Unification Accomplished and Forgotten! The story of H.T. Flint

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Since the 1970s, an ever growing number of theoretical physicists have become interested in unifying the quantum and relativity upon a quantum basis. Before the 1970s, only Einstein and a select few sought unification, but their theoretical work was based upon the continuity of relativity rather than quantum's discrete nature of reality. To date neither paradigm has developed anything that would appear to unify physics, except for the work of one physicist and a few of his colleagues. H.T. Flint published more than thirty-five articles in well-known peer-reviewed journals over a period of four decades, extending relativity to include electromagnetism and the quantum. Yet his work and that of his close associates is almost completely unknown today. Flint published his complete unified field theory in the 1960s, well before most quantum theorists even began thinking along the lines of unification. Strangely enough, Flint's unification theory has been completely forgotten by a scientific community that has become enamored enough with the idea of unification that it would accept the most outrageous and non-intuitive ideas as long as they are based on the quantum, but then Kaluza's five-dimensional unification of relativity and electromagnetism supposedly was not known until it was rediscovered by the superstring theorists, or so they claim. In reality, these ideas were lost in plain sight for decades simply because the physics community was unwilling to recognize accomplishments based on relativity theory.

Although Sir Arthur Eddington is best known for his measurements of light curves for a solar eclipse confirming Einstein’s GTR, his contributions to relativity theory went much further than just that single event

The Intro of GR to England

- Eddington became intrigued with general relativity after reading de Sitter's 1916 accounts of the astronomical consequences of the theory
- In his earlier publications on the theory, Eddington indicated that he did not fully believe in the literal truth of space curvature
- He was not versed in non-Euclidean geometries and admitted that fact
- His early interpretations of the theory were decidedly Victorian with talk of strains in the aether, but Eddington's ability to handle the different non-Euclidean concepts as well as his perspective on the theory developed very rapidly and continuously
- So it can be concluded that he made a quick study of the non-Euclidean geometries to fill in the gaps in his own knowledge of the subject and understand the new GR theory

Eddington and Clifford

- It is quite likely that his basic concepts on the non-Euclidean geometries came from Clifford’s work
- If he didn't already know of Clifford, he must have become very interested in Clifford's work because he was able to show a great familiarity with Clifford's work within just a few years
- In his 1921 popular exposition of the theory, *Space, Time, and Gravitation*, Eddington introduced one chapter by a quote from *Common Sense* while he began the chapter on "Kinds of Space" with a quotation from Clifford's "Postulates"
- The quote from *Common Sense* was the same paragraph that ended Clifford's chapter on "Position" and the very words to which Karl Pearson added the note that Clifford’s twists were the source of magnetic induction

- However, Eddington also quoted a passage from the "Unseen Universe" in which Clifford expressed his desire that physical reality would one day be expressed as the geometry of position: "Out of these two relations [nextness or contiguity of space and succession in time] the future theorist has to build up the world as best he may"
- What might help the scientist in this endeavor, suggested Clifford, was the description of distance as an expression of position as in the mathematics of 'analysis situs' and the fact that space curvature could be used to describe matter in motion.
- It was implicit in Clifford's original context of this statement that the ether could be replaced by a real space curvature for a total theory of the physical world of matter.

Whittaker on Eddington

- Two and a half decades later, E.T. Whittaker wrote a history of scientific conceptions of the external world, *From Euclid to Eddington*
- The book ended with a statement that Eddington was attempting to reduce all of physics to "one kind of ultimate particle, of which [the known elementary particles] are, so to speak, disguised manifestations.“
- A comparison of this with Clifford's goal, as expressed in the closing remarks of the *Elements*, indicates that Clifford's and Eddington's goals were essentially the same: the physical expression of the universe based upon the various manifestations of a single particle.
- But their methods of achieving that goal were quite different: Eddington did not use Clifford's ‘twists’, but did adopt Clifford's basic philosophy as well as borrow some of Clifford's mathematics.

The Fundamental Theory

- The theory to which Whittaker referred was Eddington's "Fundamental Theory"
- The Fundamental Theory was meant to be the pinnacle of Eddington's considerable work and long association with the theories of relativity, the quantum and physical cosmology
- The theory was based upon the mathematics of E-numbers, which represented the elements of an E-frame that Eddington associated with the physical space-time of relativity theory
- This E-frame, in conjunction with an F-frame to which it was related, then allowed a new interpretation of the Christoffel tensors from which Einstein had constructed his own mathematical model of space-time curvature

- The E-numbers were quaternions and shared many characteristics with both Clifford's ‘biquaternions’ and Sir Robert Stawell Ball's ‘screws’
- But Eddington's application of quaternions was different because the essential problem of finding a mathematical model was different for Eddington than it had been for Clifford
- It had become necessary for Eddington to account for all of the physical concepts and phenomena that had been discovered since Clifford's death: quantum theory, the Bohr atom, radioactivity, the atomic nucleus, electrons, protons, neutrons, the theories of relativity and others
- So Eddington's theory was different from Clifford's even though they were philosophically similar
- So Eddington’s theory could not be considered a simple continuation of Clifford's work

Other Clifford Connections

- Perhaps the earliest public mention of Clifford's work in conjunction with GR came at the hands of Ludwik Silberstein in 1918.
- Silberstein did not fully accept general relativity as written, but investigated its tenets and consequences
- In the course of this study, he noted that Clifford had already equated curvature with matter
- The fact that he mentioned this is not so important as the context: His attitude was that equating curvature to matter should not be regarded as a new accomplishment
- Clearly, he would not have given Einstein credit for this particular advance in science, but would have awarded Clifford the honor
- **This influence of Clifford on the development of Non-Euclidean hyperspaces was a basic British attribute**

Other Clifford References

- Silberstein compared GR to the "Space-Theory" and *Common Sense*, but other writers made early comparisons with Clifford's other publications
- Henry L. Brose recommended that readers of his translation of Erwin Freundlich's *Foundations of Einstein's Theory of Gravitation* refer to Clifford's article on "Loci" and H.J.S. Smith's introduction to Clifford's *Mathematical Papers*
- Sir Oliver Lodge, by no means a supporter of GR, attempted to explain away the positive results of the light bending measurements by arguing that either the ether near the sun changed the refractive index of space or the ether composing the light beam reacted to the gravitation of the sun
- Only if these hypotheses could be decisively refuted, could Einstein's theory be considered. He then referred to Clifford's “Philosophy of the Pure Sciences”
- Even then, GR was only a mathematical gimmick to give the correct experimental results, and was only palatable since Clifford had already shown the comparison of ether and curvature, or so Lodge implied by his reference to Clifford's work.
- But only those scientists who were familiar with Clifford's work, as were the British scientists of that era, would have recognized the implication. So the implication is lost to anyone reading Lodge's paper today.

Thomas Greenwood

- Thomas Greenwood did not directly mention Clifford in his 1922 essay "Geometry and Reality," even though he did relate other interesting facts regarding the general attitude toward space curvature
- After explaining that astronomers had been searching for space curvature for a long time (before GR), some time by careful observation of stellar parallax, Greenwood continued to describe another aspect of non-Euclidean science that was common knowledge before relativity:
  - But all these [parallax] observations proved negative: space presented itself as Euclidean
  - Nevertheless there was an idea amongst men of science, that more accurate observations and the development of mechanical consequences of non-Euclidean geometry with regard to astronomical problems, would certainly favor the legitimacy of non-Euclidean postulates as physical hypotheses
- These simple historical facts, as explained by Greenwood, seem all but forgotten by modern historians and scholars who study the genesis of general relativity.

Still others

- Some scientists who first adopted relativity considered the "general principle of relativity" as the more important aspect of Einstein's theory rather than the expression of space curvature as matter
- This aspect of the development of general relativity would explain why Silberstein gave Clifford rather than Einstein credit for equating space curvature to matter
- Willem de Sitter had noted this very fact in his 1916 article on "Space, Time, and Gravitation" in *The Observatory*
- If the "general principle of relativity" were considered the more significant part of Einstein's theory at this early date, then Clifford's priority for equating matter to curvature would be preserved and the early references to Clifford's other works explained
- However, Clifford never worked on Gravity theory – His curvature theory was an attempt to explain EM induction

The bottom line is that these early British interpreters of General Relativity took a five-dimensional point of view and assumed that curvature was an ‘extrinsic’ characteristic of the space-time continuum

Wilson’s early interest

- William Wilson was a teacher first and later a colleague of Flint
- He also attempted to merge quantum theory and relativity within the five-dimensional field
- In 1922, he published an article discussing the relation of quantum theory and electromagnetism
- In 1926 he extended his discussion by the addition of a five-dimensional framework.
- Although he gave no credit for the basis of this framework to Kaluza (1921), he did state in a footnote that Flint had pointed out to him that his ideas "were exactly" similar to those found in O. Klein's 1928 paper extending Kaluza’s theory into the quantum realm
- In his later paper, Wilson derived an equation which became identical to Schrödinger's equation in quantum mechanics upon a simple substitution
- The difference between these two equations being that Wilson used the concept of a 'Volume' in five-dimensions, whereas Schrödinger's Ψ function later became associated with and/or equated to a probability density.

Wilson’s development of **Ψ**

- Wilson continued his development of this equation deriving a second equation, which he showed to be equivalent to Schrödinger's equation for the Hydrogen atom under a proper choice of limits.
- From these derivations Wilson was able to define his five-dimensional 'Volume' as follows:

“If a particle at some instant is actually within a 'volume' V_o it will be within a volume V, which is the parallel displacement of V_o, at some time later (or earlier) instant. If its position at any time is unknown, the probability that it is in a specified volume will depend in some way on V. This is, in fact, the usual meaning of V or Ψ.”

- Thus, the correlation between Schrödinger's equation and those derived by Wilson seemed complete for all intents and purposes

Wilson’s other student

- In 1938, in collaboration with Miss J. Cattermole, Wilson derived the quadratic operator of Special Relativity, $p_x^2 + p_y^2 + p_z^2 - m_x^2c^2 + m_0^2c^2 = 0$, by using a five-dimensional representation of Special Relativity
- Using linear operators within the context of five dimensions, they showed that this operator was equivalent to Schrödinger's equation, $\Delta^2 \Psi - 1/c^2(\delta^2 \Psi/ \delta t^2) - (4 \pi^2 m_o^2 c^2/h^2) \Psi = 0$.
- During this period, Wilson was still collaborating with Flint in his work with the five-dimensional space-time concept

Wilson’s public support for 5-Ds

- Wilson has the distinction of being (probably) the only scientist to ***publish*** a statement clearly supporting five-dimensional theories. According to Wilson,

  “Einstein himself described a unitary theory of great interest; but this too does not seem to furnish an acceptable solution of the problem of making electromagnetic phenomena an organic outcome of the geometrical properties of the continuum. The most attractive and probably the correct solution is one which has been developed by Kaluza and others.”

- This statement of strong support, made during a time when no one else seems to have been willing to make such a statement, appeared in no article or paper on those theories but in a three-volume book by Wilson on theoretical physics.

J.W. Fisher

- J.W. Fisher also worked with the five-dimensional framework during this same period, in collaboration with Flint and alone
- He was able to derive an analogy between the wave equations of light in the space-time continuum and the wave equation for a particle in the fifth dimension
- In the five space advocated by Fisher, everything became a radiation problem. In this manner, all particles were shown to travel null geodesics in the continuum
- Flint and Wilson later used this idea in separate advances
- Fisher's early collaboration with Flint was also helpful in establishing the five-dimensional formalisms that Flint was to use throughout his career

Henry Thomas Flint

Born in 1890, Henry Flint gained a M.Sc. From the University of Birmingham before being enlisted in the Royal Garrison Artillery from 1915-1918. Following World War One, he was successively Assistant Lecturer in Physics at Cardiff University, 1919-1920, Lecturer in Physics at Reading University College, 1920, and Lecturer in Physics at King's College London, 1920-1926. Whilst at King's College, Flint gained his D.Sc. from the University of London, and went on to become Reader in Physics at King's from 1926-1944. In 1930 he gained a Diploma in Medical Radiology and Electrology from Cambridge University, and began work as a Clinical Assistant in the Radiology Department of Westminster Hospital, later becoming Consultant Physicist to Westminster Hospital and King's College Hospital. Flint was appointed Professor of Physics at Bedford College, University of London, in 1944, a post he held until 1956. He died in 1971.

H.T. Flint

- The work of H.T. Flint offered what is undoubtedly the longest (four decades) and most sustained attempt to develop a modification of Kaluza's theory
- He published more than 35 articles in peer-reviewed journals
- His efforts centered about a grand unification between field theory and the quantum theory
- The many publications of Flint's can easily be identified as a continuous development and amplification of his earlier ideas, rather than a series of changing ideas concerning the fifth dimension
- Flint incorporated new ideas in relativity theory as well as quantum mechanics into his theoretical model as soon as they appeared in the scientific literature

The Flint collection at the University of London Library

About Flint's personal papers

- It's difficult to find where he begins to unify because he wrote voluminous notes and commentaries on other articles
- It can be assumed he began no later than 1922
- In 'Lecture notes on the theory of relativity' dated January 1922
- He's teaching a generalized 4-D space of metric $(ds)^2 = dx_1^{\ 2}+dx_2^{\ 2}+dx_3^{\ 2}+dx_4^{\ 2}$
- But near the end he adds the quantum theory and notes on Kaluza's paper

Notes on Kaluza’s 1921 paper

“In the general theory of relativity the electromagnetic four-vector potential must still stand apart from the metrical four-vector dimensional tensor $g_{\mu\gamma}$ characteristic of world phenomena. This dualism takes nothing form the theories of gravitation and electromagnetism but demands afresh an attempt to overcome it by a complete unified picture. A few years ago … H. Weyl undertook a surprisingly clever attempt towards the solution of this problem which belongs to the chief of the favorite ideas of the spirit of man. IN another radical revision of the geometrical foundation he obtained another radical revision of the geometrical formulation he obtained another form of fundamental vector (ϕ_{μ}) in addition to the tensor ($g_{\mu\gamma}$). This vector he interprets as the electromagnetic potential. The complete world-metric is set up as the common source of all natural phenomena. The same purpose will here be attempted in another way. Apart from the difficulties which accompany the profound theory of H. Weyl, it is possible to imagine ideally a state(?) more complete presentation of the concept of unity: Gravitation and electromagnetism proceed from a single universal tensor. I wish now to show that such a close union between the two world-powers appears in principle to be possible.”

“The form $F_{\mu\lambda} = \frac{\delta\varphi_{\lambda}}{\delta x^{\mu}} - \frac{\delta\varphi_{\mu}}{\delta x^{\lambda}}$ of the electromagnetic field

components, but still more the unrecognizable formal correspondence in the structure of the gravitation and electromagnetic equations demand formally the suggestion that the relation could be a distorted 3-index quantity:

$$\left[{}^{\nu\lambda}_{\mu} \right] = \frac{1}{2} \frac{\delta g_{\mu\nu}}{\delta \mu^{\lambda}} + \frac{\delta g_{\mu\lambda}}{\delta \mu^{\nu}} - \frac{\delta g_{\nu\lambda}}{\delta \mu^{\mu}}$$

By giving way to this idea one sees oneself pressed along a not particularly inviting path: for in a 4-dimensioned world besides the 3-index symbols already used up by the field components of gravitation, no others exist . Thus this interpretation of the $F_{\mu\lambda}$ is scarcely permissible except by means of the strange decision to introduce a new fifth world dimension.”

“But our wealth of physical experiences has included hitherto scarcely any indication of such a supernumerary world parameter, although certainly we are forced to regard our space-time world as a four-dimensional part of an R_5, only one must take into consideration the fact that we never notice any changes except those in space-time by placing derivatives with respect to the new parameters equal to zero. (Cylinder condition) The fear is that thereby the introduction of the fifth dimension might be cancelled because of the linking of the parameters in the 3-index symbols.
We therefore pass over into an R_5 and take over Einstein’s theorems … (his mathematical development)”

“If approx. ∏ corresponds to actuality the unitary theory sought would be in its chief traits be satisfactorily attained. A single potential tensor generates a universal field which under ordinary conditions divides itself into a grav. and elec. part. But matter in its ultimate structure is at least on the whole not fully charged, its “rest on the large scale” contrasts to its “restlessness on the small scale” to quote H. Weyl and that is true according to the above conception particularly for the new parameter x^0. … But if one tries to describe the motion of the electron by means of a geodesic of R_5, one encounters at once a serious difficulty which threatens to overthrow the structure.”

“(I am grateful to the valuable interest of Prof. Einstein for pointing out the following disagreement for the original of the above theorems) Briefly, the difficulty exists in the fact that for the electron since $e/m = 1.77 \times 10^7$ (reduced to light seconds) μ^0, when the earlier assumptions are rigidly applied, is of such a high order of magnitude that the last term in (IIa) instead of vanishing assumes a value beyond everything and the absurd in respect of experience even if otherwise formally everything is the same as before. Now the transition to large μ^0 requires modifications (thus the substitution $ds = d\sigma$ fades) it thus appears scarcely possible to carry through the theory without new hypotheses, simple in the old framework. On the other hand, I believe – with due reservation – to see a way open in the following direction which when it leads to the goal encloses a slite more satisfactory standpoint. Since with not to great velocities the matter generating the field also for arbitrary μ^0 $R_{00} \sim R_{x4}$ remains the two gravitation terms in (IIa) with proper fixing of the irrelevant reality-character of μ^0 assume opposite signs and it appears then by giving up the otherwise somewhat questionable gravitational constant x to bring about a reconciliation of the contrary orders of magnitude in which gravitation remains a difference effect. This way impresses itself through the view of being able to give to the constant the role of a statistical quantity . Certainly at present the consequences of the hypothesis are hardly the foreseen, also there are other possibilities to be kept in mind. Particularly the Sphinx of modern Physics, the Quantum Theory, threatens every universal validity of postulated theories.”

“In spite of all respect of the physical and theoretical difficulties sketched here which tower above the idea developed it is difficult for one to believe that in all the formal unity in these relations only a humorous chance is playing its tempting game. If there is more behind this than an empty formalism, it would all go to support Einstein's theory of relativity as applied to a five-dimensional world.”

The 1921 Notes

- Flint made these notes **quite soon after** the publication of Kaluza's paper showing his early interest in the 5-D interpretation of GR
- He particularly noted that there seemed to be too much promise in Kaluza's 5-D theory for it to be nothing more than "a humorous chance is playing its tempting game"
- There is so far no direct evidence that anything other than Kaluza's paper influenced Flint to adopt the 5-D point of view, but the coincidence of his doing so when so many other English scientists were influenced by Clifford cannot be so easily explained away

October 1926

- In ‘Lectures to post-graduate student on the development of general dynamics’, Flint compares papers by A. Carrell, E. Schroedinger and Bateman
- Bateman developed the idea of general covariance several years before Einstein’s GR
- But then Flint goes into a 5-D cosmology later and talks about a paper by P. Jordan

Dated 1927-1928

- Notes on ‘the association of a surface with the track of a particle in space-time’
- “It is possible to fill the region of space-time with trajectories or world-lines and orthogonal surfaces bearing to each other a relationship analogous to that which exists between lines of force and equipotential surfaces in an electrostatic field ….”
- He ‘associates a phase-wave with particle movement similar to DeBroglie’. His ‘W-surfaces of 4-space are the phases waves of DeBroglie – from a 4-D point of view it is better not to consider them as waves but as static surfaces’

Flint develops the Yukawa Potential

- From his University Notebooks of 1935-1938
- On the value of the expression

$$A = \frac{1}{4\pi} \int curl' \, M \, \frac{e^{-k(\tau - \tau')}}{\tau - \tau'} dv'$$

in nuclear field theory. dv' is small volume at $\tau'=0$, M is of form fF**s** where f is constant and F is function of x,y,z

$$A = \frac{g}{4\pi} curl(\bar{s} \frac{e^{-k\tau}}{\tau})$$

Then he explains the meson field

- The meson field W_m is the source and represents the nuclear field
- The meson field can be represented in 5-D continuum by a single tensor ($T_{\mu\gamma}$)
- He explains how mass comes to be associated with geometry by looking at how l_0 represents a limit to dynamical representation leads to an interpretation of m_0 in the structure of α.

He next incorporates the quantum

- Limit of

$$\mu_0 < {}^{h}\!/_{l_0}\, c\sqrt{\gamma_{55}}$$

- He relates this to the deBroglie wave by $l_0 = h/\pi_5$ where π_5 is the fifth component of momentum
- So there is a minimum possible length that can be measured which is related to the rest mass of electron and the fifth dimensions

c1950

- “The theory of relativity and the quantum theory”
- This seems to be a complete article in the author’s handwriting
- The purpose is to portray ‘it’ by means of geometry and a theory of measurement
- Flint states that ‘it’ is based on Weyl (to add QT) and Kaluza (to unify EM & Gravity)
- The paper is about 50 pages and Flint summarizes his work in this area
- He has a 5-D worldview and seems to convert every advance made by anyone into his 5-D reality

n.d.

- Titled “Atomic movements, 4-dim. unitary theory , notes on matrix notation”
- Schrodinger equation may be regarded A definition of the change of amplitude of a vector $\Psi = \Sigma\ \psi_m A_m$ in order to satisfy the principle of superposition
- “5-dimensionality is forced upon us by the requirements of the quantum theory”
- This is a surprising statement because it implies the a physical necessity for adopting a 5-D theory

n.d.

- Flint relates the basic fundamental electric charge to a 5-D momentum
- The quantity Π_5 = g/αc (α = constant in KK theory of the EM field) is a component of momentum with the conjugate coordinate u^5
- Flint regards the electron, photon and positron as "aspects of the same thing"
- $\int \Pi_5 du^5 = nh$ and etc – Here flint defines the quantum with regard to 5-D space-time

n.d.

- “On the Electrodynamic Scalar & Vector Potential”
- Flint develops a vector math to describe these in a 4-D instead of a classical 3-D space
- He talks about a 4-D volume, but does not strictly specify what he means by it
- Follows Minkowski, but does not say that the 4-D space is a generalization of 4-D space-time

n.d.

- [Presented] Before the Society – "Is it possible to speak of the location of particles either in space or time down to the smallest intervals we can think of?"
- "in our present methods such a limit exists and that, if we go beyond it, the structure upon which our theories are based breaks down. The position is not unlike that which existed at the end of the aether theory when it became evident that inconsistencies were included in it."
- Goes on to predict elements may be limited to Z = 96
- A α is $e/m_o c^2$ by J.W. Fisher about 15 years ago
- X^5 is periodic in the value l_o or $h/m_o c$ and no less value than this is of physical significance

‘Particles’ - n.d.

- About continuity and intro of particles (chemical as per Prout) into physics
- “It seems implied that the simple assumption of a fundamental particle is not possible – the limit must result from a relativistic assumption. The only way seems to be a relativistic limit to measurement.”
- So he is using the quantum as a limiting factor within the 5-D continuous field
- “Instead of a fundamental particle would mean a limit exists, but the particle would be available for Lorentz rule of change of length in motion. The introduction would mean that a limit exists.”

‘Difficulties concerning the Theory of the Electron’ – 29 November 1954

- Discusses problem of self-energy of electron
- Summarizes Mie, Born, Infeld, Wheeler, Feynman, Dirac, H. Tetrode and G.N. Lewis
- Then he makes a 5-D attempt to explain
- A relativistic theory of electron, i.e., Kaluza
- Suggestion that in the region near electron the curvature is $\dfrac{2e^{-4r/r_0}}{r^2}$ where $r_0 = e^2/m_o c^2$

Untitled lecture, perhaps for the BA – n.d.

- 2nd lecture on discontinuity in physics
- “At present we are in a state of frustration with the field of nuclear physics”
- “The theory of the nuclear field is incompletely known. Our structures may even be on the wrong lines. … We are in the position of the practical engineer …
- It seems difficult to accept a law which gives structure to space and above all to empty space. How could properties of empty space be tested? We seem to be back again dangerously near the aether … only the geometers can give properties to space and then any properties they wish. Physicists are stuck with the relative positions of material bodies …”
- “I will conclude on the note that we seem to have come to a point in physics where a new idea is required. If it comes soon we are on the eve of a new advance.”
- This essay comes late as he talks matter-of-fact about nuclear energy

Flint’s published papers in peer reviewed journals

- In his earliest work, Flint attempted to incorporate quantum ideas directly into a space-time framework using Weyl's and Eddington's concept of parallel displacement of a vector
  - (1927 in collaboration with J.W. Fisher).
- However, Flint soon adopted the five-dimensional approach of Kaluza's theory in hope of overcoming the difficulties of his earlier work.
- He continued this line of theoretical work until the late 1950s.

- Flint eventually adopted a concept using the notion of the matrix length of a vector, which he treated as a distance under parallel displacement within the five-dimensional field, much as Weyl and Eddington treated the parallel displacement of a vector in a four-dimensional continuum.
- With this method, Flint was able to derive first order quantum equations in 1935.
- However, he was unsatisfied with the way in which the equations entered into the mathematics instead of being derived directly from the mathematics of the field.
- Subsequently, this development was continued and refined in later work by Flint and the method of a five-dimensional displacement became a characteristic of his later derivations.

Basic characteristics of Flint's work

- The use of an operator in the form of a partial differentiation with respect to the fifth coordinate, such that the operation on any function is the same as multiplying that function by 2i(mc/h). This is equivalent to the association of the fifth component of momentum of a test particle with the scalar quantity mc.
- Fundamental lengths of h/m_oc (the Compton wavelength) and e^2/m_oc^2 were used.
- A 'principle of minimum proper time' was derived, giving a smallest detectable length of $l = (h/m_oc)B(1-B^2)$ as well as a smallest detectable time of $t = (h/m_oc^2)[l/(1-B^2)]$ where $B = v/c$. For small distances, this principle corresponded to the Heisenberg Uncertainty Principle.

- Flint eventually derived first and second order quantum equations as well as an equation analogous to Schrödinger's equation directly from the field structure.
- He was also able to explain the quantization of charge and mass.
- In 1944,he applied his concept to the meson theory and a year later attempted to explain nuclear fields in a similar manner.
- In these applications of his basic five-dimensional hypothesis, Flint presented the notion that "the equations of the quantum theory are gauging equations in a geometrical and metrical system suited to the world of physics.“
- He had found in Kaluza's framework an appropriate space-time structure on which to base his own system as well as a convenient way of explaining the 'mc' term without introducing it from outside of the system. The 'mc' term corresponded to a five-dimensional momentum.

- Flint had found it necessary to make changes in Kaluza's original formulation in order to accomplish his own goals.
- Aside from the above-mentioned modifications, Flint changed Kaluza's space-time structure in order to avoid the earlier criticisms of Kaluza's work.
- He noted that the more serious objections presented were that the "general covariance is destroyed by the 'cylindrical' condition, that the g_{μ} do not contain x^5 and that g_{55} is taken as constant.“
- He overcame these difficulties by "regarding the special use of the cylindrical condition and the assumption about the way x^5 occurs in the functions as an approximation required by our need to eliminate x^5, in interpreting our results in the light of our present knowledge of physical phenomena.“
- It almost sounds as if Flint was making a qualifying statement regarding the reality of the fifth dimension

- During his development of the five-dimensional concept of the quantum theory, Flint proceeded as if there were some reality to the concept, but he made no statements which demonstrated his belief in the reality of a fifth dimension.
- It is hard to comprehend the fact that Flint did not believe in the reality of the fifth dimension when so many qualities were attributed to it.
- His one published statement regarding this subject only referred indirectly to the reality issue.
- His ambivalence in publicly supporting the reality of a fifth dimension is further evident in statements that would seem to indicate caution (at least) in granting some essence of reality to the fifth dimension, even while he publicly put forward a face displaying a safe disregard for its reality.

Flint’s final unification - 1966

- *The Quantum Equation and the Theory of Fields* Methuen’s Monographs of Physical Subjects
  - 1. The Theory of Relativity
  - 2. Theory of Kaluza and Klein
  - 3. Field Theories
  - 4. The Symmetric Energy tensor and the Tensor of Moment of Momentum
  - 5. The Derivation of the First Order Quantum Equation
  - 6. Continuation of the Field Theories
  - 7. The Basis of the Theory in Accordance with the Principles and Notation of the General Theory of Relativity

How Flint related Kaluza’s theory to Dirac’s equation in his book

“ The matrices ($\gamma\mu$) are introduced in the adoption of a line element matrix

$$ds = \gamma_\mu dx^\mu \qquad (4.14)$$

where the matrices $\gamma\mu$ are defined by the relations

$$\gamma_\mu = \gamma_{\mu\nu}\, \gamma^\mu.$$

The idea associated with the introduction of this expression is that it my be possible to discover in geometry a further unifying concept which will show the relation of the phenomena of the microscopic to those of the macroscopic world.

The notation will be developed at a later stage. Only a limited introduction is now necessary to show how a symmetric energy tensor can be obtained when the Lagrange function depends upon a spinor quantity and its differential coefficient. “

“The five matrices (γ^μ) are assumed to satisfy the relations:

$$\gamma^\mu \gamma^\nu + \gamma^\nu \gamma^\mu = 2 \gamma^{\mu\nu} . \qquad (4.15)$$

This is a generalization of Dirac’s relations:

$$\alpha^l \alpha^k + \alpha^k \alpha^l = 2\delta^{lk} \quad , \alpha^l \beta + \beta \alpha^l = 0.$$

The generalization appears to have been introduced by Tetrode for a four-dimensional continuum in which case the coefficients (g^{mn}) replace ($\gamma^{\mu\nu}$).”

This is a work in progress