Commun. math. Phys. 54, 1—19 (1977)

Communications in Mathematical Physics

The Back Reaction Effect in Particle Creation in Curved Spacetime*

Robert M. Wald**

Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA

Abstract. The problem of determining the changes in the gravitational field caused by particle creation is investigated in the context of the semiclassical approximation, where the gravitational field (i.e., spacetime geometry) is treated classically and an effective stress energy is assigned to the created particles which acts as a source of the gravitational field. An axiomatic approach is taken. We list five conditions which the renormalized stress-energy operator $T_{\mu\nu}$ should satisfy in order to give a reasonable semiclassical theory. It is proven that these conditions uniquely determine $T_{\mu\nu}$, i.e. there is at most one renormalized stress-energy operator which satisfies all the conditions. We investigate existence by examining an explicit "point-splitting" type prescription for renormalizing $T_{\mu\nu}$. Modulo some standard assumptions which are made in defining the prescription for $T_{\mu\nu}$, it is shown that this prescription satisfies at least four of the five axioms.

I. Introduction

In the past several years, a considerable amount of progress has been made in our understanding of quantum processes occurring in a strong gravitational field. A satisfactory quantum theory of the gravitational field itself still does not exist [1]. However, the framework of a semiclassical theory describing other quantum fields present in a strong gravitational field does exist and has been used to investigate particle creation effects. In this theory the gravitational field is described in an entirely classical manner as curvature in the geometry of spacetime, in accordance with the notions of general relativity. The fields (e.g., a scalar, Dirac, or Maxwell field) which are present in spacetime are described in accordance with the principles of quantum field theory. It is not believed that this theoretical framework can provide an exact description of nature, since it cannot be entirely consistent to have

* Supported in part by the National Science Foundation under grant MPS 74-17456-A01 and by the Sloan Foundation

** Sloan Foundation fellow