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THE AUSTRALIAN NATIONAL UNIVERSITY

FACULTY OF SCIENCE

DEPARTMENT OF THEORETICAL PHYSICS

ANNUAL REPORT 1971

Introduction:

Training at both undergraduate and postgraduate level is provided for students intending to become theoretical physicists. The undergraduate course also provides a background in theoretical physics for other students.

This year a University Medal, and the Shell Company Prize in Science were awarded to students in the department.

Research has been carried out in the fields of plasma physics, astrophysics, optical aberration theory, nuclear physics, general relativity theory and cosmology.

Teaching:

Student enrolments and examinations are set out in the attached table.

Work of Graduate Students:

W. Sy continued his work on problems involving non-linear interactions in a magneto-active plasma. Two papers were prepared jointly with Dr. Melrose. To date one of these has been published.

A. O'Leary continued with his investigations of the properties and design of zoom systems.

Research:H.A. Buchdahl

In the context of cosmological theory one requires to know the equations of arbitrary time-like geodesics. In fact, all geodesics of a Riemann space may be subsumed under a single two-point function: Synge's world function, or the characteristic function equivalent to it. The form of this characteristic function for an arbitrary Robertson-Walker space was obtained explicitly. A paper has been accepted for publication in General Relativity and Gravitation.

The classification, due to Schouten, of tensors and tensor densities is unsatisfactory in as far as it does not cover all possible tensorial objects which may be constructed from those included in his classification. A new terminology has been developed, and published in TENSOR.

In response to an invitation from the Tensor Society of Japan to contribute to a special volume in honour of Kawaguchi's 70th birthday, certain problems associated with the Dirac algebra, formulated in terms of a generally covariant calculus of four-spinors, were investigated. An appropriate manuscript has been submitted.

It was shown that, given any static vacuum solution of Einstein's equations, a corresponding static vacuum solution of the field equations of the so called scalar-tensor theory can be written down by inspection. A manuscript has been submitted.

Previous work on methods of calculating higher order aberration coefficients of symmetric optical systems which had covered the fifth and seventh order coefficients only was consolidated and explicitly extended to the ninth order. An extensive manuscript has been submitted.

As a counterpart to the work just described an investigation was begun of the theory of aberration coefficients of systems without any symmetries at all. Two manuscripts were submitted.

Jointly with Dr. Sands the theory of reversible semi-symmetric systems was reconsidered. A manuscript has been accepted for publication in Optik.

The generic theory of aberrations of systems which are invariant under finite, but not continuous, rotations about a line has been investigated. A manuscript has been submitted.

A good deal of other research work which has not yet led to the submission of manuscripts has not been described.

R.T. Cahill

The three body scattering problem in nuclear physics was further investigated with emphasis on the complicated unitarity constraints which arise in this problem. Work on a quasi-unitary approximation, begun while at the University of New South Wales, has shown that this approximation may be interpreted as incorporating the effect, which was shown to be large, of the initial-state interaction process in break-up reactions. This work was submitted for publication as "The n-d initial-state interaction in n-d break-up", with Dr. Sloan as co-author. Further work on the unitarity constraints led to the development of an exact unitary model which involves tractable on-energy-shell integral equations. A paper entitled "A unitary model for three body collisions" was submitted for publication. Following a seminar given at Flinders University, one of Professor McCarthy's Ph.D. students undertook a detailed numerical investigation of this model. His results have shown that the processes accounted for in this three-body collision model are those substantially responsible for the observed properties of the experimental results.

Theoretical work in collaboration with groups of experimentalists, substantially done at the end of 1970, has led to the publication of one paper and the submission for publication of two other papers, all concerning triple correlation experiments on n-d break-up. Experimental groups at California and Grenoble were involved.

D.B. Melrose

The theory of synchrotron radiation was extended to include the effects of synchrotron reabsorption, of the emission from particles with small pitch angles and at low frequencies, and of the transfer of the radiation through an inhomogeneous source on the degree of

circular polarization. One paper was published in Astrophysics and Space Science and two in Astrophysical Letters on this subject.

The classical counterpart to Compton scattering was investigated in detail. Two papers were published in Astrophysics and Space Science on this topic. Further extension of the theory to include induced scattering, double Compton scattering and the effect of a background magnetic field, the last topic in collaboration with W. Sy [Ph.D. student], were considered. Papers on the first two topics have been accepted for publication and a paper on the third topic (with W. Sy) has been submitted for publication.

An investigation of possible theories for type I solar radio bursts was carried out. The results of this investigation have been incorporated into an unpublished technical report. Non-linear processes in a plasma were studied in this connection. A manuscript on the symmetry properties of tensors describing the non-linear responses has been prepared.

Three papers presented at conferences have been published. One was concerned with the acceleration of ultrarelativistic particles in the Crab nebula (International Astronomical Union Symposium on the Crab Nebula), the second was concerned with the scattering of cosmic rays (Twelfth International Conference on Cosmic Rays), and the third, which was in collaboration with W. Sy, was concerned with the line splitting in solar radio bursts (Proceedings of the Astronomical Society of Australia).

Preparation of a text book on plasma astrophysics was suspended early in the year after about two thirds of the book had been written. Preparation of the book has been recommenced.

P.J. Sands

Previous work on the analytical tools for use in the design and analysis of optical systems incorporating inhomogeneous glasses was continued. Papers discussing (i) the third order aberrations of media with axial index distributions and (ii) the paraxial chromatic aberrations of media with either axial or cylindrical distributions were published. Work is proceeding on a computer programme which will

trace paraxial and non-paraxial rays through an arbitrary index distribution with an axis of symmetry and compute the third order aberrations of such a distribution. Based on data supplied by Professor G. Horridge (Department of Neurobiology), a model of the index distribution of an insect's eye is being constructed preparatory to a study of the performance of the eye.

A computer programme was written for the computation of the aberration coefficients of orders three, five, seven and nine of a symmetric system of spherical surfaces. Checks on the programme and the analytical formulae upon which the programme is based were devised and applied successfully.

Formulae were derived for the computation of the aberration coefficients of orders one, two and three of systems which have a plane of symmetry but are otherwise arbitrary. Two papers have been submitted to the Journal of the Optical Society of America. A paper was written and published discussing the first order image forming properties of the most general optical system.

The refraction of particles at surfaces of discontinuity of the electro-magnetic potentials was investigated and a paper has been accepted for publication in Optik. Together with H.A. Buchdahl, a paper discussing the question of reversibility of semi-symmetric systems in the context of both light and particle optics has been written. This has been accepted for publication in Optik.

Academic Staff:

Professor:	H.A. Buchdahl, D.Sc.(Lond.), F.A.A.
Senior Lecturer:	D.B. Melrose, B.Sc.(Tas.), D.Phil.(Oxon).
Lecturer:	M. Andrews, B.Sc., M.Sc.,(Qld.), Ph.D.(Birm.) (on study leave Jan. 1971 - Jan. 1972).
Temporary Lecturer:	R.T. Cahill, B.Sc., Ph.D.(N.S.W.) (vice M. Andrews on study leave).
Postdoctoral Fellow:	P.J. Sands, B.Sc., Ph.D.(A.N.U.).

Publications:

- Buchdahl, H.A. - Optica Acta, 18 (1971), 453-459.
"Hamiltonian Optics. III. The phase characteristic".
- Buchdahl, H.A. - Tensor N.S., 22 (1971), 315-316.
"Remark on the classification of tensors and tensor densities".
- Cahill, R.T. ^{**} and Sloan, I.H. [†] - Nuclear Physics, A165 (1971), 161-179.
"Theory of neutron-deuteron break-up at 14.4 MeV".
- Melrose, D.B. - Astrophysics and Space Science, 10 (1971), 186-196.
"A classical derivation of inverse Compton radiation".
- Melrose, D.B. - Astrophysics and Space Science, 10 (1971), 197-202.
"Electrostatic bremsstrahlung".
- Melrose, D.B. - Astrophysics and Space Science, 10 (1971), 458-463.
Reply to comments on "On the formation of energy spectra in synchrotron sources".
- Melrose, D.B. - The Crab Nebula, I.A.U. Symposium (ed. Davies and Smith), (1971), 296-307.
"Transfer of energy to the Crab nebula following the spin-up of the pulsar".
- Melrose, D.B. - Astrophysical Letters, 8 (1971), 35-37.
"Synchrotron radiation from particles with small pitch angles".
- Melrose, D.B. - Astrophysics and Space Science, 12 (1971), 172-192.
"On the degree of polarization of synchrotron radiation".
- Melrose, D.B. - Astrophysical Letters, 8 (1971), 227-229.
"Correlation between linear and circular polarization in synchrotron sources?".
- Melrose, D.B. - Astrophysics and Space Science, (1971).
"Induced Compton scattering by relativistic particles".
- Melrose, D.B. and Sy, W. - Proceedings of the Astronomical Society of Australia, 2 (1971), 56-57.
"Possible causes of line splitting in drift pair solar bursts".
- Melrose, D.B. - Twelfth International Conference on Cosmic Rays, 1 (1971), 390-394.
"Scattering of higher energy cosmic rays".
- Sands, P.J. - Journal of the Optical Society of America, 61 (1971), 777-783.
"Inhomogeneous lenses. II. Chromatic paraxial aberrations.

** Based on work done prior to joining this University (a substantial amount of work and compilation having been done at this University).

† Not a member of this University.

- Sands, P.J. - Journal of the Optical Society of America, 61 (1971), 879-885.
"Inhomogeneous lenses. III. Paraxial optics".
- Sands, P.J. - Journal of the Optical Society of America, 61 (1971), 1086.
"Inhomogeneous lenses. IV. Aberrations of lenses with axial index distributions".
- Sands, P.J. and Moore, D.T.[†] - Journal of the Optical Society of America, 61 (1971), 1195-1201.
"Third order aberrations of inhomogeneous lenses with cylindrical index distributions".
- Sands, P.J. - Journal of the Optical Society of America, 61 (1971).
"Inhomogeneous lenses. V. Chromatic paraxial aberrations of lenses with axial or cylindrical index distributions.
- Sands, P.J. - Journal of the Optical Society of America, 61 (1971).
"Remarks on the first order optics of the general optical system".
- Sands, P.J. - Optica Acta, 18 (1971), 627-636.
"Visual aberrations of afocal systems".
- Slaus, I. et al.[†] and Cahill, R.T.^{**} - Physical Review Letters, 26 (1971), 789-792.
"Neutron-neutron quasifree scattering".

During the year Dr. Cahill visited Flinders University where he gave a seminar. Dr. Melrose gave a lecture at the May meeting of the Australian Astronomical Society, two lectures to the C.S.I.R.O. Division of Radio Physics, and a lecture at the Twelfth International Conference on Cosmic Rays in Hobart, all these being on astrophysical subjects.

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DEPARTMENT OF THEORETICAL PHYSICS ANALYSIS OF STUDENT PERFORMANCE

Subject or unit	Enrolled	Wastage	Wastage plus failure	Sitting	High Distinction	Distinction	Credit	Pass with Merit	Pass	Fail
1	2	3	4	5	6	7	8	9	10	11
Theor Phys C01	10	0	1	10	2	3	2	-	2	1
Theor Phys C02	8	0	2	8	4	0	1	-	1	2
Theor Phys C03	6	0	3	6	1	2	0	-	3	3

	<u>Enrolled</u>	<u>Sitting</u>	<u>Results</u>	(headings above do not apply)
Final Honours	3	3	1 H1; 2 deferred	
Masters Qualifying	-	-	-	
Ordinary Degree	1	-	-	
Masters Degree	1	-	-	
Ph.D.	1	-	-	