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ASPECTS OF QUANTUM FIELD THEORY

by

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PART 1: GENERAL INTRODUCTION

'hese lectures concentrate on a series of topics in quantum field theory which, in my opin-
›n, are becoming increasingly relevant to the students of general relativity and gravity.
ince there exists several formal textbooks in quantum field theory, it is probably worth-
hile to explain how these lectures differ from standard text books and what exactly their
cope is.

For most part of the lectures I have chosen topics which are not discussed in adequate
etails in standard textbooks. Even while dealing with standard material I have tried to
›ncentrate on subtleties and questions of technique which are not usually emphasised.
his is done because it is precisely these aspects of quantum field theory which become
levant in the study of quantum fields in curved spacetimes and in other topics in the
terface of gravity and quantum field theory.

The lectures are divided into five parts. Part 2 is a fairly comprehensive and self-
›ntained introduction to the concept and application of path integrals. No previous
quaintance with the subject is assumed though familiarity with conventional quantum
echanics (at the level of a first course) is required. The emphasis is on using path integrals
a technique for studying non-perturbative aspects of quantum theory. Several important
›ncepts in field theory are illustrated in the conceptually simpler environment of quantum
echanics so as to make the transition in the latter parts 3 and 4 easier. The discussion of
ath integrals based on Jacobi action and its connection with an infinite system of harmonic
cillators is new and (as far as the author known) has not been emphasised before. This
›nnection allows one to proceed logically from the path integral for a relativistic particle
› the concept of a quantum field. Part 3 clarifies this connection and introduces the scalar
eld to describe a relativistic spinless particle. Possible generalization to other fields are
riefly mentioned.

At this juncture one could take different routes to proceed further. I have omitted
he discussion of conventional topics like canonical quantization, perturbative study of in-
eractions etc. etc. There are two reasons for this conscious choice. First of all, many of
hese concepts are fairly useless in the context in which gravitational field plays a crucial
›le. The conceptual missionary behind this approach - which has been so successful in
uantum electrodynamics and electroweak unification - fails to provide us with a clear
irection to proceed further. Personally, I consider perturbative renormalizability as an
verremphasised trick which needs to be replaced by a sounder and more fundamental con-
epts if progress has to be achieved in combining quantum theory with gravity. Since
hese lectures are primarily intended for relativists I have not bothered to include histor-
ically relevant topics like perturbation theory. Secondly there exists excellent text books
which discuss perturbation methods in quantum field theory, Feynmann rules etc. and an
interested reader will have no difficulty in learning these topics.

Instead of covering these subjects, I have devoted part 4 to a detailed discussions
of the concept of effective action. The basic idea of effective action is explained using a
quantum mechanical toy model and generalized to the study of scalar field with arbitrary
self interaction. The renormalizability (or otherwise) of a scalar field with self interaction is
discussed in the context of finiteness of effective potential. This also allows the introduction
of "running coupling constant" without having to go through the detailed discussion of

Feynmann rules etc. I have also included in part 4 an extensive discussion of Schwinger's propertime method applied to the evaluation of effective Lagrangian and pair creation in external fields. These are illustrated in the context of creations of scalar particles by an externally specified electromagnetic field from different points of view.

Part 5 discusses a series of selected examples from the study of quantum field theory in non-trivial background. The intimate connection between the choice of harmonic oscillators to describe the field and the concept of a field is illustrated by working out the ground state of the scalar field in $(1 + 1)$ dimension in two different coordinate systems. This is followed by a discussion of particle creation in several external gravitational fields. Particle creation in an expanding universe is studied by techniques similar to those used in part 4; other cases like Schwarzschild metric etc. are discussed in a unified manner using a semiclassical propagator.

Since the lectures were intended to be of pedagogical nature, I have kept citations to original literature to a minimum. The suggestions for further reading given at the end might help the reader to dwell into the original literature if he so desires.

The preprint is available on request from : *The Librarian, IUCAA*