Proc. Roy. Soc. 270 (No. 1342) - 27/11/62 - pp. 297 - 356.

Discussion on the present state of Relativity under leadership of Prof. H. Bondi

(1) ~~Mag~~ Madge G. Adam — The observational test of gravitation theory.

Summary: The advance of the perihelion is firmly established to be in accordance with Einstein's Theory. The deflection of a light ray as it passes close to a massive body is nearer to the Einsteinian value than to the Newtonian value, but the stated probable errors still leave a discordance with theory. The red shift of spectrum lines in regions of high gravitational potential seems now to be well established on the surface of the earth, but the astronomical evidence for the red shift is still inconclusive. In stars the measures are not yet certain enough, and in the Sun, where the measures are certain enough, there prove to be complicated factors that are not yet understood.

(a) The theoretically predicted excess of the perihelion advance over the Newtonian value is $12\pi^2 a^2 c^{-2} T^{-2} (1-e^2)^{-1}$ of a revolution per revolution. Clemence (1943) showed that for the most favourable case of the planet Mercury, the advance agrees with this expression of 43" per century, and Morgan (1945) has shown that the earth's perihelion motion also has the predicted value of 3".8 per century.

(b) For the deflection of a light ray, adopting a corpuscular (or photon) theory of light, and associate mass with light particles, then a light ray which passes near to a gravitating mass moves along a hyperbola with asymptotes inclined at an angle α, proportional to $GMc^{-2}r^{-1}$, where G is the gravitational constant, and r is the distance at which the light ray passes the centre of gravity. ~~Mik~~ Mikhailov (M.N.R.A.S, 119, 593, 1959) has shown that the observations do not show (after 35 years & six successful eclipse observations) that the hyperbolic law is the best representation for the observed deflection Δr (shift in a radial direction from the Sun's centre). Von Klüber states that further observations are only justified if there is real progress in fulfilling the stringent conditions required for what is the most difficult observation that can be attempted at a solar eclipse. Mikhailov suggests that further observations should be co-ordinated on an international scale.

(c) The predicted red shift of spectral lines is given by

$$\frac{\Delta\lambda}{\lambda} = \Omega/c^2 = GM/rc^2$$

Highest ratio of M/r is to be found in white dwarfs. For Sirius B, proximity of Sirius A is a handicap the spectrum of B being always overlaid by that of A. It is generally agreed that the tests so far on Sirius B are inconclusive. Greenstein of Mt. Palomar plans to use the 200 in: telescope on units of measurement which will give consistent ~~values~~ results when observations are made on objects which are moving relative to the observer, the general theory of relativity introduces units which give consistent results when measurements are made on objects in different fields of force. Both theories, he suggests, are theories of measurement, and as such are incapable of predicting physical changes to the behaviour of clocks, atomic radiations or human beings.

(3) J. L. Synge – Systematic approximations in the calculation of gravitational fields.

Synge starts with the field eqns $G_{ij} = -8\pi T_{ij}$ as 10 eqns connecting 20 quantities viz $10\, g_{ij}$ and $10\, T_{ij}$ & describes a parametric method of approximations, consistency condns & the first approxn, the second approximation, the DFS & FS methods recently adopted by him.

There is, in the discussion, some funny exchanges between him and Bondi, and also critical remarks by many speakers. Dirac enquires if there be an action principle underlying the eqns, since that would be the first stage for quantisation. Synge says no & disagrees with Dirac that having too many variables & too few eqns is a dis-advantage, and thinks it is an advantage giving freedom to construct models. Prof. Bondi disagrees with Synge's hankering after reality and says that the interest of general relativity lies in asking what the theory would say in conditions which admittedly do not occur in those parts of the Universe about which we know much.

(4) H. Bondi – Gravitational waves from axi-symmetric isolated systems (Proc. Roy. Soc. A. 269, 21) – only title given

(5) A. Trautman – Analytic solns of Lorentz-invariant linear equations.

This note presents a method of constructing classes of new solutions to linear, special relativistic partial diff. equations, and, in particular, the method may be used to produce null, curling solns of Maxwell's and linearised Einstein's eqns (special relativity & linearised gravitational theory). The method consists of a procedure earlier used by Synge

~~(6) F. Hoyle and J. V. Narlikar – Mach's Principle & the creation of matter.~~

(6) W. Kundt – Exact solutions of the field eqns: twist-free pure radiation fields.

Results obtained in the study of twist free radiation fields in general relativity theory. It is remarked in conclusion that the class of exact solutions under consideration is a fairly big one as it depends on several arbitrary functions, but, nevertheless that these fields seem to be nothing more than a crude approximation to realistic wave fields.

A discussion on papers (4), (5) & (6).

(7) F. Hoyle and J. V. Narlikar – Mach's Principle & the creation of matter.

Suggestion (not explanation) made by Mach was to the effect that inertial forces are related to the distant parts of the universe. Einstein hoped that the general Theory of relativity might provide the necessary mathematical foundation of Mach's Principle, but this hope was not realised. Yet the coincidence of the inertial frame of Newton's theory with that in which the distant ~~stars~~ parts of the Universe are non-rotating can be deduced from cosmology. The apparent paradox that the coincidence in question can be deduced from normal cosmology, but not from the normal relativity theory is explained by the ~~fact~~ circumstance that normal cosmology contains postulates that lie outside the relativity theory – Gives the two postulates and explains how the coincidence in question can be obtained – inserts Einstein's field eqns in the eqn given by the second of the above postulates viz. the Robertson–Walker line element, and shows that the procedure is contradictory to Mach's Principle. It is also pointed out that Gödel's solution of Einstein's field equations, which does not satisfy the condition of isotropy, is fundamentally different from the R–W form and cannot be obtained from it by a coordinate transformation. The most that can be achieved within the frame work of the relativity theory is to show that Newton's absolute space can be replaced in the relativity theory by initial boundary conditions on the metric tensor. In normal forms of cosmology, the required boundary condns are supposed imposed at the origin of the Universe; if this view is correct, then the coincidence implicit in Newton's bucket experiment must simply be accepted; it can never be explained – Next the theory of steady state cosmology is studied using an ~~Mach~~ Action Principle of M. H. L. Pryce, and effects of rotation is taken into account (using the notation of Raychaudhuri) – The essential point is that creation of matter keeps the universe going, it keeps ρ at a more or less constant level and the initial non-homogeneity and non-isotropy is expanded away, over specified physical distances. Rotation, such as occurs in the Gödel solution is not destroyed but is rendered more and more ineffective. The Universe persists due to the type of field C, while Einstein's eqns may be said to possess transients as solutions. If the universe itself is transient there is no reason why the geometry of space-time should have any particular regularity (such as we find it to have). Since the Universe persists due to the C-field, then the transients may be expected to die away, leaving the required homogeneous, isotropic regularity in any finite portion of space-time, however large:

Discussion: (i) Dirac – ~~I~~ I would like to ask the experimental people how accurate is the agreement mentioned by Prof. Hoyle about the ~~absolute~~ frame of absolute non-rotation provided by Newton's bucket experiment being in agreement with the frame provided by the distant stars. It is important that the accuracy of this particular experiment should be pushed up still further. It might very well show a discrepancy which would be fundamental to all theories of cosmology.

(ii) Hoyle :– In a preliminary way the agreement is very good, but it would need a lot of work to see just how good it is.

Remarks by Schlegel, Bondi, Davidson & Synge. Hoyle finally says " I think I might just add that one could say that throughout physics people have had the idea of conservation, but the quantity which is physically conserved has changed as the years have gone by, and all that is being suggested here is that a further change is necessary".

(8) A. Lichnerowicz – Propagators and commutators in general relativity.

Describes a new mathematical instrument introduced by him in 1958-59, the tensor and spinor propagators. These propagators are extensions of the scalar propagator of Jordan-Pauli which plays an important part in quantum field theory. It is possible to construct, with these propagators, commutators and anti-commutators for the various free fields, in the frame work of general relativity theory – Tensor propagators, tensor distributions, Dirac biscalar & Dirac bitensors – Elementary kernels and propagators of the operator $(\Delta+\mu)$ – Tensor fields, commutator for the free electromagnetic field – commutator for the variation of the gravitational field – Spinor fields. – Very little discussion.

(9) S. Mandelstam – Quantization of the gravitational field. – Present theories general work in 'flat space' – Gupta's original attempt – Quantisation in flat space only a provisional solution – Work of Thirring using unquantised g's – Attempt of DeWitt for quantisation without going to flat space; an improvement of this is attempted here – Work of Bergmann & collaborators suggests that a quantised theory of gravitation should deal only with observable quantities i.e. quantities independent of the coordinate system; the problem of finding such quantities is attempted by a method in what follows – First quantum electrodynamics is examined & it is shown that the use of path-dependent variables for quantising electrodynamics can be extended to quantise gravitation – This method is not so complicated as it appears – The physical significance of the method is discussed – The method is explained for gravitation & it is shown that the type of path-dependence here is inherently more complicated than that encountered in electrodynamics – Integrability condn. as in electrodynamic case obtained – Eqns of motion and commutation relations for the path-dependent variables obtained by using Fermi coordinates along the paths – Question of ordering – Sufficiency of giving local commutation relations & expansion of theory in perturbation series which, in the first order, is equivalent to Gupta's theory – Question of comparison with Feynman theory of the S-matrix & renormalisation – The ideas outlined here provide us with a natural method of quantising a theory of ~~gravit~~ curved space in which curvature itself is a dynamical variable.

Discussion – (i) D. Bohm – Suggests connecting topology & physics through the potentials

(ii) D. Kundt – Are the P.B's used here the Dirac brackets of Prof. Bergmann or the ordinary P.B's; Mandelstam states they are the Bergmann type – Also asks a question about the Bergmann-Komar approach

(10) P.A.M. Dirac – Particles of finite size in the gravitational field – Describes some work he is just engaged upon, the object of which is to set up a theory of gravitational field interacting with particles. The theory is to be in agreement with Einstein's theory of gravitation & he insists that it shall follow from an action principle since he believes that Nature works according to an action principle & if one has such a principle

one has a first step towards quantisation – Re. size of particle 4 if it is assumed that each particle must have a size no smaller than the Schwarzschild radius, one runs into difficulties & so a particle bigger than this radius is taken and the analogy of the e.m.f is applied – This problem is that of setting up a theory of an extended electron in an electromagnetic field & assumptions made are equivalent to the model of an electron as a sort of a bubble in the electromagnetic field – An action principle is set up for this model consisting of two parts a four dimensional taken over the space outside the electron (where Maxwell's eqns are satisfied) & a three-dimensional integral taken to be just a constant times the three-dimensional "area" of the surface.. This integral gives a surface tension – The variational procedure can be carried out by standard methods & eqns of motion obtained and one gets a reasonable model for the electron. The electron has no definite size or shape, which can vary, but it has an equilibrium position about which it can oscillate & the oscillations are stable. The model behaves in a proper physical way & we can apply quantum mechanical ideas. One interesting result that comes out of quantisation (applies to a sph. sym. soln) of the eqns of motions for the pulsations (size but not shape varying) is that the energy of the first excited state is about 50 times greater than the ground state. It is hoped that a more accurate theory may put up this number & will give us a theory of the mu-meson. To bring in a more satisfactory physical theory one has to bring in the spin somehow, but I do not yet know how to do that. There are possibilities on these lines of getting a reasonable theory on the basis of which one might tackle the gravitational problem.

I have been working on a corresponding gravitational problem in which there is a particle of a size greater than the Schwarzschild radius, & the action consists of the usual action of the gravitational field, outside the particle, plus a surface term, which I again take to be just the surface "area" of the tube, multiplied by a constant. One gets satisfactory boundary conditions if one assumes that the $g_{\mu\nu}$ are constant inside the particle, and continuous at the surface. I have made a detailed study of the spherically symmetrical solution, the pulsating particle. Outside the particle we have the Schwarzschild soln. & the action principle provides definite equations of motion for the pulsations. It turns out that there is a difference from the electromagnetic case – there we needed a surface tension to hold the particle together against the Coulomb repulsion. In the gravitational case, we need a surface pressure to hold it apart against the Newtonian attraction. We find that as a result of this change of sign, the particle is unstable & one has to add a further term to the action to secure stability under pulsations due to this extra term. I have not yet developed the theory sufficiently to be able to say whether it is stable also under distortions, but so long as the spherical symmetry is preserved, the model is a stable one, and so the situation is hopeful for developing this into a theory of particles of finite size interacting with the gravitational field according to Einstein's theory.

<u>Discussion</u> (i) <u>Möller</u> – Prof. Dirac that in the electromagnetic case, there were some difficulties about introducing the spin. Is it not that one could never hope to get out the Dirac electron from such a model?

(ii) Dirac – one would hope to have some generalisation of it. If you work out the Hamiltonian according to this model, a square root comes in, and somehow one has to get rid of that square root and bring in the spin matrices – a mathematical problem which needs some bright idea to solve it

(iii) Lichnerowicz – I am a mathematician, and I always have the impression that the physicist in his domain has some idolatry for the Lagrangian and the Hamiltonian. These are very useful, but it is not always the case that they are really the keys to all problems. In general the key is perhaps an operator of the second order, a good operator, which in general terms, corresponds to L or H. For the problem of interaction this is certainly necessary. But for a mathematician, many problems of interaction are without real mathematical significance.

Reviews of Modern Physics – Vol. 34, No. 4, October 1962 – In commemoration of the 60th birthday of E. P. Wigner (17/11/62).

(1) P. A. M. Dirac – The conditions for a ~~relativistic~~ quantum field theory being relativistic.

Summary – A quantum field theory in agreement with special relativity can be built up from the infinitesimal operators of translation & rotation. These operators are expressible in terms of a momentum density and an energy density. The momentum density is determined from the geometrical properties of the fields concerned. The energy density has to satisfy commutation relations for which certain conditions hold given by eqn

$$[U, U'] = a\delta(x-x') + b_r \delta_{,r}(x-x') + c_{rs}\delta_{,rs}(x-x') + d_{rst}\delta_{,rst}(x-x') + \cdots$$

$$b_r = 2K_r + \beta_{rs,s};\ \left\{\int(\beta_{rs} - \beta_{sr})\,d^3x = 0\right\}.$$

– The Born-Infeld electrodynamics is given as an example & it is pointed out that the stronger conditions needed for quantising the theory w.r.t. curvilinear coordinates are not fulfilled [Dirac, Proc. Roy. Soc. A. 257, 32 (1960)] So the Born-Infeld electrodynamics can be quantised in agreement with special relativity, but not in agreement with general relativity

(2). P. Jordan – The geophysical consequences of Dirac's hypothesis.

The Dirac's hypothesis is the idea that the "constant" of gravitation, $\kappa = 8\pi G/c^2$, might in reality ~~not~~ be a variable quantity and diminishing with time, approximately proportional to the age of the Universe. This hypothesis is meaningful in cosmology and astronomy, in connection with double stars, origin of the planetary system and astrophysical age determinations. But the most conspicuous consequences of the Dirac hypothesis are those concerning our Earth. It is shown here that modern knowledge of the earth gives what may called proof of the correctness of Dirac's hypothesis.

(3) V. Bargmann – On the representations of the rotation group (p. 829)

(4) J. A. Wheeler – ~~On the~~ Problems on the frontiers between general relativity and differential geometry (p. 873).

2/2/66 – (A) Rev. Mod. Phys. 1962 – (1) Two articles on the perceptron (brain function), pp. 123 – 142 (Theory of neurons, using also mathematical analysis

(2) Physical nature of the chemical bond by K. Ruedenberg, pp. 326 – 377 (Ref. to no. of books on Quantum Chemistry – Highly mathematical

✓ (3) Splitting of the Riemann tensor by C. Lanczos – pp. 379 – 389 – Treats of the tensor H_{ijk} derived from R_{ijkm} (instead of R_{ij}) giving a clue towards a deeper understanding of the electromagnetic and wave mechanical phenomena within the framework of general relativity – He calls H_{ijk} the spin tensor in the hierarchy ϕ_i, ϕ_{ik}, H_{ijk}, R_{ijkm} (ϕ_i = vector potential)

(4) Conformal invariance in Physics by T. Fulton etc, pp. 442 – 457.

(5) Normal constants of motion in quantum mechanics treated by projection technique – Quantum Chemistry Group of Uppsala University

(6) Contributions on Wigner's 60th Birthday – Articles by Dirac, Jordan, Bargmann & Wheeler mentioned above. – Reference to Jordan's book "Recent developments in general relativity, 1962, Pergamon Press.

(B) Rev. Mod. Phys. 1963.

(1) Relativistic invariance and Hamiltonian theories of interacting particles by Currie, T. F. Jordan and Sudarshan, pp. 350 – 375.

(2) Accelerated frames of reference by J. E. Romain, pp. 376 – 389.

(3) Semi direct products and point groups by S. L. Altmann, p. 641 (Part of discussions of the Sanibel Symposium on atomic & mol. quant. mech, 1963, pp. 415 – 735).

[Ref. to Altmann's article in Phil. Trans. Roy. Soc. (Lond), A. 255, 216 (1963)]

3/2/66. (C) Rev. Mod. Phys. 1964.

(1) pp. 1 – 503 – International Symposium on Superconductivity

(2) April 64 issue dedicated to Oppenheimer on his 60th birthday on 22/4/1964 – on p. 509, there is a ✓ letter to Oppenheimer from Max Born, very interesting letter (Born's address being 328 Bad Pyrmont, West Germany, Marcardstrasse 4) – Small article by Schiff on observational basis of Mach's Principle – Article on Chance & Choice by David Hawkins (taxonomic games) –

– An article by P. Morrison on "Thermodynamic Characterisation of self-reproduction" (Cornell University). At the beginning quotes a stanza translated from the Sanskrit in Panchatantra (translation by Arthur Ryder)

Horses, elephants, and iron,
Water, woman and man,
Sticks and stones and clothes are built
on a different plan

✓|| An article on structure, substructure, and superstructure by C. S. Smith of M.I.T with beautiful illustrations of soap bubbles, crystalline grains, blade surface etc – Beautiful article to be used for a popular lecture

✓|| – Article by Res Jost on Poisson brackets (an unpedagogical lecture) – Ref. to Dirac & Pauli

|| (3) p. 820 – Quaternions in Relativity by P. Rastall (pp. 820 – 832) – Very interesting article.

✓|| (4) Coordinate conditions and canonical formulations in gravitational theory by J. L. Anderson, pp. 929 – 938 – mentions also quantisation of general relativity on p. 937. – to be read

✓|| (5) 4-dimensional formulations of Newtonian Mechanics & their relation to the special & general theory of Relativity by Peter Havas pp. 938 – 963 – to be read

✓|| (6) A.M. wavefns constructed by Projection operators by P. Lowdin, pp. 966 – 976 – to be read

(7) Tables of Clebsch-Gordan coefficients of the group SU_3 – pp. 1005 – 1024 – beautifully prepared tables.

(8) Physical structure of general relativity by D. W. Sciama – pp. 463 – 469 (Superconducting symposium part).

5/2/66 (D) Rev. Mod Phys, 1965.

✓✓|| (9) Jan, 65, p. 84 – Keith W. McVoy – Symmetry groups in Physics – Treats of Lie Groups, spin SU_3 and beyond, isotopic spin group – to be read

✓|| (10) p. 201 – Seminar on embedding problem – Ref. to Eisenhart's book's introduction – Riemannian manifolds embedded isometrically into Euclidean spaces – of rel. R-spaces in pseudo E-spaces – under auspices of Israel A.E.C

✓| (11) p. 215 – R. Penrose – A remarkable property of plane waves in gen. rel.

✓✓|| (12) p. 221 – C. Fronsdal – Univ of Calif, Los Angeles, Calif – Elem. particles in a curved space

(13) p. 225 – D. W. Joseph – Generalises covariance – something like (10) above

(14) p. 227 – Y. Ne'eman – Embedded space time & particle symmetries

April, 65

✓|| (15) Operational foundation of Einstein's General Theory of Relativity by Saul A. Basri, p. 288

July 65 – Whole issue devoted to Conference on Correlations of particles emitted in nuclear reactions

(16) pp. 327 – 533

October, 65

(16) Our knowledge of the fund. consts. of Physics & Chemistry in 1965 – p. 537 by Cohen & Du Mond, pp. 537 – 595.

(*) Paper by A. J. Macfarlane on "Dirac matrices and the Dirac matrix description of Lorentz-transformations" in Comm. Math. Phys. 2 (1966), 133-146.

✓ (This work of the author to be extended to my spin 3/2 matrices).

(*) No. 2267 – About extension of the authors' methods for including higher-spin particles with the aid of Duffin-Kemmer & Bargmann-Wigner equations.

(17) The conceptual basis and use of the geometric invariance principles pp. 595–633, by Houtappel (Leiden, H. Van Dam (North Carolina) & E. P. Wigner (Princeton Univ, Princeton, New Jersey)

(18) Antimatter and the development of the Metagalaxy by H. Alfvén, pp. 652–66. – postulates symmetry of cosmological theory between matter & antimatter & develops a very interesting theory

(3/10/68) Notes for the Review Article on "Quantisation of general relativity"

(1) A. Trautman (in discussion on the present state of relativity 270 (No. 1342) – 27/11/62, pp. 297–358) talks of a linearised gravitational theory.

From Issues of Math. Reviews 1968

(2) Segal Irving – Proc. Nat. Acad. Sci, U.S.A., 57 (1967), 1178–1183) – Notes towards the constn of non-linear relativistic quantum fields I – look at II also.

Ibid, 1967. (January)

(3) R. M. Rosenberg (2nd Conf. on non-linear vibration problems) Warsaw, 1962, pp. 37–51 – States that "linearity implies linearity" only one in one particular reference frame; in other equally natural reference frames "linear problems" are just as non-linear as others.

(4) D. Adler – Canad. J. Phys. 44 (1966), 289–92 – Author's summary "It is shown that the theory of spin-2 particles, generated by the Lagrange function which reduces to that of linearised gravitational field theory in the limit of zero mass, is inconsistent"

(5) Two papers on Calculation of meson coupling constants in Heisenberg's non-linear field theory (Heisenberg's non-linear spinor theory of elementary particles (?) in Nuovo Cimento (10) 36 (1965), 533–41 and (10) 37 (1965), 1143–59.

(6) Paper by G. Petiau in Nuovo Cimento (10) 40 (1965) 84–104) – Using non-linearity in some quant. mech. problem & getting Sn, Cn, Dn. (Reviewer Ingraham calls this a very interesting paper)

(7) A discussion of the Born-Infeld-Kichenassamy (?) theory conducted within the frame work of the special relativity theory.

(February)*

(8) ~~No. 2267~~ No. 2379 – Some properties of the quantum linearised Einstein field – "Some aspects of the quantised linear approximation to Einstein's theory" [Nuovo Cimento (10) 39 (1965) 1159–65.

(9) Attempts to construct gravitation in terms of neutrino fields – Here the possibility is explored of showing that gravitons are bound states of photons interacting non-linearly among themselves (No. 2393)

March

* No. 3631 — The quantisation of fields with maximum spin 3/2 and the application to SU_{12}.

(No. 5259) xx Spectral representation and mass formula for spin 3/2 particles — No relativistic treatment.

(No. 5284) — P. M. Mathews — Two papers on "Relativistic ~~wave equation~~ Schrödinger equations for particles of arbitrary spin" — To find connection between this & my general wave eqn. for arbitrary spin.

✓

† Coral Gables Conferences on Symmetry Principles of High Energy (No. 7025) — W. H. Freeman & Co, 1966 (Find if this be available in the I. I. Sc. Library.

No. 7088 — Article on "Vaidya's radiating Schwarzschild metric"

†† (1) ICTP, Trieste May 3 — Proceedings

(2) Problems in elem. particle physics — Spring School held in Erevan, May 18-23, 1965
10 articles on Weak interactions and CP-parity violation, 6 articles on e-m interactions, 5 on resonances in system of elem. particles, 10 on Symmetry of elem. particles, 10 on high energy particle interactions.

To find if above are in the I. I. Sc. Library

(March)*

(10) No. 3635 – The Weyl group on a curved space-time V_4 defines a field.

(11) No. 3639 – No inconsistencies in Heisenberg's non-linear theory when applied to a particular problem.

(12) No. 3659 – Breakdown of unitary octet symmetry in a non-linear model of elem. particle theory

(13) No. 3660 – Meson states in the above theory

(14) No. 3746 – On Gravitational radiation by R. K. Sachs – monograph also gives a brief discussion of the linearised theory.

(15) No. 3751 – Spin of virtual gravitons – Problem of spin of an interacting gravitational field is discussed within the framework of linearised gravitational theory & shown that gravitons have spin 2. (Soviet Physics JETP, 21 (1965), 199-203)

(April)^{xx}

(16) "Applications of group theory in particle physics" ~~in particle physics~~ Lecture by F. J. Dyson in SIAM Rev. 8 (1966) 1-10 – To be read for getting ~~any~~ general remarks. (No. 5292)

(17) No. 5294 – Internal symmetry and Lorentz invariance by X – The reviewer remarks "This letter is one of a flood of such dealing with the so-called no-go theorems for the combination of ~~other~~ invariance under the inhomogeneous Lorentz group with internal symmetry."

(18) No. 5341 – Singularities in bootstrap gravitational geons – What does this mean! Ref to Komar's work in M. R (33, 1966) No. 7183).

(May)†

(19) No. 6974 – P. G. Bergmann – "Hamilton-Jacobi and Schrödinger theories in theories with first-class Hamiltonian constraints – Treats of the approach to a quantum version of the general theory of relativity – Reference to Dirac's article in Phys. Rev (2) 114 (1959) - 924-930.

(20) No. 7012 – Quantum electrodynamics in the non-linear spinor theory.

(21) No. 7023 – A relativistic generalisation of the SU_6 symmetry group

(22) No. 7036 – Article about resolving Duffin-Kemmer algebra into 3 subalgebras corresponding to the one, five, and ten-dimensional representations – Reviewed by E. M. Corson.

(23) No. 7093 – The mass of a neutrino from spinor connection in a Riemann space

(June)††

(24) No. 8172 – Polkinghorne – Icecream-cone singularity in S-matrix theory.

(25) ~~Intern.~~ No. 8201 – International Conference on the relativistic theories of gravitation, 1962 under direction of L. Infeld – Gauthier Villars, Paris, PWN. Editions scientifiques de Pologne, Warsaw, 1964 – heaps of people taking part on all sorts of topics. To be found if this be in I. I. Sc.

(2)

(*) renormalisability of quantum electrodynamics. The infinities come in different places. It isn't a related problem.

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* Discussion on (c) printed in full in Acta Physica Polonica, Vol 24, Dec. 63, p. 697

Moller - May I, as a non-expert, ask you a very simple and perhaps foolish question. Is this theory really Einstein's theory of gravitation in the sense that if you ~~have~~ would have here many gravitons, the equations would go over into the usual field equations of Einstein?

Feynman - Absolutely, Moller - You are quite sure about it? Feynman - A long answer

Moller: But you say you are not sure it is renormalisable

Feynman: I'm not sure, no.

Moller: Would this not matter in the limit of a large no. of gravitons?

Feynman - No. You see there is still a classical electrodynamics, & it is not got to do with the (*)

Rosen: I'm not sure of this, not being one of the experts; but I have the impression that because of the non-linearity of the Einstein eqns there exists a difficulty of the following kind. If the linear eqns have a solution in the form of an infinite monochromatic wave, there does not seem to correspond to that a more exact solution; because you get piling up of energies in space and the soln then diverges at ∞. Could that have any bearing on the accuracy of this kind of calculation?

Feynman: No, A single graviton is not the same thing as an ∞-gravitational wave, because there is a limited energy in it. There is only one ticw.

Rosen: But you are using a momentum expansion which involves ∞. waves

Feynman - (Some answer not easily understandable) - yes, there are corrections ...

De Witt - Asks for a ~~proof of~~ statement of Feynman's tree theorem & Feynman gives a long 2 page reply, highly interesting and humorous.

Another question by De Witt & a 4-5 page reply by Feynman.

Sachs - for irrational reasons people are particularly interested in those parts of ~~the~~ theory where is a possibility of real qualitative differences: what do the coordinates or topology mean in a quantised theory and this kind of junk. Now I wonder if you think that this perturbation theory can eventually be jazzed up to cover also this kind of questions?

Feynman - General remarks about difficulties of perturbation theory ~~of~~ and limitations of quantum field theory due to divergences which exist everywhere - Today there is no expression of the quantum theory which is consistent.

[Vide next page for more details]

of particular interest are (a) S. Mandelstam – Quantisation of the gravitational field (with discussion); (b) B.S. De Witt – The quantisation of geometry (with discussion); (c) Dirac – motion of an extended particle in the gravitational field (with discussion); (d) A. Lichnerowicz – Propagateurs et quantification en relativité générale (with discussion); (e)* The quantum theory of gravitation by R.P. Feynman (with discussion); (f) L.H. Thomas – Gravitation as an interaction between the large and the small; (g) Finkelstein – General relativity and elementary particles

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Introductory part of (e) – There is a certain irrationality to any work in gravitation, for eg. consider ~~energy~~ effect of gravitational attraction between an electron & a proton in a H-atom; it changes the energy a little bit. Changing the energy of a quantum system means that the phase of the wave function is slowly shifted relative to what it would have been were no perturbation present. The effect of gravitation on the H-atom is to shift the phase by 43 seconds of phase in every hundred times the life time of the Universe! An atom made purely by gravitation, let us say two neutrons held together by gravitation, has a Bohr orbit of 10^8 light years! ~~Thus~~ I wish to discuss here the possibility of calculating the Lamb correction to this thing, an energy, of the order of 10^{-120}. This is ~~–~~ Re. non-linearity says that it is not an unfamiliar difficulty quite that the theory, for eg, of the spin 1/2 particles interacting with the em-field has a coupling term $\bar{\psi} A \psi$ which involves three fields, and is therefore non-linear; that is no new thing at all.

(July) — [Mention in the Review article all the several symmetries SU(n) etc etc]

(August)

No. 2275 (p. 394) – G. Petiau – Applies a theory of non-linear wave eqns and their quantisation exposed in his previous publications (brings in elliptic fns) to the case of a system composed of spin 0 and spin 2 relativistic fields.

Nos. 2284 – 2288 – Reports of Conferences on elem. particles, nuclear physics etc.

No. 2316 (p. 400) – A. Lichnerowicz – Champ de Dirac, champ de neutrino et transformations C, P, T sur un ~~space-time~~ espace-temps courbe (to be mentioned in the review) –

(12) . He mentions spin $\frac{3}{2}$ field as due to Rarita & Schwinger (where is this?)

[Look at the paper in Ann. Inst. H. Poincaré Sect. A (N.S) 1 (1964), 233–290 & also some later issue of Bull. Soc. Math. France]

(September).

Nos. 3887 a & b – Brandeis Univ. Summer Inst. in Th. Physics – Proceedings (p. 706)

In reply to Møller's question "You are quite sure about it?" – If you do a real problem with real physical things in it, then I am sure we have the right method that belongs to the gravity theory. I can't take care of the cosmological problem, in which you have matter out to infinity or that the space is curved at infinity. It could be done, I am sure, but I haven't investigated it. I used as a background a flat one way out to infinity.

Anderson: In reply to DeWitt's question about the tree theorem Feynman talks of "some particular mathematical shenanigans"

Again in reply to a third question by De Witt Feynman says "Give me ten minutes. And let me show the analysis of these tree diagrams, loop diagrams and all this other stuff is done in a mathematical way. Now I will show you that I too can write equations that nobody can understand. ~~Trick of a theory~~ Modification of Yang-Mills theory which violates the original idea of symmetry of the isotopic spin by the simple assumption that the particle has a mass. This destroys gauge-invariance. It is just like electrodynamics with ~~mass~~ mass, it is no longer gauge-invariant, it is just a dirty theory! . . —

(Comes to a semi-colon and says)" I have to explain that the semicolon is analogous to the semicolon in gravity. The semicolon derivative $X_{;\mu}$ means the ordinary derivative of X minus A cross X, and that is the analogue of the Christoffel symbol — A lot

(3)

of meaningless mathematics ~~according to brackets~~ (perhaps purposely made so!) . . . The problem is now to do this integral on α; well, another miraculous thing happens. I have the operator A, but that this down thing is $\alpha A \alpha$ & therefore ~~the~~ its result is just determinant once; or the square of this integral is equal to this determinant, or

! something like that. Therefore when you get all the factors right X, the unknown is ~~equal to~~ given by

$$X = \left[\int e^{\alpha(B) + \frac{1}{2}(B_{\mu,\mu})^2} \mathcal{D}B \right] ! \left[\int e^{\mu^2/2 \{\alpha_{,\mu}\alpha_{;\mu} + \mu^2\alpha^2\}} \mathcal{D}\alpha \right]$$

More details in reply to Sach's question. In such things as electrodynamics and other theories, it has not been possible to figure out the consequences of the quantum field theory in the case of strong interactions, because of technical difficulties which are not technical difficulties just of the gravitation theory, but exist all over the quantum field theory. [This might ~~be~~ be mentioned as a sort of a rejoinder to in the ??? Wigner's remarks about reforming gen. relativity itself]. I do not expect that the gravitational problems will be any ~~the~~ easier in that region than they are in any other field theory, so I can say very little there . . . If you on the other hand, if you ask about the physical significance of the quantisation of geometry, in other

No. 3888 – Some other international conference of 1966 of Austria

No. 3897 (p. 708) – Book on analytic S-matrix by 4 people (C.U.P. 1966) – Reviewer talks of Feynman diagrams (?) – Still great difficulties remain

No. 3904 (p. 710) – Analytic S-matrix theory – Reference to some recent work since the article was written in 1965 – Technical difficulties still prevailing

No. 3912 (p. 711) D. Finkelstein – Kinks – According to the author "Kinks provide a covariant description of extended but indestructible particles" – According to the reviewer "the author does not suggest that any of the Kinks described in his examples correspond to particles observed in nature" – Cf. Kinks & quarks.

No. 3917 (p. 712) – Lect. Sem. on high energy physics & elem. particles (Vienna, 1965)

pp. 716-17 – Heaps of papers on SL(6), SU_6, SU(6,6), P(SU(3)), SU(2)

(October).

No. 5403 (p. 970) – Another summer institute for th. physics (Colorado Univ, 1966)

No. 5414 (p. 972) – G. F. Chew's book on "The analytical S-matrix: A basis for nuclear democracy" 1966 – nuclear democracy meaning that among the hadrons, all the particles are equivalent status and no arbitrary parameters are tolerated. In particular, it is shown that all hadrons lie on Regge trajectories.

No. 5425 a & b – SU_{22}

No. ~~5450~~ 5440 (p. 977) – On generalisations of isoparity (G-parity) – (?) – Ref to Lie groups SU_3, $\overline{R}_{2k+1}$, $\overline{R}_{2k}$ and Sp_n.

No. 5445 – The maximal chiral group with the quark model – all quarks, SU(3) etc. other articles on U(n) & SU(n) and U(n) ⊃ R(n) using Young tableau

No. 5475 (p. 982) – W. B. Bonnor – Multiple fields in linearised general relativity

No. 5479 (") – Q H. G. Loos – Rudimentary geometric particle theory – Assumes that the mathematical background is Riemannian – Reviewer remarks "It is questionable whether the importance to particle ~~dynamics~~ phenomena of external (i.e. R) curvature of the physical space-time has been demonstrated or, as seems more explicit, postulated".

No. 5492 (p. 984) – Dirac eqn in a general Riemannian space.

(November).

No. 7134 (p. 1311) – Conference on Math. Theory of Elem. particles in Mass Sept 12-15, 1965

No. 7143 (p. 1312) – M. B. Halpern – An approach to renormalisable field theory.

No. 7148 (1313) – Quantification géométrique by J. M. Souriau words about the philosophy behind it; what happens to the metric and all such questions, those I believe will be answerable, yes. I think you would be able to figure out the physics of it afterwards, but I won't to think about that until I have it completely formulated. I don't want to start to work out the answer to something unless I know what the equation is I am trying to analyse. But I don't have the doubt that you will be able to do something, because after all you are describing the phenomena that you would expect, and if you describe the phenomena that you expect you can then find some kind of framework in which to talk to help to understand the phenomena

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– 7 papers on $\tilde{U}(12)$, SU(2,2), SU(6,6), SU(6), SU(1,1), SU(2), SU(2,2), SU(3), SL(4, C) SO(6,C), SL(2,C), SL'(2,C), SO(3,C), SO'(3,C), SL(4,C), SO(6,C) symmetries

X – 7187 and 7188 – on the "flat theory of gravitation" [Rend. Mat. e. Appl (5) 24 (1965), 401–507

– 7190 – T. W. B. Kibble – The quantum theory of gravitation (from Vienna Lect. Sem of 1965) – Various approaches to the problem of quantising the gravitational field are summarised including Schwinger's method of "extended operators" (International Atomic Energy Agency, Vienna, 1965 Trieste 1965, pp. 885–910

(December).

No. 8681 (p. 1583) – Review of "Treatise on analytical dynamics" by L. A. Pars – The reviewer calls this one of the few great books on Dynamics – Why not write a book on this subject?.

No. 8743 (p. 1594) – Reference is made to the non-linear theory of elementary particles by Heisenberg and coworkers (ie spinorial theory)

No. 8754 (p. 1596) – $SL_{2,C}$ group

No. 8759 (p. 1597) – A. S. Wightman – (from Mass. Conference of 1965) – Remarks on the present state of affairs in the quantum theory of elementary particles – "The article provides an informal guide to recent trends in axiomatic quantum field theory and the problem of existence theorems for relativistic theories.

– 5 papers on SU(3) ⊗ SU(3), SO(4,1), SU_2, ISL(6), SL(6), ISL(2m,C), IU(m,m), ISL(2m,C), U(m,m) ~~symmetries and~~ $SL_{6,C}$ & SU_6

M. R. 1966.

(January).

No. 1044 – Book by Marshak & Sudarshan in French, 1964.

No. 1045 – Methods of attacking elem. particle physics are given as "field theory, S-matrix theory or dispersion relations, Complex A.M. formalism & group-theoretic methods

– 2 papers on SU(6), SU(3) ⊂ SU(6)

(February).

✓ No. 1932 – I. E. Segal – Explicit formal construction of non-linear quantum fields – The theory can be made applicable to elementary particles. It ~~also~~ avoids the difficulties associated with S-matrix theory and the necessity to consider detailed interaction as in group theory. The paper is not mathematically rigorous

J. Math. Phys 5 (1964), 269–82

No. 1935 – A. S. Wightman – PCT, spin & statistics & all that – Appeared Int. Conf. Mathematicians, Inst. Mittag-Leffler, Djursholm, 1963

No. 1948 – SU(4) symmetry & SU(n)

No. 1969 – Gürsey, Pais & Radicati – Importance of Gellmann's SU_3 – In previous (1964) approaches, one had to wait until that particle was found, and then invent a quantum wave field to go along with this particle.

No. 1967 – Rev. Mod. Phys 36 (1964), 977–1004 – The maddening crop of new particles

No. 1979 – SU (12) – $SU(12) \supset SU(2)_B \times SU(6)_\sigma$; $SU(6)_\sigma \supset SU(2)_n \times SU(3)$

(March).

No. 3062 (p. 548) – J. Schwinger – Broken symmetries & weak interactions I and II – Based on Schwinger's field theory of matter [Phys. Rev. (2) 136 (1964), B.1821 – B.1824

(14) – Another book on Elem. Particles & High Energy Physics, Gordon & Beach, N.Y, 1965

No. 3079 (p. 550) – C, P, T invariances in gravitational interactions are discussed & compared with existing exptl. evidence (? no mention) – Authors say evidence is suggestive of CPT invariance (or CP or C invariance), but one cannot rule out separate violations of C, P, T.

No. 3081 – Elementary particles – Book translated from Russian by Hindusthan Publishing Corp. 1961, Delhi – The reviewer J. Franklin makes slashing remarks like "This book is, at best, an unfortunate mistake"; "It is a blot on Russian monographs"; "It has been translated from Russian into poor, ungrammatical English. The printing is bad, the pages are not put on straight, the paper is already yellow with age" – most disgraceful example of Indo-Soviet co-operation!

No. 3192 – Contribution à la quantification des théories relativistes de l'électromagnétisme et de la gravitation – The author discusses the problem of quantising a unified field theory in terms of the methods employed in quantising general relativity (linearised)

No. 3193 – C. Fronsdal – Rev. Mod. Phys 37 (1965), 221–224 – Assumption made that a physical theory in flat space is obtainable as the limit of a physical theory in a curved space. Because of the absence of groups of motion in general curved spaces, only cases of constant curvature are

(4) discussed. ~~Then~~ The group of motions reduce very simply to those of the inhomogeneous Lorentz group in the limit of zero curvature.

(April)

No. 4450 – Introduces M (12) symmetry model of $p-\bar{p}$ annihilation [Prog. Th. Phys. 33 (1965) 524–31]

No. 4578 (p. 823) – Quantum theory and general relativity by R. Utiyama – The author discusses, in relation to the considerations of Wigner [Rev. Mod. Phys 29 (1957), 255–68]

(5) a principal difficulty which arises in uniting Relativity theory & Quantum physics. If one were to establish a local Hilbert-space corresponding to each world point, then the relation between the Hilbert-spaces of two different points is given by a non-integrable equation. Hence it is not possible to identify these Hilbert-spaces. This is explicitly shown by constructing the actual non-integrable equation, and proved that the comparison of

Prog. Th. Phys. 20, 439 (1958) (†)

" 14, 267, 1955. (✻)

1966 (May) No. 5499!

(14/10/68) – This article is the only one that I have so far seen ~~is the only one which~~

✓✓✓ (a) that gives a reference to my work ~~of paper~~ on particles of spin 2 in Proc. Ind. Acad. Sci (1942). (but not to my Royal Soc. paper)

(b) Bhabha's paper in the Rev. Mod. Phys gives references to both my papers in the Proc. Ind. Acad. Sci & J. Mys. Univ ~~papers~~ but not to the Royal Soc. paper.

(c) ~~Harish~~ Harish-Chandra's paper in Proc. Roy. Soc. 1946 on mesons and photons contains no references to any of my papers.

(d) (✻) Contains references to my work in Ind. Acad & Roy. Soc

(e) (†) " no references to my work at all

(May 1966) $\alpha = \frac{1}{137}$

No. 5658 by (J. Rayski) (Summary) – Five-dimensional unified field theory with a closed fifth dimension provides us with a geometrical interpretation of the e-m field and of the electric charge. Gauge transformations mean translation and charge conjugation means inversion in the 5th dimension. The gravitational coupling constant is related to the Sommerfeld constant, ⊗ and to the $\odot^{ce}$ of the world tube. The unified theory predicts the existence of giant particles with rest masses of at least 10^{15} times the nucleon rest mass. There are indications that the five (or more)-dimensional approach may become useful for a future understanding of weak and strong interactions.

(16/10/68)

Believer in unified field theory – interest in formulating such theories must not become of "out of date" as it means the ultimate aim of theoretical physics. — A five dimensional world tube – A variational principle – ultra-gravitons [Obtains Klein-Gordon eqns for these particles of rest mass $m_n = n/l$ $(n = 0, 1, ..)$. ~~He [illegible]~~ The 5-dimnl formalism predicts existence of such particles of spin 2 (uses weak field with

~~state~~ state-vectors at different world points is possible only for a vanishing gravitational field [Ref.—
[Reviewed by H. Treder – Ref. to Wigner's article]

No. 4580 (p. 824) – A programme of quantisation of the gravitational field by J. Rayski – If at each world point P a local inertial system is constructed, then $g_{\mu\nu P} = \eta_{\mu\nu}$, $(g_{\mu\nu|\tau})_P = 0$. Then it follows, from the general covariance of Einstein's equations, that the interchangeability of the dynamical variables $g_{\mu\nu}$ and $g_{\mu\nu|0}$ of the gravitational field at each point is in contradiction with the assumptions of the quantum theory – Using a special coordinate system it is shown that only the purely transversal tensorial part can be quantised. The non-quantisable part depends on the choice of the coordinate system [Reviewer as above]. [Acta. Phys. Pol. 26 (1964) 129–34

(May).

[J. Math. Phys. 5 (1964), 1368–70]

No. 5499 (p. 994) – Boulin & Hjalmars – The ~~authors~~ graviton is considered as a zero-mass limit of a spin 2-particle obeying a first order relativistic wave equation – Earlier Klein [Ark. Mat. Astronom Fys. 25 A (1936) no 15, 1–19] obtained, in the case of wave eqns, the matrix coefficients for particles of spin 0 and 1 from repns of the orthogonal group in 5-dimensions – Here the authors consider those matrix coeffts that may be obtained from repns of the full linear group in 5-dimensions, and show that the resulting wave equation may be used to describe the linearised gravitational field

√ || [In fact, this is actually one of the problems I wanted to solve using my commutation relations for spin 2]

No. 5532 – ~~Quarks assumed to belong~~ B = 1/3 quarks and SU(9) symmetry by Cocho & Chacan (Phys. Rev. Letters, 14 (1965), 521–23 – The authors assume that the quarks, in addition to belonging to the fund. repns of SU(3) (T, Y) [T = isospin, Y = hypercharge], belong to the fund. repns of SU(3) (S, B) [S = ordinary spin, B = hypercharge (?)]. These two groups are embedded in SU(9) ~~& assumed~~

– 2 more on SU(6) & M(12) ≡ U(6,6) & $U_2(12)$ = non-compact U(6,6)

– p. 1000 – Another Conference on Symmetry Principles at high energy [Coral Gables Conference 1965, San. Fr.] – 15 contributions reviewed. – $L\tilde{U}(4)$ group, $L\tilde{U}(12)$ & $S\tilde{U}(12)$, $\tilde{U}(8)$, U(4,4), U(8)

– talks of relativistic extensions of SU(6) [Summary with discussion re. 1964 work]

No. 5658 – Complete unification of macrophysics & microphysics need not be attainable, but a theory should indicate a meeting point at what seem to be two different views of physical reality. [Acta. Phys. Pol. 27 (1965), 89–97

(6)

(June).

6593 – Repns of SU_{mn} w.r.t. the subgroup $SU_m \otimes SU_n$ – 6594 – Repns of SU_{m+n} w.r.t.

Pauli's Relativity (last page 232) – The more general unsolved main problem of accomplishing a synthesis between the general theory of relativity and quantum mechanics.

Goldstone's theorem: A conserved operator which does not generate unitary transformations on the physical states must excite a zero mass particle.

Rayski's work: $\gamma_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$ (small) except for $n = 0$ which correspond to photons & gravitons [interactions of ultragravitons not detectable by exptl. evidence.] – Unified gravito-electromagnetic field – phasors – Geom. interpretation of electric charge and connection between fundamental constants – Sources of the unified field – Outlook [Interpretation of charge conjugation as inversion in the 5th dimension may throw light on weak interactions and their characteristic property of viola violating conservation of parity. Also throws some light on puzzle of isospin & affords a starting point for its future explanation. Two remarkable facts are (i) $Q = I_3 + b/2$ & (ii) electric charge having a geometric meaning in the 5-dimnl theory. From these it follows that I_3 is interpretable geometrically. Other speculations about isospace.

same subgroup.

No. 6645 (p. 1189) – An exact stationary solution of Einsteins equations by W. B. Bonnor and N. S. Swaminarayan [Z. Physik, 186 (1965), 222–226] – nothing wonderful

(July).

No. 770 (p. 135) – T. S. Epstein – Relation between Quantum mechanics and the principle of equivalence is not feasible even in principle. [Phys. Lett. 11 (1964), 233–34]

(7) ✓

No. 864 (p. 149) – Elementary particles & SU(4) by B. J. Bjorken & S. L. Glashow – Phys. Rev. Lett. 11 (1964), 255–57 – A new quantum number "Charm" violated by weak interactions is introduced. The model predicts the existence of new "charmed" particles whose discovery is a crucial test for the theory.

No. 882 (p. 150) – 6 papers as review reports at discussion meetings under C.E.R.N work on weak interactions.

No. 905 (p. 153) – Racah's seniority concept for identical nucleons.

No. 908 (p. 154) – T. Venkatarayudu – Group theory and nuclear spectroscopy – Math. Student 32 (1964), 39–43 – Reviewer says this brief 5-page summary can serve only to point a newcomer to the field in the right direction

No. 979 (p. 165) – A. Komar [Phys. Rev. Lett. 15 (1965), 76–78] – Emphasises the fact that there exists no unique procedure for constructing a quantum theory of general relativity (the remaining parts of the review are incomprehensible)

✓ (8)

(August).

No. 2037 (p. 344) – Summer Inst. for Th. Physics, Univ. of Colorado, 1965 on lectures in Th. Phys. – 20 lectures in all.

No. 2070–71 – Summer Inst. Lectures – 15 papers on several types of symmetries.

(9) ✓ No. 2162 (p. 362) – J. Boardman – Contributions to the quantisation problem in general relativity

J. Math. Phys. 6 (1965) 1696–1701 – uses Dirac's work of 1950 in Canad. J. Math. 2 (1950), 129–48

(September).

No. 3487 (p. 584) – D. N. Williams (Lectures at Summer Inst. Univ. of Colorado, 1964) – The Dirac algebra for any spin – No reference at all to my work on general spins

(10) ✓ No. 3562 (p. 595) – S. Weinberg – Photons & gravitons in perturbation theory: Derivation of Maxwell's eqns and Einstein's equations. [Phys. Rev. (2) 138 (1965) B988–1002] The author investigates an application of the S-matrix propagator formalism of Feynman & Dyson to the description of massless particles with spins $j = 1$ and $j = 2$. An

~~M/3562 of Sept. 66 (in Acta Phys. Pol.)~~

[Find out the meaning of these N/D eqns] identification is made between the former description and photons, and the latter description and gravitons. The attempt is made to relate these two separate systems of free particles to the Maxwell and Einstein field equations resply, and it is contended that such field eqns are obtained as soon as the requirement of Lorentz invariance is imposed on the S-matrix formalism . . . (the review occupies almost the whole of p. 596). The reviewer says that the author's attempt seems parallel to Feynman's recent work in the quantum theory of gravitation in terms of a Lagrangian formalism [Acta Phys. Polonica 24 (1963), 697-722]

No. 3563 (p. 596) – Some article ~~etc~~ on leptons – the reviewer characterises the article as some verbal musings on etc etc (I wonder if my review also be characterised like this! God forbid!!)

(p. 605) Nos. ~~3608 3615~~ 3618-20 – Brandeis Summer Institute Lectures on Particles & fields theory

No. 3619 mentions the Oxford Int. Conference on Elem. Particles, 1965.

– Heaps of papers on symmetries

No. 3649 (p. 610) – Y. Ne'eman, J. Rosen – Particle symmetries and space-time curvature

✓ – lengthy speculative paper explores "the physical implications of assuming a general relativistic origin for particle endosymmetries" – The equivalence principle in GRT (General relativity theory) raises the hope that an explanation of the mass-spectrum of "elementary" particles might be linked with internal symmetries of particles arising from a hitherto unexploited invariance group of GRT. [Ann. Phys. 31 (1965), 391-409]

(11)

No. 3799 (p. 633) – Notion of spinors in General Relativity (Cf. Wheeler's article in Rev. Mod. Phys. 1957)

No. 3804 (p. 634) – Quantisation of the gravitational field in the expanding Universe – ✓ An attempt is made to quantise in the linear approximation, the gravitational field in the expanding Universe using the Canonical formalism [Progr. Th. Phys. 29 (1963), 296-320]

(October).

No. 5040 (p. 847) – Proc. Eastern Th. Phys. Conf. 2 1962 – 24 contributions, 13 on elem. part. Phys. – ~~there can~~ Gordon & Breach Science Publishers (1963) – none can compare with Wheeler's after-dinner talk which is included as the final item

No. 5140 (p. 864) – Quantum theory of massless particles by S. Weinberg – Brandeis Summer Inst. Th. Phys. 1964, Vol I, Prentice Hall – Author concludes that no satisfactory theory can be constructed for massless particles with spin 3 or higher & that for spin 1 and 2, the Maxwell & Einstein theories appear to be the unique candidates [Author's earlier work in Phys. Rev (2) 133 (1964), 134 (1964), 135 (1964) & Phys. Rev. Letters 9 (1964), 357-59.

Put this in review article ✓

This is also in (10)

No. 5151 (p. 865) – N. Cabibbo – Unitary symmetry & leptonic decays – The eightfold way, pp. 207–209, Benjamin N.Y, 1964 – Reviewer cites the "Cabibbo current" which has had a profound influence on the theory of weak interactions.

– 30 articles on ~~group~~ symmetries.

No. 5323 (p. 893) – Geometric theory of neutrinos – Detailed discussion of parallelism between gravito-electrodynamics and gravito-neutrinodynamics.
[Phys. Rev. Lett (2) 140 (1965) B1467–1473]

(November).

No. 6901 (p. 1175) – Infrared photons & gravitons – Talks of infrared divergences arising in the quantum theory of gravitation & a lot of other meaningless things.

No. 7038 & 7039 (p. 1196) – Talk of $\tilde{SU}_3$ and $\tilde{SU}_4$ $(NU_4)^2$ and their representations

No. 7043 – An introduction to group theory and to unitary symmetry models – by de Franceschi & L. Maiani in Fortschr. Physik 13 (1965), 279–384 – Reviewer calls this a highly readable review article for beginners & also refers to F.J. Dyson's book "Symmetry groups in nuclear and particle physics" Benjamin, N.Y, 1966.

– $SL(3,R)$, W_3, $SO(8)$ or $R(8)$, $SU(4)_v$, $\tilde{SU}_{12}$, $\tilde{SU}_4$, $R_{4,2}$, SU_3/Z_3, $Sp(3)$, (1+4) de Sitter group, $Sp(3)/Z_2$

No. 7182 – Quantisation problems of gravity by K. Just – Nuovo Cimento (10) 34 (1964), 567–80

✓ – Something about S.N. Gupta's article in Recent Developments, and also about linearisation.

No. 7183 – Bootstrap gravitational geons by A. Komar, Phys. Rev (2), 137 (1965)

✓ B462–B466 –

No. 7203 – Aline Surin – Étude du schéma fluide parfait et des équations de mouvement dans les théories pentadimensionnelles de Jordan–Thiry et de Kaluza–Klein – A huge review by N. Coburn of nearly 1½ full pages of review; is it because the author is a lady?

(December).

No. 8704 (p. 1499) – Explicit wave fn for any spin – ~~Explicit~~ by X & Y – Explicit wave fns are given for spins S = 1, 3/2, 2, 5/2. (??) – Phys. Rev (2) 140 (1965), B1151–1156.

No. 8721 – On the invariance properties of the Dirac equation by N.D. Sen Gupta – Nuovo Cimento (10) 36 (1965), 1181–1216

✓ || – Attempt to extend these properties to my 3/2 spin eqn.

– no. of articles on S-matrix theory

✓✓ Refer to P. A. M. Dirac – Phys. Rev. 114, 924, (1959)

(14/10/68) ⟶ ↓ mainly refers to Hamiltonian formalism.

Last sentence of P. M. S. Blackett's Rutherford memorial lecture

I wonder what Rutherford would have thought of this exciting story with its complex interaction between theory and experiment, and of the failure of the experimenters to make the obvious experiments, and so leaving it to the theorists – playing with their symbols – to get the right answers [Proc. Roy. Soc. A. 251 (1959), p. 305]

* Proc. Phys. Soc. 87 (1966), 65-78

– 2 articles on field theory.

No. 8973 (p. 1542) – Particles of arbitrary spin in curved spaces by Dowker & Dowker* – A brief discussion is given of the Yang-Mills trick for generating the gravitational field [Proc. Phys. Soc. 87 (1966), 65-78]

Principles of Relativity Physics – Book by Anderson [J. L. Anderson, Academic Press, New York, London, 1967]

(1) Gravitational field in special relativity – Attempts to formulate a field theory of gravity within the frame work of special relativity go back to the early days of relativity theory [Einstein, Abraham and Nordström] However these and other subsequent events were soon overshadowed by the Einstein theory of general relativity. Although most physicists will agree that this latter theory affords the most satisfying description of gravitational phenomena, it is nevertheless useful to review here the problems ~~attached~~ attendant on a special relativistic gravitational theory. We shall see, in fact, that at least one such attempt leads one to the field eqns of general relativity – ~~other~~ Attempts based on works of Birkhoff, Fierz and Belinfante – A more fundamental approach to the problem of constructing a consistent theory of the gravitational field has been suggested by Gupta [Phys. Rev. 96, 1683 (1954)] and Kraichnan [ibid, 98, 1118 (1955)]. These authors require that the source of the gravitational field should be the total stress-energy tensor, including a contribution from the gravitational field itself.

(2) The Dirac equation in a gravitational field – In special relativity the Dirac ~~equation~~ wave function transforms like the basis of a spinor representation of the Poincaré group. However, there are no finite dimensional spinor type, that is, double-valued representations of the MMG (manifold mapping group) of general relativity. It is, however, possible in general relativity to write an eqn that in many respects resembles Dirac's equation by (using the generalised) ~~the~~ eqn $\gamma^\mu\gamma^\nu + \gamma^\nu\gamma^\mu = 2g^{\mu\nu}$ and dropping the requirement $\gamma^\mu_{,\nu} = 0$. This leads to the eqn $i\gamma^\mu(\psi_{,\mu} + \Gamma_\mu\psi) + m\psi = 0$, a Dirac type eqn that has both the MMG and the internal groups with infinitesimals as symmetry groups $\left[\Gamma_\mu = \frac{1}{8}\left\{\gamma^\nu\gamma_{\mu,\nu} - \gamma_{\mu,\nu}\gamma^\nu - \left\{{\rho \atop \mu\nu}\right\}(\gamma^\nu\gamma_\rho - \gamma_\rho\gamma^\nu)\right\}\right.$, known as the Fock-Ivanenko Coefficients]. The eqn is however a formal analogue since there is no relation between the internal group & the group of space-time mappings i.e. there is no relation between intrinsic spin and orbital A.M.

(3) Initial value problem for the Einstein equations – Canonical formulation of the gravitational field equations due to Arnowitt, Deser and Misner ["The dynamics of general relativity" in Gravitation: An Introduction to Current Research, L. Witten, ed (Wiley, New York, 1962), pp. 227-65]. Using this formulation an approach can be made to the initial value problem starting with the known values of the essential components on an initial surface x^0 = const, and then proceeding with the integration of the eqns satisfied by the components (of g_{rs} & π^{rs} four essential ones). However, one

one must be prepared to encounter singularities in this soln in the future (or past) of the initial value surface. Some singularities may be of the removable type like the Schwarzschild singularity, or may be intrinsic (irremovable) singularities. Raychaudhuri [Phys Rev. 98, 1123, (1955)] and Komar [ibid, 104, 544 (1956)] have shown that any Gaussian normal coord. system (~~true~~ i.e. for which $g_{\mu 0} = \delta_{\mu 0}$) will, in course of time, develop coord. singularities. Other solns of Einstein's eqns are known which, starting from non-singular initial data, develop intrinsic singularities off the initial value surface. Foures-Bruhat (Sha) ["The Cauchy ~~pb~~ problem" in same ref. as Arnowitt et al, p. 130-168] has studied this problem extensively and shown that the constraint eqns [$R^0 = 0$ and $R^r = 0$] in the initial value problem have an infinity of solns in a bounded region of space-time. However no one has been able, up to date, in constructing explicit solns of the type needed to eliminate the redundant ~~ones~~ variables from the theory. This is awkward, since without such solutions, we cannot construct ~~a~~ set of equations of the Cauchy-Kowalewski type for the gravitational field. Such equations in turn appear to be necessary for the construction of a quantised version of the Einstein-field eqns [Mention under non-linearity].

(4) The linearised Einstein equations — In going to the Newtonian limit two assumptions are made viz (i) sources of gravitational field have velocities small cf. c, (ii) gravitational field produced by the sources is weak. In 1916 Einstein developed a linear theory by using only (ii) & by putting $g_{\mu\nu} = \eta_{\mu\nu} + \epsilon h_{\mu\nu}$ and getting the linearised eqn $\frac{\epsilon}{2}\eta^{\rho\sigma}\gamma_{\mu\nu,\rho\sigma} = \kappa T_{\mu\nu}$ with the suppl. condn $\eta^{\rho\sigma}\gamma_{\mu\rho,\sigma} = 0$.

(5) Solutions of the Einstein equations — The most obvious feature of Einstein's field equations for the gravitational field $g_{\mu\nu}$ is their elephantine non-linearity. Compared to them the Navier-Stokes equations appear to be virtually linear equations. Nevertheless we possess today an enormous number of inequivalent solns to the Einstein equations, while the solns to the Navier-Stokes eqns are few and far between. In fact, we have an embarassment of riches; the rate at which solns are being generated far exceeds our ability to interpret and analyse them — The flat space-time soln is the unique stationary soln that is everywhere regular, while the Schwarzschild soln is the only spherically symmetric soln — Important role of topological considerations in the characterisation of gravitational fields; the recent discovery of the topology of Schwarzschild field has shed wholly new light on the structure of this field — Solns of linearised eqns are useful guides in helping interpret exact solns of Einstein's eqns and are also also adequate for the description of large classes of gravitational fields, owing to smallness of G [Ref. Ehlers & Kundt Ch. 2 of Intn to Current Research] — Solns of Homogeneous linearised Einstein eqns (with $T_{\mu\nu} = 0$ and gravitational waves — Solns of linearised eqn with time-varying sources — Uniqueness of the

flat-space solution and proof due to Lichnerowicz [Théories relativistes de la Gravitation et de l'electromagnetisme, Masson & Co, Paris, 1955, Chap 2]. After Einstein developed the GTR he hoped that it might serve as a model for a pure field theory of elementary particles. In such a theory, which uses only fields to describe the Kpt (kinematically possible trajectories) there would exist dpt (dynamically possible trajectories) that could be interpreted as particle-like solutions. Einstein thought he would not have to use the stress-energy tensor $T^{\mu\nu}$ at all in his field eqns, and because of the high degree of their non-linearity, he hoped that his empty-space solns might possess particle like solutions. But the theorem of Lichnerowicz makes the existence of such particle like solns appear unlikely — Spherically symmetric exact solutions — The Schwarzschild singularity & the "topology" of the Schw-field — cylindrically symmetric fields — Null gravitational fields; these give wave-type solutions and the R-C tensor $R_{\mu\nu\rho\sigma}$ plays the role of a field strength analogous to that played by the e-m tensor $F_{\mu\nu}$, and that $g_{\mu\nu}$ is the "potential" of the gravitational field analogous to A_μ — Solns with sources (a) Gravitational field of a point electric charge, (b) Gravitational field of an incompressible ball of fluid; (a) & (b) are cases where $T_{\mu\nu} \neq 0$. In (b) we have the Schwarzschild interior & exterior solutions

(6) Experimental tests of general relativity.

(7) Further consequences of general relativity — (i) conservation laws, (ii) gravitational radiation, (iii) direct-particle or action-at-a distance eqns of motion. Each of these ~~subject~~ topics is still the subject of active research. As re. (i) the question of whether one can ascribe an energy density to the gravitational field as one can to fields in special relativity is still open. ~~Re (ii)~~ Present opinion seems to lean towards the impossibility of finding such a quantity. Re (ii) opinion now seems to be that the theory the possibility of such radiation. Part of the difficulty in defining this is lack of information under (i). Re (iii) attempts are made towards simplifying the lengthy calculations involved & answering questions re. convergence of the various approximations employed. Ref. to review articles under (ii) are (a) Pirani [Witten's Edn], ~~(b)~~ and in book on Recent Developments, (b) R. K. Sachs in book on Relativity, Groups & Topology, Gordon & Breach, N.Y. 1964. (c) F. J. Dyson's Gravity Research Essay — It is ~~sad to think~~ somewhat sad to think that even with all of the work that has gone into the problem, the probability of detecting gravitational radiation within our life time is very small (I, of course, hope, with my colleagues that I will soon have to eat these words)

(8) Cosmology.

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$(\frac{1}{4}\sqrt{x}-5)$

$x = 320(\frac{1}{4}\sqrt{x}-5) + 16(\frac{1}{4}\sqrt{x}-5)^2$

$x = 80\sqrt{x} - 1600 + 16(\frac{x}{16} + 25 - \frac{5\sqrt{x}}{2})$

$80\sqrt{x} - 1600 + 400 - 40\sqrt{x} = 0$

$40\sqrt{x} = 1200 \quad \sqrt{x} = 30$

$x = 900$

$x = u(\frac{1}{4}\sqrt{x}-5) + 16(\frac{1}{4}\sqrt{x}-5)^2$

$x = u(\frac{1}{4}\sqrt{x}-5) + 16(\frac{x}{16} + 25 - \frac{5\sqrt{x}}{2})$

$u(\frac{1}{4}\sqrt{x}-5) + 400 - 40\sqrt{x}.$

$u = \frac{160\sqrt{x} - 10}{\sqrt{x} - 20}$

$g = \frac{G \cdot M}{r^2}$

$981 = \frac{6.6 \times 10^{-8} \cdot M}{36 \times 10^{16}}$

$M = \frac{981 \times 36 \times 10^{24}}{36 \times 6 \times 6.6 \times \pi \times 10^{24}}$

$\frac{327}{981 \times 7}{22 \times \frac{6}{2} \times 6.6}$

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$1600 = t^2 \quad t = 40:$

$25600 = u \cdot 35 + 16 \times 35^2$

$= u \cdot 35 + 15600$

$25600 - 15600 = 10000 = u \times 35$

$\frac{10000}{35} = \frac{2000}{7}$

16×900

14400

$14400 = 25u + 16 \times 625$

$= 25u + 10000$

$\frac{4400}{25} = 176 \text{ ft/sec}$

International Conference on the relativistic theories of gravitation, 1962 – Edited by Infeld

Conference opened by Infeld (Pergamon Press publishers) and held at Warsaw (Poland)

(1) Infeld's remarks – "Gravitation theory" means general relativity and its beginnings may be put at 1911 or 1916 on basis of Einstein's paper. In 1936 interest in the subject had ~~ceased~~ almost completely lapsed. People working at Princeton at the time could be counted on the fingers, & meetings of a few in Prof H. P. Robertson's room also ceased. Einstein himself often remarked to me "In Princeton they regard me as an old fool! Sie glauben ich bin ein alter Trottel" & situation remained unchanged till time of Einstein's death. Relativity theory was not very highly estimated in the "West" and frowned upon in the "East".

The situation has completely changed in the last few years & great interest is shown in it by many ~~yo~~ people of the younger generation. Due to (i) Biennial meetings on the subject, (ii) our knowing much more of the mathematical structure of Relativity Theory due to work of younger scientists, and (iii) Progress on gravitational waves and on quantising the gravitational field. These are the chief problems of the present day [p. 15, photo of Dirac & Feynman]

(2) Quantisation of the gravitational field by S. Mandelstam (Report based on two papers submitted to the Annals of Physics).

Present quantum theories of the g-field generally work in "flat space". The original attempt at quantisation was made by Gupta S. N [Proc. Phys. Soc. A65, 161, 608 (1952)] but the programme cannot be carried through exactly.