PRAMANA
—journal of
physics

Vol. 50, No. 2,
February 1998
pp. 133–148

Finite temperature Cornwall–Jackiw–Tomboulis formalism of Φ^6 theory

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MS received 24 July 1997

Abstract. The finite temperature effective potential for a scalar field with Φ^6 interaction is calculated by extending the CJT formalism for composite operators. It is found that unrenormalized terms appear in the effective potential due to the presence of an unrenormalized mass term. Nonzero turning points are obtained both for positive and negative λ. High temperature expansion is performed and the results are analysed numerically. Graphical analysis indicates symmetry restoration when $T \to 0$.

Keywords. Composite operator; double Legendre transform; CJT formalism; effective potential; finite temperature; symmetry restoration; high temperature expansion.

PACS Nos **11.10; 11.15**

1. Introduction

Study of symmetry changing phase transitions of a quantum field in the presence of a surrounding thermal bath is very important in the study of the evolution of the universe and in the analysis of very high energy collisions where very high matter and radiation density exist. Detailed study of these phase transitions has been done by various authors [1–4]. The effective potential method is very useful in studying spontaneous symmetry breaking (SSB) at zero temperature [5, 6]. Estimation of the critical temperature of phase transitions can be done by extending this approach to finite temperature. These studies mainly using loop expansion techniques have played a pivotal role in framing our understanding about the early universe, unified theories, quark gluon plasma etc.

Recently there has been a revival of interest in finite temperature quantum field theory, apparently caused by the recognition of the importance of symmetry breaking phase transitions and the problem of precise determination of critical temperature. An accurate analysis of phase transitions (both analytical and numerical) becomes necessary because most of the cosmological models critically depend on it. For example baryon asymmetry may be generated at the electro-weak level if the phase transition is of first order [7–10]. For calculation of critical temperature various perturbative and non-perturbative techniques have been suggested [11–19].

Effective potential defined as single Legendre transform provides an efficient way to obtain quantum corrections to the classical potential. But this popular method