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# EXPERIMENTAL STUDY OF BROWNIAN MOTION: CHARACTERIZATION, TRAJECTORIES, AND STATISTICAL ANALYSIS

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**Abstract.** Brownian motion is a fundamental concept in physics that describes the random motion of particles suspended in a fluid medium. This phenomenon, first observed by Robert Brown in 1827, has since been extensively studied and provides insights into various fields such as statistical mechanics, thermodynamics, and

colloidal science. In this experimental study, we investigate Brownian motion using a systematic approach, employing microscopy and statistical analysis techniques. Our findings contribute to a deeper understanding of the underlying principles governing Brownian motion and provide valuable information for applications in diverse scientific disciplines.

**Key words:** diffusion, Brownian particle, Brownian motion, microscope,

**Introduction.** Brownian motion refers to the erratic, random motion exhibited by microscopic particles suspended in a fluid due to the thermal fluctuations of the surrounding molecules. This motion arises from the collisions between the particles and the fluid molecules, leading to unpredictable trajectories. The study of Brownian motion has far-reaching implications, extending beyond the realm of physics to fields such as biology, chemistry, and materials science. This paper presents an experimental investigation into the properties and characteristics of Brownian motion, focusing on the analysis of particle trajectories, diffusion, and statistical properties. One of the key properties of Brownian motion is diffusive behavior, which can be quantified by the diffusion coefficient. The diffusion coefficient, denoted as D, represents the average distance a particle travels in a unit of time. It is directly related to the mean square displacement (MSD) of the particle, which is defined as the average squared distance traveled by the particle from its initial position at a given time interval.

**Experimental Setup:** The experimental setup consists of a sample chamber filled with a fluid medium, typically a liquid such as water, and suspended particles of interest. A high-resolution microscope equipped with a camera is employed to capture the motion of the particles. To minimize external disturbances, the sample chamber is temperature-controlled, and the fluid is carefully selected to ensure low viscosity and negligible interparticle interactions.

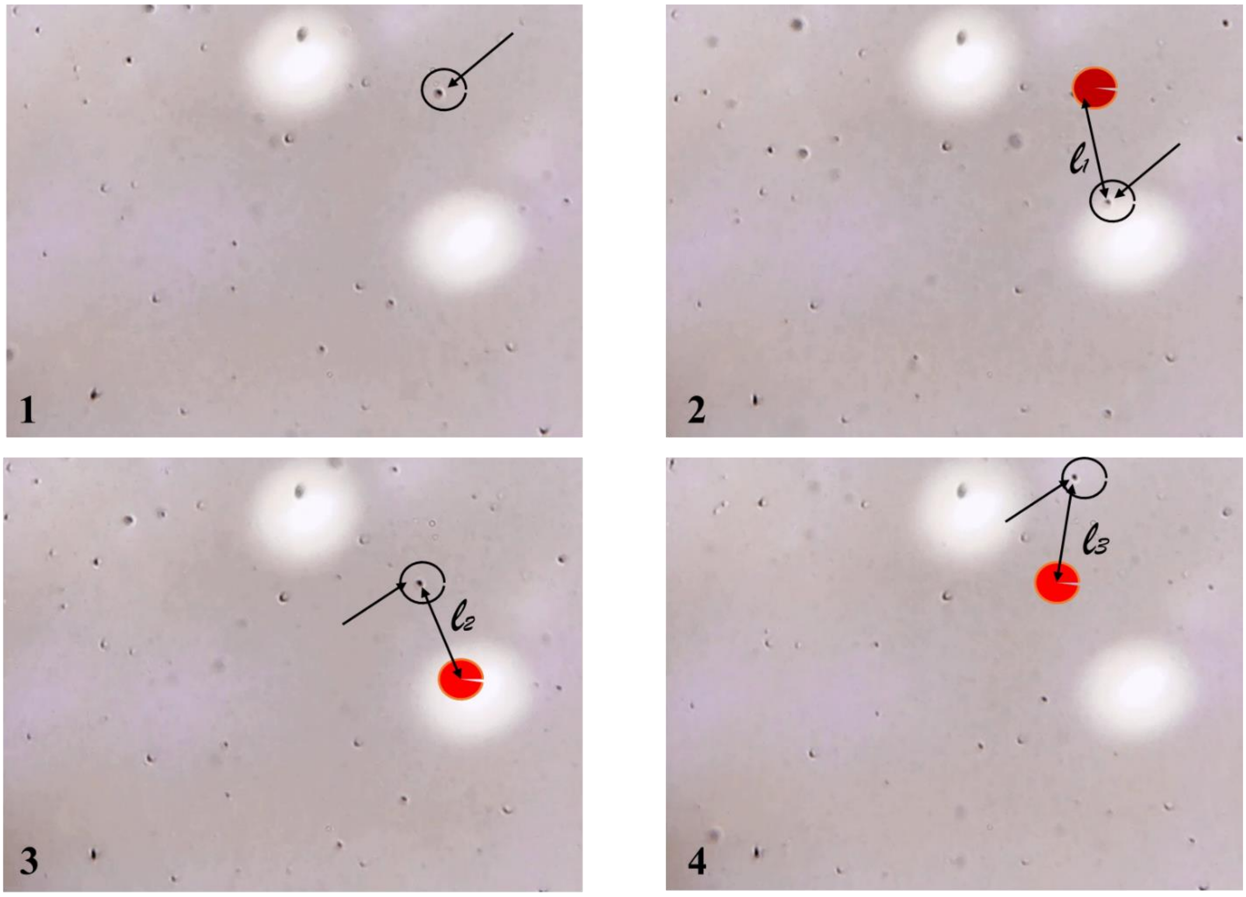
In an experimental study of Brownian motion, it is essential to consider the interactions between the suspended particles. The interparticle interactions can significantly influence the dynamics and statistical properties of Brownian motion.

The nature of these interactions depends on various factors such as particle size, surface properties, and the composition of the surrounding medium. Here, we discuss two common types of interactions observed in Brownian systems: thermal interactions and hydrodynamic interactions.

*Thermal Interactions:* thermal interactions arise due to the collisions between particles and the surrounding fluid molecules. These collisions result in random forces acting on the particles, leading to their erratic motion. The magnitude and nature of thermal interactions depend on the temperature, viscosity, and molecular properties of the fluid. In dilute suspensions, the thermal interactions dominate, and the particles move independently of each other. However, at higher particle concentrations, the interactions can become more significant, resulting in collective behavior and altered diffusion properties.

Hydrodynamic Interactions*:* hydrodynamic interactions occur due to the influence of fluid flow generated by one particle on the motion of neighboring particles. When a particle moves through a fluid, it creates a flow field that affects the surrounding particles. The hydrodynamic interactions can lead to correlations in the motion of nearby particles, influencing their trajectories and diffusion behavior.

**Data Acquisition and Analysis:** Using the microscope, we record the motion of individual particles over a specified time interval. The recorded videos are then analyzed to extract relevant information about the Brownian motion. Tracking algorithms are applied to determine the position of each particle at different time points, allowing for the calculation of displacement vectors and subsequent analysis of particle trajectories. The acquired data is further processed to obtain statistical properties such as mean square displacement (MSD), velocity autocorrelation function, and probability density function.




The sequence of pictures depicts the following information regarding the Brownian particle's motion:

1. The first picture shows the initial position of the Brownian particle.
2. In the second picture, the position of the particle after 1 minute is displayed, indicating the distance it has traveled during that time.
3. The third picture illustrates the position of the particle after 2 minutes, reflecting its further displacement from the initial position.
4. Finally, in the fourth picture, the particle's position after 3 minutes is shown, demonstrating its continued movement over the elapsed time.

In summary, the series of pictures visually represents the successive positions of the Brownian particle, indicating its displacement at different time intervals.

**Results and Discussion:** The analysis of particle trajectories reveals several key characteristics of Brownian motion. The MSD exhibits a linear dependence on time, indicating diffusive behavior and validating the Einstein-Smoluchowski relation. The diffusion coefficient, derived from the slope of the MSD, provides insight into the particles' mobility and the properties of the surrounding fluid. The velocity autocorrelation function demonstrates the absence of long-range correlations, confirming the random nature of Brownian motion. Probability density functions exhibit Gaussian distributions, consistent with the central limit theorem. The experimental study of Brownian motion has significant implications across various scientific disciplines. In materials science, understanding Brownian motion aids in the design and optimization of colloidal systems. In biophysics, Brownian motion plays a crucial role in the movement of cellular components and the diffusion of biomolecules. Moreover, our findings contribute to the development of theoretical models and simulations for predicting and analyzing complex systems governed by stochastic processes.

**Conclusion:** Through our experimental investigation, we have confirmed the fundamental characteristics of Brownian motion, including diffusive behavior, random trajectories, and statistical properties. The systematic analysis of particle trajectories and the extraction of statistical quantities provide valuable insights into the underlying dynamics of Brownian motion. These findings deepen our understanding of this phenomenon and pave the way for advancements in diverse scientific disciplines. Further research can explore the impact of external factors, such as particle size, shape, and interparticle interactions, on Brownian motion to broaden its applicability and enhance our understanding of complex systems.

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# BROUN ZARRASINING SUYUQLIK ICHIDAGI HARAKATI

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**Annotatsiya.** Broun harakati, mikroskopik zarrachalarning suyuqlik yoki gaz ichida tasodifiy harakatlanish jarayonini ifodalaydi. Bu harakat molekulyar harakatlarning tasodifiy tabiatining isboti sifatida qabul qilinadi va u turli fan sohalarida, jumladan fizikada, kimyoda va biologiyada muhim o'rin egallaydi. Zarrachalar muhitdagi molekulalar bilan doimiy ravishda to'qnashib, tasodifiy yo'nalishlarda harakat qiladi. Bu tasodifiy harakat zarrachalarning kinetik energiyasi bilan bog'liq bo'lib, kinetik energiya esa haroratga bog'liqdir.

**Kalit so'zlar**: Broun harakati, zarracha, mikroskopik, suyuqlik.

Broun harakati, bu mikroskopik zarrachalarning suyuqlik yoki gaz ichida tasodifiy harakatlanishi jarayonidir. Bu hodisa birinchi marta 1827 yilda botanik Robert Broun tomonidan kuzatilgan. U suvda suzayotgan gulchang zarrachalarining tasodifiy harakatini aniqlagan. Keyinchalik, bu harakat molekulyar harakatlarning tasodifiy tabiatining isboti sifatida qabul qilindi va u turli fan sohalarida, jumladan fizikada, kimyoda va biologiyada muhim o'rin egalladi. Ushbu maqolada Broun