THE COLLISION OF PURE PLANE GRAVITATIONAL

AND

ELECTROMAGNETIC SHOCK WAVES

by

K.J. Hinton B.E. (Hons.) B.Sc. (Hons.)

Thesis submitted in accordance with the

requirements of the Degree of Master of Science

Department of Mathematical Physics

University of Adelaide

South Australia

October, 1981

Contents

Abstract

By utilizing the Newman-Penrose tetrad formalism, we deduce the exact set of non-linear partial differential equations which describe the collision of gravitational and electromagnetic waves. Unfortunately, this set of equations is too difficult to solve using today's techniques and therefore several simplifications are adopted.
The first simplification treats the electromagnetic field as a test field and hence ignores its stress-energy. Both the exact and weak gravitational metric are used. In both cases, we deduce explicit expressions describing the effect of the gravitational wave on the electromagnetic field. Later, the validity of these expressions is discussed.
The second simplification uses a power-series approach which, although it does not give an extensive solution to the exact problem, does give several properties of the exact solution in the vicinity of the initial interaction. In particular, the applicability of the Lichnerowicz conditions is discussed.
We find that the gravitational wave changes the Petrov type of the electromagnetic field and can even reverse its direction of propagation. Also, observers may experience focusing of, and/or energy transfer to the electromagnetic field.
Finally, although the effects described above are explicit, we find that they are too small for experimental application to the detector of gravitational waves.

Statement

This thesis contains no material accepted or submitted for the award of any degree, and to the best of my knowledge and belief contains no material previously written or published by any other person except where due reference is made in the text.

Acknowledgements

The research for this thesis was undertaken in the years 1980-81 in the Department of Mathematical Physics, University of Adelaide under the supervision of Dr. P. Szekeres. The financial support of a Commonwealth Postgraduate Research Award is gratefully acknowledged.

I am greatly indebted to Dr. P. Szekeres for his guidance and support and also for the many stimulating and wide-ranging discussions.

Also, I would like to thank Ms. E. Reynolds for her endless patience and excellent typing of this thesis and my wife Rita Hinton for her proof reading and overall help and support.

Notation and Conventions

The metric tensor is denoted $g_{\mu\nu}$. Its signature is $+ - - -$. Tensor indicies μ,ν,ρ range and sum over 0,1,2,3. Spinor indicies A,B,... range and sum over 0,1. Where small roman letters appear their sum always ranges over the values 2,3. Symmetrization is denoted by round brackets.

$$A_{(\mu}B_{\nu)} = \tfrac{1}{2}(A_\mu B_\nu + A_\nu B_\mu)$$

Antisymmetrization is denoted by square brackets

$$A_{[\mu}B_{\nu]} = \tfrac{1}{2}(A_\mu B_\nu - A_\nu B_\mu)$$

Partial derivatives are denoted by

$$A_{,\mu} \text{ or } A_\mu$$

Covariant derivatives are denoted by

$$A_{;\mu}$$