Classical justification of the wave-like behavior of electron beams

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Abstract

Relying on this fact that not only role of the medium (intermediate gas) cannot be ignored in the electric discharge between cathode and anode, but also it is very important, the diffraction and interference phenomena which an electron beam can reveal are justified. This act is done after analyzing the manner in which stroke propagates via the gas valence electrons. In this respect an experiment is proposed as a test. We conclude that the cathodic ray does not carry charge, ie is not a ray of electrons being shot but is a longitudinal wave arising from the vibration of the valence electrons of the molecules of the carrying-wave medium. In this way the mechanism of production of and the difference between the longitudinal and transverse waves and that our longitudinal wave is only due to compression (not expansion) impacts are explained.

Our ability for complete deflecting and making away the electron beam (behind the anode), existence of sharp shadow of anode in the electric discharge tube, existence of dark-bright striated columns in this tube (similar to Kundt tube in acoustics), and the action mechanism of image intensifying in the image intensifier tubes are all described as witnesses to confirm the wave-like motion for electron beam proposed in this paper and reject the shooting motion for it.

Deflection of the trajectory of electron beams in electric and magnetic fields is justified in wave-like motion of "going" and "backing" for evaluation of which an experiment has been proposed. It is shown that how for transferring of momentum there is no necessity to suppose shooting motion for electron in the cathodic ray.

Two separate parallel cathodic rays repel each other. This will be contrary to what the electromagnetism predicts if a cathodic ray is to carry charge. This phenomenon is justified by the model presented here.

1 Introduction

Transferring of charge in an electron beam suggests a shooting motion for the electron in the beam, while the wave-like behavior of the electron beam, like showing interference and diffraction, suggests existence of a kind of vibratory and wave-like motion in the beam. What is at present under consideration in the world of physics for inclusion of both of these kinds of motion is considering the de Broglie wave for an electron which has a shooting motion, although details of such an action mechanism has not been known yet.

This paper intends to justify important various observed phenomena in an electron beam using only the classical physics. Details of such a justification must be known or determined with a quite clarity in order that it can be free from the shortcoming of the above mentioned mechanism.

2 Fact suggesting wavy motion for cathodic ray

Imagine a pile of molecules of a crystalline lattice as in Fig. 1. Suppose that an impact is exerted on the face xy of this pile in the positive direction of the z-axis. Suppose that due to this impact the whole pile is displaced to the extent a in the positive direction of the z-axis during the time t. The question is that whether or not any other event happens inside the pile when bearing the impact and being displaced to the extent a.

Certainly if the molecules or the units shown in the lattice are connected to each other quite rigidly, the whole pile will act as a single unit and without any disturbance inside itself will be displaced to the extent a after the time t. But when this ideal state (of rigidity) does not exist, although the whole pile will be displaced to the extent a after the time t, exerted impact will cause propagation of impulse waves inside the pile just at the moment of exertion of the impact on the surface xy. In other words when the force is exerted on a molecule or on some molecules of the surface xy it causes partial displacement of the molecular surfaces of the lattice (parallel with the surface xy) relative to each other considering lack of relative connection between these surfaces. Naturally these relative displacements are propagated along the z-axis as impulse or sound wave, and this is the case while the whole pile is being displaced to the extent a along the z-axis in the time t. In other words the pile that after the time t reaches the position z=a won't be the same first calm pile, but due to the impact there is some agitation of the impulse and sound waves inside it. Average speed of the pile is a/t while it is obvious that this is not the speed of the above-mentioned impulse or sound waves (and it is so more).

Similarly consider the closed container of Fig. 2 which contains a perfect gas which is maintained in constant pressure and temperature. This container has two similar canals blocked by two similar pistons. Suppose that an impact is exerted on the piston a such that the piston reaches from the position 1 to the position 2 after the time t. It is clear that considering that the temperature and pressure of gas are maintained constant the piston b will be displaced from the position $2'$ to the position $1'$ during this same time interval, t. But does only this happening occur? Obviously not. In fact the impact exerted from a onto the volume of gas causes propagation of sound longitudinal waves (which are due to the local alteration of the gas pressure) throughout the whole volume. It is clear that these waves are propagated in the volume of gas in a straight line along the direction of the canal containing the piston a and even it's possible that a part of them will pass across the wall of the container on which the waves strike and then the sound will be heard outside the container and another part of them will be reflected back to the volume of the gas, although the displacement of gas is not straight but is downwards towards the canal containing the piston b. (of course, by straight line we mean that the front of wave is propagated from the opening 2 in a straight line just like the straight-line propagation of light waves.)

Now see Fig. 3. Suppose that the point masses are connected to each other by similar springs. For these masses and springs we consider two states: first when the masses are such close to each other that the springs are compressed, and second when the masses are such away from each other that the springs are stretched. It is clear that in the first state that the compression of the springs causes a kind of repulsion of the masses from each other only longitudinal wave can be propagated in the string, while in the second state that the stretch of the springs causes a kind of attraction between the masses only lateral wave can be propagated in the string.

Now consider some point masses which there exists a repulsive force between them and an state similar to the above-mentioned first state governs them. (This repulsive force does not of course cause these masses to become away from each other because the supposition is that they have been positioned chiefly in their centers (eg by stationary positive centers)). Observing Fig. 4 consider a group of these masses designated by the surface a. Suppose that due to an impact this group nears the next group (b) (Fig. 4(b)). In this state we have a concentration in the region a'b and an expansion in the region a. The concentration of the region a'b will open out towards the two sides: on the one hand will cause cancellation of the expansion in the region a and on the other hand will create a concentration in the region b'c (Fig. 4(c)), and in return an expansion will be created in the region a'b. Similarly the concentration b'c will open out and not only will cancel the expansion a'b but also will create a concentration in the region c'd, and also an expansion will be created in the region b'c (Fig. 4(d)). In this manner the longitudinal wave will be propagated. Attention to this point is emphasized that as it is seen due to the impact producing this wave each particle does firstly the motion of going in the direction of the wave and then will return to its initial position, and in the state of going creates concentration and in the state of backing only cancels expansion (created at first deliberately by the impact).

Attention to another point is necessary. As we said the group a is positioned forcedly beside b (in the position a$'$) during a short time by an intentional impact (that even may be mechanical) and initiates propagation of the wave in the above-mentioned manner. Now the question is that if instead of positioning of the group a in the position a$'$ this group is positioned in a$''$ (at the left of a) in the same forced manner mentioned above (Fig. 5), or in other words if instead of having the forced concentration of Fig. 4(b) we create the forced expansion of Fig. 5, whether or not we shall have the propagation of a wave in the same above-mentioned manner. The answer is negative because as we said the force between the particles is in fact repulsive and just this repulsion causes the concentration a$'$b in Fig. 4(b) opens out towards the two sides canceling the expansion created by the impact and causing a new concentration, but in Fig. 5 there is no concentrated force to cancel the expansion but the expansion a must wait until the repulsive uniform distribution of the whole particles causes the cancellation of it; thus, we can say in simple words that what can be propagated wavily is concentration (which is of course accompanied by expansion) not expansion. And just these concentrations, propagated as wave, can cause exertion of (driving) impact or, in other words. of pressure on any obstacle existent in the way somewhere farther in the path of the wave. In other words we can say that the impact has been transferred by the longitudinal wave and will be exerted on the obstacle, while extension (related to expansion) cannot be transferred by a longitudinal wave and be exerted on the obstacle (but this occurs by lateral wave (related to attraction between the particles). Namely we can say that extension is transferred and exerted on obstacle by lateral wave).

What is the use of the above discussions? To conclude that the cathodic ray does not carry electric charge but it is only a beam of a longitudinal wave being propagated in a medium of valence electrons of the molecules of the gas of the discharge tube. Consider the circuit of Fig. 6. Exerting proper electric and magnetic fields the cathodic ray can be made so away from the circuit as to make the supposition of backing of the electrons (that their shooting motion is to make the cathodic ray) to the circuit quite irrational. A simple calculation can show that if we suppose that the cathodic ray carries negative electric charge, since negative charge is being sent out of the whole closed circuit of Fig. 6 and then successively negative charge enters onto the monitor screen shown in the figure, after a short time we must expect to have such a huge amount of positive electrostatic charge in the circuit and the same amount of negative charge on the monitor screen as appearance of action between these two huge charges to be quite noticeable, while this is not the case in practice. (Don't exemplify by saying that but TV screen is charged by the cathodic ray, while it is positively charged when the TV is turned on and will become, in some cases, suddenly negatively charged when it is turned off, or while in principle with antistatic screens we can have no charged screens.) But if the cathodic ray is to be only trajectory of a wave, not a mechanism for charge transferring, the above problem won't exist.

We can also observe the shadow of the anode, produced by the marginal rays, on the glass wall behind the anode in a proper electric discharge tube. Certainly this will be an important question that how we can justify the formation of this shadow if we already believe in shooting motion for the electrons in the cathodic ray. But if we believe in the wave-like motion of electrons, proposed in this paper, not only the formation of the shadow is justifiable easily, but also the formation of the dark-bright striated columns in the electric discharge tubes can be justified. It is sufficient to conceive that the wave-like motion of the cathodic ray, between the anode and cathode, can be reflected on itself after striking the anode, and produce the interference and many nodal and bulgy points which are the same dark and bright strips in the dark-bright striated columns. The situation is similar to the Kundt tube in acoustics.

Another case confirming the wave-like motion of electrons as proposed in this paper and refuting the shooting motion of electrons is the happening taking place in image intensifier tubes and other similar electronic devices (eg electron microscope). In these tubes, as shown in Fig. 7, different electron-trajectories intersect at a small aperture leading to the formation of an inverted intensified image. Certainly if the motion of electrons was in the shooting form, these electrons would collide with each other leading to their scattering and disorder in motion, and consequently the image would not be intensified, while this is not the case. But with believing the proposed wave-like motion of electrons, this aperture could not create any problem, just as we know that different rays of a physical wave can collide with and pass through each other.

3 Electron beam is a longitudinal wave beam propagated in a medium of molecules

We know that the electric discharge between cathode and anode will not occur in a "perfect vacuum" whatever too much the electric potential difference be given between the cathode and the anode (of course provided that the cathode and anode don't act like a capacitor and so don't produce any intensive electrostatic field between themselves which could probably release some electrons from the cathode toward the anode in consequence of the field emission phenomenon). It is obvious that the minimum potential difference necessary for starting the electric discharge between cathode and anode, which we call it as starting potential, depends on the pressure of the gas in which the discharge occurs. What the experimental works show is that with decreasing the pressure from a high pressure, this starting potential decreases up to a minimum potential near the zero pressure after which the starting potential will be increased approaching infinity with more and more decreasing of the pressure approaching the perfect vacuum (see Introduction to Atomic Physics by Enge, Wehr and Richards, Addison-Wesley, 1972). This fact states that we must consider a chief role for the medium (ie the particles) between the two electrodes. So we can say that a low pressure gas is an insulator which will become a conductor under a minimum potential difference (starting potential).

Here it is proper to see why a gas between the cathode and anode can become a conductor under a minimum potential difference. After exerting the potential difference between the two electrodes, these electrodes, depending on their configuration, will play role of a capacitor and consequently will be loaded with some electric charge with even very very small amount, which in turn will make an electrostatic field between the two electrodes with even very weak intensity. This field polarizes the gas molecules existing in the field, and this polarization will be the biggest aid in making the gas conductor. I think an experiment can evaluate the validity of this aspect. This experiment is exerting an external electrostatic field through the gas and comparing the starting potential in this state to the starting potential in the absence of any external electrostatic field. I think if the polarization caused by this external field be such that the negative poles of the polarized molecules orient toward the anode, the starting potential will be decreased; and in the case of the negative poles being toward the cathode, the starting potential will be increased.

Thus, considering the above material the space through which the cathodic ray is propagated can be considered as a medium of gas valence electrons having weak connection to their nuclei. A compressive impact is exerted into this medium of electronic particles that similar to the story (about the piston and its impact) told in the previous section (II) while this impact can be due to a mechanism of electric discharge probably occurred somewhere else via the anode (not even in the direction of impact (or the path of the cathodic ray)) causes propagation of waves (similar to the same stated sound and impulse waves) radiated in a straight line perpendicular to the surface of the cathode (which don't pass the anode necessarily because don't carry charge and are only wave-carrying motion of going and backing). Certainly it will be said that but an electroscope on the way of the cathodic ray gathers negative charge (it will be charged negatively). Answer is that gathering of negative charges in the electroscope is not because of any negative charge carried by the cathodic ray, but it is because the radiation of the cathodic ray into the Faraday cylinder connected to the electroscope prepares the ground for this cylinder, which makes up a part of the body of the tube containing the cathodic ray (and is the target of this ray), to play the role of another exit canal in addition to the main exit canal, ie the anode, for the electrons causing to flow electric current in the discharge tube; pay attention to the modeling presented in Fig. 2 and imagine that in addition to the exit canal b there exists another exit canal somewhere else on the wall. And then in addition to the main current of electrons flowing toward the anode, causing an electric current in the circuit, a part of the electron current flows toward the electroscope (as if there is an electron pressure on the whole tube wall during all the time of discharging (similar to air pressure exerted on the inner surface of a balloon filled with air) such that this pressure causes the electroscope to be charged); and of course this means that a net positive charge, equivalent to the negative charge gathered in the electroscope, is transferred to the circuit which considering its small amount such a transferring seems rational and natural (compare with the huge charge the cathodic ray, really carrying charge, is to gather on the target during a short time).

We can see the validity of this reasoning more clearly in practice: Before turning on the electric discharge tube (and radiating the cathodic ray) transfer net positive charge to an electroscope which its Faraday cylinder, while making up a part of the body of the tube, is not in the straight direction of the cathodic ray. You will see that as soon as turning on the apparatus and before you turn the cathodic ray toward the Faraday cylinder or even before complete formation of this ray the positive charge of the electroscope begins to be discharged; and this proves transfer of electrons to the electroscope in the same above-mentioned manner. Even sometimes without previous charging of the electroscope (positively) the electroscope collects gradually negative charge while the cathodic ray has not been directed toward the Faraday cylinder (particularly when the metal part of the electroscope is connected to the positive pole of the source of supply and the electroscope plays more or less the role of a capacitor).

But the reason why radiating the cathodic ray into the Faraday cylinder can prepare the ground for the electroscope to be charged via the space of the tube is a researchable problem. Whether this is because of the merely electric stimulation caused by the vibrating charges carrying wave (making up the cathodic ray) striking on the surface of the Faraday cylinder that similar to a needle piercing the membrane of a balloon filled with air create an escape canal for the pressing electrons of the whole space of the tube till the electroscope is charged or whether this is because the going and backing electrons carrying wave in the medium, which are striking on the surface of the Faraday cylinder, as any other longitudinal waves, as mentioned before, exert pressure on any obstacle on their way and then exert pressure on the electrons of the Faraday cylinder and lead them temporarily to the leaves of the electroscope making an electric dipole from the electroscope such that its positive pole is the Faraday cylinder thereafter this positive cylinder takes (negative) electrons from the tube space and altogether gets a net negative charge. That which of these two cases occurs is a problem that experiments should establish (the experiments, among numerous other ones, that in aspiration to perform them I am compelled to keep remaining as always hopelessly and helplessly). I think the first case can be verified when the canal ray produced in the tube is directed into a Faraday cylinder connected to an electroscope to be observed whether the electroscope collects negative (not positive) charge or not. If so we should conclude that this time the above-mentioned electric stimulation has been occurred by the canal ray not the cathodic one. Or in principle we can try to focus another external ray (eg an electromagnetic ray or another cathodic ray) on the Faraday cylinder existent in the tube (by its passing across the tube wall) and see whether or not the above-mentioned stimulation occurs and whether or not the electroscope collects negative charge.

Thus, we accept that as we said this is the compressive (or concentration) impact that in the form of the cathodic ray or the same longitudinal wave motion in the valence electrons of the gas of the tube space is propagated. Certainly if the cathode has hole this compressive impact will be an extension (or expansion) impact for the medium existent on the other side of the cathode ie on the path passing through the cathode hole in the direction opposite to the direction of the cathodic ray (note the explanation about this impact presented in the previous section) which, as we said, is not capable of propagation in the form of wave and then we don't have the cathodic ray on this side. But as soon as the valence electrons separate from the gas molecules adjacent to the cathode to transfer negative charge (or electron) to the anode, in a similar manner transitory produced positive ions are accelerated toward the cathode to transfer charge (that finally after colliding with the cathode cause separation of mass from the cathode). The positive ions, accelerated in this manner toward the cathode, exert a compressive impact on the gas molecules (or in fact on the positive parts (or positive ion parts not the valence electron parts) of the gas molecules) behind the anode via the above-mentioned hole of the cathode, that causes creation of a longitudinal wave motion of going and backing through the positive ion parts of the molecules (existent on that side of the cathode which is opposite to the anode) which is the same positive (or canal) ray. This compressive impact is an extension impact for the positive ions of the gas molecules existent on the other side of the cathode, ie that side which is nearer to the anode, which is not capable of propagation as wave; and then we don't have positive or canal ray in this side. It is evident that neither the positive ions can cause creation of a longitudinal wave of going and backing motion in the valence electrons nor the electrons can create such a wave in the positive ions because their influence on each other, as we said in the previous section (the discussion related to the springs), since is not repulsive is not capable of propagation in the form of wave.

If we set a thin screen of a proper metal (eg gold) as a window on the body of the tube containing the cathodic ray such that this ray strikes on this window then we can observe the existence of the cathodic ray outside the discharge tube in air (Lenard ray). Exit of the cathodic ray into air can not be justified with this supposition that the cathodic ray carries (negative) charge because considering irrationality of the supposition of return of the electrons back to the tube this means that the electric circuit of the tube is losing electrons (or negative charge) rapidly and we should expect it to obtain a huge positive charge soon while this is not the case. But with the supposition of the longitudinal wave motion of going and backing, explained in this paper, we should say that this ray has been in fact produced due to the impulsive pressure of the longitudinal wave motion of going and backing of the cathodic ray striking on the tube conductive window containing valence electrons and eventually its transferring toward the valence electrons of the molecules of air outside the tube via this window, just like the sound and impulse waves that as we saw in the previous section can pass across the wall of a closed container of gas (note the explanation related to Fig. 2).

4 How an electron beam can be deflected in external fields

But the fundamental difficulty which may show itself in the first view for this model of wave-like motion of electrons is this question that how such a wave-like motion can be deflected in electric and magnetic fields just as if the electrons are moving on an straight line with a definite velocity. Now we answer this question. Consider a wave motion with a perfect motion of "going" and "backing". Suppose that we have a group of these electrons which have the same direction in each motion. Pay attention to Fig. 8. Suppose that this group is deflected downward in the presence of a fixed uniform field, ie reaches the surface "b" from the surface "a". So an expansion will be generated in "a" and a concentration will be generated in "b". Now in the next stage a half of the concentration "b", in return, cancels the expansion "a" chiefly and the other half of this concentration causes the generation of a new concentration in "c", of course again the deflection will become more during this process. Now in position "b" there is an expansion and in position "c" there is a concentration. The above procedure will be repeated successively and the presence of the field causes more and more deflection. An accurate mathematical discussion (probably with using the computer) should show that the deflection curve that is drawn in this manner is like the deflection curve of these electrons if they would move with an initial uniform certain speed in this field without any wave-like moving. So, any field-deflection can be explained well. For example in this manner we explain this fact that the ray path in a uniform magnetic field is a circle. For this explanation we pay attention that the limit of infinitesimal deflected paths is a circle when these partial paths are set consecutively. For example suppose that each of these partial paths is of the form 1 or 2 or 3 in Fig. 9(a). In this case by setting these partial paths successively along each other we obtain Fig. 9(b) (approaching a circle).

For evaluating the validity of the above model (presented by Fig. 8), I think preparations for a proposed experiment are not difficult very much. On an extensive flat surface, uniformly fix vertically a great number of some identical springs. On the free end of each spring fix a charged ball. All of the balls should be similar. Now study on the waves propagated through these balls should be possible, especially when a strong magnetostatic field is exerted normal to the surface.

5 Transfer of momentum

Now we proceed to a some different discussion which is about the momentum transferred to the obstacle by electron beam. We first investigate the momentum transferred to the obstacle by the electromagnetic waves. What is certain is that some energy has descended on that face of the obstacle which is rushed by the electromagnetic wave. One of the most natural and easiest ways for conserving this energy (by its transformation) is that a part of this energy appears in the form of kinetic energy of the obstacle and a probably greater part of it appears in the form of thermal energy of the obstacle or the particles around the face being rushed. Since the kinetic energy of the obstacle necessitates its motion, the most evident thought that seems is that the direction of motion of the obstacle will be the same direction of the propagation of the incident wave. This is the "general feature" of the event that happens. For discovering the details of this event necessary investigations and researches should be done. The most usual result which is accepted at present is that the momentum transferred to the obstacle is in fact generated by a secondary phenomenon, ie a definite part of the wave energy is spent for warming the particles adjacent to the face being rushed (which of course this matter can be true because of the heat transfer from the surface of this face to the surroundings and of course this heat of the surface is arising from the same part of the wave energy which is changed to heat). We can imagine that the particles which have been heated in the above manner are like some particles with some definite kinetic energy (which is the same for each particle) that are moving toward the surface. When these particles hit the surface, if the surface is not reflector, the collision will be inelastic chiefly and almost the whole momentum of these particles will be transferred to the surface (or in fact to the obstacle) and their energy will be changed to the kinetic energy of the surface (ie of the obstacle) beside the thermal energy generated in the surface. If the surface is reflector, the collision will be elastic chiefly and the momentum of the surface after the collision will be almost two times greater than the momentum of the particles before the collision and the energy of the particles will be changed and conserved in the form of the kinetic energy of the surface and the kinetic energy of the recoiled particles (which is the same heat of them). (As we see there is not any necessity to the supposition of existence os some particles named as photon in the phenomenon in question.)

Now we return to the cathodic ray. It is quite rational that we accept that this ray just like the electromagnetic wave causes the generation of momentum in the obstacle in the manner explained above. Besides, since we attribute a longitudinal wave motion to the electron, we can say that one of the (probably better) ways in which the above mentioned "general feature" can occur (ie the incident energy be conserved in the form of the kinetic energy of the obstacle and the heat) is that the strokes which the longitudinal vibrations of the electrons exert on the obstacle give some momentum to the obstacle.

Thus we see here also that there is not any necessity to the supposition of existence of shooting motion of electron for justifying the transition of momentum to the obstacle.

6 Why two separate cathodic rays repel each other

We should point to another phenomenon regarding cathodic ray. Consider two separate but adjacent electrodes capable of being used as cathode separately or jointly. It is observed that when we apply these two electrodes as cathode simultaneously, and as a result there exist two cathodic rays radiated from these two electrodes, the distance between the paths of these two rays is more than the distance between the paths of these two rays when we apply each of these two electrodes as cathode in a separate time; ie it seems that the two cathodic rays repel each other when they exist simultaneously. And now an interesting question: If the cathodic ray is to be the current of electrons, how do these two parallel currents (having the same direction for current) repel each other while we know from the electromagnetic theory that they must attract each other (see the 13th paper of this book). Surely justifying this phenomenon by stating that the current-carrying electrons in a cathodic ray repel the current-carrying electrons in the other cathodic ray is quite irrational when this reasoning is not presented for other paths of electric currents (eg in two current-carrying wires) and while there is no reason for ineffectiveness of the produced magnetic field.

But if we accept that as we said in this paper the cathodic ray is, like an acoustic wave, only the path of propagation of a wave in the medium existent in the discharge tube, then we can say that in the above experiment, if the trajectories of the rays are anyhow straight, this is not the rays themselves that influence each other (and repel each other) but the mechanism of simultaneous production of the two rays has taken a divergent orientation. As extra explanation suppose that instead of one impact being exerted on the crystalline block of Fig. 1 (causing its total displacement and propagation of impulse or sound waves inside it, as explained) two adjacent, simultaneous and parallel impacts are exerted on it. Certainly the effect of these two impacts is two times more than a single impact, but this is not of importance for us. Important for us is the following supposition: Suppose that the two striking objects that will exert parallel and adjacent impacts on the block repel each other (strongly) during their preparatory acceleration for exertion of their impacts. Such repulsion causes the exerted impacts to be no longer parallel with each other but to be in divergent directions; naturally the paths of the impulse or sound waves propagated due to these two impacts won't be parallel to each other either but are divergent.

Now let's return to the cathodic ray tube. The mechanism of electric discharge that anyhow causes the electric current to flow in the circuit by passing electron from the cathode to the anode is such that in the moment of passing the electron through the cathode towards the space between the cathode and anode (which eventually leads to the transferring of charge from the space to the anode) exerts an impact on the valence electrons of this space that results in the creation of the same cathodic ray. The expression "passing the electron" in the recent sentence rather means static pressure of negative electric charges (or electrons) exerting the impact producing the cathodic ray on the pile of the space of the tube. If this exertion of pressure is to be accomplished in two adjacent electrodes, since the negative charges (or the electrons exerting the two impacts) repel each other during the time of the exertion of pressure, we must expect, like in the above-mentioned model, the directions of the exertion of the impacts to be divergent relative to each other and in other words the cathodic rays to be divergent relative to each other. Note that we want to say in simple words that the situation is as if the electrons that are to cause creation of the cathodic ray and also to flow the electric current in the circuit are waiting stationarily (and statically) in the cathode till an exertion of a high voltage causes them in a striking manner to exert pressure on the medium of the tube (and to create the ray and also flow the current). It's obvious that during the above-mentioned waiting time these electrons of one of the two electrodes also repel similar electrons of the other electrode. Therefore, when the above-mentioned high voltage is exerted, due to this repulsion exertion of pressure will have a divergent direction too and then the cathodic rays will become divergent.

This additional explanation was necessary to emphasize that this is in fact the initial static state of the electrons of the two cathodes that causes divergence of the relevant cathodic rays not their dynamic state or in fact their motion or current from the cathode to the space of the tube, because if this was the case, existence of the currents (or the same dynamic state of the electrons), when being to be parallel to each other, would cause, according to the theory of electromagnetism, attraction of the charges of the two currents and naturally convergence (not divergence) of the produced cathodic rays not repulsion of them.

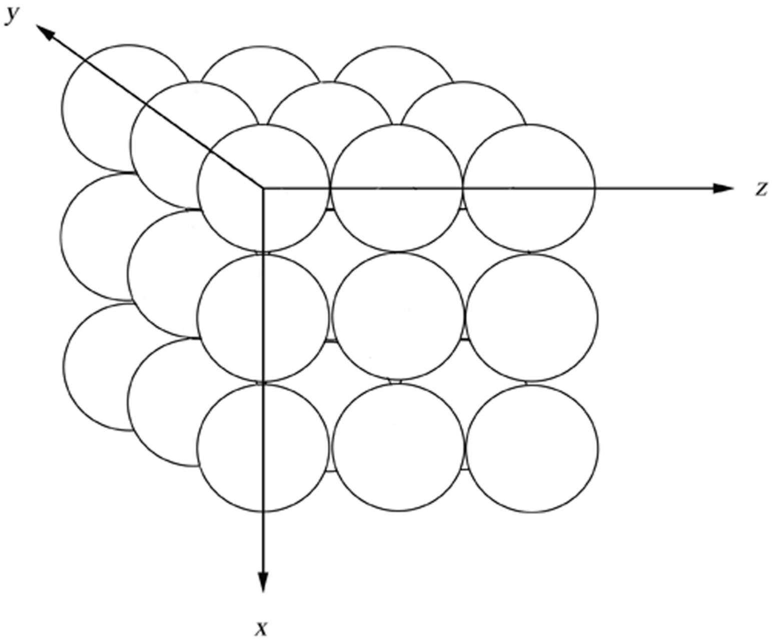

Fig. 1. *A pile of molecules of a crystalline lattice*

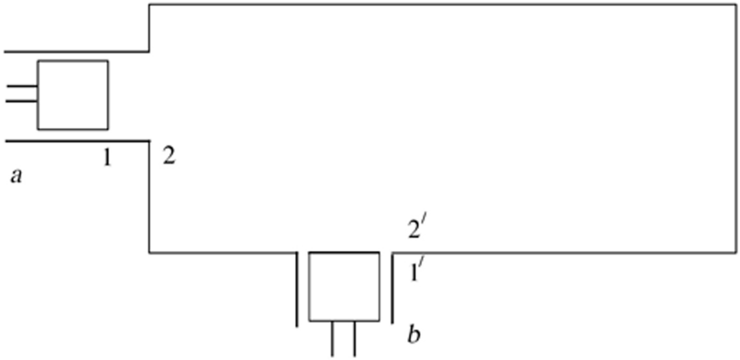

Fig. 2. *Displacement in a is transferred to b although its sound is not heard in b directly.*

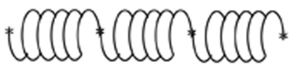

Fig. 3. *Similar point masses connected to each other by similar springs.*

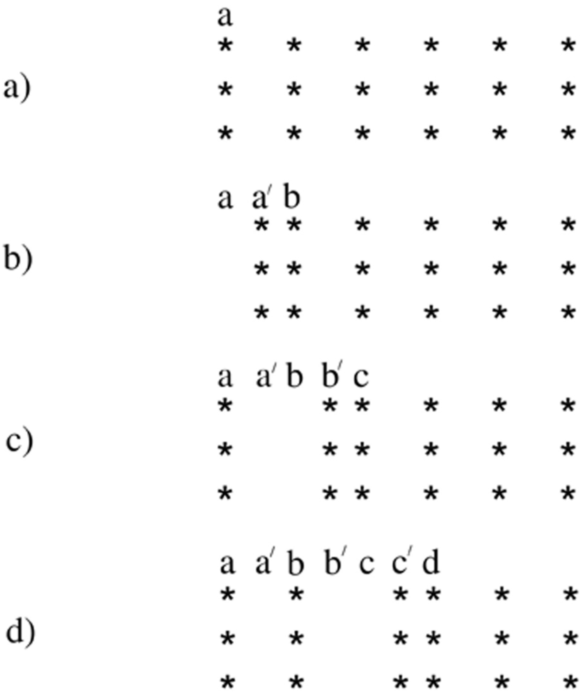

Fig. 4. *Mechanism of propagation of a longitudinal wave*

Fig. 5. *An expansion can not be propagated as a longitudinal wave*

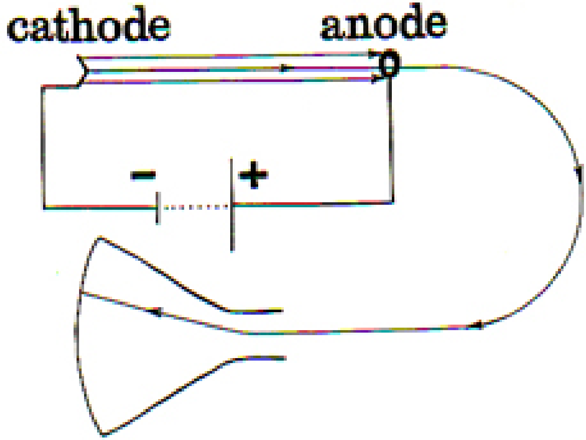

Fig. 6

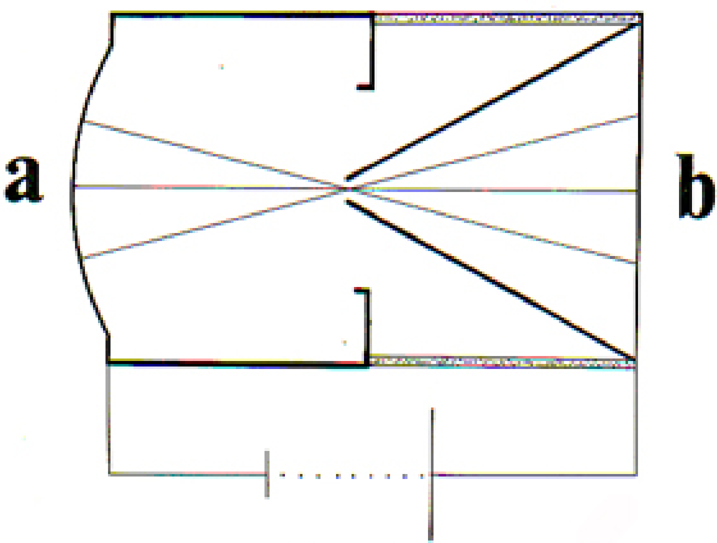

Fig. 7

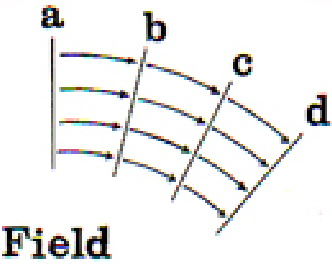

Fig. 8

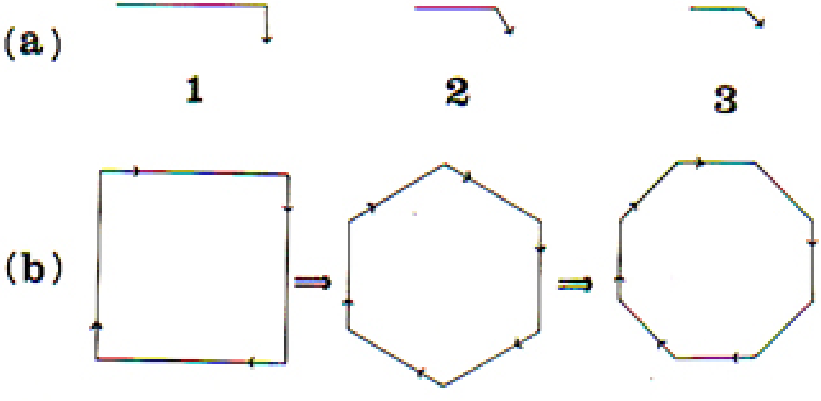

Fig. 9