Quantum physics: from atom to solid state
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Broken symmetries and quantum phase transitions

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Chapter I **Functional approach to the many-body problem**

I] Interacting bosons

1) Bosonic coherent states

2) Functional integral for the partition function

II] Interacting fermions

1) Introduction to Grassmann variables

2) Fermionic coherent states

3) Functional integral for the partition function

Chapter II **Spontaneous symmetry breaking**

I] Introduction to spontaneous symmetry breaking

1) Examples

2) Consequences of spontaneous symmetry breaking

3) Spontaneous symmetry breaking in quantum mechanics

4) Spontaneous symmetry breaking in quantum field theory

II] Spontaneous breaking of continuous global symmetry

1) Relativistic O(N) model

2) Non-relativistic U(1) model: superfluidity

3) Goldstone's theorem

III] Superconductivity (Meissner effect and Higgs-Anderson mechanism)

Chapter III **Quantum phase transitions**

I] Phase transitions and critical phenomena

1) Landau's theory and validity of the mean-field approximation

2) Phenomenology of second-order phase transitions: scaling laws and critical exponents

3) Introduction to Wilson's renormalization group

II] Introduction to quantum phase transitions

1) Zero-temperature quantum phase transitions

2) Effect of temperature: quantum-classical crossover

3) Applications: superfluid–Mott-insulator transition in bosonic gases, quantum antiferromagnetism, etc.