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Mixture of Outgoing and Incoming Electromagnetic Radiation. Change of Mass of the Source of Radiation*

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Abstract. In a previous paper the author, using a method of successive approximations, verified by means of the Einstein-Maxwell equations of general relativity the well-known result that outgoing electromagnetic radiation from a source conveys energy, so that the source loses gravitational mass corresponding to this energy. The purpose of this work is to show a similar result for the general case of any mixture of outgoing and incoming radiation.

1. Introduction

From everyday use of electromagnetic waves it is evident that they carry energy. Any source that emits them must lose energy. In a previous paper (ROTENBERG, 1966) this was verified via a method of approximation applied to the Einstein-Maxwell equations

$$R_{ik} = -8\pi E_{ik} \tag{1.1}$$

for free space, by investigating radiation from a simple source — an electric dipole oscillating smoothly for a finite period. It was shown that the source suffers a permanent reduction of gravitational mass equal to the total energy of radiation emitted. The result referred to *outgoing* waves only; the present work sets out to show a similar result for any mixture of outgoing and incoming waves, having as the source (and receiver) the electric dipole just mentioned.

The electric dipole is explained more clearly in section 2, and in sections 3 and 4 the metric and method of approximation are described. The solution (obtained in section 5 for the dipole) of the wave equation for the electromagnetic 4-potential is needed in section 6 to calculate the electromagnetic energy tensor and the total flux of energy of electromagnetic waves from the source. Finally, the main result, that the source undergoes a secular variation in mass equal and opposite to the total flux of energy of electromagnetic radiation, is established in section 7. The more complicated calculations occur in two appendices, followed by a third appendix containing a notation connected with mixed, outgoing and incoming, radiation and used frequently in this paper.

* This work is included in a thesis submitted by the author (1964) to the University of London for the degree of Ph.D.