Theoretical Physics

Autocorrelation Analysis on a 3D Ising Model near the Phase Transition

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Abstract

We study the performance of the Metropolis algorithm on the Ising model close to its magnetic phase transition. This is done by calculating the auto-correlation time function of the magnetization $\langle M(0)M(t)\rangle$. We use a three dimensional Ising model with nearest-neighbor interaction and periodic boundaries. An attempt is made to find some relation between the form of the auto-correlation as a function of temperature. The result arrives at a graph with which we can estimate the simulation time for a given temperature.

Quantum contributions to the molar heat capacity and entropy of diatomic gases

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Abstract

This bachelor thesis in theoretical physics outlines the quantum contributions to the molar heat capacity of diatomic gases. Some trivial models exist but in this thesis we go beyond the conventional models in order to characterize the deviations which more trivial models do not account for.

We study a wide range of correction terms analytically and prove rigorously which ones give a significant contribution to the molar heat capacity. Then, we numerically calculate the molar heat capacity with these correction terms. We test our model against measured data from *JANAF thermochemical tables*, M.W. Chase , J.Phys. Chem. Ref. Data (1978 Supplement). To obtain a representative sample we analyze H_2, HgF and HgI.

We find that accounting for rotational and vibrational correction terms greatly improves the model. We receive a relative error of $\pm 5\%$.

Keywords: Molar heat capacity, Entropy, Diatomic gas, Partition function, Vibration, Rotation, Translation, Coupling.

Mathematical Analysis and Simulation of Shor's Algorithm and the Quantum Fourier Transform

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Abstract

In 1994, Peter Shor, professor of applied mathematics at MIT made a revealing finding, when he presented his paper. He gave an algorithm which would factor composite integers, using exponentially less operations than the most efficient known algorithm. His algorithm requires the use of a quantum computer, a theoretical computational device using quantum mechanical effects not utilized in contemporary computers.

In this paper we have analysed the mathematics behind Shor's algorithm and the quantum circuits on which it operates. We have also studied the Quantum Fourier Transform, a central component of Shor's Algorithm. Furthermore we have written a program in C++ to simulate a quantum circuit performing Shor's algorithm and the quantum Fourier transform.

We were able to understand the critical parts of Shor's algorithm that contribute with the great increase in efficiency compared to classical algorithms.

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Keywords: Shor's Algorithm, Quantum Fourier Transform, Quantum Circuit, Quantum Computer, Quantum Information, Qubit.

Theoretical Physics

Molecular motors

A study of the Langevin equation in a thermal ratchet model of the myosin V motor protein

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Abstract

Molecular motors are one of Nature's wonders. Acting in the chaotic world of biological macromolecules, these nano-scale machines convert chemical energy into mechanical work with an efficiency unparalleled by any human made mechanical system. In this report, we investigate how these molecular motors can harness the thermal fluctuations of their environment to generate unidirectional motion. Especially, a brownian ratchet model of myosin V is investigated in two simulations together with numerical and analytical calculations. The main conclusions are that although the myosin V protein is an efficient machine, the brownian ratchet model is not.

Theoretical Physics

The Entropy of Frustrated Ising Systems Calculated Using Monte Carlo Methods

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Abstract

We use Monte Carlo simulation methods to investigate the entropy of various Ising systems. For historical and educational reasons we start by implementing the Metropolis algorithm. It has been the standard method since its introduction in the 1950s, but inherent weaknesses and the pursuit of higher resolution has recently led to the development of efficient alternatives. For the more challenging frustrated Ising systems we implement the Wang-Landau algorithm, first published in 2001. This method gives us direct access to the free energy, and thereby the entropy, as a function of the temperature. Since the frustrated systems exhibit a residual groundstate entropy, it is not obvious that the third law of thermodynamics is obeyed. We address this by giving a thorough discussion of the different formulations of the third law and their applicability.

Consequences of Violation of Special Relativity and Causality

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Abstract

Fall 2011 the OPERA collaboration reported an anomaly in the neutrino speed. The neutrinos were found to travel faster than the speed of light, a result that gave rise to a discussion about the validity of special relativity. The subject of this thesis was inspired by this discussion. We give a brief introduction to special relativity and summarize previous experiments considered to prove it and present some theories that might contradict it. Based on this we carry a discussion about possible explanations to contradictions and investigate new theories that modify special relativity. We also introduce the concept of causality and discuss its correlation with special relativity. Lastly we investigate how a hypothetical violation of these would affect different areas of physics.

On superluminal particles, tachyons, and a discussion on their existence

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Abstract

The theoretical background from which the question of the existence of tachyons arises is analysed, and the properties that distinguishes this class of particles from others are derived. A few methods that could hypothetically be used to detect tachyons are listed, along with a few of the experiments performed to look for signs of these particles. It will be discussed whether these particles are detectable or not. The results found by the MINOS and OPERA experiments which indicates neutrinos travelling with superluminal speeds will be presented, and is followed by a discussion on whether these results could be signs of tachyonic particles.