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THE AUSTRALIAN NATIONAL UNIVERSITY

FACULTY OF SCIENCE

DEPARTMENT OF THEORETICAL PHYSICS

ANNUAL REPORT 1970

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.(Q'land), Ph.D.(Birm.)
Postdoctoral Fellow: P.J. Sands, B.Sc., Ph.D.(A.N.U.)

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 student of the department was awarded the Shell Company Prize within the Faculty of Science.

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

Teaching:

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

Research:

M. Andrews

Some aspects of the physics of dense argon plasmas were investigated with a view to obtaining more accurate calculations of ionization equilibrium and the equation of state. The effect of the molecular ion Ar_2^+ was investigated and found to be not important at presently attainable densities. An attempt was made to consider deviations from Debye-HUckel behaviour but the difficulties of constructing a tractable but sufficiently accurate model have not yet been overcome.

Methods for calculating the dynamic polarizability of atoms in excited states were investigated. A method which appears to be satisfactory at least in some cases was evolved and detailed calculations are being carried out for argon and helium (with P. Meier [Research Student in the Physics Department]).

H.A. Buchdahl

A modification of relativistic cosmology was examined in which the Einstein Lagrangian is replaced by a more complicated Lagrangian. The purpose of this is to arrive at a theory which no longer implies the usual conclusion that the state of the universe necessarily becomes either singular or else one of complete emptiness in the past or in the future. A paper has been published in the Monthly Notices of the Royal Astronomical Society.

It was shown that the only static conformally flat spherically symmetric solution of Einstein's field equations is the so-called interior Schwarzschild solution. The metric was transformed to a manifestly conformally flat form. A paper has been published in the American Journal of Physics.

A certain property of segments of rays traversing an optical system was investigated. A paper has been accepted for publication in Optica Acta.

A new optical characteristic function has been defined and investigated. A manuscript has been submitted to Optica Acta.

A great deal of other work has been done which has not yet led to the submission of manuscripts, such as (i) the problem of determining all spherically symmetric distributions of ideal fluid such that the metric is conformally flat; (ii) the determination of the world functions of Robinson-Walker spaces; (iii) the problem of exhibiting the entire field of a mass point in general relativity in isotropic coordinates; (iv) extension of the Lagrangian theory of aberrations to the ninth order, and (v) the use of an hermitian formalism in the theory of the semi-symmetric optical system.

The monograph "An Introduction to Hamiltonian Optics" published by the Cambridge University Press at last appeared in February. It appears to have been very well received by the reviewers.

D.B. Melrose

Work on the theory of type II and type III solar radio bursts was incorporated into two papers to be published in the Australian Journal of Physics. Further development of the theory of the processes involved was continued in collaboration with W. Sy [Ph.D. student].

Investigation of radiation processes involving ultrarelativistic particles was continued. Four papers are to be published in Astrophysics and Space Science and one in Astrophysical Letters.

A paper was prepared for the International Astronomical Union Symposium on the Crab Nebula and presented in absentia. The paper is to be published in the proceedings of the Symposium.

A series of five papers on waves in cold plasmas has been submitted to the Australian Journal of Physics.

A great deal of time was occupied in the preparation of a text on plasma astrophysics. The text is to be published by Gordon and Breach, New York. It is hoped to submit the manuscript during 1971.

P.J. Sands

Analytical tools were developed for use in the design of optical systems when the glasses are inhomogeneous. A paper on the chromatic paraxial aberrations of inhomogeneous lenses was accepted for publication in the Journal of the Optical Society of America (JOSA). Papers on the paraxial properties of inhomogeneous lenses and on the third order aberrations of lenses with an index distribution such that the iso-indicial surfaces are planes normal to the optical axis of the lens were submitted to JOSA.

A manuscript on the third order aberrations of lenses in which the iso-indicial surfaces are cylinders coaxial with the optical axis was prepared (with D.T. Moore of Western Electric Co., Princeton, New Jersey).

The aberrations of optical systems intended for visual use (for example, periscopes) were investigated and a manuscript submitted to Optica Acta.

An hitherto unnoticed approximation in the formulae for the geometrical optical transfer function was discovered and shown to be of no great numerical consequence. A manuscript is in preparation.

Publications:

Buchdahl, H.A. - Proceedings of the Cambridge Philosophical Society, 68 (1970), 179-185.

"On functionally constant invariants of the Riemann tensor"

Buchdahl, H.A. - American Journal of Physics, 38 (1970), 291-294.

"Remark on the harmonic radius vector"

Buchdahl, H.A. - Tensor N.S., 21 (1970), 340-344.

"Reciprocal static metrics and nonlinear Lagrangians"

Buchdahl, H.A. - Journal of the Optical Society of America, 60 (1970), 996-1000.

"Hamiltonian Optics. The point characteristic of a refracting plane"

- Buchdahl, H.A. - *Optica Acta*, 17 (1970), 707-713.
"Point characteristics of some static spherically symmetric space times"
- Buchdahl, H.A. - *Monthly Notices of the Royal Astronomical Society*, 150 (1970), 1-8.
"Non-linear Lagrangians and cosmological theory"
- Buchdahl, H.A. - Cambridge University Press (Cambridge, 1970), xv + 356 pp.
"An Introduction to Hamiltonian Optics"
- *Melrose, D.B. - *Astrophysics and Space Science*, 6 (1970), 321-337.
"On the isotropization of electrons in synchrotron sources"
- **Melrose, D.B. and Wentzel, D.G. - *Astrophysical Journal*, 161 (1970), 457-476.
"Interaction between cosmic-ray electrons and cosmic-ray protons"
- Melrose, D.B. - *Australian Journal of Physics*, 23 (1970), 871-884.
"On the theory of type II and type III solar radio bursts. I. The impossibility of non-thermal emission due to combination scattering off thermal fluctuations"
- Melrose, D.B. - *Australian Journal of Physics*, 23 (1970), 885-903.
"On the theory of type II and type III solar radio bursts. II. Alternative model"

* Based on work done while a member of the Astronomy Program in the University of Maryland.

** Based partly on work completed while a member of the Astronomy Program in the University of Maryland.

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DEPARTMENT OF THEORETICAL PHYSICS ANALYSIS OF STUDENT PERFORMANCE

1	2	3	4	5	6	7	8	9	10	11
<u>Subject or unit</u>	<u>Enrolled</u>	<u>Wastage</u>	<u>Wastage plus failure</u>	<u>Sitting</u>	<u>High Distinction</u>	<u>Distinction</u>	<u>Credit</u>	<u>Pass with Merit</u>	<u>Pass</u>	<u>Fail</u>
Theor Phys 31	16	0	4	16	2	2	4	---	4	4
Theor Phys 32	6	0	0	6	2	1	2	---	1	0
Theor Phys 33	5	0	0	5	2	0	1	---	2	0

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