrm{P}}{\rho} + \frac{\boldsymbol{u}^2}{2}\right) + \mu(\partial_i(\partial_i \boldsymbol{u}_j + \partial_j \boldsymbol{u}_i - (2/3)\partial_i \boldsymbol{u}_i))$ (14)

Being ***w*** angular velocity.

It is suggested to consider the cross product as a linear acceleration field

$(\boldsymbol{w} \times \boldsymbol{u}) = l$ (15)

Being the second brackets in (14) the Bernoulli energy function that will be replaced by the potential function ϕ (16)

$\phi = \frac{\mathrm{P}}{\rho} + \frac{\boldsymbol{u}^2}{2}$ (16)

The (8) can be written as:

$\frac{\partial \rho}{\partial t} + \rho \nabla . \boldsymbol{u} = 0$ (17)

Although the system is comprehensible, it is considered that density ρ = constant since pressure variation in this model is given by an increment in the particle velocity, thus the sound does not produce any density variation. This implies that a particle velocity produced by sound is an orbital velocity (if collisions are considered, energy dissipation problem arises).

By replacing (15), (16) in (14), and applying equation (17) which indicates that velocity field divergence is null (in sound it propagate rotor fields and shearing fields).

$\frac{\partial \boldsymbol{u}}{\partial t} = -l - \nabla\phi + \mu\nabla^2\boldsymbol{u} = 0$ (18)

and after applying the rotor field to (18) is obtained.

$\frac{\partial \boldsymbol{w}}{\partial t} = \nabla \times l - \mu\nabla^2\boldsymbol{w} = 0$ (19)

By a well-known mathematical equality

$\nabla . \boldsymbol{w} = 0$ (20)

where from (13) (18), applying divergence and considering (17)

$\nabla . l = -\nabla^2(\phi)$ (21)

By the Lorentz force equation for electromagnetism

$\boldsymbol{F} = \mathrm{q}\, e + \mathrm{q}\, \boldsymbol{u} \times \boldsymbol{b}$ (22_a)

In mechanics, it will be

$\boldsymbol{F} = \mathrm{m}\, \boldsymbol{l} + \mathrm{m}\, \boldsymbol{u} \times \boldsymbol{w}$ (22_b)

where ***F***: is the force, m is the mass, ***l***: is the linear tangential acceleration.

It is noted that the product (u × w)is the normal acceleration of movement (well-known expressions), so naturally it is deducted that the parameter represented by charge in electromagnetism turns into mass in mechanics. Note that in this formula the relation is direct and it is not necessary to introduce a proportionality constant given by electrical permittivity or magnetic permeability for Maxwell equations.

From this electrical potential relations (24)

$-\nabla^2(\phi) = \mathrm{m} / 4\pi\varepsilon_f$ (23)

$\mathrm{V} = \rho / 4\pi\varepsilon_f$ (24)

With the vectorial equation, it is obtained

$\nabla . \ l = \mu . \nabla \times \boldsymbol{w} - \boldsymbol{w} . \boldsymbol{w}$ (25)

From(18) equation,*l*is:

$l = -\frac{\partial \boldsymbol{u}}{\partial t} - \nabla(\phi) - \mu\nabla^2\boldsymbol{w}$ (26)

$\frac{\partial \boldsymbol{l}}{\partial t} = -\frac{\partial^2 \boldsymbol{u}}{\partial t^2} - \nabla . \frac{\partial \phi}{\partial t}$ (27)

And by derivating the equation (15) the expression (28) is obtained,

$\frac{\partial \boldsymbol{l}}{\partial t} = \frac{\partial (\boldsymbol{w} \times \boldsymbol{v})}{\partial t} = \left(\frac{\partial \boldsymbol{w}}{\partial t}\right) \times \boldsymbol{u} + \boldsymbol{w} \times \frac{\partial \boldsymbol{u}}{\partial t}$ (28)

By replacing in eq. (28) equation (19) and (18), and by eliminating those terms representing viscosity in accordance with point 1 y.2. of Initial considerations about fluid.

$\frac{\partial \boldsymbol{l}}{\partial t} = -(\nabla \times \boldsymbol{l}) \times \boldsymbol{u} + \boldsymbol{w}(-\boldsymbol{l} - \nabla\phi) - \mu\nabla^2\boldsymbol{w}$ (29)

The following identity is obtained from the vectorial calculation,

$\nabla(u . \boldsymbol{l}) = (u . \nabla)\boldsymbol{l} + (l . \boldsymbol{\nabla})\boldsymbol{u} + \boldsymbol{u} \times (\boldsymbol{\nabla}\mathrm{x}\, \boldsymbol{l}) + \boldsymbol{l} \times (\boldsymbol{\nabla}\mathrm{x}\, \boldsymbol{u})$(30)

Considering the definition given for l,being perpendicular to u, the term on the left is zero; by calculating the third term on the right it is obtained

$-(\nabla \times \boldsymbol{l}) \times \boldsymbol{u} = -(\boldsymbol{u} . \nabla)\boldsymbol{l} - (\boldsymbol{l} . \boldsymbol{\nabla})\boldsymbol{u} + \boldsymbol{l} \times \boldsymbol{w}$(31)

Substituing (24) in (29),

$\frac{\partial \boldsymbol{l}}{\partial t} = -(\boldsymbol{u} . \nabla)\boldsymbol{l} - (\boldsymbol{l} . \boldsymbol{\nabla})\boldsymbol{u} - \boldsymbol{w} \times (\nabla\phi)$(32)

With the following vectorial equality,

$\nabla \times (\boldsymbol{u} \times \boldsymbol{l}) = \boldsymbol{u}(\nabla . \boldsymbol{l}) - \boldsymbol{l}(\nabla . \boldsymbol{u}) + (\boldsymbol{l} . \nabla)\boldsymbol{u} - (\boldsymbol{u} . \nabla)\boldsymbol{l}$(33)

Using equations (21) y (24) it is obtained,

$\nabla \times (\boldsymbol{u} \times \boldsymbol{l}) = \boldsymbol{u}\rho/4\pi\varepsilon_f - \boldsymbol{l}(\nabla.\boldsymbol{u}) + (\boldsymbol{l}\,.\nabla)\boldsymbol{u} - (\boldsymbol{u}.\nabla)\boldsymbol{l}$(34)

Where

$-(\boldsymbol{u}\nabla)\boldsymbol{l} = \nabla \times (\boldsymbol{u} \times \boldsymbol{l}) - \boldsymbol{u}\frac{\rho}{4\pi\varepsilon_f} + \boldsymbol{l}(\nabla.\boldsymbol{u}) - (\boldsymbol{l}\,.\nabla)\boldsymbol{u}$(35)

The first term in the second member in this equation, can be written as

$\nabla \times (\boldsymbol{u} \times (\boldsymbol{w} + \boldsymbol{u})) = \nabla \times (u^2\boldsymbol{w} + (\boldsymbol{u}\,.\boldsymbol{w})\boldsymbol{u}$ (36)

Therefore equation (32) can be expressed,

$\frac{\partial \boldsymbol{l}}{\partial t} = u^2\nabla \times \boldsymbol{w} - \boldsymbol{u}\frac{\rho}{4\pi\varepsilon_f} - \nabla \times (\boldsymbol{u}\,.\boldsymbol{w})\boldsymbol{u} - \boldsymbol{w} \times \nabla(\phi + u^2) - 2(\boldsymbol{l}.\boldsymbol{\nabla})\boldsymbol{u} - \boldsymbol{l}(\nabla.\boldsymbol{u})$ (37)

By defining magnitude j as,

$\boldsymbol{j} = -\boldsymbol{u}\frac{\rho}{4\pi\varepsilon_f} - \nabla \times (\boldsymbol{u}\,.\boldsymbol{w})\boldsymbol{u} - \boldsymbol{w} \times \nabla(\phi + u^2) - 2(\boldsymbol{l}.\boldsymbol{\nabla})\boldsymbol{u} - \boldsymbol{l}(\nabla.\boldsymbol{u})$ (38)

This magnitude must meet condition$\boldsymbol{j} = \frac{\partial \boldsymbol{m}}{\partial t}$

From equation (37) it is deducted,

$\frac{\partial \boldsymbol{l}}{\partial t} = u^2\nabla \times \boldsymbol{w} - \boldsymbol{j}$ (39)

This equation is the one we wanted to obtain.

At this point, Navier-Stokes equation for non-viscous fluids is written with the same configuration as Maxwell equation.

System of equations

Connection between Maxwell and Navier – Stock equations

The starting point is the analysis of theequivalences.

Table 1.Connection between Maxwell and Navier – Stock equations proposed by Marmanis (1996)[11].

Electromagnetism ≡ Hydrodynamics			
Potential Vector.	***a***(x,t)	***v***(x,t)	Hydrodynamic Impulse.
Scalar Potential.	ψ(x,t)	ψ(x,t)	MassEnthalpy.
Magnetic Induction Field.	***b***(x,t)	***w***(x,t)	Vortex.
Electrical Field.	***e***(x,t)	***l***(x,t)	Lamb or tangent acceleration field.
Electrical Charge Density.	ρ(x,t)	m(x,t)	Density.
Current.	i(x,t)	j(x,t)	Turbulent Current Vector.

Table 2.Connection between Maxwell and Navier – Stock equations proposed by RousseauxandGouyon (2002)[14].

Electromagnetism ≡ Hydrodynamics			
ScalarPotential.	V	P/ρ	MassEnthalpy.

Table 3.Connection between Maxwell and Navier – Stock,equations proposed in this paper

Electromagnetism ≡ Hydrodynamics			
Permissibility.	ε_0	ε_f	Elastic permissibility in fluids.
Permeability.	μ_0	μ_f	Elastic permeability in fluids.

Table 4. Lorentz´s Force

Electromagnetism ≡ Hydrodynamics	
$\boldsymbol{F} = \mathrm{q}\,\boldsymbol{e} + \mathrm{q}\,\boldsymbol{u} \times \boldsymbol{b}$	$\boldsymbol{F} = \mathrm{m}\,\boldsymbol{l} + \mathrm{m}\,\boldsymbol{u} \times \boldsymbol{w}$

It is noted that ***l*** is the acceleration of the tangential field and that ***v***×***w*** is the acceleration of therotational field, both are related to movement.

Table 5. Wave Equations

Electromagnetism ≡ Hydrodynamics		
Gauss (Lawformagnetism).	$\nabla.\boldsymbol{b} = 0$	$\nabla.\boldsymbol{w} = 0$
Faraday.	$\frac{\partial \boldsymbol{b}}{\partial t} = -\nabla \times \boldsymbol{e}$	$\frac{\partial \boldsymbol{w}}{\partial t} = -\nabla \times \boldsymbol{l}$
Gauss.	$\nabla.\boldsymbol{e} = 4\pi\frac{\rho}{\varepsilon_0}$	$\nabla.\boldsymbol{l} = \frac{\rho}{\varepsilon_f}$
Ampère.	$\frac{\partial \boldsymbol{e}}{\partial t} = \left(\frac{1}{\mu_0\varepsilon_0}\right)\boldsymbol{\nabla} \times \boldsymbol{b} - 4\pi\boldsymbol{j}/\varepsilon_0$	$\frac{\partial \boldsymbol{l}}{\partial t} = \left(\frac{1}{\mu_f\varepsilon_f}\right)\boldsymbol{\nabla} \times \boldsymbol{w} - \boldsymbol{j}$

Waves Geometry

When defining sound waves as transverse waves, it must be verified that all geometric optics properties are met. This confirms those already demonstrated analogies between optics and mechanics.

Table 6. Comparison between concepts from optics and mechanics (extracted from Arnold, 1983) [1].

Optics	Mechanics
Optical Mean.	Extended configuration space {(q,t)}.
Fermat Principle.	Hamilton Principle δ∫ L dt = 0.
Rays.	Trajectories q(t).
Indicators.	Lagrangian.
Normal Slowness Vector p front.	Momentum p.
Expression of p in terms of the ray velocity, q.	Legendre Transformation
forms p dq	1-forma p dq – H dt
Optical longitude of the trajectory.	Action Function.
Huygens Principle.	Hamilton – Jacobi equation.

The equivalence between the concepts of optics and mechanics is a consequence of the wave/particle duality governing physics. But it is also a clear indication that equations governing electromagnetic forces should be the same that those in mechanical forces and this is possible by the transverse wave model and the concept of pressure field.

Interpretation of problems with the proposed model

Some experiments and disciplines that cannot be correctly interpreted by the previous model are:

From the paragraphs α y a.- Explosion and classical physics. The accepted concept of pressure is the force per unit area exerted in normal form by the surface of all particles (liquid or gas) on the container walls; this magnitude is considered as resulting from the random collisions of particles moving in any of the three dimensions of space. So, pressure should depend on the product of the velocity in each of the three directions. Therefore, its units contain velocity raised to the third power. The collision process proposed by the existing model generates pressure as a mean value and imposes a problem of randomness and dissipation to energy that is higher to the one proved in experience. Instead, the proposed model indicates when propagating a transverse wave of two components, some perturbation is generated on the material, as an orbital movement on a spherical surface. This implies that it does not depend on the product of three velocities but on the product of two independent velocities. This kind of pressure will be called "field pressure" to distinguish it from the traditional concept of pressure. If mechanics of fluids is considered, the tensor of tensions is comprised of pressure in the main diagonal and the rest of terms are generated by the shearing tension. These forces (tangents) per unit area are those represented in this case through the pressure field, since they are generated by the vector product of the shearing and normal acceleration fields, which by calculations results in an antisymmetric tensor of second order. It is worth noting that pressure, force per unit area is the energy per unit volume, thus the tensor used is the energy per unit volume that is to say energy transporting waves (Schlichting, 1955)[18].

At this point, it can be asked: Why is it necessary to pass from a scalar pressure (always measured this way) to a tensorial pressure, addition of a scalar plus a vectorial component. The answer is because sound behavior can be correctly interpreted only through shearing tensions. Paying no attention to shearing terms means neglecting the energy transmitted to the rotational movement and thus the proper balance of transmitted energy is not achieved.

This implies that the propagation equation in the relationship space-time will depend on the velocity squared and not on the velocity cubed as it would correspond to a random collision. This difference allows us to understand that the expansion front of the thermal energy, related to static pressure through the thermodynamics equations, decreases in intensity much faster than sound in an explosion. Since the first is a random process of energy transfer (non-usable energy) and the second is a coherent process that maintains constant exergy (usable energy) having no friction and thus allowing the transfer of information at a distance.

In the equation of wave propagation, it can be seen that the velocity term is squared, however in this paper; it is highlighted that if the relationship with the pressure were due to a random movement, the exponent should be cubed since three are the degrees of freedom. In the formula of the wave equation in place of velocity, temperature is introduced and through this pressure and density are added. These parameters are related to random processes, but it is a constant value for sound transmission. This means that sound propagates without deformation when this parameter remains unchanged; its variation introduces distortions in information and therefore it is not the variable that transmits sound. This value must be considered as a characteristic of the medium in which information is propagated. For electromagnetic waves, this constant is represented by the permissibility and permeability, and its product gives the square of the velocity of light propagation. The same format can be seen in both expressions, where the terms within the square root are features of the medium where the wave propagates and they are not generators of propagation neither in light nor in sound perturbations. Hence, the relationship between the non-dissipative character of wave propagation and dissipative parameters is velocity; this is squared because under these conditions, signals propagate without dissipation and the only way to link it to an isentropic medium without becoming dissipative is through a constant. These two characteristics of the process are related since their nature is complementary; where one ends the next begins.

The concepts of velocity and its relationship with spatial dimensions of the problem are reflected in the Kinetic Theory of Gases where the following hypotheses are introduced:

1.- a perfect gas is used, so it can be assumed that gas molecules do not collide among themselves but only against the container wall.

2.- the molecules collide elastically against the wall. It is possible to demonstrate that this condition does not change the results but simplifies the understanding of the process (Smorodinski 1981) [17].

Considering that pressure is the individual contribution of each particle collision divided by the wall surface, and evaluating the variation in the quantity of movement per unit time $\frac{mv^2}{l}$ implies that pressure is defined by the equation

$$P = \frac{2n}{3}\frac{m<v^2>_{med}}{2} \qquad (40)$$

Where $< v^2 >_{med}$ is the mean velocity squared, assuming that velocity is the same in all directions which derives from assuming that pressure is the same in all directions. n is the number of molecules in a cm^3 and m is each molecule mass.

By usingClapeyron-Medeléiev equation$pV = NRT$

$$RT = \frac{2}{3}\frac{m<v^2>}{2}N_A \quad (41)$$

and having into account that $RN_A = k$ where k: is Boltzman constant.

$$\frac{m<v^2>_{med}}{2} = \frac{3}{2}kT \qquad (42)$$

At this point, it is found that temperature is determined by the kinetic energy of particles. In this case, value 3 is related to the three dimensions of space, so it is understood that in each direction or grade of freedom, the value between the kinetic energy and temperature is provided by

$$\frac{m<v_x^2>_{med}}{2} = \frac{1}{2}kT \qquad (43)$$

This indicates that movement in two dimensions is defined by equation

$$m < v_x^2 >_{med} = kT \qquad (44)$$

that happens to be the velocity in the wave equation and consequently the kinetic theory of gases that convalidates the hypothesis that movement has to be performed on a spherical surface in order to have a dependency on kT and to produce the pressure effect.

Being a vectorial product, the field pressure result is neither a vector nor a scalar: it is a second order antisymmetrical tensor. This mathematical entity allows us to assign it the property of generating pressure and having transmission direction. This is necessary in order to justify sound propagation and to understand why one determined direction is assigned. The concept introduced in this paper is that of field pressure which is generated by an increase in a material apparent volume when it is related to a particle orbital movement on a spherical surface.

The trajectory of the particle disturbed by the wave is restricted to a movement on a spherical field, as the rotor imposes a force to ninety degrees of the direction of wave displacement. This force corrects the address, moment to moment but not causes the particle velocity modulo variation relative to the field,only a change in direction keeping its constant magnitude. This generates a circular movement (as an electric particle in a magnetic field with a constant velocity). Must add to this that the rotor field which is perpendicular to the displacement vector of the incident wave rotates in the normal to the wave plane causes the circumference generated a sphere around the point where the particle is found (see figure 1). This new concept of field pressure allows to consider a wave that propagates in a medium and that disturbs the matter, generating an increase of the pressure without varying the density, without collisions between particles and without presence of random effects that produce loss of information.This new behavior attributed to the mechanical wave allows interpreting the difference of scope between sound wave and pressure wave propagation (temperature) in an explosion.

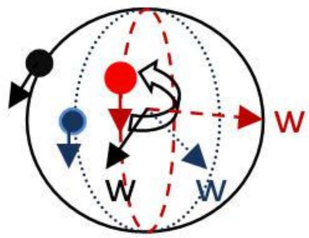

Figure 1. Oscillating particle around the original point at the moment of push produced by an elastic non-polarized wave.

The rotor field, produces a force at ninety degrees of a particle displacement velocity, thus does not produce work but a change in its movement direction. As it is not exerted work on the particle, energy is not transferred to the medium, this maintains the movement velocity module in relation to the field which, when undergoes a gradual change, moves from a zero to a maximum value and finishes again at zero as the perturbation retracts; thus the particle does not undergo any change in movement state. This way, perturbation does not lose energy in a particle and therefore is not damped when passing through the medium. If the particle in its excited state interacts with another medium, it absorbs the transferred energy and therefore it does not return to the field. In this case, the wave is damped or stops propagating. Due to this condition when the sound is heard the energy transmitted by the wave is absorbed and sound is damped.

From the paragraphs β. and e.-Kundt tube and acoustics: As the field pressure is a perturbation generated by an increase in unit volume and not by density change, the locations of the maximum and minimum values are modified. Pressure nodes (points where pressure does not vary) are the minimum pressure values, maximum values are generated between two minima at its midpoint and the wave mean value (located between maximum and minimum pressure) is not a movement node. The particle movement has stopped being purely linear to add one movement over a spherical surface. During perturbation, the average value is higher than pressure without perturbation and this value increase depends on the energy involved in the process. It is not possible to think of a mean value of equal pressure with more energy, since this is must be found within the fluid in the form of internal energy, however, as sound is a very fast perturbation, the heat flow cannot be transferred and therefore temperature does not change, while sound is present, indicating that the internal energy must remain constant. Dust particles, that are used to demonstrate the existence of waves, will be concentrated in the place where the pressure is low, since energized air occupies more volume, displaces dust and generates a node appearance where there is a pressure antinode. In this case, the pressure minima are generated where particles have less movement because they are not perturbated. It is worth mentioning that minima are always kept as minimal, hence the field pressure remains constant and the wave is not perturbated. The maxima will vary the stationary value (minima are not disturbed) to the maxima; pressure fields do not decrease at any moment. The wave fluctuates between the medium pressure in which it propagates and maximum values generated by perturbation. This is consistent with the interpretation imposed by acoustics of not allowing oscillation around an equilibrium point. If so, perturbation will lose the energy of the wave. Thus, sound perturbation is a variation above the external pressure value, and field pressure remains always positive.

From the paragraphs γ.-Wind Instrument: The interpretation of how the flute works is consistent with the idea of field pressure mentioned in the previous point, since in the holes pressure is the same as the external pressure and low pressure antinodes are produced.

High pressure antinodes are midway between two holes. Movement nodes, as in the previous case, coincide with low pressure antinodes and pressure mean values will occur at the midpoint between high and low pressure antinodes. In this process no mass movements occurs; thus no change of density is produced and consequently the problem of pressure drop in the hole by the effect of particles movement is eliminated according to Bernoulli's equation.

From the paragraphs δ.- Crystal glass: If a finger is passed through the edge of a crystal glass it gets into torsional vibration, which generates torsional and shearing waves around it, forming a very clear sound. Here, it is completely shown that there is no pressure variation because there are no change of volume in the glass or no displacementof their surfaces by compressing the air around it; thus the only possibility is that sound is generated by torsion and shearing effects which are presented in the proposed model.

From the paragraphs b.- The seismic: The waves that are studied in the seismic propagation are characterized by getting over various means over very long distances without a significant loss of energy. This condition is not fulfilled for random collisions process because it implies a constant energy loss when the wave is propagated. Experiences show that perturbation is generated by a transverse wave in a particular frequency band that propagates independently of the medium (i.e. interacting with but without damping for energy dissipation). In calculations made to determine the wave equation for elastic means [9]it was demonstrated that velocity in both cases is a function of the shearing coefficient, what confirms that elastic waves have, in their composition, shearing forces that are not present in longitudinal waves but are present in transverse waves.

From the paragraphs c.- Mathematics: When considering that wave propagation is generated by a vector product (one 2-forms or antisymmetric tensor of second order) the physical process can be conceived as a wave pressure which does not dependent on a random process, but as a field perturbation that does not suffer damping by friction or energy loss in an inelastic collision. This explains why sound is an information transmitter that not only is not degraded with distance, but also is propagated in much larger trajectory than an explosion perturbation for example (where random collisions of particles are produced in the three spatial directions). When considering the field pressure, sound wave is analyzed as a shearing field at ninety degrees from the displacement direction and the torsional field ortho normal to the two previous fields. This set of time variable fields that are generated each other, as in electromagnetism when interacting with air particles for the case of sound, describe a path on a spherical surface. This indicates that pressure depends on the size of the sphere generated, and in turn of the squared velocity as indicated by the wave equation. This perturbation increases the volume occupied and consequently generates pressure increase, that it is not dissipated because there are not shocks between particles. Sound is attenuated with the square of the distance when it is projected from a point, however it does not decrease as it propagates in a flat fashion, indicating that it depends on the geometry and not on the wave characteristics.

From the paragraphs d.- Thermodynamics: The conception of transverse wave proposed in this paper does not generate variation of exergy through collisions, hence, it allows considering the process as reversible and adiabatic. For these reasons, sound velocity can be calculated when a balance is made through the arguments of thermodynamics (Garcia, 1981), considering the circulating system as a reversible and adiabatic process. It is worth mentioning that the process is considered adiabatic because heat transfer velocity is very low with respect to wave propagation, whereby it implies that pressure (concept traditional) cannot propagate sound; this imposes the need to consider the field pressure field that proposed in this paper.

From the paragraphs f.- Quantum mechanics: The new model based on the transversal wave equation admits that wave transmission in vacuum allows the perturbance propagation in the vacuum between different subatomic particles.

On the other hand, this kind of system of equations is describing the behavior of photons which have their equivalent in the phonons, both kinds of particles are considered bosons, that is to say that respond to the same statistics, Bose - Einstein. Examples of the same behavior as phonons and photons are: laser-saser; tunnel effect for both particles (Foá Torres, 1999). [7] Other factor that supports the proposed considerations is the existence of resonant cavities with the same behavior of electromagnetism[16].

The quantum theory for fields considers that a neutron can collide with a phonon particle, absorbing it (or emitting it) and thus it may vary its energy and momentum. This model is based on the independence between wave and matter until the moment of impact, what again implies the need of the transverse wave as it is the one that can conceptually be independent from matter during movement.

From the paragraphs g.- Relativistic mechanics: The transmission of the information that a celestial body has changed its position requires that it can be propagated in interplanetary vacuum, and as it was demonstrated, transverse wave propagate in vacuum. The movement of mass from its initial position is a perturbation of mechanical nature and therefore responds to the Navier-Stock equation, being in the vacuum we neglect the terms viscous (terms that depreciated initially in the development of our equations by taking low viscosity fluids, the viscosity in this case is zero). Under these considerations, the equation of fluids was developed in the configuration the Maxwell equations. For these reasons it must be concluded that the gravitational wave is a mechanical wave and therefore it must be transverse. In accordance with lines, sound, as mechanical wave, must be transverse.

RESULTS

Propagation in vacuum

Transverse wave equations imply the propagation of themselves in vacuum. This concept collides with sound propagation, because experimentation shows that sound fades down when air density decreases and sound disappears with the lack of air. However, at a subatomic level, analysis showed that when matter is concentrated in small regions and the rest of the space is vacuum, waves should propagate through vacuum. In order to justify this action, it must be understood that the signal is transmitted in vacuum and interacts with the medium; that the medium becomes non-dissipative for a certain frequency spectrum; and that sound, ultrasound, seismic waves, etc. effects are present under such conditions. It means that the signal is propagated at a constant speed (depending on the medium), that is excited without losing energy in the process, and is transmitted without any random behavior that might perturb the coherence of the information transmitted. Its propagation in vacuum is an indisputable fact due to conformation to matter which imposes that the wave equation fulfills the condition of independent propagation of the medium although the effects generated are perceived only in the presence of matter.

Gravitational waves

This analysis opens the door for understanding an effect directly related to mass, which is the gravitational wave. Its mechanical effects are described by the transverse wave equation (sound equation), This is so because that behavior of the matter should be as indicated by Navier-Stock equations which answer the conditions of being non-viscous as demanded by Maxwell equations (for electromagnetism or for fluids). Electromagnetic or mechanical wavesare oscillations of vectorial fields capable of propagating in vacuum. Phonon and graviton are interpreted as the same particle, because they are generated in the same way and respond to the same wave equation.

Optics

The comparison made in relation to the concepts of geometrical optics and mechanics of the continuum (See Geometry of waves) are a clear indication that sound waves behavior is equal to electromagnetic waves, and consequently both must be transverse waves.

Sound velocity

Some questions arise here: Why sound velocity does not respond to light characteristics? Why does it vary if the air is moving in the same direction or in opposite direction? Why is not an absolute value like light? The first thing to note is that waves being measured propagate in a medium and therefore the value is not its maximum. Sound wave (wave/particle) propagates and interacts with the medium, is spread as a wave in the vacuum between air particles and is absorbed as energy (phonon) when it interacts with air particles. The propagation time is determined by the interaction of wave particles and air particles. Sound velocity varies with material, pressure, temperature which determine the time of absorption; it also varies when air particles are in movement.

Gases and shearing forces

Why gases do not transmit shearing forces and consequently sound waves cannot be generated by transverse perturbation?

This preconception has spread as a quick answer to the question, "Why is a wave longitudinal?" lacking of a deep analysis on the topic and as it was shown in the interpretation of field pressure (force per unit surface), shearing effects are important in fluids, whether liquids or gases, and are exactly the ones which produce sound transmission.

CONCLUSIONS

The introduction of the longitudinal wave model was an ad hoc conception, that is to say, it does not meet the condition of being falsifiable and there is not an argument to derive validity from it. For this reason, it does not meet the central concept of the epistemological theory known as Karl Popper falsifiability. On the contrary, the transverse wave model is deducted from Navier Stock equations, re-written as Maxwell Law. This means that it is deducted from the behavior of material media, fluids (analyzed in this paper) and solids, see [6].

The model from transverse waves is not only demonstrated in all the experiments analyzed, but also allows interpreting physical processes from the point of view: of the infinitely small (quantum mechanics) in the propagation of phonon, of the extremely large (general relativity) in the propagation of gravitational waves, and particle physics by defining phonon and graviton as a unique particle.

The information transmission is a key point in the definition of sound propagation characteristics. The process cannot be random because information arrives without distortion. In this case, it is not true to say that when the number of particles is extremely huge, the result will converge into the value that generated it, since there is not any reason to say that a value is more probable than other. On the contrary, the most probable value of pressure is the pre existing one before the perturbation and therefore it would not propagate without distortion. It is worth mentioning that the randomization process involves a relationship with the cubed velocity, which sound does not meet.

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Author' biography with Photo

Degree title: Aeronautical Engineer (1982)
Current status: Teaching in the Department of Physics in the Faculty of Engineering of the University of Buenos Aires (Buenos Aires, since 1997).
Previous teaching: Professor of the Department of Physics,at the National University of the South (Bahía Blanca, 1985-1993).
Professor of the Department of Engineering,at the Rawson Regional TechnologicalFaculty (Rawson, 1994-1996).
Professor at the Physics Department of the University of Quilmes (Quilmes, 2008-2009).