GRAVITY RESEARCH FOUNDATION

New Boston, New Hampshire 03070

Abstracts of Award Winning and Honorable Mention Essays for 1968

Award Winning Essays

First Award - Gravitational Collapse, Cosmic Black-Body Radiation, and the Origin of Astronomical Systems. Professor David Layzer, Harvard College Observatory, Cambridge, Massachusetts.

Abstract - The current interpretation of the cosmic microwave background as the remnant of an unexplained primeval fireball would make it impossible to construct a self-contained theory for the origin of galaxies and other astronomical systems. The alternative interpretation presented here accounts for both the quality and the quantity of the observed radiation, and provides a framework for a self-contained cosmogony. The microwave background is identified with the thermal output of certain cataclysmic processes whose nonthermal manifestations include quasars and cosmic rays.

Second Award - On Gravitational Collapse and Cosmology. Stephen Hawking, University of Cambridge, England, and Roger Penrose, Birkbeck College, University of London, England.

Abstract - The authors present a new theorem on space-time singularities. On the basis of the Einstein (or Brans-Dicke) theory, and without using any Cauchy surface assumption, they show (essentially from the property that gravitation is always attractive) that singularities will occur if there exists either a compact spacelike hypersurface or a closed trapped surface or a point whose past light-cone starts converging again. The first condition would be satisfied by any spatially closed universe, the second by a collapsing star and the third by the observable portion of our actual universe - as is shown to follow from observations of the microwave background radiation.

Third Award - The effect of Mass on a Frequency. Dror Sadeh, Naval Research Laboratory, Washington, D.C.

Abstract - Two experiments are described in which the influence of a mass on the frequency of a spectral line was measured. In the first experiment, the 21 cm line from Taurus A was detected when the sun approached the line of sight. A decrease of the frequency of the line was detected which indicated that the frequency decrease was caused by the presence of the mass. The second experiment confirmed this indication as it showed a decrease of the frequency of a cesium beam oscillator as it was affected by the earth's mass. This effect does not disagree with the observed cosmological red shift and not with other relevant experiments.

Fourth Award - The Gravitational Influence of Quasar Clusters on the Cosmic Black Body Radiation. D. W. Sciama and M. J. Rees, University of Cambridge, England.

Abstract - The cosmic black body radiation is observed to be highly isotropic, but if quasar clusters exist their gravitational effect should induce small (~ 0.1 per cent) anisotropies in the radiation. There is some preliminary evidence in favour of this idea and so it seems worth discussing in detail. The authors begin by examining the possibility that quasars are clustered, and then calculate the gravitational effect the clusters would have on the effective temperature of the black body radiation. The effect depends significantly on whether the universe has a low density or a high density, and would be observable in future experiments.

Fifth Award - Analysis of the Rotating Flat Plate Newtonian Gravitational Constant Experiment. David Berman, Hughes Research Laboratories, Malibu, California.

Abstract - This essay covers one portion of the Hughes program to find a new experimental method of improving our knowledge of the Newtonian gravitational constant (G). According to the NBS Technical News Bulletin (October 1963) the presently accepted value is $6.670 \pm 0.015 \times 10^{-11}$ $m^3kg^{-1}sec^{-2}$ (three standard deviations). The rotating flat plate experiment utilizes the gravitational interaction between two optically flat and parallel rectangular solids, one of which is rotating at constant speed and the other in a resonant mount. The analysis establishes that the gravitational interaction between

Fifth Award - continued.

the two plates is a second order gravitational gradient and that the dynamic interaction will be at twice the rotation frequency of the rotating plate. The magnitude of this gravitational gradient is of the order of $10^{-8}sec^{-2}$ and depends only on the density of the plate for fixed dimension ratios. Similar experiments have already been carried out at the Hughes Research Laboratories, and it has been found possible to eliminate all external sources of dynamic noise from the detecting system except for the internal thermal noise. An error analysis has been carried out on all the primary system parameters to determine their required precision. Most of the technology required in this experiment has been developed in previous gravitational experiments. The author concludes that if the interferometer techniques are successful and if the noise isolation techniques can be extended so that the instrument noise is predominantly thermal noise, accuracies approaching one part in 10^6 should be obtained in the measurement of the gravitational constant. To reach this level of accuracy requires an experiment time of half a day. The primary limitations of this experiment will be density inhomogeneities in the plates, the stability of the mechanical damping constant, and the nonlinearities and drift in the suspension system.

Honorable Mention Essays (Alphabetical Order)

1. Classical Relativistic Origin of Spin 1/2 and Double Magnetism of the Electron. Winston H. Bostick, Stevens Institute of Technology, Hoboken, N.J.

Abstract - The author has previously shown (in his 1958 and 1961 Gravity Research Foundation Award Winning Essays) that it is quite reasonable to argue that the energy and spin of an elementary particle are entirely electromagnetic in origin, and that this electromagnetic energy is kept from exploding the particle by self gravitational effects. Although the particle model which was set forth contained the second order correction to the Dirac equation which gives the anomalous magnetic moment to the electron, the model gave spin 1 instead of spin 1/2. This essay corrects an error involving the neglect of a general relativistic effect (an error made in the 1961 essay) and shows how a value of spin 1/2 and the double magnetism of the electron can be obtained.

2. On the Possibility of Using Pulsars to Test Relativistic Theories of Gravitation. Paul A. Feldman, Stanford University, Stanford, California.

Abstract - The possibility of using the remarkably constant periods of any pulsars that might be found in the ecliptic plane to test gravitation theory is discussed. The general relativistic frequency shift of radiation from an interstellar pulsar source is derived and shown to amount to about 1 part in 10^9 just before and after occultation by the sun. The conditions under which such an experiment could be performed are considered. It is concluded that it may well soon be possible to carry out this test of relativistic theories of gravitation in a meaningful way.

3. A New Terrestrial Experiment on General Relativity. Daniel Greenberger and Kenneth Rubin, City College of the City University of New York.

Abstract - A new laboratory test of general relativity is proposed. The main idea is to split coherently a beam of atoms in the earth's gravitational field and measure the phase difference accumulated before the beams are recombined. This allows one to measure the effect of gravity on the time scale of an atom, and also for the first time the applicability of quantum mechanics to gravitational forces. A double slit experiment in the earth's gravitational field is analyzed in detail.

4. The Possibility of a Closed Universe with Negative Curvature. Clark Jeffries, University of Washington, Seattle, Washington.

Abstract - It is often implied by relativists that a universe with negative sectional (Riemannian) curvature need be closed and finite. This is of course true if one assumes the simplest possible topology: a 4-sphere if $K = +1$, and 4-hyperbolic paraboloid if $K = -1$. However it turns out that there exist closed Riemannian 2-spaces with curvature -1. These are tori of genus greater than one. Hence it is suggested that the universe may be closed and have curvature -1 provided it has a four dimensional pseudo-Riemannian topology analogous to the presented tori.

5. Qualitative Features of Quantized Gravitation. Arthur Komar, Belfer Graduate School of Science, Yeshiva University, New York, N.Y.

No. 5 continued.

Abstract - From a re-examination of a discussion by Bohr and Einstein of a gedanken experiment designed to violate the uncertainty relations, it is suggested that a qualitatively new feature of the emerging quantum theory of gravitation is that it may provide a new understanding of the "reduction of the wave packet" of quantum mechanics. In brief, for finitely massive observers, half of the classical dynamical variables must be employed to specify the frame of reference, whereas only the remaining half of the dynamical variables are available for unequivocal observation. Observers whose frames of reference cannot be related by definite C-number transformations would, in general, "reduce wave packets" differently.

6. Perihelion Advance and Linearized Field Equation. K. Kraus, Institut für Theoretische Physik der Universität, Marburg, Germany.

Abstract - Contrary to a wide-spread opinion, the nonlinearities of Einstein's field equation do not significantly contribute to the perihelion advance of planetary orbits. This is demonstrated by a straightforward calculation, which yields the usual result from the linearized field equation. Roughly two-thirds of the effect is shown to be due to space curvature. Some general remarks on nonlinearities of classical and quantized field theories are added.

7. Gravity and Electric Charge. C. C. Leiby, Jr., Air Force Cambridge Research Laboratories, Bedford, Massachusetts.

Abstract - The electron and proton may be characterized by tensors having components in a complex (coulomb) charge plane. Appropriate inner products of these tensors generate the coulomb interactions between charged particles and the gravitational attraction between hydrogen atoms. Several models, differing only in their predictions of charged particle-neutral atom interactions, are possible. A simple vector model appears to be consistent with recent experiments. Complex charge implies the existence of a gravitational "magnetic field." This extremely weak field, acting over eons, could be responsible for the shape of spiral galaxies and the present orientation of planetary orbits and spins.

8. Wideband Gravitational Radiation Antenna Design.
L. R. Miller, Hughes Research Laboratories, Malibu, California.

Abstract - This paper describes a preliminary design for a wideband antenna for detecting extraterrestrially generated gravitational radiation in the region from 400 to 2000 Hz. A wideband design is more suitable for detection of certain potential stellar sources, such as collapsing binary systems, which radiate at a varying frequency. The present system is intended as a prototype for the solution of design problems before a more massive system is constructed. It consists of a pair of 3 kg masses joined by piezoelectric strain transducers. The masses are supported on an acoustical isolation stack in a vacuum. The strain gage output is amplified and fed to a frequency analyzer, consisting of twenty tuned filters spanning the passband. The noise level per unit bandwith of the present system over the 1600 Hz passband approaches that of a resonant antenna of the same mass. Future plans include correlation of the output with the expected behavior of the signal using matched filters, investigation of different transducers, and increasing the size of the detecting masses.

9. Perturbation Expansion in the Quantum Theory of Gravitation.
Ulrich Hans Niederer, Institute for Theoretical Physics, University of Berne, Switzerland.

Abstract - This paper is devoted to an analysis of a quantized model for the scalar theory of gravitation. It is shown that, in the framework of this model, a certain matrix element of physical interest, considered as a function of the coupling constant K of the gravitational field to the matter field, is not analytic at $K = 0$. As a consequence the conventional perturbation theory is valid only in the sense of an asymptotic expansion in the limit $K \to 0$.

10. The Origin of Galaxies in an Expanding Universe.
Joseph Silk, Harvard University, Cambridge, Massachusetts.

Abstract - A model of the origin of galaxies in an expanding universe is described. The starting point is an initially cold mixture of protons, electrons, neutrinos and neutrons in equilibrium for the reaction $p + e \to n + \nu$. A self-consistent explanation is described of how galaxies may have formed from this initially structureless cold universe. Also described is the origin of the present isotropic $3^{o}K$ black body radiation.

No. 10 continued.

A corollary of the model is that the universe may contain an overwhelming abundance of meteoroids and planets. Matter in this form is not directly observable outside the solar system, and could conceivably account for the "missing mass" required to gravitationally close the universe.