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Abstracts of Award Winning and Honorable Mention Essays for 1975

Award Winning Essays

First Award - The Non-Linear Graviton by Roger Penrose, Mathematical Institute, Oxford, England.

Abstract - A new approach to quantized gravitational theory is suggested. It is argued by analogy with Maxwell theory - and also from a principle that (physical) gravitons should carry space-time curvature - that a free graviton should be describable by a complex solution of Einstein's vacuum equations. For a left-handed graviton (pure helicity state $-2\hbar$) we require a solution which is of a particular kind, called right-flat, and which is of positive frequency. A construction is given for obtaining all such solutions, in terms of general curved (top halves of) twistor spaces.

Second Award - Gravitons and Photons: The Methodological Unification of Source Theory by Julian Schwinger, University of California, Los Angeles, California, 90024.

Abstract - The phenomenological, non-speculative attitude of source theory is used in parallel developments of electromagnetism and gravitation, based on the analogous properties of the massless particles, photon and graviton, thus providing a methodological unification of these two areas of physics. The power and economy of the approach is illustrated by an application to perihelion precession.

Third Award - Gravitational Potentials: A Constructive Approach to General Relativity by Niall Ó Murchadha and James W. York, Jr., Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27514.

Abstract - Recent investigations of the initial-value problem of general relativity have shown that the initial-value constraints can be formulated in all cases as a system of elliptic equations with well defined physical and mathematical properties. The solutions of these equations can be regarded as generalized gravitational potentials. These potentials are interrelated and depend on their sources quasi-linearly. They are particularly useful in analyzing asymptotically flat solutions of Einstein's equations. The authors have found from these results (1) a technique for constructing physically meaningful initial data in the integration of Einstein's equations, and (2) a method for characterization and analysis of the spacelike mass, momentum, angular momentum, and multipole moments of gravitational fields.

Fourth Award - On a Possible Unification of Gravitational and Weak Interactions by F.A. Kaempffer, Department of Physics, The University of British Columbia, British Columbia, Canada.

Abstract - Within the framework of Cartan's generalization of Einstein' theory of gravitation one can achieve a unification of gravitational and weak interactions by appropriate choice of the parameter which couples spin and torsion. The proposed spin-torsion coupling has negligible cosmic effects except at stages of evolution when 10^{81} nucleons are confined to a sphere with a radius of about one astronomical unit. For a single nuclear particle the gravitational effects of mass and spin balance at a radius of about one percent of its Compton wavelength, thus stabilizing it against gravitational collapse.

Fifth Award - A New Test of General Relativity by Robert V. Wagoner, Institute of Theoretical Physics, Department of Physics, Stanford University, Stanford, California 94305.

Abstract - The emission of gravitational radiation by the recently discovered binary pulsar system will cause its orbital period P to decrease at a rate which can now be predicted to be $P^{-1}dP/dt = -(3 \pm 2) \times 10^{-9}$ year^{-1} if the only orbital perturbations are of general-relativistic origin. It is shown that other sources of period change are probably less important. The accuracy of this prediction as well as the possibility of its verification will improve greatly over the next few years. This is the first observation that can test general relativity beyond the post-Newtonian approximation.

Honorable Mention Essays (Alphabetical Order)

1. The Most Viable Gravitational Theory by Robert W. Bass, Professor of Physics and Astronomy, Brigham Young University, Provo, Utah 84602.

Abstract - Abundant geophysical, astrophysical and cosmological evidence is explainable most readily by consequences of an Einstein desideratum for Mach's Principle: Cavendish parameter G should increase as one approaches a massive body (exact opposite of Brans-Dicke hypothesis, but a feature of Einstein-Hlavaty asymmetric, non-metric theory). A corresponding physically viable (95% probability) scalar-tensor theory predicts (as did Milne, in exact opposition to Dirac) that G increases in time, and that complete gravitational collapse is impossible: black holes do not exist; quasars are merely compact pulsating stars. A new critical test aboard the Helios satellite and nuclear applications are proposed.

2. Radiation as a Source of Gravitation by H. Bondi, King's College, London, England.

Abstract - The non-Newtonian character of radiation as a source of gravitation is explored for cylindrical symmetry in the absence of circulating radiation. The case with purely radial rays exemplifies the focussing singularity on the axis, and is Lorentz transformed to give a "unidirectional" model. Certain other unidirectional cases appear to be massless. A self contained case with ± z symmetry is displayed, and its structure explored.

3. A New Approach to Relativistic Gravitation by F.I. Cooperstock and G.J.G. Junevicus, Department of Physics, University of Victoria, Victoria, British Columbia, Canada V8W 2Y2.

Abstract - A new, physically motivated relativistic theory of gravitation is proposed which has its origin in the work of Schiff. The theory is simpler than general relativity and leads to the Schwarzschild solution in the spherically-symmetric case. Thus, the standard tests are satisfied in the proposed theory.

4. Time-Dependent Gravitational Accretion by Lennox L. Cowie, Physics Department, Harvard University, Cambridge, Massachusetts 02138.

Abstract - The author has re-investigated the Bondi-Hoyle-Lyttleton model of gravitational accretion onto fast-moving massive bodies. The stability of the steady state solution has been analyzed, and the accretion column shown to be unstable against the formation of perturbations. Time dependent numerical solutions are presented for the case of a gravitating body entering a semi-infinite cloud, and cyclic solutions, with periods of approximately 6 GM/V^3, are found to occur. The average accretion rate is approximately $3\pi G^2M^2\rho/V^3$.

5. Complete Geometrisation Attempt in General Relativity by A. Crumeyrolle, Department of Mathematics, Paul Sabatier University, Toulouse, France.

Abstract - The author constructs relativistic schema, welding together Einstein's gravitationnal, Maxwell's electromagnetic fields, and some spinning continued media. The geometric setting is the tangent bundle over space-time (state space) endowed with a particular pseudo-euclidean connection. Without phenomenologic considerations, he obtains equations ruling gravitation and spin effects. In the asymmetric case equations appear describing gravitation, spin density and a maxwellian field. It is possible to construct a unitary Einstein-Dirac theory (in spin maximum 1) giving again the preceding results in a particular case. Einstein-Schrodinger theory is a truncated Einstein-Dirac theory in spin 1). There exists a close relation between torsion-vector and Schrodinger's potential; nullity of torsion-vector has a spinor meaning. A spinor approach gives also a geometrisation in general relativity concerning gravitation, electromagnetic fields, and spinning media.

6. Gravity and Neutrinos - Paradoxes and Possibilities by Talmadge M. Davis and John R. Ray, Department of Physics and Astronomy, Clemson University, Clemson, South Carolina 29631.

Abstract - The authors study the interaction of neutrinos with gravitational fields. Using the classical neutrino theory of Brill and Wheeler, they find that static plane- and static cylindrically-symmetric spacetimes allow only "ghost neutrinos" (zero energy and momentum). Spherically-symmetric spacetimes allow no neutrinos at all. Several solutions to these problems are discussed including averaging the spherical symmetry, allowing the neutrino to have a rest mass, and the possibility of no classical neutrino theory.

7. A Quantization Program for the Gravitational Field by Arthur E. Fischer and Jerrold E. Marsden, University of California, Santa Cruz and Berkeley.

Abstract - Recent progress in describing the space E of true gravitational degrees of freedom is outlined. It is shown how results in abstract mechanics and nonlinear analysis can be used to give insight into the structure of the space E. The new understanding of this space is used to sketch out a quantization program for gravity. The important questions concerning the structure of E, this program and future prospects, are laid out.

8. White Holes and Galaxy Formation: A Newtonian Approach by John Gribbin, Nature, London, England.

Abstract - With recent and continuing discussion among mathematicians about whether General Relativity or some other theory offers the best description of our Universe, it is often forgotten that for almost all descriptive purposes even Newtonian theory is adequate to explain the Universe as we see it. Even such

exotic objects as black and white holes can be accommodated in a simple way in the Newtonian approximation, which provides a good physical insight into how galaxies might grow in an expanding universe. In addition, this simple treatment, no less than the sophisticated models beloved of mathematicians, provides a guide to where all our theories of gravity are lacking and points the way for further research into the nature of gravity.

9. Universal Antigravity - The Cosmological Constant by James E. Gunn, Department of Astronomy, California Institute of Technology and Beatrice M. Tinsley, Lick Observatory, California.

Abstract - A positive value for Einstein's cosmological constant is suggested by recent observations of distant galaxies. The best interpretation of these data leads to the conclusion that the universe is accelerating, which, in the framework of General Relativity, can be due only to a repulsive cosmological constant.

10. Plane-Wave Solutions in General Relativity Plus Torsion by Kenji Hayashi, Institute of Physics, University of Tokyo, Komaba, Meguro-ku, Tokyo 153, Japan.

Abstract - It is shown that in Cartan's theory torsion is frozen inside spin-polarized stars and invisible from the outside. To explore the possibilities of observable torsion, the author revisits general relativity plus torsion: He obtains a gravitational theory that permits torsion to propagate in vacuum as a massive spin 2 field in addition to helicity ±2 gravity waves allowed in general relativity. The theory, including Cartan's as an extreme case, agrees with experiment and is at present experimentally indistinguishable from general relativity. There is a chance to detect high-energy torsion particles emitted by distant strong sources, provided torsion mass is sufficiently small.

11. Geometrical Uniquemess Theorems in General Relativity and Mach's Principle by Edwin Ihrig, Department of Mathematics, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

Abstract - Recent work on geometrical uniqueness problems in general relativity is discussed, and its relation to Mach's principle is considered. Important unsolved problems are mentioned.

12. The M87 Jet - A Tidal Catastrophe? by Bernard J.T. Jones, Institute of Astronomy, Madingley Road, Cambridge, England.

Abstract - The author presents a novel picture for the origin of the jet-like structure seen at the centre of the giant elliptical galaxy M87. The underlying idea is that the "jet" has been formed as a result of the passage of another galaxy through the very centre of M87. The strong tidal forces exerted by M87 on the infalling galaxy strip the latter of its outer layers of stars and gas: the material that has already passed through the centre of M87 is strongly sheared and is to be identified with the "jet", while the gas that is still falling in is to be identified with the so-called "counterjet". The model provides an estimate for the mass and density of the "jet" in the light of which it is possible to review some of the earlier theoretical discussions of the "jet".

13. Cosmology without singularity by Bronisław Kuchowicz, University of Warsaw, Department of Radiochemistry and Radiation Chemistry, Warsaw, Poland.

Abstract - It is pointed out that the cosmological singularity, which is an undesirable feature of general relativity, can be avoided by using the Einstein-Cartan theory of gravitation. This is a slight modification of Einstein's original theory, and at the present observational level its consequences are practically the same as those of general relativity. It constitutes an extension of the latter theory, with the spin being incorporated from the beginning as a dynamical quantity. A characteristic spin-spin repulsive interaction arises in the Einstein-Cartan theory which dominates the behavior of matter at extremely high densities (above approximately 10^{54} g/cm^3), and prevents the occurrence of singularities. It is shown explicitly how this mechanism works for the two versions of the interpretation of the spin terms: a class of models with random spin distribution, and a second class in which the spins are aligned along some symmetry axis. With a classical description of spin, it is always possible to prevent the singularity by the square terms from random spin interaction, while it is not always possible to introduce an aligned spin distribution into a cosmological model of given symmetry.

14. Generalized Theory of Gravitation and Elementary Particles, by Behram Kursunoglu, Center for Theoretical Studies, University of Miami, Coral Gables, Florida, 33124.

Abstract - The unification of gravitation and electromagnetism yields for an elementary particle an infinite sequence of stratified layers of magnetic charge densities of alternating signs. Such a structure generates short range forces in addition to gravitational and electromagnetic forces. The theory predicts four fundamental particles, proton, electron, ν_e, ν_μ, and their antiparticles, corresponding to solutions of the field equations, which are regular everywhere. The entire spectrum of elementary particles can then be constructed from these eight fundamental particles.

15. Black hole - Neutron Star Collisions, by James M. Lattimer, University of Texas at Austin and David N. Schramm, University of Chicago.

Abstract - This essay discusses what would happen if the two most interesting general relativistic objects, a black hole and a neutron star, collided. The tidal forces of the black hole create a "tube of toothpaste effect" on the neutron star, spurting out neutron-rich matter which might escape from the system. This neutron-rich matter conceivably could be the source of the neutron rich heavy elements in the galaxy, or maybe even the deuterium. The essay also discusses the relative probability for such events. It is indicated that massive close binary star systems might eventually evolve into black hole-neutron star systems whose orbits decay by gravitational radiation until a collision occurs. It is interesting that the use of the balck hole here is as a catalyst in the formation of new interstellar material rather than its usual use as the final resting place of old material.

16. A Remark on Isolated Systems Essay on the Theory of Gravitation, by Gerd Leipold and Martin Walker, Max-Planck-Institute, Munich, Germany.

Abstract - In order that a system be considered to be isolated, two conditions should be fulfilled. Firstly the source of the system must be spatially bounded, and secondly the system must not be disturbed by outside influences. We discuss an invariant formulation of these criteria for zero rest-mass fields of spin zero, one, and two in flat spacetime. It turns out that the second of the above conditions depends on the spin of the field. Finally we generalize the criteria to curved spacetime: for gravitation, the criteria are that spacetime be asymptotically flat, and that the Bondi-Sachs news function vanish at past null infinity.

17. Length Contraction in a Gravitational Field by K.R. MacKenzie, Department of Physics, University of California, Los Angeles, California, USA.

Abstract - A simple picture of Thirring's precession of inertial axes inside a rotating mass shell shows at once that length elements can shrink, without motion with respect to the observer. The cause must be attributed to the gravitational fields of masses in motion. By considering potential energy changes a connection is made with length contraction in a static field. Schiff's simple physical method of calculating the bending of light is then extended to calculate the delay of radar signals past the sun.

18. The Gyron Gravitational Force by Donald H. Menzel and Winfiled W. Salisbury, Harvard College Observatory and Smithsonian Astronomical Observatory, Cambridge, Massachusetts.

Abstract - A mathematical comparison of electromagnetic forces and gravitational forces in a special equilibrium case demonstrates the existence of a gravitational force analogous to the magnetic force between moving charges, a force the authors call the gyron force. The expression derived for this force differs from the expression for magnetic force between moving charges because electric charge is conserved with respect to velocity while mass is increased by velocity according to the laws of relativity. The gyron force expression forms a basis for experimental verification of gravity waves and the interaction between the spin of a rotating body in a satellite and the spin of the earth.

19. Entropy and Gravitation by G. Neugebauer, Sektion Physik der Friedrich-Schiller-Universitat Jena, GDR.

Abstract - Einstein's gravitational theory is analyzed from a thermodynamic point of view. A thermodynamic potential characterizing the sources of gravitational fields is presented. By means of this potential the entropy production density is derived. Einstein's equations with dissipative terms appear as linear phenomenological laws in the sense of irreversible thermodynamics. Some thermodynamic influences on gravitational phenomena are discussed.

20. Is the Collapse of Massive Stars Really Inevitable? (A Criticism of the Penrose Theorem) by J. Pachner, Department of Physics and Astronomy, University of Regina, Regina, Saskatchewan, Canada.

Abstract - The Penrose theorem on the inevitable occurence of a gravitational collapse of massive stars is subjected to a criticism. It is shown that one of its assumptions seriously restricts its applicability in the actual Universe. The generalized Raychaudhuri's formula clearly indicates that the rotation of the star can stop the increase of its mass density. Under the assumption that the gravitational wave generated by the collapsing rotating star has no influence at all upon the star itself, the rotating star will end as a disc-like object.

21. A Possible Experiment with Two Counter-Orbiting Drag-Free Satellites to Obtain A New Test of Einstein's General Theory of Relativity by R.A. Van Patten, Department of Aeronautics and Astronautics, Guidance and Control Laboratory and C.W.F. Everitt, W.W. Hansen Laboratories, Department of Physics, Stanford University, Stanford, California 94305.

Abstract - In 1918, J. Lense and H. Thirring calculated that a moon in orbit around a massive rotating planet would experience a nodal dragging effect due to general relativity. The authors describe an experiment to measure this effect by means of two counter-orbiting drag-free satellites in polar orbit about the earth. For a 2½ year experiment, the measurement should approach an accuracy of 1%. In addition to precision tracking data from existing ground stations, satellite-to satellite Doppler ranging data are taken at points of passing near the poles.

22. 3C268.4 - Evidence for the Presence of a Gravitationally Lensed Secondary Image by N. Sanitt, Institute of Astronomy, Madingley Road, Cambridge, England.

Abstract - A direct observation of the gravitational lens effect is important since it could provide an independent measure of the Hubble constant, establish the cosmological nature of quasar redshifts, and act as a probe for detecting massive objects in the universe. In this essay five quasars are examined which for various reasons show evidence for the presence of intervening galaxies. An analysis of the observational evidence results in one of these - 3C268.4 - being a good candidate for the occurrence of a visible secondary lens image of expected apparent brightness $M_v = 21.2 \overset{+1.2}{-.9}$. Further observations are suggested which would confirm or deny the predictions made in this essay.

23. Dual Model Approach to a Renormalizable Theory of Gravitation by J. Scherk and John H. Schwarz, California Institute of Technology, Pasadena, California, 91125.

Abstract - It is proposed that dual models be considered as a framework for constructing a modified theory of gravitation. A scheme of this type achieves the elimination of the ultraviolet divergences of quantum gravity at the cost of introducing an infinite number of (unobserved) high-mass particles. The unification with weak and electromagnetic interactions as well as the need for a torsion field are also discussed.

24. On an Extension of the Principle of Covariance by A. Sebestyen, Central Research Institute for Physics, H-1525. Budapest 114, P.O.B. 49, Hungary

Abstract - The principle of covariance is extended to coordinates corresponding to internal degrees of freedom. The conditions for a system to be isolated are given. It is shown how internal forces arise in such systems. Equations for internal fields are derived. By an interpretation of the generalized coordinates based on group theory it is shown how particles in the ordinary sense enter into the model. As a simple application the gravitational interaction of two pointlike particles is considered and the shift of the perihelion is deduced.

25. Gravitational Clock: A Proposed Experiment for the Measurement of the Gravitational Constant G by Larry L. Smalley, Space Sciences Laboratory, Marshall space Flight Center, Huntsville, Alabama 35812.

Abstract - The increased importance and fundamental significance of more accurately measuring the gravitational constant G is discussed. Recent or proposed experimental measurements of G are reviewed. The most promising method uses mutually gravitating bodies in the "clock" mode in a drag-free satellite. In this view, a satellite experiment consisting of the flat-plate spherical mass oscillator proposed here combines the mathematical and experimental conveniences most simply. Hopefully these measurements can be pushed to the level of 1 part in 10^{11} at which time (and other) variations in G can be observed.

26. Gravity and the Origin of the Universe by Edward P. Tryon, Department of Physics and Astronomy, Hunter College of The City University of New York, New York, New York, 10021.

Abstract - The unique properties of gravity may lead to large scale quantum fluctuations of the vacuum, giving rise to universes such as ours. The primeval fireball and subsequent expansion of our universe have a natural explanation in such a theory. The relations between cosmological and microscopic quantities emphasized by Eddington, Dirac, and Joradn suggest a connection between cosmology and quantum physics, and might eventually be explicable within this framework.

27. The Earth-Moon System, the Terrestrial Climate, and the Evolution of Life by William R. Ward, Center for Astrophysics, Harvard College Observatory and Smithsonian Astrophysical Observatory, Cambridge, Massachusetts.

Abstract - Continued tidal evolution of the earth-moon system will lengthen the day and expand the lunar orbit. Both of these changes increase the present 27,000 year equinoctial precession period. In less than two billion years, this period will become comparable to the 69,000 year precession of the earth's orbit produced by the gravitational perturbations of the other planets. At this time, a coupling between the motions of the equatorial and orbit planes will generate large variations in the obliquity of the ecliptic. For the idealized case of uniform orbital precssion discussed here, the obliquity oscillates between $\sim 16^{\circ}$ and $\sim 58^{\circ}$ with a time scale of a few hundred thousand years. Severe climatic alterations will accompany this event.

28. Gravitational Collapse and the Origin of Life by J. Craig Wheeler, Department of Astronomy, University of Texas at Austin.

Abstract - The heavier elements, particularly carbon and oxygen, are generated in stars. Before incorporation in living matter these elements must be ejected from the stars. Most stars are unable to both manufacture and expel these elements. A process of elimination leaves only high-mass stars as candidates for the production of the bulk of the elements necessary for life. A further process of elimination shows that the most probable source of energy to hurl these elements into interstellar space is gravitational collapse.

29. Generalized Field Theory of Gravitation by Hüseyin Yilmaz, Perception Technology Corporation, Winchester, Massachusetts 01890.

Abstract - It is shown that if, on empirical grounds, one rules out the existence of cosmic fields of Dicke-Brans (scalar) and Will-Nordvedt (vector, tensor) type then the most general experimentally viable and theoretically reasonable theory of gravitation seems to be a λ-dependent generalization of Einstein and Yilmaz theories, which reduces to the former for $\lambda = 0$ and to the latter for $\lambda = 1$.