The death of electric current

A contribution to electromagnetic theory

by Ivor Catt CAM Consultants

Conventionally a signal can be understood either in terms of electricity in conductors, with associated fields, or in terms of electric and magnetic fields terminating on those conductors. In this article the author steps outside the accepted dualism and proposes a mechanism of signal transmission based on Oliver Heaviside's 'energy current' without recourse to 'conductors' in their conventional role.

A major advance in electromagnetic theory, which I shall call the transition from Theory N to Theory H, was made by Oliver Heaviside a century ago. What is proposed here is a transition from Theory H to a third theory, Theory C. It is to be hoped that the response to Theory C will be more perceptive than was the general response to Theory H a century ago, as typified by Sprague, quoted in this article. Until it was revived recently by CAM Consultants, Theory H had been ignored and then suppressed for a century. It was revived because of its great value in digital electronic design.[1,2]

Theory C has major implications across a whole spectrum of subjects. It could trigger an exciting renaissance in many fields of endeavour.

Whereas the conventional approach to electromagnetic theory is to concentrate on the electric current in wires, with some additional consideration of voltages between wires, Heaviside concentrates primarily on what he calls 'energy current', this being the electromagnetic field which travels in the dielectric between the wires. It has an amplitude equal to the Poynting Vector, $E \times H$. Heaviside's phrase, "We reverse this"; points to the great watershed in the history of electromagnetic theory – between the 'ethereals', who with Heaviside believe that the signal is an 'energy current' which travels in the dielectric between the wires, and the 'practical electricians', who like Sprague believe that the signal is an electric current which travels down copper wires, and that if there is a 'field' in the space between the wires, this is only a result of what is happening in the conductors.

Oliver Heaviside announced Theory H a century ago[3]:

"Now in Maxwell's theory there is the potential energy of the displacement produced in the dielectric parts by the electric force, and there is

the kinetic or magnetic energy of the magnetic induction due to the magnetic force in all parts of the field, including the conducting parts. They are supposed to be set up by the current in the wire. We reverse this; the current in the wire is set up by the energy transmitted through the medium around it . . ."

The importance of Heaviside's phrase, "We reverse this;" cannot be overstated. It points to the watershed between the 'practical electricians', who have held sway for the last half century, promulgating their theory – which we shall call 'Theory N', the Normal Theory: that the cause is electric currents in wires and electromagnetic fields are merely an effect – and the 'ethereals', who believe what we shall call 'Theory H': that the travelling field is the cause, and electric currents are merely an effect of these fields.

Opposition to any attempted change from the familiar Theory N to Theory H was forceful and successful for the next century. Sprague, a 'practical electrician' wedded to Theory N, with its retention of a phlogiston-like 'fluid'*, electricity, at the centre of the electromagnetic stage, wrote[4]:

"A new doctrine is becoming fashionable of late years, devised chiefly in order to bring the now important phenomena of alternating currents under the mathematical system. It is purely imaginery . . . based upon Clerk-Maxwell's electromagnetic theory of light, itself described by a favourable reviewer as 'a daring stroke of scientific speculation,' alleged to be proved by the very little understood experiments of Hertz, and supported by a host of assumptions and assertions for which no kind of evidence is offered; but its advocates now call it the 'orthodox' theory.

"This theory separates the two factors of electricity . . ., and declares that the 'current', the material action, is carried by the 'so-called conductor' (which according to Dr Lodge contains nothing, not even an impulse, and according to Mr O. Heaviside is to be regarded as an obstructor), but the energy leaves the 'source' (battery or dynamo) 'radiant in exactly the same sense as light is radiant', according to Professor Silvanus P. Thompson, and is carried in space by the ether: that it then 'swirls' round (cause for such swirling no one explains) and finds its way to the conductor in which it then produces the current which is apparently merely an agency for clearing the ether of energy which tends to 'choke' it, while the conductor serves no other purpose than that of a 'waste pipe' to get rid of this energy . . .

"This much, however, is certain; that if the 'ether' or medium, or di-electrics carry the energy, the practical electrician must not imagine he can get nature to do his work for him; the ether, &c., play no part whatever in the calculations he has to make; whether copper wire is a conductor or a waste pipe, that is what he has to provide in quantity and quality to do the work; if gutta percha, &c., really carry the energy, he need not trouble about providing *for that purpose;* he must see to it that he provides it according to the belief that it prevents loss of current. In other words, let theoretical mathematicians devise what new theories they please, the practical electrician must work upon the old theory that the conductor does his work and the insulation prevents its being wasted. Ohm's law (based on the old theory) is still his safe guide.

"For this reason I would urge all practical electricians, and all students who desire to gain a clear conception of the actual operations of electricity, to dismiss from their minds the new unproved hypotheses about the ether and the abstract theory of conduction, and to completely master the old, the practical, and common sense theory which links matter and energy together, . . . "

* Phlogiston was a 'subtle fluid' postulated by the German chemist G. E. Stahl (1660-1734). It was thought to be combined with a 'calx' or ash in combustible materials and to be given off by these materials in the process of burning, leaving the ash behind. This hypothesis was strongly held in the 18th century but was eventually upset by Lavoisier's deductions leading to the theory of the conservation of mass. – Ed.

Sprague accurately described Theory N.

One of the few supporters of Theory H was J. A. Fleming, who wrote[5]:

"It is important that the student should bear in mind that, although we are accustomed to speak of the current as *flowing in the wire* in one direction or the other, this is a mere form of words. What we call *the current* in the wire is, to a very large extent, a process going on in the space or material outside the wire. Just as we familiarly speak of the sun rising and setting, when the effect is really due to the rotation of the earth, so the ordinary language we use in speaking about electric currents flowing in conductors retains the form impressed upon it by older and erroneous assumptions as to their nature."

Heaviside's view

As time went by, support for Theory H gradually died out. Let us end Theory H with a long discussion by its originator[6]:

"Consider the electric current, how it flows. From London to Manchester, Edinburgh, Glasgow, and hundreds of other places, day and night, are sent with great velocity, in rapid succession, backwards and forwards, electric currents, to effect mechanical motions at a distance, and thus serve the material interests of man.

"By the way, is there such a thing as an electric current? Not that it is intended to cast any doubt upon the existence of a phenomenon so called; but is it a current – that is, something moving through a wire? Now, although nothing but very careful inculation at a tender age, continued unremittingly up to maturity, of the doctrine of the materiality of electricity, and its motion from place to place, would have made me believe it, still, there is so much in electric phenomena to support the idea of electricity being a distinct entity, and the force of habit is so great, that it is not easy to get rid of the idea when once it has been formed. In the historical development of science, static phenomena came first. In them the apparent individuality of electricity, in the form of charges upon conductors, is most distinctly indicated. The fluids may be childish notions, appropriate to the infancy of science; but still electric charges are easily imaginable to be quantities of a something, though not matter, which can be carried about from place to place. In the most natural manner possible, when dynamic electricity came under investigation, the static ideas were transferred to the electric current, which became the actual motion of electricity through a wire. This has reached its fullest development in the hands of the German philosophers, from Weber to Clausius, resulting in ingenious explanations of electric phenomena based upon forces acting at a distance between moving or fixed individual elements of electricity.

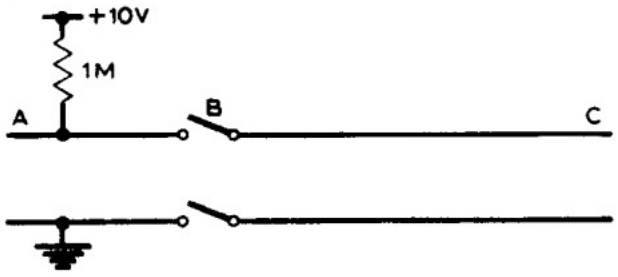
"Return to our wire from London to Edinburgh with a steady current from the battery in London. The energy is poured out of the battery *sideways* into the dielectric at a steady rate. Divide into tubes bounded by lines of energy-current. They pursue in general solenoidal paths in the dielectric, and terminate in the conductor. The amount of energy entering a given length of the conductor is the same wherever that length may be situated. The lines of energy-current are the intersections of the magnetic and electric equipotential surfaces. Most of the energy is transmitted parallel to the wire nearly, with a slight slant towards the wire in the direction of propagation; thus the lines of energy-current meet the wire very obliquely. But some of the outer tubes go out into space to an immense distance, especially those which terminate on the further end of the wire. Others pass between the wire and the earth, but none in the earth itself from London to Edinburgh, or vice versa, although there is a small amount of energy entering the earth straight downwards, especially at the earth "plates". If there is an instrument in circuit at Edinburgh, it is worked by energy that has travelled wholly through the dielectric, then finding its way into the instrument . . ."

If we keep to Theory H, the theory that the field $E \times H$, travelling along between

the wires at the speed of light – what Heaviside called the 'energy current', is the cause, then electric charge and electric current are merely what define the *edge* of an energy current. If electric current is that which defines the side of an energy current, then we may with equal justification postulate 'displacement current' as that which defines the front face of a step of energy current[1].

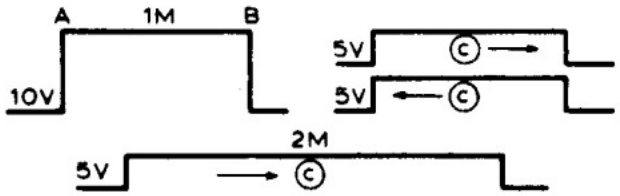
Now let us move on to Theory C, when we drop the dualism – circuit and field – that has until now been the foundation of electromagnetic theory. First we shall discuss the reed relay pulse generator, which illustrates some of the ideas underlying Theory C.

The reed relay pulse generator was a means of generating a fast pulse using rather primitive methods. A one-metre section of 50-ohm coaxial cable AB was charged up to a steady 10 volts (say) via a one megohm resistor, and then suddenly discharged into a long piece of coax BC by the closure of two switches.



A five-volt pulse two metres wide was found to travel off to the right at the speed of light for the dielectric on closure of the switches, leaving the section AB completely discharged. (The practical device lacked the second, lower switch at B, which is added in the diagram to simplify the argument).

The curious point is that the width of the pulse travelling off down BC is twice as much as the time delay for a signal between A and B. Also, the voltage is half of what one would expect. It appears that after the switch was closed, some energy current must have started off to the *left, away* from the now closed switch; bounced off the open circuit at A, and then returned all the way back to the switch at B and beyond.



This paradox, that when the switches are closed, energy current promptly rushes *away* from the path suddenly made available, is understandable if one postulates that a steady charged capacitor is not steady at all; it contains energy current, half of it travelling to the right at the speed of light, and the other half travelling to the left at the speed of light.

Now it becomes obvious that when the switches are closed, the right-wards travelling energy current will exit down BC first, immediately followed by the leftwards travelling energy current after it has bounced off the open circuit at A.

We are driving towards the principle that *energy (current) $E \times H$ cannot stand still; it can only travel at the speed of light.* Any apparently steady field is a combination of two energy currents travelling in opposite directions at the speed of light[7].

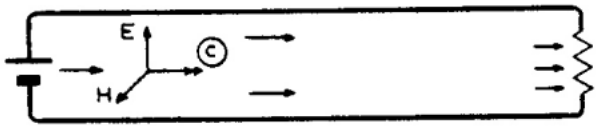
E and H always travel together in fixed proportion Z_0.

Electric charge does not exist according to Theory C. The so-called electric charge is merely the edge of two reciprocating energy currents. In the case of the so-called steady charged capacitor, the

electric fields of the two energy currents add but the magnetic fields cancel, so that

it has come to be thought that a charged capacitor is devoid of magnetic field.

Now let us consider a simple circuit with battery and resistor. Two conductors guide the energy current from battery to resistor. It enters the resistor *sideways*



(Kip 1962)[6]. 'Electric current' is merely the side of a wave of energy current. If a 'conductor' is perfect, the energy current has a sharp side; the so-called 'electric current' has infinite density in the outside surface of the 'electric conductor', which Heaviside called an obstructor.

Energy current penetrates an imperfect conductor in the same way as it enters a resistor, from the side. In this case, the region containing a variation in energy current density, the so-called 'electric current', widens and penetrates into the conductor; skin depth is no longer zero.

Nothing exists behind a mirror; nothing happens there. The velocity of the 'things' behind a mirror does not depend on the medium, or material, behind the mirror[8].

As Maxwell's equations show,[9] 'electric current' is always derivable as the gradient on the side of a wave of energy current. Unlike energy current (but like the immages in a mirror), electric current contains no energy, it has no function, and it explains nothing. Electric current does not exist.

Although a cloud cannot exist without edges, the *edges* of a cloud do not exist. They have no width, volume, or materiality. However, the *edges* of a cloud can be drawn. Their shapes can be manipulated graphically and mathematically. The same is true of the so-called 'electric current'.

In the following analogies, the sheep represent energy, the dogs electricity.

Theory N. The sheep are forced out of the pen by the sheep-dogs. The dogs then run alongside the sheep. There can only be a forward flow if sheep-dogs first advance on both sides of the flow of sheep, which the dogs direct and cause.

Theory H. The sheep rush out of the pen into the great open spaces. They will go forward regardless, but their direction is actively guided by the sheep-dogs running alongside, the front of the line of dogs always keeping level with the foremost sheep.

Theory C. There are no sheep-dogs. The sheep leave the pen and flow out into the great open spaces. Some of the space is rougher. (This rough space was previously thought to be the terrain preferred by the dogs.) Here fewer sheep go, and their rate of advance is slower. Some ground is very obstructive, nearly impassable for sheep.

Although it might appear that the sheep are actively guided by the rough terrain towards the smooth terrain, this is not so. Neither does a grease mark on blotting paper actively guide the ink towards the ungreasy areas. There is no active guidance mechanism; greasy paper is merely bad blotting paper with poor capillary action, passively guiding the ink.

The excision of sheep-dogs from the theory is a giant simplification. Nothing

flows in the conductor; nothing happens therein. Heaviside was right to call it an obstructor. Half of the primitives in electromagnetic theory disappear, and it ceases to be a dualistic theory. ρ and $\mathcal{J}$ disappear, becoming merely the physically non-existent results of the mathematical manipulation of E and H, with no more significance than "circularity"' (Letters, June 1979 issue, p. 82).

The direct transition from Theory N to Theory C is similar to the change in combustion theory from phlogiston to oxidation, but is more difficult. Phlogiston is very similar to electricity, being a strange 'fluid' which permeates solids. But whereas the oxygen which 'replaced' phlogiston was still within the same body, the energy current which replaces electricity is not where the electricity was; it is where it was not. This is a very difficult transition. If the idea of replacing the well known phlogiston by oxygen caused mirth at High Table, we have to expect Theory C to generate widespread hilarity.

I would like to thank David Walton and Malcolm Davidson of CAM Consultants for their dogged support for six years. This article is taken from the book Electromagnetic Theory Vol 2, pub. CAM Publishing, 17 King Harry Lane, St. Albans, England.

References

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8. Catt, I., 1979, Electromagnetic Theory Vol 1, pub. CAM Publishing, p.93.
9. Bell, D. A., 1980, *Wireless World*, September 1980, p.50, first sentence.

Appendix

Definition of a perfect conductor: $\epsilon=\infty$.
It follows that velocity of energy current

$$=\frac{1}{\sqrt{\mu\epsilon}}=0$$

Impedance $Z_0=\sqrt{(\mu/\epsilon)}=0$

In an imperfect conductor, ϵ is very high.
Impedance $(=Z_0)\rightarrow 0$
Penetration velocity is very slow. □

DISPLACEMENT CURRENT

Dozens of people in this country, professors and Nobel Laureates, have gained financially from the subject of electromagnetic theory. Something is expected from them in return. It would be a great shame if Professor D. A. Bell, the only man among them who has bothered to contribute to the discussion in *Wireless World*, should suffer thereby. We should congratulate him for standing up to be counted.

Ivor Catt
St Albans
Herts.

DISPLACEMENT CURRENT

In order to avoid any suggestion of 'increasing the noise level' in this seemingly interminable correspondence (November letters) I will limit myself to one fact, one question and one comment.

(1) The fact. My reference to Hobbes' *Leviathan* was correct. I noticed it in 1943 and verified it in 1978.

(2) The question. A body continues in motion *or at rest* unless disturbed by some force. Electromagnetic radiation has momentum, so once launched it appears to behave according to Newtonian mechanics. If there be 'energy current' what force accelerates it (instantaneously?) to the velocity of light?

(3) The comment. L.H. Higgins says in November letters that Catt, Davidson and Walton "only need to define what they mean by energy current". But so far they have not done so and I do not believe they can.

D.A. Bell
Beverley, Yorkshire

THE DEATH OF ELECTRIC CURRENT

I refer to the interesting article by Mr Ivor Catt in your December 1980 issue. It is indeed refreshing to find Mr Catt having a sideways look at the apparently trivial matter of electric current.

If one rewrites the Maxwell equations using tensor notation in a four dimensional Riemannian Space, the effects predicted by Mr Catt become more obvious. E and H cease to have separate meanings, removing that most embarrassing of dualisms and the electromagnetic field (complicated in three dimensions) becomes a simple tensor field in four dimensions.

N. D. Levin
Telecommunications Accessories Ltd
Thame
Oxon

The author replies:

It's a pity that the obfuscation has to continue like this. I did not realize that my December 1980 article predicted any effects. What were they?

Ivor Catt

THE DEATH OF ELECTRIC CURRENT

If Ivor Catt had read physics instead of engineering he might not now spend so much time agonizing over the "right" mechanistic model for processes which, in reality, are outside the area of our everyday perception (December 1980 issue, p. 79). It is true that what is happening in a charged capacitor can be considered to be the result of interference between two waves travelling in opposite directions, but it is easier to consider it as a distribution of charged particles. Similarly, one can map the currents flowing in the walls of a waveguide, but only a fool would treat waveguide theory in terms of current electricity.

E and H have no more physical reality than do ρ and J, being merely constructs in mathematical models. The usefulness of any mathematical model is measured by the accuracy of its predictions and the ease with which those predictions may be obtained. Although there is no real difference between predictions from the two models, in general it is easiest to use current theory for low frequency, or long term or continuous situations and e-m waves for high frequency or short duration or quantized situations. (This is a broad generalization and, like all such, has exceptions, so please don't rush to quote them at me!)

The proof of any pudding is in the eating. The machines on which much of our civilization is founded (that is, alternators and motors) are designed with the aid of the electric current model. You may not like civilization, but, clearly, the designs work. However, to say that electromagnetic theory has been ignored and suppressed is blatantly untrue. Where appropriate, e-m theory has been used in design; the delay-line modulator, developed to pulse radar magnetrons, is an example. That there are few others that spring to mind is indicative only of the historical superiority of the current model.

To use an overworked phrase, it is simply a matter of horses for courses. Mr Catt and his colleagues believe that the digital microelectronics course is one for which their rediscovered horse is superior. This may be so, but it is hardly justification for an attempt to put down the other contestant.

R. T. Lamb
Post Office College of Engineering Studies
Milton Keynes, Bucks

The author replies:

In his first paragraph, I think Mr Lamb has reversed physicists and engineers. I find the "charged particles" in a capacitor very difficult to consider, in view of their apparant need to shoot off instantaneously at the speed of light (for the dielectric) from a standing start when the capacitor is discharged. I wonder if our brothers the electrons consider it easy; or can a TEM step advance down a transmission line at the speed of light *without* any electrons being required to change velocity so abruptly? I consider such questions far from easy – hence Theory C.

Regarding para. 2, if neither E, H, ρ nor J have physical reality, then what does have physical reality? You seem to have ruled out the physical reality of electromagnetism – a far bolder step than my modest Theory C, which merely gets rid of ρ and J. The first sentence of this paragraph could come straight out of Osiander or Berkeley, and is discussed by Popper under the title "The Science of Galileo and its new betrayal" (K. Popper, "Conjectures and refutations", RKP 1963, page 97. See also M. Polanyi, "Personal Knowledge", RKP 1958, pages 145-147). I agree with Kepler that "It is indeed a most absurd fiction to explain natural phenomena by false causes." Bruno was burnt alive for taking this stand against the mediaeval church (and Lamb).

Regarding para. 3, as with Lamb, my work on alternators, motors etc. never led me to question Theory N. However, my work on high speed logic *did*. I have not said that electromagnetic theory has been ignored and suppressed. As to the suppression of Heaviside, you will not find mention of him in books on electromagnetic theory published during the last fifty years. It is scandalous the way he has been ignored and suppressed, in view of the great contribution he made to the subject. (Lamb seems to call Theory N "the current model" and Theory H "e-m theory".)

Regarding para. 4, I am perfectly happy to see people use Ohm's Law and current meters far into the future. I shall do so myself. This is not the same question as fundamental theory. Theory H has been re-discovered and found valuable in digital electronics. Theory C has only recently been discovered.

THE DEATH OF ELECTRIC CURRENT

My thanks to Ivor Catt for giving me a good laugh at myself for nearly being duped. I read his article "The death of electric current" (December 1980 issue) carefully, and then came to the analogies. Memorable things analogies (witness that damned mutual impedance somewhere in the hot water system), but so dangerous.

The theory C analogy succeeded in giving me a vivid picture of Catt's travelling wave packets going out into the world along what I used to think were insulators, but which I now see are the very opposite. But just a minute, isn't that the philosophical point from which I started: something travelling along the easiest path? It's just back to the wave-particle duality. They're in different places, that's all. I honestly don't know which to call correct and I should like to hear if Catt will swear that nothing that exists is a particle. The trouble with theoreticians is that they can begin to speak as if their self-consistent mathematics were the fact. OK Catt, your maths may be right, and I don't doubt that it is more helpful in your field of practical endeavour, but for me the AVO meter theory of electrical current has more deductive and predictive power. My money goes on Sprague, but when I need you, Catt, I'll gladly acknowledge it. In the meantime please don't put me down as a fool because I tend to live my life close to one side of the duality only. (I never got a shock from an insulator yet.)

The reference to the phlogiston theory was a red herring; *that* was proved by experiment to be untenable.

J. H. J. Dawson
Amsterdam
Netherlands

The author replies:

The duality (Theories N and H) inherent in classical electromagnetism is not the same thing as wave-particle duality. (See for instance D. A. Bell, *Wireless World* Sept. 1980, page 50, first para.) As to "They're in different places, that's all," my reply is that the location of a thing is one of its most important characteristics. As to ". . . . . nothing that exists is a particle," it depends what you mean by 'particle'. I have no sympathy for the billiard ball idea, and no sympathy for the notion of wave-particle duality. The idea of wave-particle duality could probably only have been concocted by people who did not know Heaviside's concept of a slab of energy current, now called the Heaviside signal (see *Wireless World*, July 1979). In these particular matters my view coincides with Einstein's;

> ". . . . . We all of us have some idea of what the basic axioms in physics will turn out to be. The quantum or the particle will surely not be amongst them; the field, in Faraday's and Maxwell's sense, could possibly be, but it is not certain."
>
> "Quantum Mechanics and Reality. In what follows I shall explain briefly and in an elementary way why I consider the methods of quantum mechanics fundamentally unsatisfactory."
>
> (Max Born, "The Born-Einstein letters", pub. Macmillan 1971, pp. 164, 168.)

The most prominent feature of the maths of "OK Catt" is its virtual non-existence. E-m theory was buried in nonsensical, complex maths a long time ago, and I am extricating it. (See "Maxwell's equations revisited", *Wireless World*, March 1980, pp 77-78.)

(I would get a real shock if I got a shock from a conductor.)

Ivor Catt
St Albans

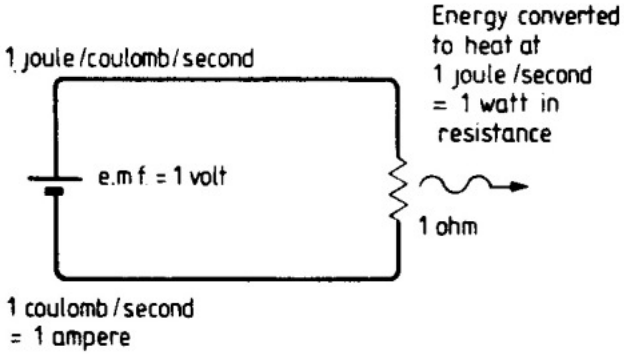
Comment in 2011. Here, in August 1981, Peter G. M. Dawe of Oxford led me to my first enunciation of the flaw in classical theory now called "The Catt Question". It is not easy to see such a flaw in a ruling paradigm.

WIRELESS WORLD AUGUST 1981

THE DEATH OF ELECTRIC CURRENT

Mr Ivor Catt's very interesting article in your December 1980 issue obviously calls for some discussion, since, if he is correct in his analysis it would imply that a lot of our fundamental teaching in electronics is wrong.

Let me recapitulate first, simply, on the Normal theory of electric current flow. It is now widely taught that in the following circuit the electric current consists of a flow of electrons, between adjacent atoms which make up the material of the wires; the electrons either carrying, or being, elements of electric charge. The



charges are given energy by the electromotive force of the battery, such that if 1 coulomb (6.24×10^{18} electrons) of charge is raised through a potential difference of 1 volt, it acquires 1 joule of energy; which is then expended when the current (rate of flow of charge) flows through the external circuit resistance. If the charge is flowing through the wire at 1 coulomb/s, then the current is said to be 1 ampere, and the resistance of the circuit would be 1 ohm; while the energy of the current would be dissipated (e.g. converted into heat) by resistance, at the rate of 1 watt, or 1 joule/s.

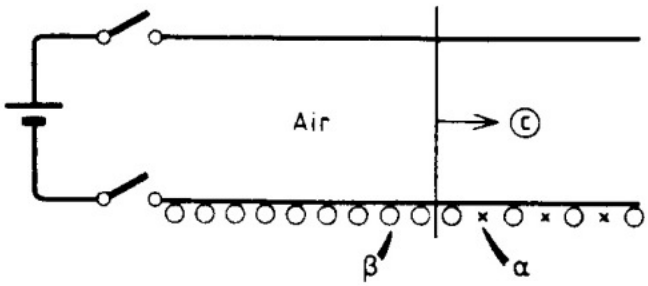
It would seem from the successes we have had, for example, in making colour television, radio and stereo systems available to so many people, that these circuit fundamentals must be quite a valid and useful way of thinking. I am also at a loss to see how Mr Catt can develop his theory of the battery and resistor, with the 'energy current' entering the resistor sideways (on p. 80, December issue) into giving such useful quantitative concepts as the above circuit does; but maybe he doesn't want to, at present. It would seem, however, that he is at least asking us to lay aside our hypotheses about the existence of protons, electrons, and therefore presumably even atoms; for we are told that electric charge does not exist, and nothing flows in a conductor. This could indeed be revolutionary.

As a philospher, I am only in sympathy with Mr Catt's initiative. Although I can't really follow the flight of his imagination at present, I have argued elsewhere ("Mind & Machine," *The Listener*, Oct. 17th, 1963) that the concepts and inventions of physics, and indeed the Universe itself, should be understood in terms of the concept of imagination, e.g. of the writing of scientists, and not vice versa. My attempt to argue this viewpoint however, i.e. that scientific knowledge does not have to be taken literally as ultimate truth, was not very well received, and I was accused of 'dangerous obscurantism'. It may, I suppose, one day be possible to explain the 'imaging' or 'imagining' function of the brain in physical concepts. However, although I wish Mr Catt every success in developing his imagination and new theories, I think he should be warned, or reminded, that the imagination of scientists does have to be supported, or tested, by observations and experiments. In short, it seems that he may be unwise in reviving a Heaviside theory, published in 1892, and in quoting J. A. Fleming (1898) and Clerk Maxwell (1831-1879), who lived before the discovery of the electron (1897), through the experiments of J. J. Thomson, had become well known and accepted.

Peter G. M. Dawe
Oxford

The author replies:

Mr Dawe's recapitulation, para. 2, deals with a so-called "steady state" situation. Conventional theory covers for these quite well; it was developed for that purpose. However, conventional theory cannot cope with the transient condition, as we shall see. Consider the situation ¼ nanosecond after we close the switches in the diagram below.



A voltage-current step has advanced three inches to the right. Behind the step, there is a voltage drop between the wires. The E lines must terminate on electrons in the lower wire. It follows that behind the step the lower conductor contains more electronics per inch than is contained in the uncharged section ahead of the step.

As the step advances further forward, extra electrons must appear in locations such as α to terminate the new E lines involved in the voltage difference which now exists in the next inch of transmission line.

Where does the electron come from to fill the next gap α as the step front advances forward? It cannot be one (say β) from behind the step, because this electron is not travelling at the speed of light. For β to arrive at location α in time, it would have to travel at the speed of light, since the voltage-current step is travelling forward at the speed of light (for the dielectric). A central feature of conventional theory (N or H) is that the drift velocity of electric current is slower than the speed of light. Therefore Theory N, where electric current is the *cause* and $E \times H$ field an effect, breaks down for the simple reason that a cause travelling slower than the speed of light cannot create an effect travelling *at* the speed of light. It seems clear that if we retain a dualistic theory (N or H), the present discussion forces us to conclude that Theory H obtains; the cause must be the $E \times H$ field in the dielectric, energy current, which does travel at the speed of light, and the slower electric current in the wire is merely an effect of that cause.

I would agree with Mr Dawe, para. 3, that practical success would tend to indicate that our fundamental theory is sound. However, counter-instances abound. Lacking sound theory, the Romans still built many impressive bridges. Like Mr Dawe, I shall use whatever suits me to calculate dissipation in resistors, etc. We do not have to use the theory we believe, when it is inconvenient, rather than travel by another more convenient path in our day-to-day affairs. Calculation of the steady current from a (car) battery to a resistor (car headlamp) will not become the stamping ground for theoretical discord. Similarly, I think quite happily about how to avoid "losing the cold" in my deep freeze. There is a time and place for theories. The policeman who charges you with driving without due care and attention should not have to bother with Newton's Laws of Motion, and is not charging you for ignoring them.

With regard to the last paragraph, the electron is not necessary (indeed, it creates major problems) in explaining the passage of a TEM step guided between two conductors. Should it be necessary in other situations, it can be expected to turn out to be a standing wave energy current. This was proposed by Schrödinger. Jennison's design of such a structure (*Wireless World* June 1979, pages 45-47) goes wrong because, like so many others, he is trapped within the conceptual confines of the sine wave. Once you drop the sine wave, it is not difficult to construct an "electron" out of energy current. (However, it would then be illogical to hold onto Theory N or Theory H, since energy current would then be bordered by energy current (i.e. electrons). Similarly, once it is realized that a capacitor is a transmission line, it is not logical to retain the alternate lumped L and C (transmission line) model for the transmission line.)

I think the first part of the last paragraph, like Osiander, is wrong. It is a tragedy that virtually all contemporary scientists are siding with the mediaeval church against Galileo. I stand with Galileo, Bruno and Kepler, but unlike Bruno I shall not be burnt alive for it. (See M. Polyanyi, "Personal Knowledge", RKP 1958, pp. 145-6.) As to the second part of the last para., I am making *discovery*, not indulging in imagination. As to the electron, although I may allow the existence of the standing-wave electron, I find the billiard-ball electron incomprehensible. Like Einstein, I do not accept the quantum. (Max Born, "The Born-Einstein Letters", Macmillan 1971, pp. 164, 168.) However, this does not bear directly on Theory C, which merely removes the (possibly in other situations surviving) electron from the theories of (a) the "steady charged capacitor" and (b) "electric current in a wire".

Ivor Catt

THE DEATH OF ELECTRIC CURRENT

I was pleased to note that Ivor Catt, in his reply to my letter (March issue), gave yet another example of the truth of its principal assertion. Before dealing with this latest example of nit-picking, it would seem advisable to tackle the question of reality. I think that most readers of this journal would agree with the physical reality of the phenomenon whereby energy converted at one location can be transferrred, with or without the aid of an intervening medium, to a distant location. If you wish to call that electromagnetism, then, certainly, electromagnetism exists. However, to explain the phenomenon we have developed, over the years, a complicated model which includes such concepts or constructs as E, H, ρ and J. Since they are part of the model, these constructs no more have reality than a ventriloquist's dummy has life. As a further consequence, any model that shows that electric current does not exist shows nothing more than that electric current is not needed in that model.

The credibility of a model, or its implications, can be a stumbling block. Kepler's problem was that the central construct of his model could be refuted by the observations of any normally-sighted layman on a fine day! Clearly, the attitudes of electrons to the implications of the electric current model are beyond conjecture. Whether we see the detail seized on by Mr Catt as a problem depends on how we model electrons themselves; if we see tham as diminutive billiard-balls, then Mr Catt's problem may be real, but if we use a probabilistic model things may not look so bad. In any case, credibility may be affected by extraneous factors, such as religious beliefs (Kepler again) so that other means are used to test the viability of a model.

We require first that the model be mathematically rigorous (and I have been led to believe that Heaviside tended to be lax in this respect) and then test the model in the light of its agreement with observations. Hence, Kepler's model survived because it fitted stellar and planetary observations better than its rivals. Similarly, electric current theory gives results that agree well with observations –

$$i = I_0 e^{-\frac{t}{CR}}$$

gives a close fit to the observable effects when a capacitor discharges through a resistor. The finer the detail of the agreement, the better the model, although it never becomes reality.

Now physicists realise that models can be refined, or replaced by better ones, so that the other test concerns the predictions of the model. What new facts or relationships does the model offer, and can they be tested by observation? Note that a model is not refined simply by making its structural details more credible to the user, because of the subjective nature of that assessment. If Mr Catt has, indeed, a better model could he not tell us either where it gives better agreement with known results or what testable predictions it makes? Until then, I suspect that most of us will continue to muddle through with the current version.

To end on a personal note, I would like to assure Mr Catt that there is no truth in the rumour that it was I who applied the torch to Bruno's pyre.

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C.A.M.

Concepts in physics

Although I work in the field of electronics, I am by both training and inclination a physicist, and it is in this field that I have earned my living for the past thirty years. It is in this context, therefore, that I have watched with growing dismay and dissatisfaction the trend of theoretical and academic physics towards progressively more weird and seemingly irrational concepts.

As a physicist, one could look back with an amused tolerance at the absurd notions of phlogiston and caloric and essential spirits having negative weight, summoned up by our brothers in the field of chemistry at the end of the eighteenth century, in their struggles to explain the phenomena of combustive oxidation. However, there is a growing feeling among physicists that we, ourselves, may be climbing up an equally absurd gum tree in our attempts to reconcile ourselves to the apparent constancy of the speed of light.

Unfortunately, one of the consequences of the acceptance by the academic establishment in the early 1920s of the general concepts expressed by Einstein in his special and general theories of relatively, has been that there is an effective academic censorship of any ideas which have tended to cast doubt on the validity of these theories.

This censorship has been effective throughout my own professional career, and its effect has been such that any public expression of doubts on the Fitzgerald-Lorentz-Poincaré-Einstein sequence of theories has resulted in a minor avalanche of privately published papers, from authors who have found no way of expressing their views apart from this.

I have therefore noted with very great approval the opportunity provided by *Wireless World*, as a respected journal on the fringes of physics, to authors such as Essen[1], Catt[2], Dingle[3] and Wellard[4,5], and your other contributors Aspden[6], Francksen[7], Diamond[8], Theocharis[9,10], and Morris[11], to express alternative views which would certainly not have been permitted publication in any of those journals more specifically dedicated to theoretical physics.

In particular, I think that the stress laid upon the conservation of energy, by Wellard[5], is one which should be taken seriously, along with the implications of Maxwell's equations, as discussed by him – chief among which is the need for some medium in which electromagnetic waves may be propagated. Even Einstein, who was not noted for doffing his cap to his predecessors, in his own book admitted that the concept of a completely empty space was incomprehensible to him.

If, therefore, we assume that there *is* some medium for e.m. propagation, and that, in order to satisfy the findings of the Michelson-Morley experiment it was, at least locally, geocentric, it would seem strange that we had not observed it.

Any good detective story writer would allow his readers to discover, in due course, that the thing for which they sought had been under their noses all the time, but that they had not recognised it for what it was. May I suggest that this function can be filled, in the case of e.m. propagation, by the gravitational field within which we all must work. Surely it is too weak to carry any but the most feeble modulation as a symmetrical excursion in its value, but perhaps it is capable of being modulated, upwards, in an unsymmetrical manner.

This would account for the otherwise inexplicable duality of continuous wave vs. photon propagation, would give the results found by Michelson and Morley, as well as that found by Fizeau, which people now conveniently ignore. Moreover, it would satisfy the requirement for the conservation of energy, since e.m. radiation could not go where it would be lost.

If I may attempt a similar debunking of the concept of 'black holes', to that offered by Morris[11] in the case of the twins paradox, I would argue that if a 'black hole' can form at all, the conditions necessary for it most certainly existed at the centre of the universe at the time of the 'big bang', in which case we are all inside one right now.

C.A.M.

Incidentally, if anyone, not a physicist, would like to read a lucid and analytical account of the revolution of the relativity theories, I would recommend that by Cullwick in the *Journal of the IEE* (March 1979, pp. 172-178).

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2. Catt, I. March 1980, pp. 77-78.
3. Dingle, H. Oct. 1980, pp. 54-56.
4. Wellard, M. G. March 1981, pp. 83-86.
5. idem May 1981, pp. 86-89.

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6. Aspden, H. July 1981, p.51.
7. Francksen, C. B. July 1981, p.51.
8. Diamond, R. J. June 1979, p.81.
9. Theocharis, T. Oct. 1979, p.72.
10. idem May. 1981, p.58.
11. Morris, W. T. Nov. 1979, p.79.

The death of electric current

Mr Catt attempts to argue in his reply to my letter in the August issue that the conventional theory of the electron current cannot cope with transient conditions, to which I cannot agree. He instances a voltage-current step advancing along a transmission line at the velocity of light. This fact, however, does not in the least require that the drift velocity of the electrons needs to be equal to the velocity of light as Mr Catt argues for in his para. 3. Indeed, as Mr Catt agrees, and as we can calculate quite simply, the drift velocity of the electrons along a conductor is very slow indeed (in fact, of the order of 9mm/s for a 10-ampere current in a copper wire of 1mm diameter).

The point is, surely, that a conducting wire contains a very large number of free electrons (e.g. for copper, 8.5×10^{28}/cu. metre) physically close to each other from end to end. Hence, firstly the electrons transmitting the wavefront do not have to come from anywhere, since they are already present everywhere along the wires. Secondly, a voltage-current step can therefore be transmitted at a very much higher velocity than the electron drift velocity (in fact, at the velocity of light for the dielectric) for the reason that each individual electron needs only to move quite slowly for a very short distance, in order that the voltage-current step can be transmitted very rapidly over a much larger distance. A cause travelling much slower than the speed of light thus creates an effect travelling at the speed of light.

A simple analogy often given in explanation is that of the transmission of a forward movement along a line of trucks, each in contact with the next, along a railway line. If a push is applied, each truck moves quite slowly and only a short distance, but the 'step' of movement, or push, is very rapidly transmitted from one end of the line to the other.

I am therefore still somewhat at a loss to understand what discovery Mr Catt has made, or what experiments support his ideas; I continue to find the 'billiard-ball electron' a valid and useful concept in dealing with everyday electronics or telecommunications, and I would even suggest that the refined theory of the standing wave electron is of little use, and therefore meaning, in solving normal electronic problems. Even in waveguide transmission, the movement of electrons needs to be invoked, e.g. to explain the attenuation of the voltage vector of a TEM wave in a padding attenuator.

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