

Paignton Devon

June 28. 93

14/16

Dear Fitzgerald.

I have been considering your letter of 21<sup>st</sup> to see if I could get electricity to have inertia. First of all, though, as regards the transference of the idea of momentum from  $A$  to  $B$ , I am quite willing to take the credit of it if it is offered me, though I really obtained the notion when reading Maxwell's volume 2, and thought his statement calling  $A$  the el. kin. mom. inconsistent with his theory then, though I only felt sure later. It may be that  $A$  is a kind of generalized momentum, with the current density as velocity to correspond, but I feel sure it is a very artificial kind of momentum, not suited to the propagation theory.

Now as regard "local currents", or singular electromagnetic vibrations. I look upon a piece of matter as being full of them, in virtue of the temperature not being zero. But the mean magnetic force, or electric force, is zero, if we say  $E=0$ ,  $H=0$  in Maxwell's theory. I look upon the depolarization of  $E$  (with concomitants) in a conductor as a thoroughly singular affair,

affair, and believe Ohm's law is a law of averages. Whether there is, or is not, evident  $H$  (or more strictly  $H$  with curl) depends upon the want of balance or balance of the "displacement current" and the conduction current, it being the latter that is associated with the dissipation essentially. I do not see my way to any theory of conduction currents without taking matter in the gross,<sup>i.e. arranging to obtain Ohm's law.</sup> Between molecules it must I think be all displacement current, and then a condenser discharge without  $H$  there is a balance between the  $H$  that would be evident if there were no conduction and the  $H$  ditto if no displacement. But I think conductors must always be dielectrics, though undoubtedly the elastic yielding has no sensible influence being swamped by conduction, in ordinary large units with good conductors. As for the momentum, there is momentum associated with the singular  $H$  (or  $B$  say) but it cancels out in taking averages. I don't see why the electricity shd have inertia, or the electric current (literally) have momentum.

Comparing with a spring, the work has to be done internally, not externally with visible kinetic energy. Internal purely local dissipation. Again, it requires heterogeneity I think and averages. Now here is your

significant point turning up. You will say, that even with purely internal dissipation, there is still actual bodily kinetic energy of the mass of the spring during the dissipation, though it may be only a little. So there is, but why, considered as illustrative of condenser. Because it is not a perfect analogy. To make a perfect analogy with Maxwell's theory, there must be no such Kin-energy. This raises the question of models in general. Plainly, if a model is ~~to be~~ not exactly representative of certain phenomena expressed exactly by certain equations, should we find fault with the eqns (or abstract they represent) or with the model? It may be best to make the model work in conformity; it may require special expedients, ~~as~~ massless springs, connecting rod, etc. Or, perhaps there are two ways in which models may fail. If your model ~~leads~~ to being heterogeneous, does not represent things in individual parts, ~~but~~ <sup>does</sup> in the gross, by averages, then <sup>the</sup> inertia of parts associated ~~purely~~ with potential energy is immaterial. This would only be failure in detail if failure at all. If, however, it leads to outstanding effects that ought not to be, then they ~~should~~ be ignored if possible, or done away with. Any way, the model fails. (I am myself shy of models, for two reasons. First because I am not mechanical to any important extent, & next because as regards the working out of electrical or especially electromagnetic problems it is easier to follow <sup>the behaviour of</sup> rules of diff<sup>t</sup> & induc<sup>m</sup> than the corresponding quantities in a model). You know how Kelvin's rotational ether. One way of applying it to electrical equations is to suppose the rotation (which is elastically resisted) represents el. displacement, and the potential energy of the rotation represents the electric energy. Now there are no count taken of rotational Kin. energy. You can indeed, add a term to rotation by kinetic energy. You can indeed, add a term which will bring it in. But then it will no longer correspond to the electrical theory. The explanation of the quasi-elastic resistance to rotation by kinetic energy is a distinct matter. 16/16

I certainly think that the elastic resistance in ether should go with the displacement, not with the curl of H.

As regard a perfect homogeneous conductor, I said nothing about it because it is such a very extreme case, hard to imagine. I make extensive use of perfectly conducting sheets, or boundaries, but it is much harder than you want homogeneity & no resistance to discharge.

in bulk. It is the limiting case of finite great conductivity, discharge being instantaneous. Now I can get some idea of the interpretation by concentrating the conductance. Imagine a static state of displacement in a nonconductor. Introduce any number of parallel perfectly conducting thin sheets. There will be a rapid conversion of the displacement to oscillations (electromagnetic) by the reflections and crossing of waves. This goes on between the sheets. It can be fully worked out. When you increase the number of sheets & their closeness, you increase the rapidity of the transformation. In the limit, it is instantaneous. The average  $E$  &  $H$  are zero. Energy  $\frac{1}{2} K m \cdot \frac{1}{2}$  potential. Similar, & more singular when you don't use plates, but connected cells, or any permeating structure of perfect conductance. I should think it would not be quite the same when the perfectly conducting barriers are distinct & separate, for then there would be leakage of the vibrations all round the body. In application to molecules, no doubt this motion has to be considered. Perhaps a controlling factor.]

If the initial state is one of  $H$  instead of  $E$  the case is different. The reflection is quite of a different nature, and  $H$  continues. In the limit of a perfect homog. conductor,  $H$  is constant,  $E = 0$ .

The charging of a spherical condenser (by an impressed force in connecting wires) would be very complicated in the mathematics, but I do not think it would contain anything anomalous or out of harmony with more easily worked cases.

Yours very sincerely

Oliver Heaviside.

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