2.18.20

THE AUSTRALIAN NATIONAL UNIVERSITY

FACULTY OF SCIENCE

DEPARTMENT OF THEORETICAL PHYSICS

ANNUAL REPORT 1982

GENERAL COMMENTS

The purpose of courses in theoretical physics is, on the one hand, to provide an appropriate background for those students intending to take up a career in the subject and, on the other hand, to lead to an appreciation of the formal notions which underlie the physical sciences in general.

Student performance, especially in the second semester, was well above average. As in 1981, we again had one honours student, last year's being awarded an 1851 scholarship enabling him to pursue his studies towards a Ph.D. degree at King's College, London. Though the academic staff of the department has now shrunk to two, any talk of "non-viability" would be difficult to support.

During the second semester Dr Hamer (Department of Theoretical Physics, R.S.Phys.S.) gave a course, at third year level, on elementary particle physics, which was also attended by 4th year Physics students. We are always grateful for the help given to us by members of the IAS.

STAFF

Professor: H.A. Buchdahl, D.Sc. (Lond.), F.A.A.

Senior Lecturer: M. Andrews, B.Sc., M.Sc. (Qld.), Ph.D. (Birm.)

ENROLMENTS AND EXAMINATION RESULTS

See Appendix. In the table actual numbers are given since these are too small to make percentages meaningful.

RESEARCH

M. Andrews

The work on concatenation of characteristic functions of optical systems without symmetries, described in last year's report, was completed and published in the *Journal of the Optical Society of America*.

Further work has also been done on the evolution of moments of clusters of particles in classical mechanics. New results have been obtained on the third-order moments and on determining the evolution of the second-order moments to the third order.

H.A. Buchdahl

In general relativity theory the so-called Schwarzschild interior solution is usually exhibited in curvature coordinates. When one seeks to exhibit it in isotropic coordinates, it turns out that to a given density and coordinate radius, there correspond, in general, two possible physical configurations. A manuscript setting out the details of this state of affairs has been accepted for publication in the *American Journal of Physics*.

The optical behaviour of an object described by the Schwarzschild interior solution may be shown formally to be the same as that of the classical Maxwell fish-eye, truncated at some finite radius. A manuscript concerned with the details of the consequences of this state of affairs has been accepted for publication in *Journal of Physics A*.

In the classical work of Einstein and Gibbs it is shown how, starting from the generic form of the canonical probability in phase, one may infer relations which mirror the central equations of phenomenological thermodynamics. In a paper published in *Foundations of Physics* in December 1979, the following question was posed: Granted only certain generic assumptions of a statistical mechanical formalism, to what extent can one infer the explicit form of the canonical probability in phase on the basis of the general premise that the laws of phenomenological thermodynamics are valid? The argument used at the time did, indeed, lead to the desired result but involved the appearance of the absolute temperature and metrical entropy where it should have sufficed to introduce only empirical entropy with no explicit reference to temperature of any kind. These difficulties have been resolved and the details of the work have been accepted for publication in *Journal of Physics A*.

The Luneberg lens is a well-known classical optical system. It turns out that if one contemplates the equations for the propagation of light in a Hamiltonian formalism, this "lens" is invariant under unitary transformations. This makes it possible to write down enough ray integrals not to have to integrate any differential equations at all and, moreover, the determination of the explicit form of the point characteristic is greatly facilitated. This work has been accepted for publication in the *Journal of the Optical Society of America*.

In modified theories of relativity, based on so-called non-linear Lagrangians, there are virtually no known solutions of the field equations with which one is confronted. In fact, no essentially non-trivial solutions are known where the Lagrangian is the sum of the scalar curvature and some higher order invariant of the Riemann tensor. A solution may, in fact, be found when one contemplates metrics representing so-called pp-waves. A manuscript has been submitted to *Journal of Physics A*.

A good deal of other work is in progress. For instance, (i) investigation of various aspects of the compatibility problem for relativistic wave equations in Riemann spaces is continuing; (ii) an attempt is being made to determine the radii of convergence and the asymptotic behaviour of the power series which occur in optical aberration theory; and so on. These will be reported upon in due course.

G.W. Forbes (Ph.D. student)

Fermat's principle can be used to show that once the path of a general ray through an optical system has been determined to a given order of accuracy, the characteristic function (hence all the geometrical optical information) of the system may be determined to twice this order of accuracy. A short manuscript on this topic was published as a letter in the *Journal of the Optical Society of America*.

Manuscripts containing the definition of a new class of characteristic function (namely, the "restricted characteristic functions") and the application of the techniques of concatenation to restricted point, mixed and angle characteristics have also been accepted for publication by *Journal of the Optical Society of America*. Further manuscripts on the concatenation of symmetric systems and the application of "order doubling" in the calculation of aberration coefficients using a combination of Lagrangian and Hamiltonian methods have also been submitted to the same journal.

The incorporation of chromatic effects into these studies and the asymptotic behaviour of the resulting expressions is presently being investigated.

R. McKenzie (Honours student)

Various aspects of the theory of gravitational lenses were dealt with within the framework of the equations of general relativity theory, in an attempt to avoid ad hoc mixtures of Newtonian and non-Newtonian hand-waving. In particular, one can cleanly take into account the fact that the distances between source, "lens" and observer are generally on a cosmical scale. The multiple image theorem was shown to rest upon a rather general topological basis.

W. Spence (Honours student 1981)

Some of the work done in 1981 on the compatibility problem referred to above was extracted from the Honours thesis and incorporated in a manuscript accepted for publication in *Journal of Physics A*.

PUBLICATIONS

Andrews, M. "Concatenation of characteristic functions in Hamiltonian optics", *Journal of the Optical Society of America*, 17 (1982), 1493-1497.

Buchdahl, H.A. "Energy fluctuations of thermodynamic systems: higher moments", *International Journal of Theoretical Physics*, 21 (1982) 369-381.

Buchdahl, H.A. "On the compatibility of relativistic wave equations in Riemann spaces: II", *Journal of Physics A*, 15 (1982), 1-5.

Buchdahl, H.A. "On the compatibility of relativistic wave equations in Riemann spaces: III", *Journal of Physics A*, 15 (1982), 1057-1062.

Forbes, G.W. "Order doubling in the determination of characteristic functions", *Journal of the Optical Society of America*, 72 (1982), 1097-1099.

THE AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF THEORETICAL PHYSICS ANALYSIS OF STUDENT PERFORMANCE

			Number Enrolled		Number Sitting					
1	2	3	4	5	6	7	8	9	10	11
Unit	Enrolled	Sitting	Wastage	Failure	Sitting	High Distinction	Distinc-tion	Credit	Pass	Fail
B01	10	8	2	2	8	2	3	0	1	2
C01	8	8	0	1	8	2	1	0	4	1
C02	5	5	0	0	5	2	3	0	0	0
C03	5	4	1	0	4	0	4	0	0	0

N.B. The actual numbers are given since these are too small to make percentages meaningful.

	Results		
	Enrolled	Sitting	H1
Theoretical Physics IV	1	1	1