Published in *Instantaneous Action At A Distance in Modern Physics:"Pro" and "Contra"*, Nova Science, Commack, NY (1999)

Have You Seen the Light ?

Neal Graneau
Dept. of Engineering Science, University of Oxford
Oxford, OX1 3PJ, UK

Abstract

Throughout the history of the study of natural philosophy has run a constant conviction that light is a substance or effect that is separate from the matter that emits and receives it. This has led to many useful but nevertheless paradoxical theories that have at various times viewed light as a ray, a wave or a particle. In parallel, attention is drawn to the 200 year period after Newton during which Newtonian Instantaneous Action-At-A-Distance (IAAAD) force laws were being actively investigated. The equations from this era have pointed to a novel IAAAD theory of light, which preliminary calculations demonstrate has great potential to provide a more unified picture of matter forces which include what are now considered optical and radiation effects

1. Introduction

The title of this piece demonstrates the depth to which the notion of light has pervaded our everyday thinking, even in a completely non-scientific way. So familiar is this habit that such expressions are no longer referring to optical phenomena, but rather have taken on more spiritual tones of divine revelation or deeper understanding. The relevant feature with regard to this chapter is that we no longer think about what these linguistic "tricks of the light" really mean. The most important way in which light has entered our collective minds is that we are convinced that it exists. Possibly the oldest recorded theory of light comes from Empedocles in Sicily from around 450 B.C. He expressed the notion that an object emits rays of light. Vision was the result of a different type of ray that emanates from the eye and returns the image to the brain. Thus at this earliest dawning of man's investigation into the mysteries of vision, we have the first mention of some substance, loosely called light, the properties of which have remained the subject of great debate for the last 2500 years.

It is of no use to this essay to exhaustively survey the multitude of theories that have led to our present understanding of light. They have been well presented in two recent histories [Park (1997)] [Zajonc (1993)]. However there is one common thread, that seems to run through every theory proposed, to which it is necessary to draw attention. It is always accepted that light is a real entity which has an existence separate from matter. It will be demonstrated in the later sections that this is purely an assumption, which has never been sufficiently examined in the history of western science. The hypothesis was most succinctly confirmed in line 3 of the most read book in history, the Old Testament, when God said "Let there be light, and there was light". After such a definitive statement, it has taken several thousand years to recover our composure that we may now question such a previously unassailable truth.

Of course it is now known that light is simply a subset of phenomena which go under the banner of electromagnetic radiation. Thus to question the Empodoclean postulate regarding the reality of light is to doubt the hypostasis of electromagnetic radiation as a substance separate from the pieces of matter which are usually called the source and detector.

A brief history of the physical theories that have led to our present understanding of electromagnetic field theory will be given. Although it is only a small window in the long history of this subject, there was a period between Newton and Maxwell (1670-1870), when Instantaneous Action-At-A-Distance (IAAAD) theories were fully accepted to explain all observable mechanical forces. However the study of light was concluded to be a separate issue. Maxwell [Maxwell (1873)] proposed the connection between electrodynamics and light and set the stage for the unification of the two concepts. The reality of Maxwell's proposed waves were famously seen to be confirmed by the results presented by Hertz [Hertz (1893)]. However Maxwell's theory was soon found to be imperfect, and Einstein's theory of relativity was created when it became clear that Maxwell's field equations were not invariant under Galilean transformations. As a result of the subsequent discovery of the quantum nature of the universe, it has become clear that Maxwell's theory is certainly not a complete description of electromagnetic radiation, however there is a general attempt now to retain both the wave and particle theories of light even though they seem to be fundamentally conflicting, implying that light phenomena are observed to possess either wave-like or particle-like properties but never both at the same time. The physics community has decided to accept this paradox as part of nature, but it is proposed here that since theories are only man made devices, then it is more likely that the theories are incomplete than that Nature is internally paradoxical.

It will then be demonstrated that there have been recent empirical discoveries that show that neither the Lorentz force nor the field energy concept deep in the heart of modern relativistic electromagnetism are consistent with simple laboratory experiments [Graneau & Graneau (1996)]. The resolution of these inconsistencies is found not by seeking yet more esoteric multi-dimensional descriptions of nature, but rather by returning to the pre-Maxwellian electrodynamic theories of Ampère, Neumann and their contemporaries. Their laws, which belong to the Newtonian IAAAD tradition are naturally Galilean invariant, and are shown to be consistent with all known observations involving electric conductors.

Our interest over the last 20 years has been to develop these mid-19th century concepts and equations into late 20th century form. This has required reinterpretation of some of the modelling involved in the laws. This is to be expected for there was no knowledge of the electron or the mechanism of electric conduction when these theories were created. Similarly, calculations involving these formulae are now performed on computers in a manner that was not possible when they were first published. Not only is this analysis informative, but since these laws describe interactions between discrete elements, solutions to most problems are only achievable by computer. In a parallel vein, there are now high current sources that allow experimental testing of some of the predictions of Ampère's force law. Thus we presently have two major advantages over those scientists who at the end of the last century made the apparently arbitrary choice of adopting a field theory for the description of electromagnetism when they could just as easily have retained the existing IAAAD theories which had never disagreed with a single experiment. While the choice may then have been arbitrary, and it may have been wiser to keep both options open, nevertheless field theory was accepted and IAAAD theory rejected. It will be shown that Lorentz, Einstein and their colleagues seem to have made the wrong decision.

A computer calculation will be described that demonstrates that these interpretations of electromagnetic forces are intimately related to the phenomena which include optical effects. It employs nothing more than Ampère's force formula, first proposed in 1822 [Ampère(1822)], and now tested extensively for its ability to predict electromagnetic forces of attraction or repulsion between current element pairs. It will also be shown that it creates mutual torques on them which attempt to rotate the direction of current in each element. The results from the computation indicate that this law may be able to predict all of the observable effects that we ascribe to the radiation and detection of oscillating electromagnetic signals which naturally include light.

This is quite a radical new step to take even inside the world of IAAAD theory. From Newton through to Ampère and Weber, who all maintained that mechanical forces were described by IAAAD forces, there was still conviction that light was a separate phenomenon and involved the transmission and detection of a real spatial effect, loosely called radiation. While these calculations will be seen to be in their infancy, there seems to be strong correspondence between their predictions and the rather ill defined but nevertheless extremely useful quantities called probability amplitudes in the theory of Quantum Electrodynamics (QED) [Feynmann (1985)]. Due to the overwhelmingly successful predictive ability of QED, it is proposed that this new IAAAD theory based on Ampère's force law may be able to explain all known optical effects. This would prove to be a large surprise to the physics community, that has previously assumed that a theory built on instantaneous interaction could never predict the observed time delays that are normally associated with the constant $c = 2.998\times10^8$ m/s, that is known as "the speed of light". However this constant is shown to have a long and chequered history and actually fits very neatly into the realm of IAAAD theories, by whose creators it was first proposed and measured, even though at that time it was not called the speed of light.

Finally, an attempt to summarise our present state of understanding will show that some laws such as the Lorentz electromagnetic force law may have to be replaced, however many well tested laws such as the Lorentz transformations, atomic quantum theory and indeed QED will remain with their equations intact. However conceptually the universe would no longer appear to be threaded together by photons or waves, and we would be pushed into an IAAAD vision of the universe with truly empty spaces between matter that has not been considered in the western world for over 2500 years.

2. From Aristotle to Einstein

The history presented here will be necessarily incomplete and only aims to highlight the salient events that have affected the accepted outlook on the laws of physics pertaining to IAAAD forces as well as to phenomena associated with light. Modern scientific principles stem from the ancient Greek philosophers, who managed to produce an almost unbelievable amount of reasoned discussions concerning nature and mathematics. Of the many manuscripts that eventually found their way into the early European universities, Aristotle's work was considered to be the most correct. In his writings, which became the standard scientific text until the mid-16th century, the universe was completely full. There existed matter and an intervening ether that transferred messages about force and light between elements of matter by direct contact action. There was no mental picture of empty space or the concept of "nothing" in such a model, probably because this concept simply did not seem necessary or even possible. In modern times, such concepts are now physically and conceptually viable, and as a result found themselves well suited to the IAAAD theories that finally overthrew the Aristotelian dogma.

Without precedent, the scientific world was thoroughly revolutionised by the discoveries of Copernicus, Galileo, Kepler and Newton. Overcoming the mighty resistance to change perpetrated by the Vatican, these pioneers succeeded on the strength of empirical observation. Newton, who of this group had the most impact on theories of matter interaction, appeared to be convinced that the high correlation between his mathematical formulae and astronomical observations was evidence that there was a force of attraction between any two bodies which was proportional to the product of their masses and inversely proportional to the square of their distance of separation. For such an enquiring mind, it must have been unsatisfying not to provide a mechanism for this force, but true to one of his dicta, "hypothesis non fingo" (I do not frame hypotheses), he chose not to speculate on the cause of these forces. A brief discussion was undertaken by Roger Cotes in his preface to the 2nd edition of *Principia* [Newton (1713)] in which he proposes that there could be no mechanical ether for otherwise the planets would experience friction and would spiral in toward the sun, which disagreed with observation. However in a private letter to Richard Bentley, Newton expressed his opinion that a force being conveyed between objects without the mediation of anything between them was "so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking, can ever fall into it."

This quotation is often used in texts purporting to show that Newton, the father of IAAAD force laws was vehemently opposed to the concept of action-at-a-distance. In fact, Newton in his next sentence of this famous quote reveals that he leaves the choice of models to the consideration of his readers. This passage was only inserted into the appendix of the modern editions of *Principia* [Newton (1713)] published this century. The other, possibly more well known quotation that is often used to attack IAAAD theories is taken from a letter from Einstein to Max Born in 1947 [Born (1971)] in which he refers to "spooky action at a distance". It seems that on the basis of these two purely intuitive and private comments, the complete IAAAD theories that are an integral part of our scientific heritage have been eradicated from the textbooks. One can only assume that the long arm of Aristotle is still waving over our heads.

Before returning to Newton's work on the theory of light, a brief account of his legacy in the domain of IAAAD forces will be presented. In 1750 a Cambridge physicist, John Michell, proposed an inverse square law describing the force between a pair of magnetic poles with the same form as Newton's law of gravitation. Charles-Augustin de Coulomb provided confirmation of this finding a few years later and also added his own force law predicting the attraction or repulsion between electric charges. Both of these two new laws predicted mutual attractions or repulsions equal to the product of the elemental quantities (be they quantity and sign of electric charge for Coulomb's law or polarity and strength of pole for Michell's law) multiplied by a constant and divided by the square of distance of separation. The Newtonian form of the force law gained credibility from these subsequent laws for it was now seen to be applicable to more situations than just gravity.

The final classical IAAAD force law was discovered by Andre Marie Ampère in 1822. In Maxwell's treatise [Maxwell (1873)], he describes Ampère as the "Newton of electricity", and his equation as "the cardinal law of electrodynamics". This law, which is precisely analogous to the three previously discussed, will be discussed in more detail in the next sections. Like its predecessors, its form was the product of two current elements and a constant divided by the inverse square of distance, and this was also multiplied by a dimensionless angle function due to the fact that the current elements have direction. As with all of these IAAAD force laws, they were developed without theory and entirely based on experimental results. Due to their empirical nature, they are easily confirmed and have never been found to be in disagreement with experiment. Some might argue that the Newtonian gravitation law does not predict the correct precession of the perihelion of mercury, but this result is shrouded in controversy and will not be discussed here.

Between these four force laws, (Newtonian gravitation, Michell's force between magnetic poles, Coulomb's law of electrostatics and Ampère's law of electrodynamics) related by their Newtonian inverse square form, they could predict all of the observable forces between objects which contained the only properties that could be measured, namely mass, charge, magnetic strength and electric current strength. Thus apart from light effects, the 19th century almost witnessed a unification of the physics required to explain all known phenomena.

Newton's research on optical phenomena was never such a heralded success for it did not contain the predictive ability of his earlier work on mechanics, and in his book, *Opticks* [Newton (1704)], there were a considerable number of assumptions made regarding the nature of light. He felt justified in claiming that light must be particulate, the entities of which he called corpuscles, because otherwise it would not be observed to travel in straight lines as demonstrated by the casting of shadows and reflections. Newton also discovered the optical spectrum by means of a prism, and his attempts to explain this in his corpuscle model leave the overall impression of light to be both a particle and a vibration.

In Holland, the late 17th century burst of discovery included the publication of Christiaan Huygens' *Treatise of Light* in 1690, in which he formalised the argument that light is a wave-like motion of a material ether [Jenkins & White (1981)]. It was a highly elaborate theory and for it's predictive qualities it has been in continuous use until the present day. His primary principle is that a light source produces a spherical wave front of oscillating longitudinal pressure waves. Presumably based on observations of other wave effects, he speculated that every point on the expanding wavefront also becomes a source of another spherical wave, and this process is referred to as Huygens' principle. This model beautifully describes the inverse square nature of the intensity of the received light at a distance from the source and can predict the complex processes of interference and refraction. Even though the authority of Newton's work convinced many scientists that the wave theory which implied a mechanical ether was not consistent with the observed ray-like properties of light and the consistent planetary orbits, the wave theory lurked successfully in the background.

In England, Thomas Young, most famous for his two slit experiment, was primarily responsible for reviving the wave theory in the early years of the 19th century. While still remaining a thorough Newtonian scholar, he sought to ensure that Huygens' theory was kept up to date. He performed exhaustive calculations to demonstrate that all of the known optical effects could be explained by the wave theory. Most notably he made the strong claim that the diffraction pattern observed with his two slit experiment was entirely inconsistent with the Newtonian particle theory. Working at the same time in France, an engineer named Augustin Jean Fresnel performed similar calculations to Young, and was able to provide an even clearer explanation for diffraction which was the last remaining nail in the coffin for Newton's theory. Both Young and Fresnel proposed that the polarisation of light was not explicable by longitudinal pressure waves as Huygens had proposed, but that they must be transverse to their direction of propagation, and the plane of the oscillation of the wave was the plane of polarisation. This new picture fitted all known polarisation experiments and was treated as a resounding success. Thus by the mid-19th century, light was viewed solely as a transverse wave phenomenon in an ether.

By this point it was well known that there was a time delay between the transmission and detection of a signal, which was consistent with both wave and particle models. It seems a natural guess that one should associate this delay with the transit of some mechanical entity with a measurable velocity, which we now call c. This constant is probably the most interesting number in physics. Incredible ingenuity has been exploited in its measurement. What is remarkable is that different successful attempts to measure it have been measuring entirely different quantities. The first successful attempt to measure the delay caused by the speed of light was performed by Ole Roemer in 1676, by a clever analysis of the irregular period of the eclipse of a moon of Jupiter. He proposed a figure which was two thirds of today's accepted figure. Since this time there has only been one other one way light speed measurement, by James Bradley, who in the early 18th century cleverly exploited a measurement of stellar aberration of a nearby star to deduce an even more accurate figure. The first series of experiments to precisely measure this speed of light by well calibrated earth bound experiments were performed by Fizeau and Foucault in 1849. These measurements all aimed to time the two way speed of light by reflecting light off a distant mirror a known distance away. These results soon became as precise as the surveying accuracy would allow producing figures very close to the value used today. Even by 1851, Fizeau and Foucault had already measured that the speed of light is slowed down when it goes through a transparent substance.

During the period when these delay measurements were being performed, several important milestones passed by, some more well known than others, and for this reason they will be presented in order of decreasing entries in the citation index rather than chronologically. The first event was the publication of Maxwell's Treatise [Maxwell (1873)] in 1873. Even though he believed that it would probably be impossible to prove by experiment, the notion of the wave theory of light as an electromagnetic phenomenon was born. This theory was not immediately popular for it did not sit easily with the IAAAD theories currently prevailing in continental Europe. However, the radiation aspect of Maxwell's theory was posthumously championed by a group of English and Irish scientists calling themselves “The Maxwellians”. They were, most notably, Heaviside, Fitzgerald, and Lodge. These gentlemen were trying to perform experiments to test Maxwell's theory. Their happiest moment was the announcement of the second milestone, namely the publication of Heinrich Hertz's experimental results in 1888.

By means of an oscillatory spark discharge and a large reflection plane, Hertz [Hertz (1893)] found nodes and anti-nodes of electrical activity at different locations in his laboratory and thus deduced a wavelength. Since in wave theories the velocity of the propagation was always the product of frequency and wavelength, he estimated the frequency of his discharge from a circuit theory analysis, and as a result made the first measurement of the speed of electromagnetic radiation for non-optical frequencies. That his value agreed with the figures arrived at by the delay measurements, encouraged physicists to assert that light and electromagnetic radiation were the same phenomenon which could be described by a wave propagating through an invisible ether.

The third milestone in the development of c came 30 years earlier in 1857, and is the least well known part of the story. This was in fact the first measurement of a constant called c. It was not called the speed of light, but was a dimensional constant that had fallen into Weber's rendition of the IAAAD electromagnetic force law [Whittaker (1951)]. Weber was attempting to combine Ampère’s law of electrodynamics with Coulomb's law of electrostatic force into a unified equation. His attempts suffered from not yet knowing any details of individual charges and their motions inside electric conductors. Nevertheless in his theory, c was purely a factor of proportionality which had to be introduced when electrodynamic phenomena are described in terms of units which have been defined electrostatically or vice versa. That the factor which is introduced on such occasions must be of the dimensions (length / time) may be easily seen, for the electrostatic force between point charges is a quantity of the same kind as the electrodynamic force between two definite *lengths* of wire, carrying currents which must be specified by the amount of charge which travels past any point in unit *time*.

The value of this constant was measured in 1856 by Weber and Kohlrausch who charged up a Leyden jar with a known capacitance and voltage and thus worked out the stored charge in electrostatic units. They then discharged the jar into the coil and measured the force that the transient current impressed on a magnet, thus measuring the charge in electromagnetic units. They found the ratio of electrostatic charge to electromagnetic charge to be 3.1×10^8 m/s. This was the first measurement of the constant, c, taken from an empirically grounded IAAAD theory. Crucially this measurement had absolutely nothing to do with radiation.

The coincidence that c was equal to the measured speed of light was first taken up by Kirchoff, who was at the time developing what is now called “circuit theory”. His development of the now well used concepts of inductance, capacitance and resistance stemmed from the electrostatic and electrodynamic theories of Ampère, Neumann, Weber and Coulomb. Using these principles, he was the first to derive the velocity of voltage and current disturbances down a transmission line circuit [Assis & Graneau (1994)], and found that it was c. This was achieved in 1857, almost ten years before Maxwell began publishing an explanation based on radiating fields. Kirchoff's calculation gives us the first clue that the Newtonian IAAAD theories can yield a mechanism to explain the phenomena that are traditionally ascribed to electromagnetic radiation.

Kirchoff also made a statement [Assis & Graneau (1994)] [Whittaker (1951)] that c is the velocity at which charges moving toward each other no longer exert a mutual force. Even though electrons and particle accelerators were not a part of mid-19th century consideration, Kirchoff's claim seems to explain why particles cannot be accelerated beyond the speed of light. Note that this is now considered to be an observation that is only explicable by the velocity related inertial mass variation predicted by special relativity, whereas in fact it appears that it is a natural conclusion of IAAAD theory.

The electron beam was a newly discovered phenomenon at the end of the 19th century, and the theories that attempted to explain it may have been provided rather hastily and without full consideration. A major success was the measurement of *(e/m)*, the electron charge to mass ratio which yielded a constant and gave credibility to the proposed particle nature of this new entity. However there was a need to find a force law to fit the new discoveries. This was not going to be an empirically derived Newtonian IAAAD formula because it would require the measurement of the force between two isolated and moving electrons. This result is still not known. Such a desperate situation opened the door for a new force law to be developed via theory rather than by experiment.

To fully appreciate why we now use the modern Lorentz force law, we have to look back to Maxwell's Treatise [Maxwell (1873)] again. He was aware of Grassmann's law which was, of the IAAAD laws, the greatest rival to Ampère’s. This law involved a vector cross product, which Grassmann himself had a role in inventing, and as a result did not predict Newtonian attractions or repulsions in an element by element manner. However it did predict that the mutual force between two complete circuits would obey Newton's third law. Unfortunately the only experiments by which Maxwell was able to judge between the two laws was a force measurement between a pair of circuits and thus he was forced to conclude that either law may be correct, however Ampère’s law was “undoubtedly the best, since it is the only one which makes the forces on the two elements not only equal and opposite, but in the straight line that joins them”.

Given that we no longer use Ampère’s force law, one can only ponder why scientists threw away a principle as stunningly powerful and empirically tested as Newton's third law without a solid argument. The answer probably lies in Lorentz's desire in the early 1890's to be the first to publish a force law for the free electron. Electron beams were observed to move in circular trajectories when influenced by magnetic fields, so he sought a force law which placed the force always perpendicular to the current element, and found that Grassmann's law did just this. Therefore Lorentz combined the Grassmann, Biot-Savart and Coulomb laws into one equation, redefined the current element as a moving charge, and was able to predict the force on the electron beam. However in this bold step, he threw away the strong connection between Newtonian physics and electromagnetism. It will be shown in the next section that the experiments that Maxwell had hoped for, that could separate the predictions of the Ampère and Grassmann laws, have now been performed and they favour the Newtonian Ampère law. The manifestation of these discoveries is that the magnetic force component at the core of the presently used Lorentz force formula is incorrect.

The other pressing issue of the day was the resolution of the results of the Michelson-Morley (M-M) experiment, which attempted to detect the ether wind. Maxwell's theory was dependent on the existence of the ether to support its waves, and thus one should have been able to perceive it by comparing the relative speeds of light parallel and perpendicular to the ether wind that was caused by the earth's orbital velocity of 30 km/s. This was expected to produce a positive result based on the 1859 findings of Fizeau and Foucault [Jenkins & White (1981)] who had measured the velocity of light in moving water and had discovered that the moving medium did affect the measured speed of light. Famously, the M-M experiment produced a much smaller effect than was expected and thus was taken by the physics community to represent a null result. This plunged late 19th century physics into turmoil. Between Fitzgerald in Ireland and Lorentz in Holland, they developed the equations known as the Lorentz transformations, which define how the events in one inertial frame are interpreted when viewed from another one. Since viewing involved light processes, these equations naturally included the speed of light. They seem to predict that an object moving through the ether with a velocity v, actually contracts by the factor , $\sqrt{1-v^2/c^2}$, and this was initially Fitzgerald's explanation for the quoted null result of the M-M experiment, because it predicted that the path length of the experiment parallel to the ether wind was shorter by just the amount required to hide the difference in velocities.

This explanation was accepted until the arrival of Einstein's famous 1905 paper [Einstein (1905)]. To remain brief he simply made the assumption that there is no ether and thus without the ether wind, the null result of the M-M experiment is expected. He was worried however that removal of the ether meant that motion of material objects could no longer be viewed as absolute, and that since no observer could ever be considered stationary, all motions must be viewed as relative to another body or frame. Einstein used his famous light postulate that the speed of light is constant and independent of the motion of the source to re-derive the Lorentz transformations, however he interpreted them rather differently. He concluded that it was not just objects that contracted but that space and time were constantly distorted by relative motions.

It is now well known from the development of modern Global Positioning System (GPS) technology that the surface of the earth is certainly not an inertial frame, and that light arriving from the east and west approach a land based receiver at different speeds. As a result it is clear that with sufficient precision, the M-M experiment must have produced a positive result and a true reporting of this fact would have removed the confusion that led to the development of the Lorentz transformations and special relativity.

By removing the ether, special relativity greatly weakened the Maxwellian wave theory which requires energy transfer by waves through space. This conceptual conflict necessitated the invention of electromagnetic field energy and was fulfilled by the notion of energy containing photons and a return to an era where light again was both a particle and a wave. Einstein eventually won his Nobel prize, not for his work on relativity theory but for his role in the discovery of the photoelectric effect, which along with the Compton effect convinced people that photons were indeed a reality. It is less well known that Schrödinger [Schrödinger (1927)] published a classical solution to the Compton effect which did not require photons, and Planck and others developed similar interpretations of the photoelectric effect [Mandel et al (1964)].

To conclude this chain of events it can be said that even during the quantum revolution and the discoveries that have occurred throughout the remainder of the 20th century, our model of light is still a blurry mix of particle and wave properties which are separate from the properties of matter and somehow mechanically transfer energy across empty space at a finite speed which is dependent on the environment..

Running in parallel to research on light, recent confirmation by [Aspect et al (1982)] of the non-local nature of quantum mechanics predicted by John Bell [Bell (1987)] has yielded clues that instantaneous interactions between distant particles do indeed occur. This has caused great debate because these interactions appear to be inconsistent with the local relativistic concept of travelling photons as the only method of distant particle interaction. It will be shown in Section 4 however, that such IAAAD interactions are still consistent with observed signalling delays, but imply that the travelling photon model is incorrect.

3. Experimental Discrepancies with Modern Theory

Over the last 20 years Peter Graneau and I have been performing experiments which have been confirming the existence of longitudinal electrodynamic forces. Unlike the forces on electrical conductors predicted by the conventional Lorentz law which are always perpendicular to the current in the conductor, a longitudinal force acts in the same direction as the current. In many of our papers, summarised in [Graneau & Graneau (1996)], we have demonstrated that Ampère's force law when applied element by element to calculate the force between two sections of a current conductor predicts a net longitudinal repulsive force, the magnitude of which depends on the square of the electric current and the geometry of the circuit. To date, there has been no published attempt to demonstrate how the Lorentz law could predict longitudinal electrodynamic forces.

There is a long standing debate between supporters of Ampère's law and its opponents regarding whether the IAAAD law is equivalent to the Lorentz law. The two formulae do agree on the force between two circuits, and they also predict roughly the same transverse forces on a conductor due to the current in its own circuit. Further they both predict zero net longitudinal force on a current element due to its interaction with the rest of its circuit. However this type of calculation gives us no information about internal stresses in the conductor. Tensile and compressive stresses are defined by engineering textbooks as caused by the net perpendicular forces across an interface between two sections of an object. Such stresses are in fact Newtonian concepts by their necessary compliance with the definition just given. They can only be calculated by summing the forces of attraction or repulsion (resolved in the direction perpendicular to the interface) between every element pair where one of the pair is on one side of the interface, and the second is on the other side. Due to the finite element nature of Ampère's force law and the fact that every interaction produces a Newtonian balanced attraction or repulsion, a calculation involving this law can be easily performed to find the tension across any arbitrary interface that cuts the circuit.

Since the Lorentz force can only predict the force on a current element as a result of an interaction with a magnetic field, no Newtonian tension calculation as just described is possible, and as a result no tension could be predicted. Consequently the two laws are not identical.

[Graneau & Graneau (1996)] details the many experiments that have now revealed these tensile forces and as a result have justified the use of Ampère's force law. The simplest of these is the observation of thin aluminium wires when subjected to appropriate high current pulses. These 1mm wires are found to break into pieces that fall on the floor and can be analysed, showing that they were subject to tensile forces which resulted in brittle fracture. Accurate measurements of the strength of these tensile forces have revealed very good agreement with the Ampère force prediction.

We have also found that there is a major experimental discrepancy in the modern understanding of electromagnetic field energy. This fault can be detected by the analysis of any electrical machine. In previous publications [Graneau & Graneau (1996)] we have analysed the railgun which is a pulsed device, but here a calculation based on an induction motor will demonstrate that the same problems occur in a non-pulsed device. The induction motor is chosen because there is no electrical connection between the stator and the rotor, so by the theory of relativistic electromagnetism all of the momentum received by the rotor must have been caused by the impact of photons which contained the same amount of momentum and gave it up on collision. While these photons in the induction motor field are certainly not of optical frequency, they must nevertheless be photons for there is no other possible energy transfer mechanism in the present theory. This amount of photon momentum is equal to

$$p_{\text{field}} = m_e\, c \quad , \tag{1}$$

where m_e is the equivalent electromagnetic mass of the field. According to Einstein's famous field equation

$$E_{\text{field}} = m_e\, c^2 = p_{\text{field}}\, c \quad , \tag{2}$$

it can then be said that the field energy consumed is the rotor momentum multiplied by the speed of light. The three expressions for the momentum, energy and power of the rotor are given by

$$\text{angular momentum} = M\, k^2\, \dot{\theta} \quad , \tag{3}$$

$$\text{kinetic energy} = \tfrac{1}{2}\ M\, k^2\, \dot{\theta}^2 \ , \tag{4}$$

$$\text{mechanical power} = M\, k^2\, \dot{\theta}\ddot{\theta} \quad , \tag{4}$$

where M is the mass of the rotor, k is the radius of gyration and $\dot{\theta}$ and $\ddot{\theta}$ are the angular velocity and acceleration respectively. If a linear impulse (Ft) is given to the rotor by field momentum impact at a distance r from the axis of rotation, then using Eqs.(1) and (3)

$$F\,t\,r = r\,\Delta p = M\,k^2\,(\dot{\theta}_2 - \dot{\theta}_1) = M\,k^2\,\Delta\dot{\theta} = r\,p_{\text{field}} = r\,m_e\,c \quad . \tag{5}$$

Using Eqs.(2) and (5)

$$E_{\text{field}} = \frac{M\,c\,k^2}{r}\Delta\dot{\theta} \quad . \tag{6}$$

Therefore the power requirement in the field can be expressed as

$$\mathbb{P}_{\text{field}} = \frac{M\,c\,k^2}{r}\frac{\Delta\dot{\theta}}{\Delta t} = \frac{M\,c\,k^2}{r}\ddot{\theta} \quad . \tag{7}$$

Also if T is the efficiency of the motor then using Eq.(4)

$$\mathbb{P}_{\text{rotor}} = T\,\mathbb{P}_{\text{supplied}} = M\,k^2\,\dot{\theta}\ddot{\theta} \quad , \tag{8}$$

so combining Eqs.(7) and (8) and employing the principle of conservation of energy, we can write

$$\frac{\mathbb{P}_{\text{field}}}{\mathbb{P}_{\text{supplied}}} = \frac{T\,c}{r\,\dot{\theta}} \le 1 \quad , \tag{9}$$

which implies that

$$\dot{\theta} \ge \frac{T\,c}{r} \quad . \tag{10}$$

Eq.(10) tells us that if we take a 50% efficient induction motor with a rotor radius of 10 cm, which are very reasonable figures, then this motor can only run at speeds faster than 1.4×10^{10} rpm !

This is clearly not true and demonstrates quite conclusively that the present picture of electromagnetic field energy and momentum is not consistent with energy conservation and is therefore incorrect. It is this theory that was required for Einstein to remove the ether and yet still retain a theory of transmission of electromagnetic radiation. Thus if present radiation theories are inconsistent with an ether as Einstein suggested, then it appears there is also no satisfactory ether free solution available either. Therefore it is logical to pursue the next alternative which is to find if there can be a law which determines optical effects that does not rely on radiation and yet still predicts the delays and optical effects that are normally attributed to light.

4. A New Theory of Light

The most useful form of Ampère's law that we have been using for the force calculations described so far in this paper is

$$\Delta F_{m,n} = -\left(\frac{\mu_0}{4\pi}\right)\frac{i_m\,\mathbf{dm}\,i_n\,\mathbf{dn}}{r_{m,n}^2}\left(2\cos(\beta-\alpha)-3\cos\alpha\cos\beta\right) \quad . \tag{11}$$

$i_m\mathbf{dm}$ and $i_n\mathbf{dn}$ are the two current elements where i is the strength of the current in the element and **dm** and **dn** are vectors equal to the length of the sides of the cubic volume current element and pointing in the direction of current flow. $r_{m,n}$ is the distance between the elements and the angles α and β are defined with reference to the line joining the elements as displayed in figure 1.

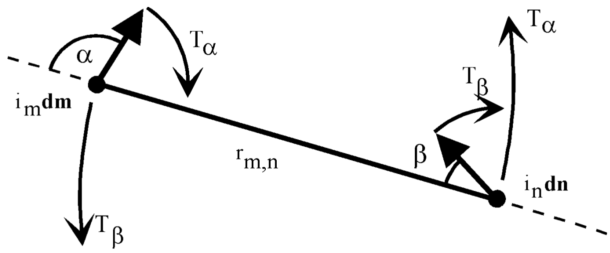

Figure 1: Two current elements, demonstrating the angles in Ampère's force law

It is shown in [Graneau & Graneau (1996)] how Neumann used the concept of virtual work to derive an equation of an electrodynamic potential based on Ampère's law that gave the expression for the magnetic energy stored by two interacting circuits. It was thus analogous to the Newtonian gravitational potential. Since attractive forces are traditionally taken to be negative, the negative derivative of the potential with respect to the separation distance yields the value of the force. Using Maxwell's criteria that only forces between complete circuits could be measured due to the limited experimental techniques of his day, Neumann only published his law in a form that defines the potential between complete circuits. It was not until 1985 that his law was represented by P. Graneau [Graneau (1985)] in its elemental form as the stored potential energy between a pair of current elements, $\Delta P_{m,n}$.

$$\Delta P_{m,n} = -\left(\frac{\mu_0}{4\pi}\right)\frac{i_m\,\mathbf{dm}\,i_n\,\mathbf{dn}}{r_{m,n}}\left(2\cos(\beta-\alpha)-3\cos\alpha\cos\beta\right) \quad . \tag{12}$$

The Newtonian stored gravitational potential represents the ability for two objects to fall toward each other, and similarly the Neumann potential provides the energy for electromagnetic acceleration. In this manner the IAAAD theory, unlike the modern theory, does not depend on the transmission of energy from one object to another in order to achieve relative acceleration, but nevertheless is still consistent with energy conservation.

In the same way as the negative of the derivative of Eq.(12) with respect to $r_{m,n}$, yields the mechanical force, Eq.(11), the negative derivatives of Eq.(12) with respect to the angles α and β give forces tending to turn the elements. These have been derived in [Graneau & Graneau (1996)] and are called the α and β torques and shown below.

$$(\Delta T_{m,n})_{\alpha} = -\left(\frac{\mu_0}{4\pi}\right)\frac{i_m\,\mathbf{dm}\,i_n\,\mathbf{dn}}{r_{m,n}}(\sin\alpha\,\cos\beta + 2\,\cos\alpha\,\sin\beta) \quad , \tag{13}$$

$$(\Delta T_{m,n})_{\beta} = -\left(\frac{\mu_0}{4\pi}\right)\frac{i_m\,\mathbf{dm}\,i_n\,\mathbf{dn}}{r_{m,n}}(\sin\beta\,\cos\alpha + 2\,\cos\beta\,\sin a) \quad . \tag{14}$$

A positive torque tends to increase the respective angle. As shown in figure 1, each torque affects both elements. For instance the α torque has the effect of trying to change the direction of i_m**dm** while at the same time changing the position of i_n**dn**. It is not yet known whether a current element can pivot freely as hypothesised here. However as discussed later in this section, this freedom to rotate may determine whether an element is a conductor or an insulator.

The concept of pivoting current elements allows us to model alternating current in a transmitting antenna as a contiguous block of elements, all spinning in phase at a certain frequency. The current in the antenna is thus taken to be the average of the sines of the angles of all the current element vectors with respect to a specific direction. According to Eqs.(13) and (14) this would cause remote elements to feel torques that would cause them to pivot. The strength, direction and effect of these distant IAAAD torques have been examined by computer modelling.

The computer program created three blocks of elements, labelling one the source, one the reflector and one the detector. They were positioned such that the source and detector were next to each other but were not allowed to interact with each other as if separated by a screen and the reflector was a known distance away. The source and reflector were allowed to interact and the reflector and detector as well. The elements in the reflector and detector were initially pointing in random directions with random angular velocities. The elements in the source were all aligned and at time zero, the elements were allowed to interact. The net torques on the source elements were ignored as it was considered that they were being driven by a strong power supply. However the total torque on each other element was summed and then multiplied by a constant which represents a type of elemental angular inertia to predict an angular acceleration. This could be multiplied by the length of the time step to give the change in angular velocity which was then added to the existing velocity to give the new velocity. This new velocity was then also multiplied by the time step to give the change in angular position, so that all of the elements could be set into their new directions, and then the algorithm was repeated for successive time steps. After each step, the sine of each element was averaged for each block of elements and stored. The source elements were rotated in phase at a fixed angular frequency and the results for the three element blocks over time were plotted. Calculations have been performed using thousands of elements in each block and several hundred time steps, however these results are still very crude because it is unrealistic to perform this calculation with such a small number of elements, which are attempting to model all of the atoms in a real conductor.

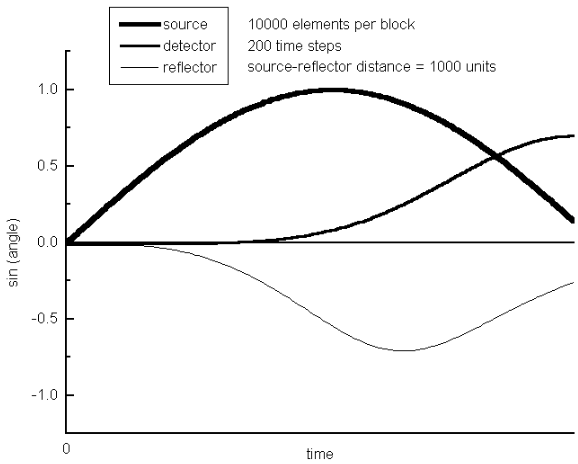

Figure 2: Current in the three element blocks, demonstrating the distance related delay

In figure 2, the signal at the three locations is plotted. There is a delay of the signal observed at the reflector and a further equal delay before the elements at the detector start moving coherently. Even though the mutual forces are instantaneous the delays appear (a) due to the angular inertia of each element that limits the angular acceleration and (b) because a group of randomly moving elements requires time to develop into a coherent motion. In a similar manner to Newton's second law, the weaker the force due to a greater separation, the lower the acceleration and in this situation this gives the appearance of a delay which depends linearly on distance.

Secondly the signal is observed to be weaker at the detector than at the reflector. If the signals shown in figure 3 are the wave amplitudes, then their linear decrease in amplitude with distance produced by the calculation is in agreement with the observed fact that light intensity is an inverse square quantity. Intensity is the square of the wave amplitude.

Figure 3 reveals another very important quality of light which is a precise frequency pickup in the detector. Thus whatever frequency is in the source will be detected at a remote location. Both figures 2 and 3 also display the phase reversal on reflection which is a well known experimental occurrence.

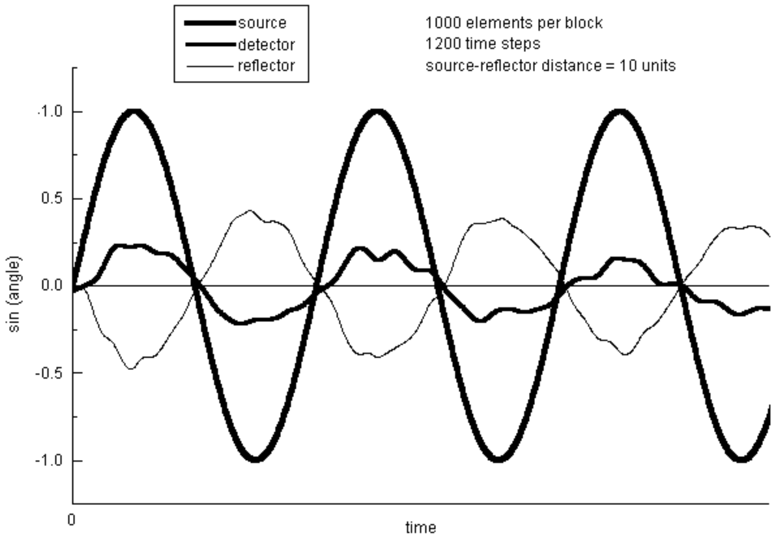

Figure 3: Current in the three element blocks, showing amplitude decay and frequency pickup

These results provide a promising prospect for a purely IAAAD theory of light. If we had also calculated the average cosines as well as the sines, then we would have generated the components of a vector that seems to be equivalent to the quantum amplitude vector of QED theory which apparently occurs at every point in the universe where there is matter. From the conclusions drawn here, these amplitude vectors may well be the pivoting Ampèrian current element. In Feynmann's famous lecture on QED [Feynmann (1985)], he explains that these probability amplitudes have now been used to explain all known optical effects, and in fact all of physics except gravitation and nuclear physics. He has left the physical interpretation of these probability vectors as an unsolved mystery, however the proposed IAAAD calculation may be the solution. A treatment [Brown (1963)] using the IAAAD interaction of distant dipoles in a source, slit edge and screen has shown specifically that optical diffraction can be explained by such a mechanism.

It remains to be shown how these apparently wave-like predictions can be consistent with the observed photon-like nature of light. The nature of photon detection can be viewed, not necessarily as the arrival of a photon but as a random event, such as an electron release from a screen, being influenced by coherent electrical activity caused by remote interaction with a distant source. A possible illustration of this process exploits our understanding of the nature of a shirt drying on a clothes line. Since water molecules leave the shirt one by one, this process can be called quantized. They apparently leave the material when they have sufficient thermal energy to break their bond with the fabric. If one were to use an infra-red heat lamp and a suitable two slit screen, one could project a Fraunhofer diffraction pattern onto the fabric. Thus there would be regions of the shirt which would be heated more than other areas. As a result, more of these quantized events would happen in the bright regions rather than the dark areas. However we would not therefore necessarily say that each water molecule released corresponds to the arrival of a single photon. Similarly, in any detector material we can influence the probability of quantum events occurring by using a radiation source, however the quantum events in the detector may be quite separate from the activity and quantum events in the source. Most importantly we cannot correlate each quantum event with the arrival of a photon because the photon itself can never be observed.

The final issue to be resolved is the search for the physical explanation of the value of the speed of light. For this we may look back to the fact that Kirchoff discovered the theory of transmission lines using only the currently available IAAAD force laws of Ampère and Coulomb. The velocity of propagation, v_p, which can now be viewed as an IAAAD quantity, is always less than the speed of light in free space, c. This is true even if the insulating medium is a perfect vacuum. The value of this velocity is the inverse of the square root of the product of L, the inductance per unit length, multiplied by the capacitance per unit length, C,

$$v_p = \frac{1}{\sqrt{LC}} \quad . \tag{15}$$

According to Eq.(15), as the conductors are separated, v_p approaches but never exceeds c. With an IAAAD theory that can consider instantaneous interactions between all bodies in the universe, we can imagine the transmission line can become as big as the universe and this determines the universal speed of light in free space. This concept could possibly be used to understand why light appears to slow down near massive bodies such as the sun [Shapiro et al (1977)], which effectively locally change the values of L and C of the universal transmission line.

To complete this consideration, it should be recognised that our modern calculations of L and C involve knowledge of the parameters μ and ε. Since modern theory has considered that all of the radiation activity occurs in the space between the conductors, these parameters have always been considered to be material properties of the medium between the transmission line conductors. This concept looks partially suspect when the values of μ_0 and ε_0, the permeability and permittivity of free space, are deduced. These appear to be the *material* properties of a *vacuum*, which is indicative of the kind of paradox that seems to be acceptable in modern physics.

It seems more likely that μ_0 and ε_0 are representative of the material properties of the interacting current elements which are used to calculate L and C using Ampère's and Coulomb's law respectively. These constants may well represent a given element's ability to pivot and pass current, and their consistent values represent the average values for good conductors. In the same vein, if there is an insulating medium, its own electrical activity can influence the net interactions between the conductor elements and this effect can be quantified by the values of μ_r and ε_r, the relative permeability and permittivity of a medium. Even though this part of the theory has not been developed, the measured vacuum light speed seems to be giving us the values of μ_0 and $\varepsilon_{0,}$ which may yet yield details about the average chemical constitution of the universe.

5. Conclusions

By presenting a brief historical view of the major events in mankind's study of light and radiation, one can see that the concept of light as a radiant substance or a vibration of a mechanical ether has focused attention on extremely productive areas of physical research. However there is a paradoxical aspect of these theories that implies that light sometimes behaves as a wave and sometimes as a particle. As well, radiation theories have been experimentally demonstrated to be inconsistent with both ether and ether-free models. We have discovered the parallel IAAAD school of thought that began with Newton's work and has led to a series of Newtonian inverse square force laws that seem to explain virtually all known physical results except the force between free electrons and nuclear phenomena. Feynmann [Feynmann (1985)] left it as an unresolved issue whether QED, which now appears to have an IAAAD pedigree, was also a prototype of another theory that would eventually explain nuclear and particle effects. Most importantly, this novel outlook has allowed us to propose a new IAAAD theory of light which does not involve a substance separate from the matter that transmits or receives signals, but rather relies on instantaneous interactions between pairs of distant atoms. Consequently, not only may you never see the light, but there may be no light to see!

References

A.M. Ampère (1822), *La Determination de la Formule Qui Represente L'action Mutuelle de Deux Portions Infintement Petites de Conducteur Voltaiques*, L'Academie Royale des Sciences, Paris

A. Aspect et al (1982), *Phys.Rev.Lett.,* **49** , 1804

A.K.T. Assis, P. Graneau (1994), *Apeiron*, **19** , 19

J.S. Bell (1987), *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press, Cambridge

M. Born (ed.) (1971), *The Born-Einstein Letters*, Macmillan, London

B. Brown (1963), *Contemporary Physics*, **5**(1), 15

A. Einstein (1905), *Ann. der Physik*, **17,** 891

R.P. Feynmann (1985), *QED, The Strange Theory of Light and Matter*, Princeton University Press, Princeton, N.J.

P. Graneau (1985), *Ampère-Neumann Electrodynamics of Metals*, Hadronic Press, Palm Harbor, FL (1994)

N. Graneau, P. Graneau (1993), *Newton vs. Einstein*, Carlton Press, New York, N.Y.

N. Graneau, P. Graneau (1996), *Newtonian Electrodynamics*, World Scientific, Singapore

H. Hertz (1893), *Electric Waves*, Dover, New York, N.Y. (1962)

F.A. Jenkins, H.E. White (1981), *Fundamentals of Optics*, 4th ed., McGraw Hill, New York, N.Y.

L. Mandel et al (1964), *Proc.Phys.Soc* (London) **A276**, 475

J.C. Maxwell (1873), *A Treatise on Electricity and Magnetism*, Dover, New York, N.Y. (1954)

I. Newton (1704), *Opticks*, Dover, New York, N.Y. (1952)

I. Newton (1713), *Principia, 2nd ed.*, F. Cajori ed., Univ. of California Press, Berkeley (1934)

D. Park (1997), *The Fire Within the Eye*, Princeton University Press, Princeton, N.J.

E. Schrödinger (1927), *Ann.Phys*, **28** , 257

I.I. Shapiro et al (1977), *J.Geophys.Res*, **82**(28), 4329

E. Whittaker (1951), *A History of the Theories of Aether and Electricity*, Dover, New York, N.Y. (1989)

A. Zajonc (1993), *Catching the Light*, Bantam Press, London