GRAVITY RESEARCH FOUNDATION

New Boston, New Hampshire 03070

Abstracts of Award Winning and
Honorable Mention Essays for 196~~8~~9

Award Winning Essays

First Award - Experimental Test for Mass Anisotropy Based on Nuclear Magnetic Resonance.
Vernon W. Hughes and W. L. Williams, Yale University, New Haven, Connecticut.

Abstract - A highly sensitive experimental test for an anisotropic component of inertial mass is described, which is based on a study of nuclear magnetic resonance. If the interpretation of the experiment is based on the model of Cocconi and Salpeter*, the limit to the anisotropic component Δm of inertial mass is:

$$\frac{\Delta m}{m_o} < 5 \times 10^{-23}$$

in which m_o is the usual scalar mass. This null result constitutes an extremely severe test of the local isotropy of space.

*G. Cocconi and E. Salpeter, 1958 first award winner for Essay on Gravitation; Gravity Research Foundation.

Second Award - Lemaitre Universes and Galaxy Formation.
Kenneth Brecher, Massachusetts Institute of Technology, Cambridge, Massachusetts, and Joseph Silk, Institute of Theoretical Astronomy, Cambridge, England.

Abstract - The authors assume the conventional "hot big bang" description of the universe, in which the universe is initially homogeneous, isotropic, and radiation dominated. Then only by adoption of the Lemaitre cosmological model with a characteristic stagnation period can it be hoped that the formation of galaxies may be explained. The authors discuss the stability of the

Lemaitre universe to galaxy formation. The duration of the stagnation period must be less than about one hundred billion years: otherwise catastrophic collapse back to the initial singularity wi-l ensue. Finally, two observable features of the stagnation period are predicted.

Third Award - Testing Einstein's Inhomogeneous Gravitational Field Equations. Kenneth Nordtvedt, Montana State University, Bozeman, Montana.

Abstract - It is shown that all the historical tests of Einstein's gravitational theory test only his homogeneous field equations $R_{uv} = 0$. The author points out in this paper that celestial "Eotvos" experiments which measure the gravitational to inertial mass ratio of massive bodies like the Sun or planets, will be sensitive to features of Einstein's inhomogeneous field equations $R_{uv} = k(T_{uv} - Tg_{uv}/2)$.

Fourth Award - Randomness and Regularity in Cosmic Structure. David Layzer, Harvard College Observatory, Cambridge, Massachusetts.

Abstract - A newly developed theory of cosmic evolution based on Einstein's theory of gravitation and on a symmetry postulate called the strong cosmological principle shows that the gross structure of the universe is characterized by a collection of simple numerical regularities reminiscent of those that govern atomic structure.

Fifth Award - The Creation and Annihilation of Matter by a Gravitational Field. Stephen Hawking, University of Cambridge, Cambridge, England.

Abstract - It is shown that in classical general relativity, if space-time is nonempty at one time, it will be nonempty at all times provided that the energy momentum tensor of the matter satisfies a physically reasonable condition. The apparent contradiction with the quantum predictions for the creation and annihilation of matter particles by gravitons is discussed and is shown to arise from the lack of a good energy momentum operator for the matter which obeys the covariant conservation equation.

Honorable Mention Essays (Alphabetical Order)

1. The Self-Interaction of Gravitational Radiation. W. E. Couch, University of Texas, Austin, Texas, and R. J. Torrence, University of Calgary, Calgary, Alberta, Canada.

Abstract - A sourceless, first-order pulse of gravitational radiation imploding from infinity to the origin and then exploding back out to infinity is examined to second-order. It is found that, contrary to what might be expected, the second-order field contains no radiation. In spacetime regions outside of the pulse the second-order field is nonvanishing only in the region with retarded times earlier than the passing of the exploding pulse and advanced times later than the passing of the imploding pulse. In this region the second-order field is that of a Schwarzschild mass, plus a nonradiative quadrupole, plus a nonradiative sixteen pole.

2. An Analytic Solution to the Problem of Isostasy. LeRoy M. Dorman and Brian T. R. Lewis, University of Wisconsin, Madison, Wisconsin.

Abstract - The authors have derived a relationship between topography and Bouguer gravity anomaly which allows the isostatic response function of the earth to be measured. (This is the change in the gravity field observed at the surface resulting from the isostatic compensation due to a concentrated load.) This function has been computed using data from the continental United States and inverted to obtain the density change versus depth relation characterizing the isostatic process. The result is in agreement with independently determined seismic data.

3. Multidirectional, Multipolarization Antennas for Scalar and Tensor Gravitational Radiation. Robert L. Forward, Hughes Research Laboratories, Malibu, California.

Abstract - Some gravitational radiation antenna designs are discussed which are capable of distinguishing between the spin zero scalar radiation predicted by the Brans-Dicke theory of gravitation and the spin two tensor radiation

predicted by the Einstein theory of gravitation. The antennas will also give information concerning the direction to the source of radiation, and will measure the polarization of the tensor radiation. The designs consist of symmetric masses with appropriately spaced and oriented transducers. The transducers are combined to give orthogonal outputs. Linear combinations of these orthogonal outputs then are uniquely associated with the various possible combinations of radiation type, propagation direction and polarization orientation.

4. On Singularities in Cosmology. Petr Hajicek, Institute of Theoretical Physics, Berne, Switzerland.

Abstract - A generalization of a definition of cosmological singularity is proposed, which allows to formulate singularity theorems so that they refer only to a finite domain of space-time. In this way, two theorems due to Hawking are sharpened, by means of which it can be shown that our Universe cannot be saved from singularity, unless the causal loops violating the strong causality required by Hawking entirely lie in an explicitly indicated compact region of our past.

5. Annihilation of the Gravitational Field. John C. Hegarty, Boston University, Boston, Massachusetts.

Abstract - The decay of a particle into electromagnetic radiation is investigated to learn if the active gravitational mass of the radiation is twice that of the particle. The results show that, to first order in g_{ij}, the radiation tends to destroy the gravitational field; this is expressed mathematically by the equation $R_{ijk\ell} = 0$ for all space points lying inside the future light cone whose apex is at the decay event.

6. The Absolute Zero of Time. Charles W. Misner, University of Maryland, College Park, Maryland.

Abstract - A singularity involving infinite densities a finite proper time in the past is strongly suggested for the beginnings of the Universe by Einstein's general relativity theory, and by the few relevant observational data. There is no reasonable point at which to anticipate a failure of the theory, especially since a simplified quantum calculation predicts, quite surprisingly, that quantum effects can be neglected near the singularity.

Therefore we suggest that the singularity be treated as an essential element of cosmological theory, and indicate how this can be made more palatable by refining our concepts of time.

7. Essay on the Problem of Singularities in General Relativity. J. Pachner, University of Alberta, Edmonton, Canada.

Abstract - Singularity is here defined as a state with an infinite mass density. First it is proved that any inhomogeneity and anisotropy in the distribution of a non-rotating ideal fluid accelerate the collapse. Einstein equations for a rotating incoherent matter are then deduced. They show that the rotation decelerates the contraction of space not only in the direction perpendicular to the vector of angular velocity, but indirectly also along this vector and can avoid the occurrence of a singularity. The regions gone through a maximum density may take a flat form not dissimilar to that of galaxies.

8. Relativistic Gravitational Bremsstrahlung. P. C. Peters, University of Washington, Seattle, Washington.

Abstract - The current situation with regard to calculations of gravitational radiation is discussed. A different approach to the problem is outlined, and results are given of a calculation of the gravitational bremsstrahlung from a mass with arbitrary velocity deflected by the gravitational field of a massive body. Among other things, the calculation shows that the "fast motion approximation" is not valid.

9. The Collapse of the Universe: An Eschatological Study. Martin J. Rees, Institute of Theoretical Astronomy, Cambridge University, Cambridge, England.

Abstract - A closed universe, in which the deceleration parameter exceeds 1/2, is fated to collapse. During the contraction, clusters, galaxies, and eventually stars lose their identity. However, fluctuations with scales $\sim 10^{14}\ M_\odot$ may, in some form, survive into the next cycle of an oscillating universe. The existence of bound groups of galaxies with large velocity dispersions could be understood if they contained collapsed objects with masses of this order.

10. An Integral Re-Formulation of Einstein's Theory of Gravitation. Peter C. Waylen, University of Cambridge, Cambridge, England.

Abstract - The theory of gravitation has been reformulated in terms of an integro-differential form of Einstein's field equations; the boundary conditions are thereby incorporated directly into the theory. This integro-differential form is derived by the application of a specific limiting procedure to an explicit representation of the approximate solution of the initial-value problem for a varied form of Einstein's field equations. Its nonlinearity is reflected in its kernel, which is constructed from the metric tensor. It may be used to examine the validity of a gravitational Huygens' principle, and to restrict the boundary conditions according to each interpretation of Mach's principle.