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Abstracts of Award Winning and
Honorable Mention Essays for 1973

Award Winning Essays

First Award - Global Analysis and General Relativity by Arthur E. Fischer, Department of Mathematics, University of California, Santa Cruz, California and Jerrold E. Marsden, Department of Mathematics, University of California, Berkeley, California.

Abstract - This essay presents an outline of recent applications of modern infinite dimensional manifold techniques to general relativity. The uses, scope, and future of such methods are delineated. It is argued that the mixing of the two active fields of general relativity and global analysis provides stimulation for both fields as well as producing good theorems. The authors' work on linearization stability of the Einstein equations is sketched out to substantiate the arguments.

Second Award - Solar Gravity Waves: Cause of Terrestrial Ice Ages by F.W.W. Dilke and D.O. Gough, Institute of Astronomy, University of Cambridge, England.

Abstract - Gravity waves cause the solar interior to mix approximately every 250 million years. The mixing throws the sun out of thermal equilibrium for about 10 million years, decreasing the solar neutrino flux and reducing the solar luminosity. The authors argue that this mechanism resolves current debate on the validity of solar models and provides a plausible explanation for the ice ages.

Third Award - On Retardation Effects in the Planetary System by Andrzej Staruszkiewicz, Institute of Physics, Jagellonian University, Cracow, Poland.

Abstract - The author has discovered that a system of two bodies interacting by means of retarded forces has an infinite number of nonclassical normal modes of motion. In this essay the physical nature of those modes is described; they turn out to correspond to the oscillations of an external shock between two bodies. Some applications in the theory of planetary motions are suggested.

Fourth Award - The Asymptotic Symmetry Group of General Relativity by Patrick J. McCarthy, University of British Columbia, Vancouver, Canada.

Abstract - It is suggested that, in a quantum theory which takes gravity into account, isolated quantum mechanical systems should be described by unitary representations of the asymptotic symmetry group of general relativity. In particular, elementary particles should be described by irreducible representations. It is pointed out that, in contrast to the conventional non-gravitational scheme, the particles all necessarily have discrete spins and a finite number of polarization states. This agrees with observation. A physical picture of the resulting particles is given. The possibility of using the scheme to account for internal symmetries is discussed.

Fifth Award - Classification of Stationary Space-Times by Zoltán Perjés, Department of Mathematics, Birkbeck College, University of London, England.

Abstract - A systematic approach to the geometric structure of stationary gravitational fields is presented. The algebraic type of the trace-free Ricci tensor together with the propagation properties of the eigenrays in the background 3-space defined by the Killing trajectories serve as a basis for classifying the solutions of the stationary field equations. The eigenrays are the integral curves belonging to the solutions ξ_A of the eigenvalue problem $G_A^B\xi_B=\mu\xi_A$, G_A^B spinor representing the gravitational field in the background space. Many of the already known stationary metrics can be derived in the present scheme but new solutions of the field equations are also obtained. The possible types of the vacuum and electrovac fields are discussed in their connection with the corresponding exact solutions.

Honorable Mention Essays (Alphabetical Order)

1. Mach's principle and Time Varying Inertial Mass by James L. Anderson, Stevens Institute of Technology, Hoboken, New Jersey.

Abstract - Mach's principle suggests that inertial, but not necessarily gravitational, mass must vary with time in an expanding universe. If one requires the approximate numerical relation $(\hbar^2H_o/G_c)^{1/3}\approx m_\pi$ to hold at all times, then inertial mass must vary as $t^{-1/3}$. Since all frequencies and decay rates will also vary in the same way, estimates of the age of the earth and the galaxy based on the assumption of constant decay rates will be too large by a factor of 3/2. The age of the universe computed from the Hubble constant must also be modified in a varying mass cosmology. The resulting age is compatible with the scaled down estimates of the age of the earth and galaxy.

2. An Explicit Physical Interpretation of General Relativity by Y. Avishai, University of the Negev, Beer Sheva, Israel and H. Ekstein, Argonne National Laboratory, Argonne Illinois.

Abstract - The powerful concepts of presymmetry, slightly changed and augmented, are used to derive Einstein's equivalence principle. General relativity appears as a system of operationally testable covariance (more precisely, presymmetry) principles which include the Poincaré group of special relativity and the family of acceleration groups M_x that induce automorphisms of the algebras Q_x of observation procedures at the points x. The principal deviation from the usual curved-manifold formulation of general relativity is based on the observation that all points are intrinsically equivalent, which the authors interpret as the operationally testable statement: Motion induces an isomorphism of point observation procedures. The intrinsic physical space-time is therefore homogeneous, i.e., its group of automorphisms is transitive. From among the few such spaces that are available, the authors choose the flat V_4 space as the one in which observation apparatus is located. The motion of observed objects, on the other hand, is more naturally described in Einstein's pseudo-Riemannian manifold. An operational form of the equivalence principle is then stated and its relationship to the conventional statements is discussed.

3. The Velocity of Gravity and Possibilities for its Measurement by S.P. Boughn, Department of Physics, Stanford University, Stanford, California.

Abstract - Recent advances in the development of low temperature gravitational wave detectors have made feasible a laboratory experiment capable of measuring the velocity of propagation of gravity. In addition, it is possible to determine the velocity of gravity from extraterrestrial pulses of gravitational radiation, as reported by Weber, in a way that doesn't depend on accurate timing of the pulses. A measurement of the velocity of gravity would constitute an important test of general relativity and could provide the first direct evidence that gravity, along with the other fundamental interactions of physics, locally obeys the principle of special relativity.

4. Systems With Long Relaxation Time in the Gravitational Experiments by V.B. Braginsky, Department of Physics, Moscow State University, Moscow, U.S.S.R.

Abstract - An analysis of the sensitivity in gravitational experiments involving measurement of small acceleration is made. The use of a system with long relaxation time permits a very high sensitivity in such experiments to be obtained. As an example, a new verification of the principle of equivalence is described. In this experiment the relaxation time of a torque balance was 6×10^7 sec. The sensitivity of heterodyne type gravitational detectors is discussed. A new type of shortwave gravitational detector is described.

5. Time, the Grand Illusion by Homer G. Ellis, Department of Mathematics, University of Colorado, Boulder, Colorado 80302.

Abstract - The reconcilability of gravitational with electromagnetic clocks foretells that a rigorous analysis of time will provide understanding of the unity of gravity and electromagnetism. Time is found to be fundamentally a property of elementary particles, only derivatively a property of clocks. A manifesto is proclaimed, that the flow of an elementary particle's time is the change of its radius, that time is therefore illusory. The de Sitter expanding universe is derived from this principle by treating elementary particles as spheres in Euclidean space. The hyperspheres of de Sitter space call up a five-dimensional metric manifold whose geometry models gravity, electromagnetism, and other phenomena tied to the structure of matter; neutrinos are provided for. Distance in this manifold is related to a secondary time, not correlated to primary time, but just as illusory. A particle's inertial rest mass is the relative rate of its two proper times; mass and charge are jointly, not individually, conserved.

6. An Experimental Test of the Gravitational Property of Antimatter by Chang-Yun Fan, Department of Physics, University of Arizona, Tucson, Arizona 85721.

Abstract - An experiment is proposed to determine whether or not antimatter has a negative passive gravitational mass. This possibility is based on the fact that muonium and anti-muonium have an identical atomic structure but, if antimatter has a negative passive gravitational mass, a muonium has a potential energy in the earth's gravitation field 2.34×10^{-13} erg higher than an anti-muonium. As a consequence, in the conversion from a muonium to an anti-muonium, there will be an impulsive increment in momentum towards the earth's center. The downward velocity would be $\sim 1.6 \times 10^6$ cm/sec if the muonium beam is properly aligned along the horizontal direction. The technique of the beam alignment and the method of the detection of the downward motion are suggested.

7. Tides in Strong Gravitational Fields - Differing Viewpoint by John Faulkner and Brian P. Flannery, Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, California.

Abstract - The authors discuss methods of calculating tidal effects in strong gravitational fields. By introducing gravitational "probes", they show that the usual Riemann tensor approach is unnecessarily complicated. As illustrations they treat (i) a radially infalling star, (ii) a star in circular orbit (the relativistic Roche problem). In neither case is the Riemann tensor computed. Reconciliation between the authors' approach and the usual method (required by deficiencies in the latter) leads to an illuminating strong field generalization of de Sitter's weak field precession for slowly spinning gyroscopes.

8. The Rotating Universe by Alphonsus J. Fennelly, 96 Bergen Street, Brooklyn, New York.

Abstract - A rotation of the universe is derived from the number counts of radio sources, which gives further a slope of 5.5 for the magnitude-redshift relation for distant objects in cosmology. The anisotropy in the number counts then gives the direction of the center of rotation of the universe. The existence of rotation and of parity-nonconserving fields in the universe allows spacetime to have nonzero torsion, which implies a Möbius-strip or Klein-bottle topology for the universe. The nonexistence of a detected quadrupole moment of the universe makes the centers of rotation and mass of the universe coincide, in the direction of the constellation Coma Berenices.

9. The Mass of the Graviton by Alfred S. Goldhaber and Michael Martin Nieto, Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico.

Abstract - After emphasizing that it remains an open question whether one should try to quantize gravity theory (which would mean gravitational force is propagated by a graviton particle), we nevertheless ask whether a limit can be set on the rest mass (μ_g) of the "graviton". By recalling that gravitational force is clearly exerted over large distances in systems of galaxies and is not killed by a graviton mass Yukawa cut-off, the authors find a limit. So, although it is not known if the graviton exists, one can still say that its rest mass is less than 2×10^{-62} g.

10. A Note on Extensions of Spacetimes by A.E. Hwang and D.P. Duncan, Center for Relativity Theory, Physics Department, The University of Texas, Austin, Texas.

Abstract - It is shown that a maximal extension of the bundle of orthornormal frames over a spacetime gives rise to a maximal extension of the spacetime. This result enables one to directly apply several criteria which assure the inextensibility of Riemannian manifolds to the study of the inextensibility of spacetimes. These criteria are chosen on the basis of their simplicity and physical relevance. In particular, no complicated constructions are required to apply these criteria to spacetimes. The authors demonstrate the usefulness of the bundle approach by explicitly constructing the well-known Kruskal-Szekeres extension of the Schwarzschild solution.

11. The Masses and Dynamical Stability of Small Groups of Galaxies by Bernard J.T. Jones, Princeton University, Department of Physics, Jadwin Hall, Joseph Henry Laboratories, Princeton, New Jersey.

Abstract - Observations of the gravitational interaction on scales ranging from 1 kpc. to 1 Mpc. suggest that the larger spiral galaxies may have extended halos with masses up to 4×10^{12} $M_{\odot}$ and radii on the order of 1 Mpc. The consequence of this as regards small groups of galaxies consisting predominantly of spiral galaxies is that they are probably gravitationally bound and thus fit into the framework of conventional ideas on the origin and evolution of galaxies.

12. On Forging the Link Between Quantum Gravity and Particle Physics by Janet Jones, Department of Physics, Princeton University, Princeton, New Jersey.

Abstract - This essay discusses the possibility of linking certain speculations concerning quantum gravity with other speculations concerning gravity-modified field theories in particle physics. Inasmuch as the suggestions considered here are representative of the problems in each field, such a link-up may provide the means of deriving a reasonable theory of quantum gravity. The key feature of the technique is the use of spontaneous symmetry breaking; its effectiveness in the case of scalar fields is illustrated, and comments are made on its generalization to spin 2 fields.

13. Some Consequences of the Classical Coupling of Gravitation to Quantum Systems by J.K. Lawrence and G. Szamosi, Department of Physics, University of Windsor, Windsor 11, Ontario, Canada.

Abstract - The authors suggest that otherwise quantum mechanical systems couple classically to the Einstein gravitational field. For a fermion undergoing 'Zitterbewegung', a time dependent rest mass results from the continuous emission of gravitational radiation. At the presently accepted cosmic age, this mass is in good agreement with observed particle masses and is insensitive to the initial mass. Some implications of this hypothesis are examined, including the possibility of accounting for the 'missing mass' of the universe. The present mass loss rates of astronomical bodies are found to be within observational limits. Some possible criticisms of the theory are anticipated and discussed.

14. A Restricted Proof that the Weak Equivalence Principle Implies the Einstein Equivalence Principle by Alan P. Lightman and David L. Lee, California Institute of Technology, Pasadena, California 91109.

Abstract - Schiff has conjectured that the Weak Equivalence Principle (WEP: universal free fall) implies the Einstein Equivalence Principle (all nongravitational laws of physics the same in every freely falling frame). This essay presents a proof of Schiff's Conjecture, restricted to (i) test bodies made of electromagnetically interacting particles falling in a static, spherically symmetric gravitational field; (ii) theories of gravity within a very broad class. The proof shows that every "nonmetric" theory in the class must violate WEP. A formula is derived for the magnitude of the violation. Comparison with the results of Eötvös-Dicke type experiments rules out various nonmetric theories in the literature.

15. Quasi-Stellar Objects and Gravitational Collapse of the Galactic Nucleus by S.K. Luke and R.D. Kent, Department of Physics, University of Windsor, Windsor, Ontario Canada.

Abstract - A summary of arguments for a Local Theory of Quasi-Stellar Objects from which the observational data can be consistently explained by assuming an ejection of coherent objects from the nucleus of our galaxy some 2×10^6 years ago, is presented. On this basis many physical parameters can be derived for the quasars. The ejection mechanism is discussed in terms of conventional theories of star cluster dynamics and stellar evaporation. It is emphasized that a general relativistic theory is required in order to construct a realistic model of the high density galactic nucleus.

16. Saving the Universe With Second Viscosity by George L. Murphy, Westminister College New Wilmington, Pennsylvania.

Abstract - A uniform cosmological model filled with fluid which possesses pressure and second viscosity is developed. The Einstein equations can be integrated exactly. One solution is the steady state cosmology but this is unstable. Other solutions start from the steady state one in the infinite past but expand more and more slowly as viscosity dies out. They never become singular. Some comments on possible origins of the viscosity are given.

17. Singularities as Knots by K.A. Papp, 3131-39 St. SW, Calgary, Alberta, Canada.

Abstract - The notion of gravitational singularities viewed as knots embedded in the space is presented. While keeping the approach nonrigorous an attempt is made to indicate the feasibility of such a definition in view of the fact that no other solution has been successful to date. Two possible definitions of a curvature function are given and some comments concerning their interpretation are provided. Further suggestions of "dimpling" effects which have the appearance of gravitational fields, of pulsed phenomena called "blinking" and some comments on tidal effects due to a singular region are presented.

18. Black Hole Universe and the Mystery of Cosmological Coincidences by R.K. Pathria Department of Physics, University of Waterloo, Ontario, Canada.

Abstract - When the customary view of the universe, which is necessarily internal, is supplemented with an external view, the universe appears to be a black hole, confined to a localized region of space which cannot expand without limit. The limiting size of this region is determined by the Schwarzschild radius of the universe, which provides a natural time-invariant yardstick for measuring distances on the cosmological scale. The introduction of this concept enables us to see Dirac's postulate on large dimensionless numbers in a new light; it also reduces the element of mystery surrounding cosmological coincidences.

19. The Thin-Sandwich Conjecture and a Fifth Initial Value Equation for the Gravitational Field by C. Martin Pereira, Center for Theoretical Physics, Department of Physics and Astronomy, University of Maryland, College Park, Maryland.

Abstract - The thin-sandwich conjecture for Einstein's field equations of general relativity is discussed. Three of the four initial-value equations of general relativity are considered. This system of three equations is shown to have an integrability condition when the spatial metric, its time rate of change and the lapse function N are given. The nature of this integrability condition is discussed in detail. It is also noted that this integrability condition can be expected to play a significant role in any proof of existence for a thin-sandwich problem in which the spatial metric and its time derivative are chosen arbitrarily.

20. The Poorly Known Gravitational Constant by F. Reines and J.R. Pellam, Department of Physics, University of California, Irvine, California.

Abstract - Though the gravitational interaction dates back to Newton and is the first discovered of the four fundamental interactions in nature, it is known with an accuracy which has been improved by significantly less than a factor of 100 since the original determination of Cavendish in 1798. In this essay the authors propose a new method employing a space platform which removes certain limitations on strengths of materials and measures the forces between two gravitating spheres by observing the associated resonant frequencies in restraining quartz fibres.

21. A Course in Modern Gravitational Theory for First Year College Students by Jack Sandweiss, Physics Department, Yale University, New Haven, Connecticut.

Abstract - A course for first year college students which covers special and general relativity with applications to topics of current interest has been developed and taught at Yale University for two years. The approach is generally rigorous and the necessary mathematical apparatus is developed. However, the physical content is illustrated via numerous examples and applications which emphasize problems of classical and recent interest in gravitational physics. A detailed syllabus is presented and the results of two years experience, are discussed.

22. Speculations on the Effects of Gravitation and Cosmology in Hadron Physics by Jack Sarfatt, 4982 Tierra Baja Way, San Diego, California.

Abstract - It is conjectured that there exists a truly fundamental particle ("on") of mass 10^{-5} gm., arising from quantum fluctuations in the geometry of space-time. The on is described by a possibly charged Kerr metric, and can be thought of as a nonluminous "quantum blackhole". Ons are conjectured to account for 10^{56} gm. of mass in the universe, whereas leptons and hadrons only account for about 10^{53} gm. It is predicted that ons will be detected directly if they are looked for. Hadrons are formed in the gravitational collapse of a possibly superfluid phase of ons with the release of $\approx 10^{19}$ Gev. The characteristic hadron mass of 1 Gev. may be determined by the Hubble radius in a manner reminiscent of Eddington's conjectures. The initial singularity in the big bang cosmology, as well as the "interiors" of gravitationally collapsed cold stars, should consist entirely of ons. The relation of the on hypothesis to Salam's f-gravity; Bjorken scaling in deep inelastic lepton-hadron scattering; reggeons, pomerons, and duality in diffraction dissociation hadron-hadron collisions is discussed.

23. An Interpretation of Newton's Gravitational Constant by David R. Skillman, 2922 Briggs-Chaney Rd., Silver Spring, Maryland.

Abstract - This study explores a Newtonian cosmology in which the gravitational constant is a function only of the average density of the universe. A governing equation is found, a solution suggested, and a resulting estimation of Hubble's constant and G are given.

24. "Solution" of the Gravitational Problem of Three Bodies and Its Applications by Victor Szebehely, The University of Texas at Austin, Austin, Texas.

Abstract - The long-time qualitative behavior of three gravitationally interacting masses is described. The (global) behavior may be considered the "solution" of this nonintegrable problem. The motion is unbounded and the triplet breaks up into a binary and a third body escaping relative to this binary. Such behavior immediately suggests an expanding universe and mechanisms for the formation of binary stars, for the creation of run-away stars, for the high-velocity separation of galaxies, etc. This instability persists generally for arbitrary initial conditions, with positive and negative total energy.

25. Rotating Cylinders and the Possibility of Global Causality Violation by Frank J. Tipler, Department of Physics and Astronomy, University of Maryland, College Park, Maryland.

Abstract - In 1936 van Stockum solved the Einstein equations $G_{\mu\nu} = -8 T_{\mu\nu}$ for the gravitational field of a rapidly rotating infinite cylinder. It is shown that such a field violates causality, in the sense that it allows a closed timelike line to connect any two events in spacetime. This suggests that a finite rotating cylinder would also act as a time machine.

26. Gravitation Research Using Atomic Clocks in Space by R.F.C. Vessot, Smithsonian Institution, Astrophysical Observatory, Cambridge, Massachusetts.

Abstract - Advances in space technology and communications combined with the development of extremely stable atomic clocks now permit us to perform experiments using apparatus placed anywhere in the solar system. Gravitation effects that bend the space-time coordinate frames can be measured directly by means of atomic clocks in space probes. An experiment is in preparation wherein the earth's gravitational redshift is to be measured with an accuracy of 20 parts per million. This experiment, to be performed in 1975, will be a forerunner of others using the sun's gravity.

27. Electromagnetic Fields and Massive Bodies by Robert Wald, Department of Physics and Astronomy, University of Maryland, College Park, Maryland.

Abstract - In this essay, the author describes a calculation of the general relativistic effects of massive bodies on static electromagnetic fields. He calculates the electromagnetic field of an arbitrary stationary charge and current distribution placed inside a massive spherical shell. When the shell is large compared with its Schwarzschild radius, it has negligible influence on the electromagnetic field. However, in the limit as the shell approaches its Schwarzschild radius, an observer outside the shell sees only a spherically symmetric monopole electrostatic field, independent of the details of the charge and current distribution inside the shell. This yields considerable insight into the fade-away of multipole moments in gravitational collapse.

28. Gravitational Potentials and the Spacelike Structure of Gravitational Fields by James W. York, Jr., Joseph Henry Laboratories, Princeton University, Princeton, New Jersey.

Abstract - A complete description of the spacelike structure of gravitational fields is found by introducing scalar and vector potentials. These quantities are defined in a coordinate-free manner and exist uniquely in a global sense. The additional structure is characterized by anisotropy, shear, and the Hubble scalar, related to the expansion of space. Anisotropy and the free part of the shear describe gravitational waves. The constrained part of the shear is orthogonal to the free part and arises from non-uniform expansion of space (and from external currents of matter, if any) and is determined by the vector potential. The scalar potential acts as a conformal factor of the anisotropy metric and determines the mass of an isolated system. The radiative parts of the field are conformally invariant.

29. A Quark-Geon Model of Hadronic Matter and Forces by Stanford P. Yukon, Yukon Research Associates, Inc., 24 Sacramento Street, Cambridge, Massachusetts.

Abstract - The generalized Dirac equation for a classical spin 1/2 field, interacting with the metric and torsion fields of general relativity is derived and solved numerically. Highly localized solutions are found having mass m~m* = Planck mass and radius r~r* = Planck length, and are taken as representing classical models of quarks. Due to the highly localized nature of these solutions, the universal spin-spin interaction term, induced by the interaction of spin with torsion, is no longer vanishingly small and can be of the order of normal weak interaction forces. The model is thus potentially capable of explaining, in a unified manner: superstrong quark-quark forces, symmetry-breaking forces, weak forces, strong nuclear forces, and long range macroscopic gravitational forces. An experiment is proposed, using existing gravitational wave detectors, that could test the basic assumptions of the theory.

30. Creation of Particles by Gravitational Fields by Ya. B. Zeldovich and A.A. Starobinsky, Academy of Sciences of U.S.S.R., Institute of Applied Mathematics, 4 Myuskaya Square, Moscow, U.S.S.R.

Abstract - Particle creation and vacuum polarization in a strong external classical gravitational field and their possible cosmological applications are considered. The theory is developed for a quantum scalar field with arbitrary mass in an anisotropic uniform nonstationary space-time, including the renormalization leading to finite expressions for vacuum average values of the field energy-momentum tensor. The anisotropic metric is not conformally flat, therefore particle creation is possible even in the case of massless field. Near the singularity these average values are propotional to t^{-4} (t is the time interval measured from singularity). Particle creation in the stationary Kerr metric is also discussed.