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times, or 44 orders of magnitude (between ions - 30 orders) weaker than their electrostatic interaction. Thus, gravitation is much too weak to provide the short range repulsion. Nuclear forces act on distances at or below a fermi. However the **range** of the repulsive interaction in molecules and solid lattices is ~ 6 angstrom, or $\sim 600,000$ fermi. In the epola, the range of the repulsive interaction is between 4 and 8 fermi. Hence, nuclear interactions cannot provide the short range repulsion.

Therefore, the short range repulsion in molecules and solid lattices can be inertial and magnetic, as shown in Ref.1, 2. In the epola, it is due to the repulsion between the intrinsic magnetisms of electrons and positrons on proximity. At a distance $l=2l_0=8.8$ fm, this magnetic repulsion is still screened by two layers of epola particles, but grows sharply with decreasing distance. At $l=l_0$, the repulsion force is already equal to the force of electrostatic attraction. At distances below the lattice constant, the magnetic repulsion is not screened, therefore it skyrockets with each further decrease in distance between the electron and positron. This corresponds to the behavior of the short-range repulsion in the epola.

Chapter 6. WAVES IN ATOMIC MATTER AND IN SPACE, THEIR PHONONS AND PHOTONS

6.1. Waves in Atomic Bodies. To us, waves are what we see on elastic strings or on the surface of water. These are more or less "*transverse waves*", in which the displacements of vibrating spots are perpendicular to the direction of wave propagation. *Longitudinal waves*, in which the particles of the media vibrate *along* the directions of wave propagation, cannot be seen directly, and are hard to depict or visualize.

A wave in the **bulk** of a body is impossible to depict or visualize, and not easy to imagine. In a **bulk deformation wave**, the particles vibrate in all possible directions, in addition to their other vibrations. The **amplitudes** (i.e., maximal displacements of particles) in all these vibrations are much smaller than the distances between the particles. In gases at normal conditions, the amplitudes may be an angstrom, but in solids and liquids they are in the hundredths of an angstrom.

During the time of one **period**, the constituent molecule, atom or ion of the body performs one full vibration, and the wave spreads over a dist-

ance of one **wavelength**. For example, if the **frequency** of vibrations and of the wave is 1000 per second, or 1000 hertz=1 kilohertz (1 kHz), the period is a thousandth of a second or 1 millisecond (1 ms). The velocity of bulk waves in air at 20°C is 340 m/s, so that during one period this wave spreads in air through a distance of $(340 \text{ m/s}) \cdot 0.001 \text{ s}$, and the wavelength is 0.34 m, or 34 cm.

Bulk waves of frequencies from 16 Hz to 20 kHz can be perceived as **sound**. Thus wavelengths of sounds in air vary from 20 m to 17 mm. **Velocities** of bulk waves do not depend on their frequency or amplitude. Thus, the upper C tones of the soprano voice (frequency 1024 Hz), the lowest frequency tones of a bass violine (30 Hz), and the highest frequency tones of a piccolo (4 kHz) reach us with the same velocity, whether performed “forte” or “piano”, at largest or smallest amplitude.

Each constituent of a body, reached by a bulk wave, becomes a center of propagation of a spherical bulk wave. Superposition of such spherical waves from all centers creates the **wavefront**, spreading with the velocity of the wave. All constituents of a body that are crossed by the wavefront at any given instant, have the same **phase** of vibration.

6.2. Half-Wave Deformation Clusters of Bulk Waves. We present bulk deformation waves as consisting of half-wave deformation clusters. On a *wavelength* of the wave, there are two half-wave deformation clusters. One of them contains an excess number n of constituents, above the equilibrium number N ; in the other, the number n is missing. The clusters are formed by vibrating atoms or molecules of the body. Shifting in a certain direction, they increase the number of particles in this direction, thus in the cluster there, and reduce their number in the backward direction. Half a **period** later they shift backwards, increase the particle concentration in the cluster there, and reduce it in the forward direction. Hence in the whole wave the number of constituents is the same as in equilibrium. In a bulk wave, there is thus a **net flow of energy** at the velocity of the wave, **without any transfer of particles beyond their vibrational amplitude**.

In gases, increased particle concentration raises the pressure, which is the elastic energy density. The bulk wave transfers the increase in pressure or in elastic energy density from cluster to cluster. However the molecules are not bound to one another, some “free lancers” may move

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between clusters and penetrate deep into them. Therefore, the borders or surface areas of the half-wave clusters are not sharply defined.

In solids and liquids, constituents cannot depart from equilibrium positions farther than the average distance between them. The excess constituents are thus confined to a very thin layer (monolayer) on the surface of the cluster. Each **excess** constituent brings its binding energy into the cluster. Though the bulk wave transfers the increase in energy density "collectively" from cluster to cluster, there is also an **individual** transfer of vibrational energy from each constituent to the next one, by distinct energy "**quanta**".

6.3. Quantization of Energy Transfer in Waves. The wave energy E of a half-wave deformation cluster can be fully absorbed by sufficiently large targets (detectors). Targets smaller than the cross-section area of the cluster absorb a smaller part of its energy. However the wave energy, absorbed by a target, cannot be smaller than the energy transferred in the wave by a single constituent (ion, atom, molecule) of the body. A very small target may not absorb the wave energy at all, or may absorb the energy transferred in the wave by one, two, or any appropriate **integral** number of constituents. However this *quantization* does not occur in gases, because a small target, placed in a gas, will anyhow absorb the energy of "free-lance" molecules, whether or not hit by molecules participating in the wave process. Hence,

the wave energy in a solid or liquid body is quantized.

*The quantum of the wave energy is the energy E_p ,
transferred in the wave per single constituent of the body.*

To calculate E_p , we have to divide the wave energy E of a half-wave cluster by the number N of constituents in the cluster ($E_p = E/N$). The calculation (see Ref. 2, 3) yields $E_p = h' f$, where h' is a proportionality factor. Hence, *the quantum of wave energy in solids or liquids is proportional to the frequency of the wave.*

The proportionality of the quantum energy of **light-waves** to the wave frequency was introduced in 1900 by Max Planck as a postulate, without an explanation, derivation or proof. It is still unexplained in quantum mechanics, and the "proof" is that "it works". And because it works so well, the postulate is related to as Planck's Law. The formula of the law is $E_p = h f$, and reads that the energy of the **photon**, which is the