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Mar 11, 1997.

Dear Mr. Catt,

Thank you for your letter and your book. I found the contents very interesting, but am afraid I have to disagree with you with regard to your assertion: "Where does this new charge come from? ... not from somewhere to the left, as such charge would have to travel at the speed of light in a vacuum." This assertion may be 'obvious to the untutored mind', is in fact incorrect.

This was argued by McEwan, but it may be easier to follow the argument if we move from the arena of electrons in a metal to the more visualisable one of boats on the Cam. Imagine we have a series of stationary boats, with uniform spacing d. At time $t0$ a pistol is fired, and each crew when it hears the pistol starts moving with velocity v (we assume for simplicity, unphysically, that the boats accelerate instantaneously to this velocity; the outcome is the same whether we assume this or not).

Each crew hears the pistol going a time d/c earlier than do the crew of the boat next in front, c being the velocity of sound, and they move forward a distance dv/c in this time. The spacing of the boats thus changes from d to $d - v/c$ as the sound pulse passes. An observer in an (aero)plane overhead would see a density discontinuity (smoothed out in the real case where the boats take time to get going), with the front moving with velocity c, since it is driven by the sound of the starting pistol.

If we change sound wave (pulse) to electromagnetic pulse, and boats to electrons, we get the situation of your 'anomaly'. It is no more necessary for the electrons to travel at the speed of light for the front to travel at the speed of light than it is for the boats to travel at the speed of sound for the front to travel at that speed: what is necessary is for there be a way for the guiding *information* to travel rapidly.

I contacted Prof. Pepper about this and enclose the email I sent him since it includes a more detailed analysis. He told me that he had been under the impression that you were talking about a waveguide not a transmission line, and had addressed his comments to that situation (he makes this impression as to what the issue is quite clear in the letter from him that you reproduce, hence I think your comments on this letter are rather aimed at the wrong target).

In any event, the upshot after discussion with Pepper seems to be that all three 'experts' at the Cavendish are currently in agreement (here I am guessing what Howie said, since you do not give details).

I am afraid that from my analysis there is no Catt anomaly (disagreement with

Maxwell's equations), but only an instructive Catt paradox (dissgreement with what intuition tells one). Nevertheless I find your 'experiment' of sending the same question to large numbers of 'experts' quite interesting, as the reactions parallel those that I get when I bring up subjects such as the paranormal and homeopathy with people — when orthodoxy is under threat, rightly or wrongly it makes no difference, hasty gut reactions tend to take the place of science.

Yours sincerely,

Brian Josephson

P.S. You may if you feel it necessary circulate this, and also the attached letter to Pepper, but I would appreciate your letting me know your intentions if you do plan to do this.

Previous letter to Prof. Pepper:

>
>
> ... I've received a letter from one Ivor Catt raising the question of
> what happens if a step voltage is applied to a transmission line, which
> question I gather the Master passed on to you for a response. Catt's book
> reveals an interesting variety of replies. It seems to me that the correct
> answer lies along the following lines:
>
> 1) After the step has passed we have a steady voltage across the lines, and
> there must be a corresponding charge per unit length on each line of +- CV,
> where C is the capacitance of the line per unit length and V the voltage.
>
> 2) This charge cannot be entirely explained by displacement of charge from
> the interior (your explanation), since charge is conserved and such
> displacements would not alter the net charge per unit length.
>
> 3) It must therefore come from the left. In fact a current V/Z, where Z is
> the characteristic impedance of the line, is to be expected, and presumably
> a simple calculation would show this to be exactly what is needed to create
> the charge left on the line.
>
> 4) Your, and Catt's assertion that this cannot happen (and the official IEE
> response also) because the electrons do not travel at the speed of light,
> is incorrect, as noted by Neil McEwan. What actually happens is that an EM
> pulse travels along the line at the speed of light and this gives a kick to
> the electrons locally to get them moving at the right speed. At the edge
> of the step there is a very large electric field as the voltage changes
> discontinuously (assuming zero resistance; as McEwan observes; the step
> will spread out (and also attenuate) if there is any resistance). What
> limits the resulting current is not inertia (though this would limit how
> fast it would rise), but back-emf.

>
> 5) There is however some degree of truth in your assertion about electrons
> coming from the interior, because the charge distribution that one ends up
> with is on the surface while the current that feeds it is distributed
> uniformly through the cross-section of the conductor.
>
> 6) The plot thickens at this stage, because if the conductor really had
> zero resistance it would be a superconductor and the current would flow
> only on the surface, so assertion 5 would be incorrect. A realistic model
> must put attenuation in.
>
> 7) The resulting situation must have some resemblance to what happens if
> one suddenly applies a voltage across a length of wire: at first the
> current will flow on the surface, and then with the relevant characteristic
> time it will spread itself more uniformly.
>
> 8) My conclusion: the Catt anomaly is quite a tricky problem, so it is not
> surprising that different people, even very distinguished people, come to
> different conclusions about it (however, I'm sure Brian Pippard would have
> got it right immediately had he been asked!). To a first approximation 1-4
> above provide the answer, but to answer questions about the distribution of
> current through the wire in the transient phase near the step one would
> have to get down to solving differential equations, either numerically or
> finding suitable approximations. It is a tricky situation to have to
> puzzle over, but I see no reason to consider it challenges orthodox
> physics. What do you think?
>
>
> Best wishes,
>
>
> Brian
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